A STUDY OF THE ECOLOGY OF SELECT SPECIES OF WEEDS IN DIFFERENT VEGETATION TYPES OF NILGIRI BIOSPHERE RESERVE

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in Environmental Sciences

by

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CERTIFICATE

This is to certify that the thesis, entitled " **A study of the ecology of select species of weeds in different vegetation types of Nilgiri Biosphere Reserve"** is a record of original research work done by **Ms. Maya V. Mahajan** in the Division of Environmental Impact Assessment, Salim Ali centre for Ornithology and Natural History, as a full time Research Scholar during the period of study 1996 - 2000 under my guidance and supervision for the award of the Degree of Doctor of Philosophy in Environmental Sciences. I further certify that this research work has not previously formed the basis for the award of any other Degree or Diploma or Associateship or Fellowship or other similar title to any candidate of this or any other University.

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DECLARATION

I do hereby declare that the thesis entitled **"A study of the ecology of select species of weeds in different vegetation types of Nilgiri Biosphere Reserve"** submitted to the Bharathiar University, Coimbatore, for the award of the Degree of Doctor of Philosophy in Environmental Sciences, is a record of original and independent research work done by me during 1995 - 2000 under the supervision and guidance of **Dr. P. A. Azeez,** Principal Scientist, Salim Ali centre for Ornithology and Natural History, Coimbatore, and it has not previously formed the basis for the award of any other Degree or Diploma or Associateship or Fellowship or other similar title to any candidate of this or any other University.

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Dedicated to my beloved daughter
RUCHI

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SUMMARY

Invasion by weedy species of plants has serious impact on natural and managed ecosystems. Weedy species invade agricultural lands, fallow lands, roadsides, disturbed forests and plantations. Invasion by such species modifies the ecosystem structure and function. Invading species may dominate and displace the native vegetation and cause extinction of certain native species, leading to alteration in the original biodiversity of an area. In recent years, biological invasion is being recognised as a serious threat to biodiversity conservation (Pimm and Gulpin 1989, Vitousek *et al.* 1996).

In contrast to studies in agricultural fields, not much attention is given to plant-invasion in natural ecosystems. Nevertheless, the colonisation of natural forest ecosystem by weedy species is growing as a threat. In recognition of the threats posed by plant invasions in natural vegetation and realising the scarcity of ecological information on various colonising plant species, the present study was undertaken with the following objectives.

1. Documentation of major invading plants in various habitats of NBR.
2. Study the seasonal variations in density and growth of select weedy species.
3. Study the phenology and ecology of select weedy species.
4. Study impact of weeds on native vegetation.
5. Study relation between human disturbance and weed invasion.

Nilgiri Biosphere Reserve (NBR) which is located in south-west India between $10^{\circ} 45' - 12^{\circ} 15'$ N and $76^{\circ} 10' - 77^{\circ} 45'$ E was selected as the area of study. NBR is known for its rich biodiversity. Eighty percent of flowering plants reported from Western Ghats are found in NBR (3182 species), out of which 82 species are endemic to the area (Nair and Daniel 1986). The NBR covers major vegetation types of Western Ghats, such as evergreen, moist and dry deciduous forests, scrub jungles and grass lands.

The study was undertaken in two phases. The first phase involved survey in various vegetation types of NBR. Field surveys during the first phase were conducted, seasonally at different vegetation types of Nilgiri Biosphere Reserve from 1994 to 1996. Following locations from NBR were selected for the study: 1) Mudumalai Wildlife Sanctuary, 2) Silent Valley National Park, 3) Upper Bhavani (Nilgiris) and 4) Siruvani forests. The second phase was confined to the study of weedy species in Siruvani forest. Vegetation data from all the study sites were collected seasonally during the period of 1994 to 1996. During second phase (1996 - 1998), vegetation sampling was done in alternate months to study the seasonal fluctuation in the number and growth of selected weedy plants in Siruvani forest.

The vegetation data were analysed for dominance, density, frequency and their relative values, using standard methods. These quantities were summed to obtain Importance Value Index of individual species (Curtis 1959). Species diversity was determined using Shannon - Wiener information function (H', Shannon and Wiener 1963). Similarity, based on total number of selected weedy species among the different vegetation types was estimated using Horn's similarity index. Species association was estimated using Jaccard's index. Niche breadth of all the species were calculated using Levin's niche breadth formula.

To examine the relation between human disturbance and weed invasion, three transects each were laid in dry deciduous forest and scrub jungle and four transects in the moist deciduous forest along the disturbance gradient, starting from villages extending towards undisturbed forests.

Soil samples collected seasonally from different plots in Siruvani mixed deciduous forest were analysed for different physical and chemical parameters. Pearson's correlation and multiple regression analyses were attempted to assess relations among the total number and species richness of herbs and weeds, and different physical and chemical parameters of soil.

Total 376 species of herbs and shrubs belonging to 69 families were recorded from the study area. Poaceae, Papilionaceae, Asteraceae, Rubiaceae, Cyperaceae and Acanthaceae were the dominant families among the herbs and shrubs. Total 179 species of trees were recorded from the study sites. Out of 376 species of herbs and shrubs, 85 were found to have weedy characteristics. Of these, 15 species namely *Chromolaena odorata* (L.) King & Robinson, *Lantana camara* L., *Mimosa pudica* L., *Eupatorium repandum* Willd., *Ageratum conyzoides* L., *Cassia occidentalis* L., *Opuntia dillenii* (Ker - Gawl.) Haw., *Euphorbia hirta* L., *Synedrella nodiflora* (L.) Gaertn., *Triumfetta pilosa* Roth., *Sida acuta* Burm. f., *Tephrosia purpurea* (L.) Pers., *Barleria mysorensis* Heyne ex Roth., *Justicia betonica* L., and *Stachytarpheta jamaicensis* (L.) Vahl. were selected for further study.

Total number of individuals of most of the weedy species in all the habitats of NBR increased at every season, except summer, than the previous season. In summer there was slight decrease in total number because of a) most of the annual species complete their life cycle before summer and b) scarcity of moisture curtailing growth in the season. There was an increase in total number of individuals of all weedy species in the second year compared to the first year in all the habitats.

Dry deciduous forest, moist deciduous forest, mixed deciduous forest, scrub jungle and teak plantation were more affected by weed invasion compared to high altitude forest types. Species richness (number of species) as well as number of individuals of weedy species were less in high altitude forests such as shola and wattle plantation.

In the mixed deciduous forest in Siruvani, which was selected for further study, total number and height of most weedy species were highest in winter, in both the years. Total number and height of all weedy species in most of the seasons of the second year were generally higher than respective seasons of the first year. While, the number of individuals as well as species richness (number of species) of other native plant species decreased during the second year, which indicates the growing menace of weeds in natural forests in NBR.

Phenological observations were made on selected weedy species in Siruvani mixed deciduous forest. When similarity among vegetation types in terms of weedy species was assessed using Horn's similarity index, wattle plantation and evergreen forest showed maximum similarity. Moist deciduous forest showed 75% similarity with coffee plantation, 65% similarity with teak plantation and 61% similarity with mixed deciduous forest. Mixed deciduous forest showed 67% similarity with teak plantation. Shola forest showed 65% similarity with wattle plantation. Association among select weedy species in different habitats of Nilgiri Biosphere Reserve was estimated using Jaccard's index.

When the distribution of weeds were examined with respect to human habitations, in all the three habitats namely dry deciduous forest, scrub jungle and moist deciduous forest, species richness as well as density of weeds were highest near the village. Species richness and density of weeds gradually decreased towards the undisturbed forest area, which indicates that human disturbance is one of the major factors which promotes weed invasion.

Soil in the Siruvani mixed deciduous forest is loamy sand. Total number of herbs showed significant positive correlation with soil pH and rainfall and negative correlation with electrical conductivity (EC) and available nitrogen. Species richness of herbs showed significant positive correlation with pH and rainfall and negative correlation with EC, available nitrogen and available potassium. Total number of weeds was positively correlated with pH and negatively correlated with available potassium. Species richness of weeds was positively correlated with pH and rainfall and negatively correlated with EC, available nitrogen and available potassium.

The study sheds light on the distribution and invasion of weedy plants in various habitats of NBR, their seasonal variations in number, growth, and phenology and associations, and indicates the threat posed by these colonizing species to natural vegetation. It is also noticed that disturbance is one of the major factors, which enhances the weed invasion. However, undisturbed areas are also seen invaded by weeds. The growing population of invaders indicates a risk of suppression and even elimination of some native species. The invaded areas in Nilgiri Biosphere Reserve need immediate attention to arrest further invasion and colonization by weeds.

Chapter I

1 INTRODUCTION

Invasion by certain plant species outside their native range, posing threats of varying nature to natural ecosystems is being increasingly recognized worldwide (Usher 1988, Usher *et al.* 1988, Soule 1990, Westman 1990, Anonymous 1993, Tanner and Nolan 1995, Randall 1996, Colton and Alpert 1998, Simberloff and Alexander 1998). Threat of invasion by species is rampant in both natural and managed ecosystems and biological invasion is cited as one of the world's worst ecological problems (Vitousek *et al.* 1996, Williamson 1996).

Invasive plant species are commonly known as weeds. From an agricultural viewpoint, the common definition of weed could be a plant out of place or an unwanted plant or a plant with a negative value, or a plant which competes with man for soil (Muzik 1970). In the context of natural ecosystems, weeds can be defined as those species, which were not originally seen in the area and can outcompete the original species for local resources. In recent years, to refer to pest plants in wild-areas the term 'environmental weeds' is used by some researchers (Randall 1996).

Weeds invade various types of lands such as fallow, agricultural, plantation, disturbed areas, and natural forests. Although they apparently invade areas cleared of vegetation faster (Appleby 1998) they also invade areas rich in species (Wiser *et al.* 1998). The invaders often compete with and displace native species (Randall 1996). Their impact on the biodiversity, biomass and productivity may result in alterations of the population and community structure of native ecosystems and may lead to local extinction of some native species (Elton 1958, Mooney and Drake 1986, Pimm and Gilpin 1989). Invasion by animal species is also known to have such impacts in population and community (Zaret and Paine 1973, Lodge 1993, Vander Zanden *et al.* 1999). Weed colonies are also known to alter the soil characters and cause major changes in composition of microfloral and microfaunal communities in the soil.

Weeds cause tremendous losses to agricultural production worldwide. According to De (1995), out of 30000 species of weeds in the world, 18000 cause serious losses. They interfere with man's utilization of land and water in different ways such as increasing the cost of cultivation and reducing quality of crops. The cost of tillage operations comes to around 10% of the expenses for raising a crop of which more than 50% is required for only controlling weeds (De 1995). In 1992, loss due to weeds in USA and Canada was estimated as US $ 4.1 billion with an estimated loss exceeding US $ 19 billion if herbicides were not used (Bridges 1992). India loses more than 13 million tons of food grain annually (Sen 1981) at a cost of Rs. 1980 to 2800 crores due to weeds (Sahoo and Saraswat 1988, Mukhopadhyay *et al.* 1992).

In India, the extent of yield reduction caused by weeds in different cropping system varies widely. In some field crops, annual yield losses may reach up to 80%. 10 to 86% reductions in soybean production due to infestation of weeds in the country are widely reported (Tiwari and Trivedi 1985, Muniyappa *et al.*

1986, Singh *et al.* 1986, Singh and Singh 1992). Similar drastic reduction due to weeds in sorghum is also widely documented (Hosmani 1975, Bhade and Nalamutar 1981, Lopez and Goleto 1983, Ali and Sankaran 1984). 12 to 83% of potential loss due to weeds in sugarcane is reported by many authors (Mani 1968, Singh *et al.* 1983, Chauhan 1988). Nutsedges (*Cyperus rotundus* and *C. esculenthus*), considered among the world's worst weeds (Ray 1975), cause severe loss in yields; 65.6% in bajara and 45% in sesamum (Sen 1977). Turner (1985) reported that *Cyperus rotundus* decreased yield of sugarcane by 85% and 83% in heavy and light soils respectively. In groundnut, yield reduction in the order of 20 to 90% is reported due to weeds (Brar *et al.* 1980, Yaduraju *et al.* 1980, Kulandaivelu and Sankaran 1985, Praveen *et al.* 1987 and Ali and Rao 1990). Sarswat *et al.* (1993) noted 18-76% yield-loss in oil seed crops due to weeds. Weed accounts 10 to 97% yield-reduction in rice (Mani 1968, Shetty 1973, De 1981, Prasad *et al.* 1988 Reddy and Gautam 1993, Hassan and Rao 1993, Saxena and Vaishya 1993). In Maize, yield reduction due to weeds ranged from 29 to 74% (Mani 1968). Prakash *et al.* (1989) and Kondap *et al.* (1980) reported 50% reduction in green gram due to inadequate weed management.

Loss due to aquatic weed, *Eichhornia crassipes* in Bengal was estimated to be around Rs. 11 crores. *Eichhornia* and *Salvinia* have invaded agricultural plots and interfered with crop production (Mitchell *et al.* 1980, De 1995). In Orissa, Philipose *et al.* (1970) indicated that 30-40% of ponds, 60-75% of small lakes and reservoirs, and 90-95% of swamps are infested by aquatic weeds. In Andhra Pradesh severe infestation of aquatic weeds cause serious damage to rice fields (Chandra Singh and Rao 1976). In Rajasthan 5000 acres has been made useless because of submerged aquatics invasions.

Apparently, a large number of studies have examined plant invasions in agricultural fields in India. However, no comparable attention is given to this aspect in natural ecosystems, which are the pristine repositories of our natural biodiversity. India, for its geographical, altitudinal and climatic diversity, is one of the biodiversity-rich countries (Sastry and Sharma 1991, Sathishkumar 1991, Nair 1991, Khoshoo 1995, Nayar 1996, Hajra and Mudgal 1997). Two of the 18 biodiversity 'hot-spots' in the world are situated in the country, the one being Western Ghats and other Eastern Himalayas (Khoshoo 1995, Chatterjee 1995). Nilgiri Biosphere reserve (NBR), extending about 5520 km^2 covers various vegetation types of Western Ghats, such as evergreen, moist and dry deciduous forests, scrub jungles, sholas and grasslands (Bist 1999). It is estimated that 20% of angiosperms, 15% of butterflies and 23% of vertebrates recorded in India excluding the marine species, are found in the NBR (Nair and Daniel 1986). Eighty percent of flowering plants reported from Western Ghats are found in NBR (3182 species), out of which 82 species are endemic to the area (Nair and Daniel 1986). Total 175 species of orchids in 60 genera are recorded from here, out of which 85 species are confined exclusively to it (Mohanan and Balakrishnan 1991). Of the 285 species of vertebrates endemic to Western Ghats, 156 are found in NBR (Smith 1935, Whitaker 1965, Prater 1965, Ali and Ripley 1983, Swengel 1991, Daniels 1993).

As indicated earlier there are a very few studies on ecology of weeds in natural vegetations in India. Rao (1920) had conducted a survey of *Lantana camara* from 1916 to 1919 on an all India basis, but no such survey is known since then. Ecological studies on *Chromolaena odorata, Ageratina adenophora* and *Mikania micrantha* were carried out in north eastern India by Yadav and Tripathi (1981), Dev and Ramakrishnan (1987), Saxena and Ramakrishnan (1984) and Swamy and Ramakrishnan (1988). However, such work in other areas in India is rare (Muniappan and Viraktamath 1993). Tadulingam and Venkatanarayana (1932) published a detailed account of 108 weed species of the plains of Madras presidency. Later Mudaliar and Rao (1955) added 64 more species, revising the above publication. In 1980, Nair *et al.* (1980) published a checklist of the weed flora of South India. Some of the weedy species reported from South India are given in appendix 1.

As mentioned earlier, in spite of exhaustive ecological investigations in NBR in recent years sufficient attention was not given to weed colonization. However, preliminary investigation indicates that the biodiversity of natural vegetation is facing threat from weeds. Hence, the present study was undertaken primarily aiming at documentation of plant invasions from an ecological point of view in select natural forests in Nilgiri Biosphere Reserve in Western Ghats.

1.1 Objectives

The objectives of the study were to

1. Document distribution of major invading plants in various vegetation types,
2. Study the seasonal variations in population and growth of select species,

3. Examine the phenology and ecology of select species,

4. Study the impact of weeds on native vegetation, and

5. Examine the relation between human disturbance and weed invasion.

These objectives were based on the following hypotheses,

1) Weed invasion poses serious threat to the original floral species composition in various habitats of NBR, 2) The weedy species show wide ecological amplitude enabling them to exploit wide ranges of environment, and 3) Invasion by weeds in specific habitats is influenced by human activities.

Chapter II

2 WEED ECOLOGY - A REVIEW.

2.1 Weeds: definition and classification

Weed is a general term for any troublesome or otherwise undesirable plant, which is usually inadvertently introduced and grows without intentional cultivation (Herbert 1962). According to Encyclopaedia Americana (1962) weed is a plant growing out of place, where it is not wanted because it is taking the place reserved for something else. More or less closely similar definition is accepted by National Academy of Sciences, Washington (1971), Gupta and Lamba (1978), Rao (1983) and Indian Society of Agronomy (1987). Crafts and Robbins (1973) proposed a more realistic definition of the weeds as "plants, out of place, unwanted, not useful, often prolific and persistent, competitive, harmful and even poisonous and interfere with agricultural operations, increase labour, add to costs, reduce yields and detract from the comforts of life".

A variety of classifications based on various criteria are proposed for weeds. A brief discussion of such classifications is given here. According to their life cycle, weeds can be annuals, biennials or perennials. Based on their association with human habitations they are classified as obligate weeds and facultative weeds (Zohary 1962). Those found only in association with man and never in wild are obligate weeds. While those that grow both in wild (in primary habitat) and in association with man in cultivated fields are facultative weeds. According to their origin, weeds can be called as 1) alien (foreign in origin) 2) apophytes (indigenous to a country). Many of them introduced by man are known as anthrophytes. Weeds are also classified according to stem character, those having aerial stem (herbs, shrubs, bushes or woody species) and those having sub aerial stem with storage organs (nuts or rhizomes). Both dicot and monocot plants are seen as weeds. Weeds can be also classified according to their soil preference; some plants prefer alkaline soil and some acidic soil (Table 2.1).

Table 2.1 Classification of weeds

Classification based on		**Example**
Life cycle	Annuals	*Argemone mexicana*, *Tephrosia purpurea* *Chenopodium album*, *Phalaris minor*, *Eleusine indica* and *Avena fatua*.
	Biennials	*Daucus carrota* and *Zingiber casumunar*
	Perennials	*Lantana camara, Cynodon dactylon* and *Imperata cylindrica.*
Association with man	Obligate	*Convolvulus arvensis, Phalaris paradoxa, Amaranthus hybridus, Chenopodium murale* and *Anagallis arvensis.*
	Facultative	*Argemone mexicana, Euphorbia dracunculoides* and *Indigofera cordifolia.*
Origin	Alien	*Argemone mexicana, Parthenium hysterophorus, Eichhomia crassipes, Chromolaena odorata* and *Lantana camara.*
	Apophytes	*Acalypha indica, Sida* spp. and *Cassia tora.*
Stem characters	Herbs	*Chenopodium album* and *Eclipta alba.*
	Shrubs	*Abutilon indicum* and *Lantana camara.*
	With storage organs	*Cyperus rotundus, Inula indica* and *Colocasia antiquorum.*
Habitat	Terrestrial	*Lantana camara, Sida acuta and Cassia tora.*
	Aquatic	*Pistia stratiotes, Eichhomia crassipes, Potamogeton pectinatus* and *Vallisneria spiralis.*
Soil preference	Alkaline	*Cressa cretica* and *Sporobolus diander.*
	Acidic	*Rumex acetosella* and *Pteridium aquilinum.*

(Sen 1981, De and Mukhopadhyay 1984, De 1995).

2.2 Introduced weeds

Species which have originated through evolution and natural selection in the particular region, are called native or indigenous, while those species which have not originated in the region but have immigrated from elsewhere, are known as alien, exotic, non-indigenous, adventitious, neophyte, introduced or migrant (Mack 1985, Saxena 1991). Exotic weeds are very vexatious and aggressive than the indigenous ones. Many of them establish self-sustaining population outside their native range (Lodge 1993). According to Saxena (1991), 40% of the species in the Indian weed flora are introduced. A successful invasion by exotic species is because of the similarity of the original habitats of exotics and the new habitats in climatic and edaphic conditions (Holdgate 1986) and absence of their competitors and predators in the new location (Pimm and Gilpin 1989).

There are over 2000 species of non-native plants in the United States of America, many of which cause significant economical and ecological damage (Anonymous 1993). Since European settlement, 1500 - 2000 species of plants have been introduced in Australia. Over 200 plant species are considered noxious weeds in one or more states of Australia and many of them are environmental weeds (Humphries *et al.* 1991, Parsons and Cuthbertson 1992). In US and Australia many invasive plant species are found to have the ability to spread over large areas and threaten the natural ecosystems. Still plant introduction continues at an alarming rate (Anonymous 1993). In India and other countries plant invaders successfully colonise open habitats, created by a high degree of disturbance (Crawley 1987, Ramkrishnan and Vitousek 1989, Hobbs 1989, DeFerrari and Naiman 1994). Invaders cause change in disturbance regimes, which profoundly alters the composition and succession of the community and affects the ecosystem development (Mack and D' Antonio 1998).

Many exotic weeds in India (Table 2.2), were introduced intentionally for agricultural, forestry, ornamental and other purposes. A few were introduced accidentally through transportation by people and because of negligence. *Parthenium hysterophorus, Phalaris minor* and *Avena fatua* were introduced with imported seeds. *Chromolaena odorata, Mikania micrantha, Erigeron* spp., *Ageratum conyzoides, Lantana camara, Parthenium hysterophorus,* all of tropical American origin are well adapted to manmade habitats. Many of these species have also invaded areas far from human habitations (Azeez *et al.* 1999) and have expanded at an alarming rate during the last few decades.

Table 2.2 Common exotic weeds in India

Species	**Native to**
Acanthospermum hispidum	South America
Ageratina adenophora	Central America
Ageratum conyzoides	Tropical America
Argemone mexicana	West Indies
Bidens pilosa	South America
Chromolaena odorata	Subtropical and tropical America
Croton bonplandianum	South America
Eichhornia crassipes	America
Eupatorium riparium	Tropical America
Eupatorium repandum	South America
Galinsoga parviflora	Tropical America
Lantana camara	Subtropical and tropical America
Lippia germinata	South America
Mimosa invisa	South America
Mikania micrantha	South America
Mimosa pudica	South America
Opuntia dillenii	South America
Parthenium hysterophorus	West Indies & North Central America
Prosopis juliflora	Central America
Synedrella nodiflora	West Indies
Tridax procumbens	Central America
Xanthium strumarium	South America

(Sen 1981, Saxena 1991, Matthew 1991, Muniappan and Viraktamath 1993).

Parthenium hysterophorus, a native of West Indies and North Central America was introduced with food grain imports. Within a few decades, it became a serious weed in the country. According to Rao (1956), it was first time occurred in the western part of Peninsular India in 1956, while according to Bennet *et al.* (1978) the species was reported since 1810 in different herbarias. Towards the end of 1970s it had spread all over the country and became a dominant weed (Rao and Suryanarayanan 1979). The weed has spread all over India, covering approximately five million hectaresof land. It has taken over many cultivated areas. *Parthenium hysterophorus* is more successful in open habitat where native vegetation is severely damaged. It is a less aggressive invader in natural forest because of its small size, limited competitive ability, and is mostly incapable of colonising areas with thick vegetation.

Because of railways and steam-ships, many weeds got entry in India. *Acanthospermum hispidum*, *Alternanthera echinata* and *Croton bonplandianum,* native to America and introduced via surface transport, grow abundantly in south India. *Acanthospermum hispidum* was first noticed near a railway station (Tadulingam and Venkatnarayana 1932). *Croton bonplandianum* is found mostly along the east-coast railway. *Flaveria australasica* first appeared near ports of East Coast in south India. Some inadvertently imported common weeds are; ornamentals (*Saponaria, Linaria, Polygonum, Eichhornia, Salvinia* and *Lantana*), forage and grazing plants (grasses) and kitchen garden herbs (*Brassica* and *Portulaca*).

Lantana camara is a native of tropical and subtropical America. It was introduced as an ornamental plant to Asia and Africa in early 1800s (Muniappan *et al.* 1996). Today this aggressive, fast growing, drought tolerant plant is ranked among the ten most troublesome weeds in the world (Holm *et al.* 1977). *Lantana camara* has established as a weed throughout the tropics and sub tropics from the USA and the Mediterranean in the North to South Africa and the northern tip of the New Zealand in the south (Swarbrick *et al.* 1995). *Lantana camara* was first introduced in Calcutta in 1909 as an ornamental plant. It forms monospecific stands along the road sides, fence lines and waste lands, disturbed forests, pastures and plantations (Thaman 1974, Waterhouse and Norris 1987). On invading disturbed forests and plantations the species dominates the under storey.

Chromolaena odorata, a native of subtropical and tropical America from Florida to Argentina is commonly found in areas below 1000 meters altitude except undisturbed rain forest (Chevalier 1949, Waalkes 1953, McFadyen 1989, Gautier 1993). It is considered as a noxious weed in 23 countries of the world including India (Olaoye 1986, Torres and Paller 1989, Waterhouse 1994, Slaats *et al.* 1996). It has infested millions of hectares of natural grazing lands in Asia and Africa. In Asia it is a major weed of the pasture and plantations and disturbed forests (Ivens 1974, Soerjani *et al.* 1975, Ambika and Jayachandra 1980, Leggitt 1983, Wu *et al.* 1984, Olaoye 1986, McFadyen 1995, McFadyen 1996, Slaats *et al.* 1996). It was introduced in India in 1840s, probably via the Botanical Garden in Calcutta (McFadyen 1989, Gautier 1992). From Calcutta, the species spread east into Assam and Myanmar (Burma), and then to east and southeast through Indonesia and Indochina (McFadyen 1989). It has become a serious menace specifically in the southwest and northeast warm humid regions of India within a period of 50-60 years (Saxena 1991). In Kerala, it was accidentally introduced via clothings of soldiers of II World War returning from Bengal (Maheshwari 1962, Muniappan and Viraktamath 1993). Its invasion is responsible for shifting entire villages in some areas of India (Holm *et al.* 1977). It was first noticed in the Philippines in the late 1960s (Pancho and Plucknett 1971). It came to the West Africa in the 1930s (Prasad *et al.* 1996), to Guam in 1963 (Marutani and Muniappan 1991), to Marianas in 1973 (Fosberg and Falanruw 1973) and to East New Britain in 1982 (Henty and Pritchard 1982). In all the affected countries it has spread rapidly and has been a serious weed of plantations, disturbed forests and pastures (Ivens 1974, Soerjani *et al.* 1975, Ambika and Jayachandra 1980, Leggitt 1983, Wu *et al.* 1984, Olaoye 1986, Slaat 1996, McFadyen and Skarratt 1996, Gautier 1996).

Argemone mexicana, commonly known as Mexican-poppy was introduced in India, from Mexico and is a weed of fallow land. It competes well with other species. *A. mexicana* and *A. ochroleuca* are two closely related exotic species distributed throughout the Indian subcontinent (Ramakrishnan 1972).

Prosopis juliflora was introduced in India in 1870 from Mexico. This species introduced in Rajasthan, due to its sand stabilisation qualities, currently is invading fertile agricultural land and is very difficult to control (Singh *et al.* 1999). *Mimosa invisa,* native of South America, invades vacant land as well as agricultural field. It does not invade closed forests. This species forms thickets that are impenetrable. *Bidens pilosa* (known as Spanish needle or beggar's tick), of neotropic origin, has spread in coffee plantation and roadsides. *Mikania micrantha,* commonly known as 'mile a minute plant', is also of neotropical origin. This species has become a serious problem species in many natural forest patches in central and south Kerala (Muniappan and Viraktamath 1993, Azeez *et al.* 1999, Sankaran and Sreenivasan 1999)

Ageratina adenophora, known as crofton weed, is a native of Mexico. In India it is mainly observed in the forests of Himachal Pradesh, foothills of Himalayas, north-east India and the Western Ghats. It prefers humid temperate climate. It invades vacant lands, roadsides and disturbed forests, grows rapidly, and produces many shoots. *Ageratina adenophora* is now very common in higher elevation areas with cooler temperature and high rainfall (Saxena 1991).

Eichhornia crassipes, the aquatic weed, grows in a wide range of habitats and exhibits phenotypic plasticity. It is native of America and has spread extensively into subtropical parts of USA, Portugal in Europe, tropical Australia, Africa and Asia, wherever climatic conditions are comparable to the native sites (De 1987). It was introduced in eastern India as an aquatic ornamental flowering plant. It is a most troublesome aquatic weed spreading all over country because of its fast vegetative multiplication. It is a serious pest of Bengal and is known as a Terror of Bengal. *E. crassipes* has choked the canal system of Bhakra, Rajasthan and many other canals and water ways. It multiplies by stolon and seeds. It can produce up to 5000 seeds per plant. The seeds sink to the bottom and remain viable for at least 15 years (Chandra Singh and Rao 1976). It has upright leaves serving as sails helping in its distribution. Petiole is long, round and bladder shaped which helps in keeping the plant self-buoyant. It contaminates drinking water. Many water bodies are so thickly infested with this weed that they resemble a green terrestrial field.

Sub optimal conditions may adversely affect native species but help in invasion of an exotic species. *Eichhornia crassipes* has selective advantage over native *Pistia stratiotes* in the Asian tropics, which is related to their pH tolerance. *Pistia* has a narrow tolerance range with optimal growth at pH-4, while *Eichhornia* has wider ecological amplitude with optimal growth in close to neutral water. Growth of *Pistia* was more in nutrient rich water, while *Eichhornia* grows better and rapidly multiplies in both nutrient rich as well as poor waters (Chadwick and Obeid 1966).

Alien species like *Xanthium strumarium*, *Parthenium hysterophorus, Argemone mexicana*, *Ageratum conyzoides* and *Erigeron linifolius* usually dominates highly disturbed and artificial landscapes. Species such as *Citrullus vulgaris* and *Canabis sativa,* which were deliberately introduced, have started to grow wild.

2.3 Adaptations

Weeds have unique capability for adaptation. They can survive in varied environmental conditions and have high potential to adapt to changed situations. Most of the weeds produce large number of seeds, which can remain dormant in unfavourable conditions. They have ability to grow rapidly, multiply fast under stress conditions, and can compete successfully with native vegetation. According to Saxena (1991), fast growth and multiplication through an effective utilization of environmental resources in disturbed habitats are the key strategy characteristics which contribute to success of plant invaders. Weeds compete with other species mainly for space, nutrients, light and water. Most of the invaders are r- strategist. This is one of the reasons of their successful invasion and establishment (Ramakrishnan 1991). Seed polymorphism, existence of ecotypes and ecological races are some of the other features, which help weeds to cope with varying microenvironment (Table 2.3).

Table 2.3 Weeds and their adaptations

Adaptations	Weedy species
Adaptations to various environmental changes	
Drought	
Small leaves, spines, deep root system	*Prosopis juliflora*
Coiled root system	*Convolvulus microphyllus*
Stoloniferous under ground stem and tuber	*Cyperus* spp. *Cynodon dactylon* *Eleusine compressa*
Tolerance to hot and dry conditions	*Trianthema portulacastrum* *Portulaca quadrifida* *Cyanotis cucullata*
Plasticity and adaptability to environmental extremes	*Chromolaena odorata* *Lantana camara* *Parthenium hysterophorus*
Photoperiodically and thermoperiodically neutral	*Parthenium hysterophorus*
Capacity of resprouting after burning	*Lantana camara* *Chromolaena odorata*
Allelopathy	
Allelopathic to other plants	*Parthenium hysterophorus* *Argemone mexicana* *Prosopis juliflora* *Mikania micrantha* *Chromolaena odorata*
Morphological adaptations	
Imitating general appearance of crop plant	*Phalaris minor* *Avena fatua*
Special devices of armatures, such as spines, prickles, bristles, stinging hair and glandular hair.	*Mimosa* spp. *Bidens pilosa*

	Tribulus terrestris
Ecotypic and Phenotypic plasticity	*Lantana camara* *Ageratina adenophora*
Multiplication	
Both vegetative and reproductive multiplication	*Cenchrus setigerus* *Mikania micrantha*
Numerous seed production	*Argemone mexicana* *Chromolaena odorata* *Parthenium hysterophorus* *Phalaris minor* *Ageratina adenophora* *Mikania micrantha*
Rooting at nodes	*Citrullus colocynthis* *Ipomoea pescaprae*
Presence of adventitious roots from aerial node	*Eriocaulon* spp. *Cyperus* spp. *Sphaeranthus* spp. *Cynodon dactylon*
Seed dispersal	
Anemochory (by wind)	
Seeds having pappus	*Chromolaena odorata* *Pulicaria* spp *Echinops* spp.
Seeds having fine hairs	*Calotropis* spp. *Asclepias* spp. *Pergularia* spp.
Seeds can move on soil surface	*Aristida* spp. *Tragus* spp. *Cenchrus* spp.
Extremely minute seeds can be easily blown by wind.	*Orobanche* spp. *Striga* spp.
Exozoochory (seeds get attached to animals skin and get dispersed)	
Seeds having hooks, spines and stiff hair.	*Bidens pilosa* *Tribulus terrestris* *Achyranthes aspera* *Aristida funiculata* *Triumfetta rotundifolia* *Tragus racemosus* *Xanthium strumarium* *Alternanthera echinata*
Endozoochory	
Attractive to birds	*Loranthus* spp. *Viscum* spp. *Abrus precatorius* *Lantana camara* *Croton bonplandianum*
By field rats and rabbits	*Cenchrus setigerus* *Dactyloctenium aegyptium*
Having explosive, twisting mechanism for seed dispersal.	*Ruellia prostrata* *Ruellia patula*

	Clitoria ternatea *Tephrosia* spp. *Argemone mexicana*
Seed dormancy and viability	
Having seed dormancy and viability	*Cenchrus* spp. *Dactyloctenium* spp. *Indigofera* spp. *Lathyrus* spp. *Heliotropium* spp. *Citrullus* spp. *Chenopodium album*
Resistance to fire	*Crotalaria medicaginea*
Parasitism	
Stem parasites	*Loranthus* spp. *Cuscuta* spp.
Root parasites	*Striga* spp. *Orobanche* spp.
Adaptations to escape from control measures	
Deep penetrating root system and storage organs to escape chemical treatment and ploughing	*Imperata cylindrica* *Sorghum halepense*

(Sen 1981, Rao 1983, De 1995)

2.3.1 Adaptations to various environmental changes

As weeds have large ecological amplitude, they are capable of multiplying and flourishing even in changing environment. Weeds are tolerant to adverse edaphic, climatic and biotic factors as compared to other plants and crops. They bear certain special attributes, which help in their perpetuation, multiplication, dissemination, stabilisation and overall adaptation (Table 2.3, De 1995).

2.3.1.1 Drought

In order to tide over drought conditions many species have modified morphology. Reduction in leaf size, mucilaginous and hairy stems, rapidly spreading and deep penetrating root system and physiology which maintains higher osmotic potential, translocation, storage and photosynthetic pathways are common adaptations (De 1995). Weeds are mainly C4 plants or under drought change to C4 pathway to achieve higher efficiency in photosynthesis (Sen 1981). Because of restricted availability of water, many weeds in arid regions complete their seed germination and establishment in a brief span. Many of them bear special structural modification to curtail water loss during drought, such as thick cuticle, sunken stomata and waxy coating (Mohan Ram and Gupta 1997). In arid regions like deserts in Rajasthan, *Prosopis* and other weed species compete with other plant species for soil moisture. *Prosopis juliflora,* an aggressive, fast spreading and highly adaptable species for all types of soils including saline alkali soils, is seen almost everywhere except cold deserts and stagnant water areas (Troup 1983, Vimal and Tyagi 1984, Singh 1994, Singh *et al.* 1999). It is also a halophyte as it can tolerate high soil salinity (Felker 1981). *P. juliflora* has high nutrient uptake capacity and tolerates temperatures up to 46°C. Under dry situation, its roots can reach to 7-18m depth. In certain situations, the roots are found even up to 50m depth and lateral root up to 48m depth (Prajapati 1971). *Prosopis* also shows other adaptations to arid conditions such as small leaves and spines. In weeds like *Convolvulus microphyllus* root system is coiled to increase surface area and length for increased absorption efficiency. Arid zone plants such as *Boerhavia diffusa* and *Crotalaria burnia* have tapering main root and limited number of laterals. Grasses such as *Cynodon dactylon, Cyperus* spp. and *Eleusine compressa* are known to survive under very dry conditions. Leaves of these grasses may get dried up but the thick roots, swollen stoloniferous under ground stem and tuber remain alive to regrow in favourable conditions.

Weeds have a wide range of moisture requirement for seed germination. Weed species efficiently utilise available moisture. Many weeds are tolerant to crowding. They have higher relative frequency and density compared to other plants in the community (De 1995). Some weed species either endure, escape or evade unfavourable environmental changes by adopting various dormancy forms (De 1995). Many weeds have thick cuticle, cork and bark as defence against fungi, insects and adverse climate. Weeds such as *Parthenium hysterophorus, Lantana camara* and *Chromolaena odorata* are not much affected by soil, climate and other environmental conditions and have remarkable plasticity and adaptability to environmental extremes except extreme cold. *Chromolaena odorata* shows strong climatic adaptations and competes well with native vegetation. It dries during summer but clumps remain alive to sprout after the first rain. However, *Chromolaena odorata* can not survive in shady vegetation in dense undisturbed forests.

When certain weeds migrate from moist to dry area, they exhibit some changes e.g. *Echinops echinatus* and *Convolvulus arvensis* are winter season weeds of Rabbi crop in north India but they have established well in arid zone by germinating in rainy season. In many weeds of Indian deserts, growth of shoot stops temporarily for certain duration after producing first few leaves but root system penetrates deep down into soil and absorbs moisture from deeper layers. After establishing a deep root system, they can compete with other plants and even if shoot is damaged, young plant can sprout vigorously from well-established roots (Sen 1981). In dry lands, weeds exhaust the soil moisture,

En.8.6

putting the crop in stress. Weeds with radicoid forms easily escape drought, fire, soil erosion and man made modifications such as repeated cultivation, ploughing and irrigation (De 1995). Some weeds such as *Trianthema portulacastrum, Portulaca quadrifida* and *Cyanotis cucullata* can survive in hot dry conditions for many days.

2.3.1.2 Light

Some weeds like *Parthenium hysterophorus* are photoperiodically and thermoperiodically neutral (Sen 1981). Many of them can sustain themselves even at ten percent of incident light (sciophytes).

2.3.1.3 Fire

Lantana camara burns rapidly even when green and creates additional favourable sites for own expansion. *Lantana, Chromolaena* and *Mikania* regenerate more profusely after fire, and suppress other native species. *Chromolaena odorata* can resprout after burning and converts the forest in to thickets by its vigorous growth and sprawling habit (Rouw 1991).

2.3.2 Allelopathy

Allelopathy is one of the important strategies that increase the competitive ability of a species (Fischer *et al.* 1994, Langenheim 1994). Molisch (1937) suggested the term allelopathy for expressing the detrimental effects that one plant species has on another through the formation of chemical retardants. The concept of allelopathy was further developed by Bonner (1950), Bonner *et al.* (1959), Grummer and Beyer (1960), Evenari (1961), Tukey (1969), Sen *et al.* (1969), Muller and Chou (1972), Rice (1974), Roy (1974), Putnam and Duke (1978), Achhireddy and Singh (1984) and Sahid and Sugau (1993).

A broad-spectrum of growth inhibitors is found in different parts of the weeds. They liberate these metabolites through the process of weathering, leaching, exudation or volatilisation. *Parthenium* contains allelochemicals such as caffeic, vanillic, fernlic, chlorogenic and anisic acids and sesquiterpene, lactone and parthenia. Seed leaching in *Parthenium* inhibits germination of other seeds. Its association deleteriously affects seedling growth and root proliferation of wheat, because of allelopathic syndrome (Sen 1981). Toxic compounds such as chlorogenic, P-commaryquinic and gentisic acids produced by Eucalyptus suppress under growth under the plantations (Del Moral and Muller 1970) but, this suppressive effect is less apparent under high rainfall because of its dilution effect (Ramakrishnan and Vitousek 1989). *A. mexicana* has allelopathic chemicals,which inhibit growth of other plant species (Sen 1980). Leaf litter of *Prosopis juliflora* inhibits germination of black gram and sorghum due to its allelopathic phenolic compounds. Leaf extract and root extract of *P. juliflora* reduced the germination percentage of *Parthenium hysterophorus* (Chellamuthu 1994). *Mikania micrantha* is allelopathic to other plants. It climbs as a vine on other plants and smothers them. *Chromolaena odorata* and *Lantana camara* are known to be highly allelopathic to other plants (Mersie and Singh 1987, Prasad and Srivastava 1991, Sahid and Sugau 1993, Gentle and Duggin 1997a).

2.3.3 Morphological adaptations

Some weeds have developed the special measures of defence by imitating general appearance, colour, shape or typical feature of other crop plants e.g. seedlings of *Phalaris minor* and *Avena fatua* are similar to wheat and barley seedling, making it very difficult to eradicate them from the field. Some weeds bear special devices of armature such as thorns, spines, prickles, bristles, stinging hair and glandular hair. For example *Mimosa invisa,* a giant sensitive plant, is a fast growing scrambler having four to five rows of sharp prickles and armed stems, which protects them from destruction by animals and human beings.

Aquatic weeds shows morphological adaptations such as aeranchymatic cells, absence of stomata or functionless stomata on the lower surface of leaves, breathing roots, absence of root hair and root cap instead of root packets and even absence of roots.

2.3.4 Ecotypic and phenotypic plasticity

Plant invaders have wide ecological amplitude through extreme phenotypic plasticity or due to ecological races adapted to specific habitat (Ramakrishnan 1991). In southern India, *Lantana camara* covers an altitudinal range up to 2000m altitude in the Palni hills, because of its phenotypic plasticity (Matthew 1972). *Ageratina adenophora* an exotic weed in Meghalaya in north-east India, which occurs between 550-1960m altitude shows both plasticity and ecotypic variations (Dev 1981). Some weeds have ecotypes with differential resistance to insect attack and varied nutrient absorbing capacities (Cooley and Martin 1978).

2.3.5 Multiplication

Most weeds have great reproductive capacity and massive potential to recoup. Perpetuation of weeds can be through either seeds or vegetative propagules. In unfavourable environmental conditions adult mother weed plants produce propagules which are resistant to extreme adverse conditions, before their death and maintain their survival (De 1995). Weeds have fast regenerating, restoring, rejuvenating and resurging capacities of both roots and shoots. They are quickly responsive to favourable environment after passing through stressful conditions. Some weed species can produce few million seeds per square meter of field, and enrich the weed-seed population in soil. Some times number of seeds produced by weed per unit area are hundred times more than crop plants (De 1995). Seed production in *Chromolaena odorata* is prolific; the achenes bear a small stiff pappus and are wind dispersed. In Sri Lanka, it has been found that on an average, each plant produces 93,000 seeds (Weerakoon 1972). Seed output of *Argemone mexicana* is 476 per plant (Sen 1981). *Mimosa invisa* produces large number of seeds and they remain viable for a long period. Weeds such as *Pulicaria, Echinops* and *Parthenium* mostly propagate through seeds and a single plant is capable of producing more than 10,000 seeds. Those weeds which reproduce by vegetative method as well as by seeds, multiply enormously (De *et al.* 1986). For example, a successful weed in Indian desert, *Cenchrus setigerus,* regenerates by both seed and vegetative reproduction. *Parthenium hysterophorus* has invaded all over India in a very short period because of its fast vegetative multiplication and numerous seed production (Sen 1981). *Phalaris minor* can produce a number of mature seeds even after uprooting and heaping at the flowering stage (De 1995). Unlike exotic weeds belonging to Asteraceae, *Lantana camara* does not produce large number of seeds. It propagates by seeds, distributed by birds (Mishra and Mishra 1996, Balasubramanian *et al.* 1998) and animals and through hardy root suckers. *L. camara* is not as aggressive as *C. odorata*. In the Western Ghats, the *Lantana* is suppressed and replaced by *Chromolaena odorata* in due course in many locations (Matthew 1972) because aggressive invaders are known to monopolise the ecosystem (Saxena 1991). *Mikania micrantha* roots at nodes when it comes in contact with soil. It reproduces by seeds as well as clonal propagation. Some weeds germinate periodically and some of them germinate throughout the year. In weeds like *Citrullus colocynthis* and *Ipomoea pes-caprae* rooting at thick nodes helps multiplication of plants. Weeds like *Eriocaulon* sp., *Cyperus* spp., *Sphaeranthus* sp. *and Cyanodon dactylon* remains firm in the soil because of presence of adventitious roots from aerial nodes. Even after pulling or grazing a considerable part of the plant remains intact in the soil to regenerate quickly. *Echinochloa colonum* and *E. indica* can re-establish even if a single root is left in the soil.

2.3.6 Seed Dispersal

Seeds of weeds are dispersed by birds, animals, wind, water and by man and his activities. In agricultural fields weed seeds are disseminated by man through handling contaminated food grains, organic mulch, manures, tillage implements, soil and water. Most seeds remain unaffected in the digestive systems of animals and birds, and get dispersed easily through faecal matter, e.g. *Cassytha, Loranthus, Opuntia* and *Lantana*. Hardy seeds of *Trianthema portulacastrum* remain unaffected in the alimentary canal of cattle and disperse through dung. Many weed-seeds are dispersed by birds. For example, seeds of *Loranthus* and *Viscum* stick to beaks of birds while eating fruits and carried by them, get stuck to branches of other trees when they clean their beaks on them. Seeds of *Croton bonplandianum* resemble beetles and may be picked by insectivorous birds and thrown away after finding them useless. Field rats, rabbits and ants help in seed dispersal of *Cenchrus setigerus* and *Dactyloctenium aegyptium* in deserts of Rajasthan. The seeds of weeds such as *Pulicaria, Echinops* and *Parthenium* possess pairs of wings or pappus and can be carried by wind to long distances (Sen 1981). Weeds like *Calotropis, Asclepias* and *Pergularia* of family Asclepiadaceae have fine hairs by which they float in the air and get carried for long distances. Parasitic weeds such as *Orobanche* and *Striga* produce extremely small seeds, which can be easily blown by wind. Downy seeds of grasses such as *Saccharum* and *Cenchrus* are also carried several kilometres by wind. Like other Asteraceae members *Mikania micrantha* and *Ageratina adenophora* produce numerous seeds, which are dispersed by wind. Some weed seeds have hooks, spines and stiff hair, which get attached to the fur of animals, shoes and clothing of people and disperse to a long distances, e.g. *Bidens pilosa, Tribulus terrestris, Achyranthes aspera* and *Aristida funiculata*. *Triumfetta rotundifolia*, *Tragus racemosus, Xanthium strumarium* and many other plants have hooks on the fruit coats or on bracts and are dispersed by sheeps and goats (Fischer *et al.* 1996). In

Alternanthera echinata, the perianth of the fruit is very flat and spine tipped, which sticks to shoes and tyres of vehicles and getcarried for long distances.

Many species of Acanthaceae like *Ruellia prostrata* and *Ruellia patula* have explosive mechanisms for seed dispersal. Fruits of these weeds have elastic valves, which spring back forcefully with a slight explosion on getting wet by rain and shoot out seeds to a long distance away from mother plant (Tadulingam and Venkatnarayana 1932). In *Clitoria ternatea* and *Tephrosia* spp. pods dehisce by sudden twisting and throw seeds to considerable distance to prevent shading by mother plant. In *Argemone mexicana* the capsule breaks at the top only by the short valves and numerous seeds inside the fruit scatter over a large area, when the branches shake in the wind.

2.3.7 Seed dormancy and seed viability

Seed dormancy, delayed germination, longevity, and viability of buried seeds for years, help in reproduction and completing the life cycle of weeds year after year. Dormancy is a state of suspended development of seed. Hard seed coat prevents entry of water, light and gas and helps in delaying the germination until suitable environmental conditions occur. Dormant weed seeds are more likely to escape chemical sprays. Many weeds belonging to families such as Fabaceae, Malvaceae, Tiliaceae, Cucurbitaceae, Convolvulaceae and Poaceae show seed dormancy due to hard seed coat, which is impermeable to water. In *Amaranthus retroflexus, Alisima plantago* and *Ipomoea aquatica*, although seed coats are permeable to water, embryo expansion is resisted. Some weed seeds contain inhibiting chemicals such as coumarin, ferulic acid, parascorbic acid, dehydracetic acid and ammonia to delay germination. Many weed seeds can remain viable for ten to forty years. Weeds of Poaceae (e.g. *Cenchrus, Dactyloctenium*), Fabaceae (*Indigofera, Lathyrus*), Boraginaceae, (*Heliotropium, Arnebia*) and Cucurbitaceae (*Citrullus, Mukia*) show seed viability varying from 1 to 15 years (Sen 1981). Seeds of *Chenopodium album* are reported to germinate after remaining buried for 20 to 40 years. Generally, low temperature promotes germination of weeds while high temperature inhibits it. However, weed-seeds of Indian desert germinate only after passing through high temperature of 60 to 70^{o} C during day and low temperature at night, following rainy season. Seeds of *Crotalaria medicaginea* resist even fire. Even after burning in weed infested field, after rains, profuse germination is seen.

2.3.8 Nutrient uptake efficiency

Weeds produce a higher biomass than crop plants per unit area and time. Many of them are capable of absorbing higher amount of N, P and K and other plant nutrients than crop plants. Weeds assimilate six times N, eight times P_2O_5 and three times K_2O, than sugarcane crop at 35 days after planting (Sankaran 1988). Verma *et al.* (1983) estimated N losses up to 64.4 kg/ha in the unweeded control plot within a period of 85 days after planting. Vengris *et al.* (1953) noted that because of high nutrient uptake capacity of weeds, maize yield reduced up to 51-56%. In Indian arid zone, weeds compete with crop for nitrogen, where soil is very poor in nitrates (Sen 1981). Shetty (1973) observed that 65% of N, 62% of P and 65% of K were shared by weeds in direct sown rice crop. A significant negative relationship was observed between N uptake by the crop and weed (Raja 1985, Cinnamuthu 1990). Bai *et al.* (1992) reported that weeding had significantly increased N and P uptake in green grams. Superiority in nitrogen extraction from soil, along with an efficient retranslocation of nitrogen from senescing leaves, is one of the adaptations which enables *Lantana camara* to perform as an invasive species in different sites (Rawat *et al.* 1994).

2.3.9 Adaptations, which help weeds to escape from control measures

Many weeds escape from chemical treatment, as they have deep penetrating root system. Chemicals, which do not leach with water, can not reach down to the absorbing region of the roots. Even after applying adequate control measures some weed seeds escape, as all plants of a single species in a particular habitat do not germinate or grow or bear seed synchronously (De 1995). Changes in weed community in response to tilling are reported by Sans (1993) and Sans and Masalles (1992, 1995). Weeds such as *Imperata cylindrica* and *Sorghum halepense* hide their storage organs well below the plough layer so that they can regenerate even after ploughing the land. Ground stratum weeds escape the reaping and uprooting type of harvesting and produce large number of seeds during the post harvest period (De 1995).

2.3.10 Chemical defence against predators

Many weeds contain poisonous substances such as latex, alkaloids, irritating, bitter, or substances with bad odour that help to protect them from natural enemies (De 1995). *Lantana* is poisonous to domestic as well as wild animals (Swarbrick *et al.* 1995) and affects their liver on consumption. It contains poisonous chemical, lantadene, toxic to cattle and goat (Lal and Kalra 1960, Sastry and Mahadevan 1963). It promotes allergic skin reactions in sensitive individuals (Muniappan and Viraktamath 1993). *Lantana* also shows allelopathic potential to a number of crops (Sahid and Sugau 1993). This feature offers the species a selective advantage over palatable native species.

Ipomoea carnea, Lochnera pusilla, Crinum defixum and *Abrus precatorius* are poisonous to mammals. *Xanthium strumarium, Martynia annua* and *Asphodelus tenuifolius* affect the quantitative and qualitative products of livestock. After consuming weeds such as *Cleome viscosa* and *Paederia foetida,* milch animals produce bad flavoured milk. *Astragalus lentiginosus, Astragalus pubentissimus* and *Oxytropis sericea* cause abortion and congenital malformation in sheep and cattle. *Lupinus* sp. causes 'crooked calf disease'. After consuming fresh leaves of *Phalaris tuberosa*, cattle die within 6 hours. *Polygala klotzchii* causes gastro-enteritis and pulmonary haemorrhage in cattle. Fruits and seeds of *Xanthium strumarium, Triumfetta rotundifolia, Pupalia atropurpurea* and *Achyranthes aspera* entangle with the wool. Hooks of *Martynia annua* cause injury to hides. Weeds such as *Parthenium hysterophorus, Chenopodium album, Argemone mexicana* and *Heliotropium indicus* cause irritation, allergy and eczema to animals and labourers on contact. Skin rashes caused by *Parthenium* are slow to heal. Weeds such as *Mimosa pudica, Tribulus terrestris, Centipeda minima* and *Datura stramonium* cause wounds, headache, sneezing, giddiness and vomiting. *Datura stramonium* is a deadly poisonous weed. Consumption of plant or its seeds may cause death, disorder or permanent disability. *D. metel* contains alkaloids such as atropine and hyoscyamine, which are poisonous to human beings and animals. Pollen grains of certain weeds cause hay fever. *Rhus diversiloba, R. toxicodendron* and *R. vernix* are poisonous to touch and occasionally cause death after eating fruits, seeds and tubers. In the western USA, *Halogeton glomeratus* kills thousands of sheep every year. Horses suffer with throat ache after consuming barley mixed with *Euphorbia drancunculoides*. Seeds of *Withania somnifera* are poisonous, containing an alkaloid called somniferin (Table 2.4).

Table 2.4 Poisonous weeds and their effects.

Harmful effects	Weedy species
Poisonous to animals	*Lantana camara* *Ipomoea carnea* *Lochnera pusilla* *Crinum defixum* *Abrus precatorius*
Deadly poisonous	*Phalaris tuberosa* *Datura stramonium* *Halogeton glomeratus*
Poisonous to touch, poisonous tubers, seeds and fruits	*Rhus diversiloba* *R. toxicodendron*
Contains lantadene, poisonous to cattle	*Lantana camara*
Seeds contain poisonous alkaloid, somniferin	*Withania somnifera*
Contains poisonous alkaloid such as atropine and hyoscyamine	*Datura metel*
Causes wounds, headache, sneezing, giddiness and vomiting	*Mimosa pudica* *Tribulus terrestris* *Centipeda minima* *Datura stramonium*
Hazardous to human health	*Rhus radicans* *Rhus vernix* *Lolium temulentum* *Agrostemma githago*
Causes death, disorder or permanent disability	*Datura stramonium*
Affects quality and quantity of products of livestock	*Xanthium strumarium* *Martynia annua* *Asphodelus tenuifolius*
Affects flavour of milk of milch animals	*Cleome viscosa* *Paederia foetida*
Causes abortion and congenital malformation in sheep and cattle	*Astragalus lentiginosus* *Astragalus pubentissimus* *Oxytropis sericea*
Causes crooked calf disease	*Lupinus spp.*
Causes gastroenteritis and pulmonary haemorrhage in cattle	*Polygala klotzchii*
Fruits and seeds entangle with wool of animals and cause injury	*Xanthium strumarium* *Triumfetta rotundifolia* *Pupalia atropurpurea* *Achyranthes aspera* *Martynia annua*

Causes skin allergy, irritation, eczema to animals and labourers	*Parthenium hysterophorus* *Chenopodium album* *Argemone mexicana* *Heliotropium indicus*
Causes throat ache to horses	*Euphorbia drancunculoides*

(Tadulingam and Venkatnarayan 1932, Sen 1981, Rao 1983, De 1995).

2.4 Impact of weeds

2.4.1 Parasitism

According to Loomis and Wilson (1953), there are about 2500 species of parasitic flowering plants. Loranthaceae and Scrophulariaceae are the families with largest number of parasitic weeds. The commonly seen destructive genera are *Loranthus, Cuscuta, Orobanche* and *Striga. Loranthus* and *Cuscuta*, known as stem parasites,are seen on the aerial portions of the plants. *Orobanche* and *Striga* are root parasites. *Orobanche* causes damage to crops such as tobacco, tomato and brinjal. The economic losses in solanaceous crops due to *Orobanche indica* and *O. cernua* are to the extent of 5-10% in West Bengal, 15-20% in Maharashtra and Gujarat, 20-30% in Madhya Pradesh and 30-33% in Tamil Nadu (Sen 1986). Seeds of *Orobanche* are minute and very similar to tobacco seeds. *Loranthus* causes serious problem in Indian forest plantations especially of teak, casuarina and wattle. Wattle plantation in Nilgiris, southern India, is seriously affected by this parasitic weed. It attacks about 110 species of trees including *Tectona grandis* and *Acacia* spp. *Loranthus longiflorus* attacks *Mangifera* spp., *Albizia* spp., *Acacia* spp. and pomegranate. *Loranthus elasticus* prefers mango, cashewnut, orange and nutmeg as host plants. *Viscum monoicum* and *Viscum orientale* affect *Albizia* spp., *Pongamia* spp. and

Santalum album affects pomegranate. *Cuscuta* attacks lucerne, clovers, ipomoea and lagasca.

Striga angustifolia, a root parasite has come from south India to north India. It causes enormous damage to maize, sorghum and sugarcane in several states (Hosmani 1975). In western Indian desert, it has established on *Pennisetum typhoides* (bajra), the main crop under rainfed agriculture. In Kerala loss by this weed was estimated to be about 80%. *Balanophora* causes serious damage to coffee. Parasitic weeds badly affect the plant growth and may even kill the host plants.

2.4.2 Competition with crop plants

Agricultural field is a favourable ecosystem for weeds to germinate and flourish. They compete with crop plants for nutrients, light, air, water, space and other factors in the micro-environment. They reduce the effectiveness of irrigation. Competition between weed and crop is acute when available resources become limited for plant growth. Weeds affect the standing crop as well as crops in sequence. They also have an effect during fallow period. Weeds in crop fields interfere in inter-cultivation, harvesting, threshing and cleaning. Weed competition can reduce the quality of produce. In root crops, it alters size, quality and distribution of tubers. Some weeds like *Trianthema portulacastrum* produce mature seeds much earlier before we recognise their flowering stage as they produce very minute or inconspicuous flowers (De 1995). Some weeds like

Echinochloa colonum produce mature seeds before the crop seedlings get ready for uprooting for transplanting. Weeds like *Crotalaria medicaginea* and *Merremia aegyptia* appear dominantly in alternate years making better chances of their survival. Many weeds like *Avena ludoviciana*, *Cleome viscosa* mature at the same time of crop and they mostly shed their seeds before the harvest of crop so that the weed seeds get harvested with the crop plants.

2.4.3 Harbouring insect pests

Weeds provide feeding, breeding and hiding sites for insect pests, pathogens and parasites. Many Solanaceous weeds harbour insect pests feeding on leaves. Some weeds like *Echinochloa, Panicum* and *Zizania* are alternate hosts for rice stem borer. These pests infect crop plants and weeds get opportunity to dominate the infected weak plants.

2.5 Association of weeds

Some weeds like *Cynodon dactylon,* and *Echinochloa colonum* do not show any specificity with respect to season and site occurrence. While, some weeds prefer to grow in crop field only and some of them have a distinct association with specific crops (Table 2.5), may be due to their life cycle, growth habitat and other characteristics necessary for successful competition with the crops. Many weeds associated with grain crops are not found in sugar cane field and vice versa (De 1995).

Table 2.5 Associated weeds of different agricultural crops.

Crop	Associated weeds
Barley	*Phalaris minor, Avena fatua, Chenopodium album*
Black gram	*Solanum nigrum, Physalis minima*
Chick-pea	*Croton bonplandianum, Cleome viscosa*

Cotton	*Cyperus rotundus, Ageratum conyzoides, Abutilon indicum*
Groundnut	*Phyllanthus niruri, Ageratum conyzoides*
Jute	*Corchorus acutangulus, Cyperus rotundus*
Maize	*Eclipta alba, Echinochloa colonum*
Peas	*Lathyrus aphaca, Gnaphalium indicum*
Pigeon-pea	*Cyperus rotundus, Echinochloa colonum*
Potato	*Chenopodium album, Spergula arvensis, Anagallis arvensis*
Rape and mustard	*Cleome viscosa, Spergula arvensis, Chenopodium album*
Rice	*Echinochloa colonum, Echinochloa crus-galli*
Sorghum	*Striga lutea, Tridax procumbens*
Sugar-cane	*Sorghum halepense, Imperata cylindrica*
Tobacco	*Cyperus rotundus, Orobanche indica*
Wheat	*Chenopodium album, Phalaris minor*

(De 1995)

In brief, it could be noted from the discussion above that the weedy species of plants show wide adaptations to tide over environmental vagaries. However, many of these adaptations are not specific to weeds. A number of other plants show such adaptations to survive in the natural conditions. Weeds generally are euryoecious (wide range of tolerance), while native plants are comparatively stenoecious (narrow range of tolerance). Weeds have wide-ecological amplitude, are more opportunistic, and hence are more successful.

To explain the process of biological invasion, two alternative hypotheses are considered by Hengeveld (1988). One is based on the theory of the balance of nature and other on non-equilibrium theory and individualistic species responses. The theory of balance of nature is based on the classical work of the Elton (1958). It is based on the logic that competition, predation, diseases and other such biotic interactions help in maintaining multispecies equilibrium by curtailing the predominance or extinction of individual species in the community. Biotic interactions in more saturated native community resist the exotic invasions. Diverse, complex and mature forest ecosystems are likely to be less invadable than the less diverse, comparatively homogenous and open communities (Saxena 1991 and Lodge 1993).

On the other hand, non-equilibrium theory is based on the hypothesis that species shift their region or expand or contract their geographical range in response to spatio-temporal variations. These two theories by Hengeveld explain invasions at different time scales and situations (Saxena 1991). 'Geographical- range expansion of a species in response to change in climate', can not explain the invasion of Indian sub-continent by the alien species, as most of them are introduced by man accidentally or intentionally (Saxena 1991). According to Crawley (1987), existence of vacant niches in the community, created by different perturbations, makes community invasible. Slobodkin (1980) also gives similar indications. Disturbances created by anthropogenic activities are responsible for increasing distribution of species outside their native range (Ramakrishnan and Vitousek 1989, Lodge 1993).

As discussed earlier in this chapter, invaders bear certain characteristics such as r- selected traits, dual reproduction (vegetative and sexual), high dispersal rate, high genetic variability, phenotypic plasticity, allelopathy, high nutrient uptake efficiency, and human commensalism, which help them to successfully invade different areas (Saxena 1991, Lodge 1993). However, many of these characteristics are yet to be quantitatively tested and proved. Nevertheless, early successional, climatically matched with native habitats of invaders, less diverse, and disturbed habitats are found more vulnerable to the invasion by exotics (Saxena 1991, Ramakrishnan 1991, Lodge 1993).

Chapter III

3 STUDY AREA

3.1 Nilgiri Biosphere Reserve (NBR)

The Nilgiri Biosphere Reserve is located in south-west India, between 10° 45' - 12' 15° N and 76° 10' - 77° 10' E. Geological evidences suggest that the underlying rocks are archaean, about two billion years old. Topography ranges from low-lying valleys in the west to mountains over 2000m (2695m being the highest) and a flat elevated table land at 800 - 1000m above sea level. The wide altitudinal and geographic variation has resulted in diverse climatic vegetation zones (Daniels 1993). The NBR receives both south-west and north-east monsoon. South-west monsoon extends from June to September and north-east monsoon from October to December. The NBR embraces Mudumalai and Wynad Wildlife Sanctuaries, Nagarhole, Bandipur, Silent Valley and Mukurthi National Parks, forest hill slopes of Nilambur and Nilgiris, the Upper Nilgiri plateau, and Siruvani hills (Figure 3.1).

3.2 Locations selected for study

Study sites in various vegetation types were selected in 1) Mudumalai Wildlife Sanctuary, 2) Silent Valley National Park, 3) Upper Bhavani and 4) Siruvani forest. The vegetation types present in the different study locations were moist deciduous forest, dry deciduous forest, mixed deciduous forest, scrub jungle, evergreen forest, shola, coffee and tea plantation, teak plantation, eucalyptus plantation and wattle plantation. Eleven locations (Table 3.1) in total, distributed in the above vegetation types, were selected for laying transects and plots.

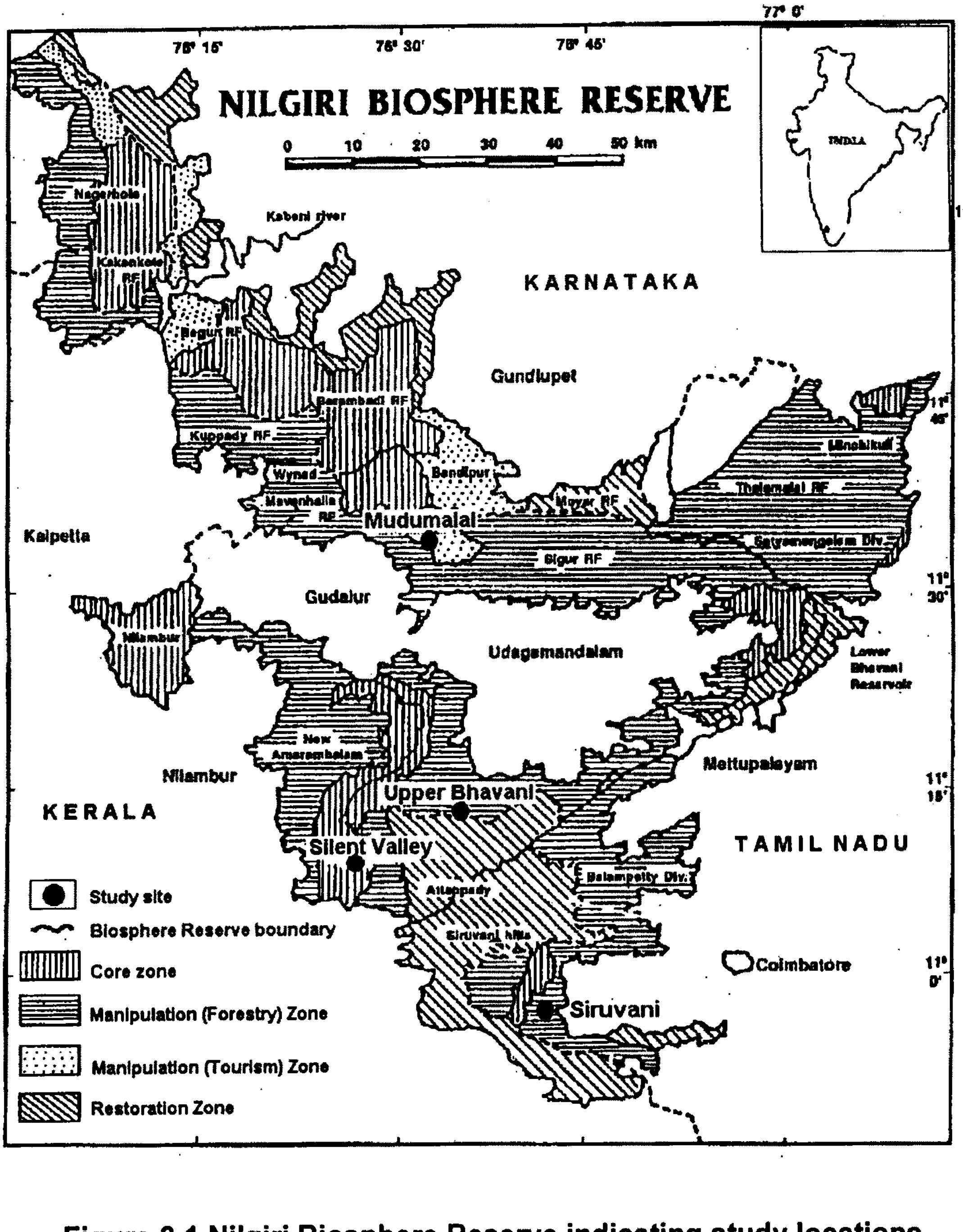

Figure 3.1 Nilgiri Biosphere Reserve indicating study locations

Table 3.1 Locations selected for the study

Forest types	Study sites
Mudumalai Wildlife Sanctuary	
Moist deciduous forest	Benne, Nagampally and Chinakooly
Dry deciduous forest	Masingudi, Kalmalai and Kakkanalla
Scrub jungle	Anaikatti,Valethottam and Mavanahalla
Coffee and tea plantation	Biderkad
Ecalyptus plantation	Masingudi
Teak plantation	Thorpalley
Silent Valley National Park	
Evergreen forest	Sirendhri
Upper Bhavani	
Sholas	Bison Swamp
Wattle plantation	Bison Swamp
Siruvani forests	
Mixed deciduous forest	Siruvani

3.2.1 Mudumalai Wildlife Sanctuary

Mudumalai Wildlife Sanctuary, situated between 11° 32' and 11° 43' N and 76° 22' and 76° 45' E, lies along the eastern slopes of Western Ghats. The sanctuary, a part of NBR, falls in the Nilgiri district of Tamil Nadu state and extends over an area of 321 km^2. The sanctuary is bounded on the north by the Bandipur National Park of Karnataka and on the west and south-west by the Kerala state (Figure 3.2).

The sanctuary consists of undulating hills with elevations ranging from 850 to 1258 m. Moyar river flows through the sanctuary and is the major water source. Rocks are of typical archaean biotite and horneblendic gneiss with intensive bands of charnokite and much younger biotite, granite, pegmatite and basic doleric dykes. Black sandy loam and red heavy loam soils occur in this area. April and May are the hottest months and December and January the coldest.

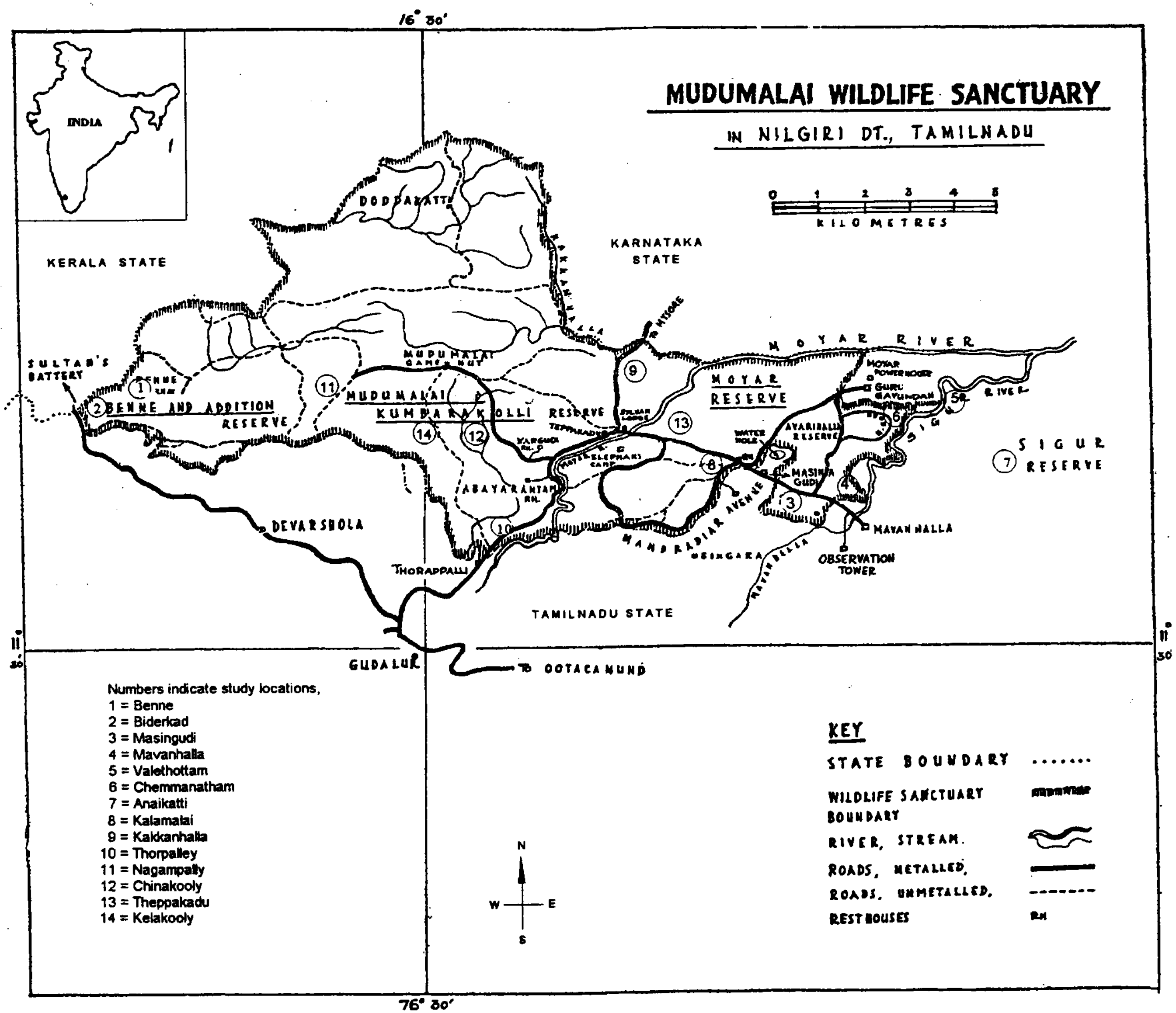

Figure 3.2 Mudumalai Wildlife Sanctuary indicating study locations

Sanctuary receives rain from both the monsoons. Western side of the sanctuary receives more rainfall than eastern part during the south-west monsoon between June to September and eastern side receives the rainfall mostly during the north-east monsoon between October and December. The mean annual rainfall varies from 600 to 2000 mm. Because of the variation in the rainfall, vegetation also varies in different parts of the sanctuary. Tropical moist deciduous, tropical dry deciduous and southern tropical thorn forests (Champion and Seth 1968, Azeez *et al.* 1997) are the three major vegetation types present in the sanctuary.

In the south-west part of the sanctuary, where annual rainfall is about 1800 mm per annum, tropical semi-evergreen forest is present. Dominant trees include *Meliosma simplicifolia, Olea dioica, Glochiodion velutinum, Viburnum punctatum* and *Memecylon* spp. Tropical moist deciduous forest occurs in the western and southern areas of the sanctuary. This region receives above 1500 mm rainfall per annum. Dominant tree species are *Lagerstroemia lanceolata, Terminalia crenulata, Pterocarpus marsupium, Bischofia javanica, Grewia tiliaefolia, Kydia calycina, Terminalia bellirica and Radermacheria xylocarpa.* Understorey is dominated by shrubs such as *Helicteres isora, Desmodium pulchellum* and *Curcuma* spp. and grasses such as *Themeda cymbaria*, *Apluda mutica, Imperata cylindrica* and *Cymbopogon flexuosus* .

In the eastern side of the sanctuary, having rainfall in the range of 900 - 1500 mm per annum, tropical dry deciduous forest is present. *Anogeissus latifolia, Tectona grandis, Dalbergia latifolia, Bombax ceiba, Madhuca indica, Gmelina* *arborea, Phyllanthus emblica, Butea monosperma, Cassia fistula* and *Mitragyna parvifolia* are some of the dominant tree species found here. Shrubs include *Helicteres isora, Pavetta indica* and *Lantana camara*. Ground layer consists of grasses such as *Heteropogon contortus, Themeda cymbaria, Themeda triandra* and *Cymbopogon flexuosus*.

Southern tropical thorn forest occurs in the eastern part of the sanctuary, where annual rainfall is in the range of 600 to 900 mm. This forest is dominated by *Acacia* spp. While, some elements of dry deciduous forests are also seen here. Dominance of thorny species, which have xerophytic adaptations, are characteristics of this vegetation. Dominant trees are *Acacia sundra, A. leucophloea, A. ferruginea, Givotia rottleriformis, Premna tomentosa, Albizia amara, Zizyphus mauritiana, Z. xylopyrus, Z. oenoplia, Erythroxylon monogynum, Chloroxylon swietenia, Strychnos potatorum, Elaeodendron glaucum and Naringi crenulata*. Shrubs include *Opuntia dillenii, Euphorbia* spp., *Acacia intsia, Capparis sepiaria, Carissa carandas, Scutia myrtina, Gymnosporia montana, Flacourtia indica* and *Argyreia cuneata*. Grasses such as *Heteropogon contortus, Digitaria* spp. and herbs like *Leucas aspera, Evolvulus alsinoides* and *Indigofera* spp. dominate the ground cover.

Mudumalai has a diverse fauna consisting of Asian Elephant (*Elephas maximus*), Gaur (*Bos gauras*), Sambar (*Cervus unicolor*), Chital (*Axis axis*), Four horned Antelope (*Tetracerus guadricornis*), Black buck (*Antilope cervicapra*), Mouse deer (*Tragulus meminna*), Barking deer (*Muntiacus muntjak*), Tiger (*Panthera tigris*), Leopard (*Panthera pardus*), Indian Wild dog

Plate 1 Moist deciduous forest in Mudumalai Wildlife Sanctuary

Plate 2 Evergreen forest in Silent Valley

(*Cuon alpinus*), Sloth bear (*Melursus ursinus*), Wild boar (*Sus scrofa*), Bonnet macaque (*Macaca radiata*) and Giant squirrel (*Ratufa indica,* Suresh *et al.* 1996).

3.2.2 Silent Valley National Park

The Silent Valley National Park is situated at the south-western corner of Nilgiris on a plateau of 1000 m elevation, in the Palghat district of Kerala (Figure 3.3). It is a part of the core area of NBR, covering an area of 89. 52 km^2, and is located at 11° 00' and 11° 15' N and 76° 15' and 76° 35' E (Chand Basha 1999, Swaminathan 1999). It is bound by high and continuous ridges (over 2000m above MSL) along its entire north, north-east and east borders and little lower ridges (over 1200m above MSL) along the entire western and southern border. The highest peaks on the northern and north-eastern boundary are Anginda (2383m) and Sispara (2206m) and on the west, Poochapara (1376m) and Valiamullumala (1237m, Manilal 1988). Major watercourse in this park is the perennial river Kunthipuzha, a tributary of Bharathapuzha.

The prevailing rock formations in Silent Valley are foliated gneisses to grantoid gneisses and granites referable to Archaen complex (Manilal 1988). Both south-west and north-east monsoons occur in Silent Valley. Silent Valley receives over 5000 mm of rainfall annually (Singh *et al.* 1984). Maximum precipitation is during the south-west monsoon. The area receives highest rainfall in July. In dry months of January, February and March, also Silent Valley receives scanty showers. Average minimum temperature ranges from 8 to 14 °C and the average maximum temperature from 23 to 29 °C.

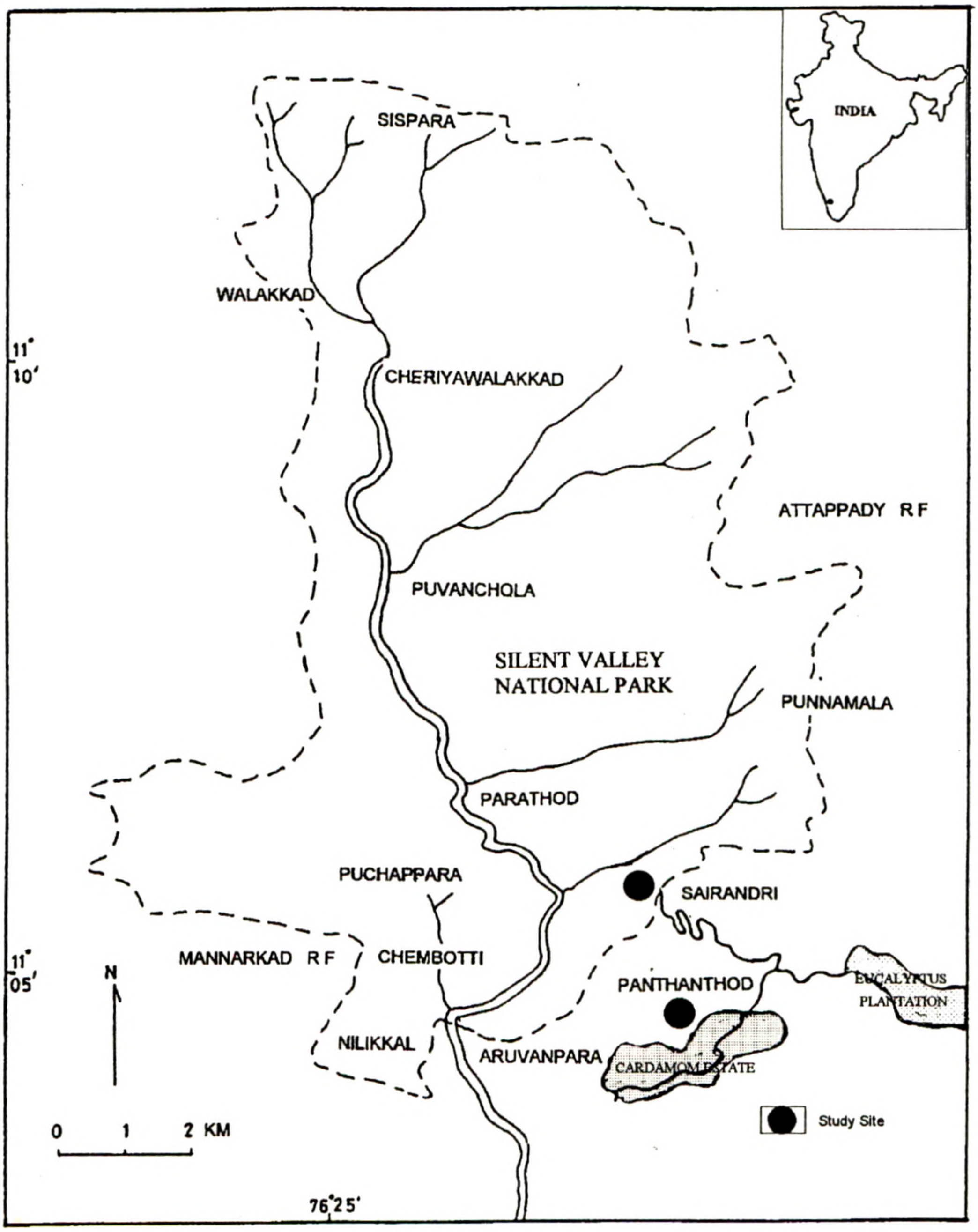

Figure 3.3 Silent Valley National Park indicating study locations

Silent Valley vegetation consists of primarily wet evergreen forest, with a multi-storeyed and dense canopy. It harbours 2000 plant species including over 1000 species of flowering plants (Pushpangadan and Sathish Kumar 1999). Trees are very tall (up to 50m). Epiphytic orchids and ferns are frequent. Common trees are *Actinodaphne malabarica, Litsea* spp., *Cinnamomum* spp., *Palaquium ellipticum, Cullenia exarillata, Syzygium laetum, S. mundagum, Garcinia morella, Elaeocarpus* spp., *Artocarpus heterophyllus, Mesua ferrea, Mallotus philippinensis, Eugenia* spp., *Agrostistachys borneensis, Gomphandra tetrandra* and *Myristica fragrans*. Shrub layer includes *Thottea siliquosa, Psychotria nigra, Pavetta indica, Laportea crenulata, Saprosma foetens, Elatostemma lineolatum, Memecylon heyneanum, Antistrophe serratifolia and Strobilanthes* spp. and climbers such as *Thunbergia mysorensis, Smilax perfoliata* and *Smilax zeylanica*. *Sarcandra chloranthoides* and *Rhynchotechum permolle* are common herb species.

Fauna of Silent Valley includes many endangered animals (Prasad *et al.* 1979, Balakrishnan 1999, Ramachandran and Gigi 1999) such as Lion tailed macaque (*Macaca silenus*) and Nilgiri Thar (*Hemitragus hylocrius*). Other common animals found are Asian Elephant, Gaur, Sambar, Chital, Mouse deer, Barking deer, Tiger, Leopard, Indian Wild dog, Leopard cat (*Felis bengalensis*), Ruddy mongoose (*Herpestes edwardsii*), Small Indian civet (*Viverricula indica*), Nilgiri langur (*Trachypithecus johnii*), Bonnet macaque and Sloth bear.

3.2.3 Upper Nilgiris (Upper Bhavani)

The Upper Nilgiris is located between 11° 10' and 11° 30' N and 76° 25' and 77° 00' E at the junction of the Eastern Ghats and the Western Ghats (Figure 3.4). It covers an area of 800 km^2. The Upper Nilgiris ranges from 1800 to 2500m above MSL in altitude and falls steeply to the surrounding plains.

The vegetation of the Upper Nilgiris consists of stunted evergreen forest, called sholas, and grasslands (Champion and Seth 1968). Original shola and grasslands are found only in small pockets as natural vegetation has been replaced at many places by plantations like wattle, pine, tea and eucalyptus. The rainfall ranges from 5000 mm on the western slopes to 1000 mm in the east.

Upper Bhavani receives rainfall mainly from south-west monsoon from June to August. Maximum rainfall is during July. It does not receive much rainfall from north-east monsoon. In dry season temperature ranges up to 20°C and night temperature may fall below freezing point. Because of high wind velocity, the trees in sholas are stunted with rounded canopies. The shola vegetation is dominated by members of families Lauraceae, Rubiaceae, Symplocaceae, Myrtaceae and Euphorbiaceae (Sukumar *et al.* 1995).

The major trees are *Daphniphyllum neilgherrense, Mahonia leschenaultii, Michelia nilagirica, Rhododendron nilagiricum, Syzigium montanum*, *Symplocos* spp., *Viburnum hebanthum and Cryptocarya lawsoni.* Understorey consists of shrubs such as *Psychotria congesta, Strobilanthes* spp, *Lasianthus* spp., *Gaultheria fragrantissima, Polystricum* spp. and climbers like *Piper*

Plate 3 Scrub jungle in Mudumalai Wildlife Sanctuary

Plate 4 Shola vegetation in Upper Bhavani

Plate 5 Shola patches mixed with Wattle plantation

Plate 6 Dry deciduous forest in Mudumalai

Plate 7 Tea plantation

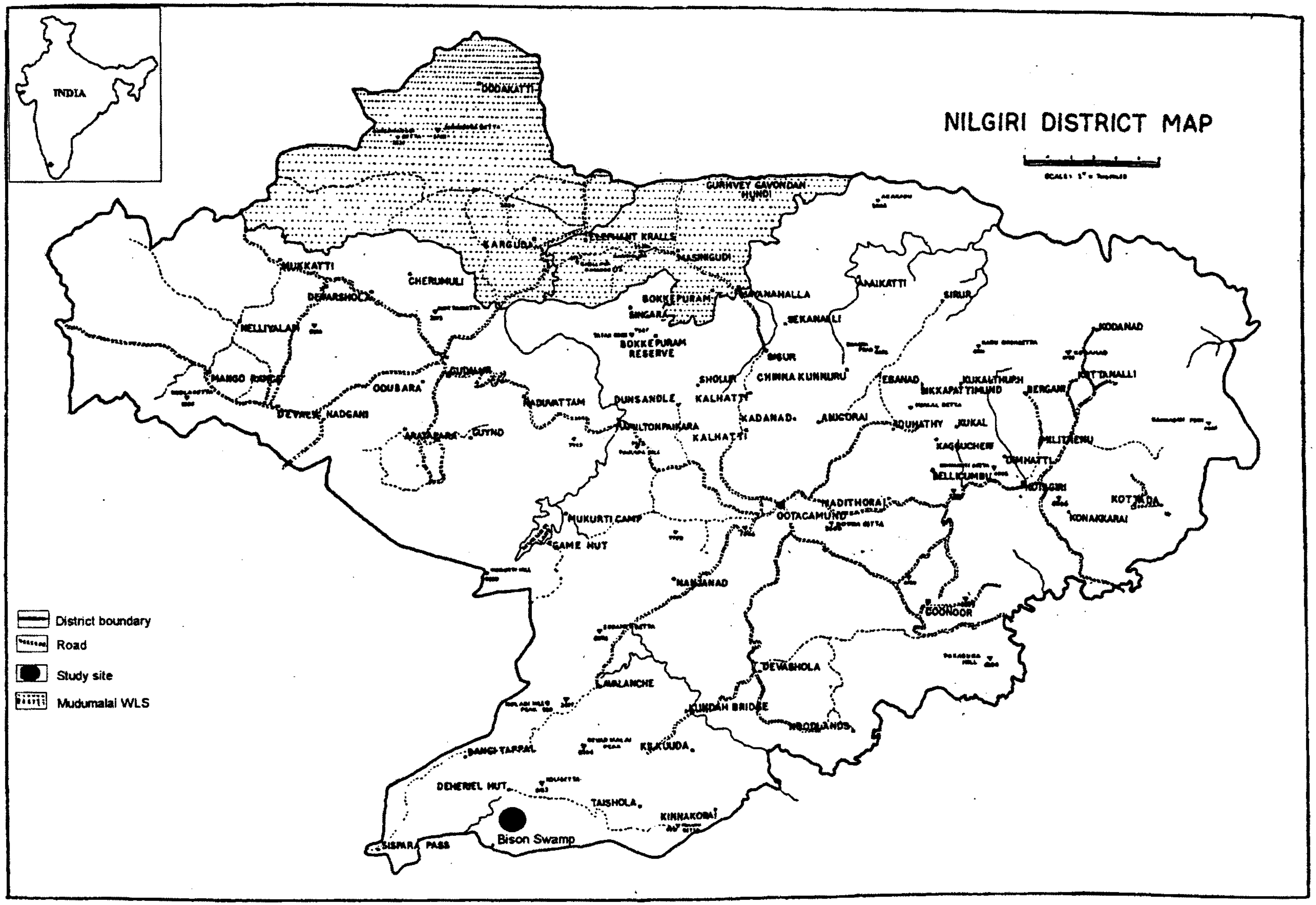

Figure 3.4 Nilgiri District indicating the study area – Upper Bhavani (Bison Swamp)

argyrophyllum, *Smilax* spp. Herb layer is not much dense and includes species such as *Fragaria* spp., *Themeda* spp. and *Cymbopogon* spp.

Fauna of Upper Bhavani includes Nilgiri thar, a highly endangered species. Other mammals found here are Sambar, Asian elephant, Barking deer, Jackal (*Canis aureus*), Jungle cat (*Felis chaus*), Leopard cat, Ruddy mongoose, Small Indian civets, Nilgiri marten (*Martes gwatkinsi*), Indian Wild dog (*Cuon alpinus*), Leopard, Tiger, Nilgiri langur and Bonnet macaque. Malabar Rock Pit Viper (*Trimeresurus malabaricus*) and Horse-shoe Pit Viper (*Trimeresurus strigatus*) are common reptiles.

3.2.4 Siruvani

The mixed deciduous forest of Siruvani, which is situated in the foot hills of the Western Ghats of Tamil Nadu lying north to Palghat gap,was selected for further ecological studies on select weedy species (Figure 3.5). The Siruvani area is situated 34 km west of Coimbatore city. Siruvani forest falls under Boluvampatti range of Coimbatore forest division, Tamil Nadu, which lies between 10° 15' and 11° 0' N and 76° 42' and 76° 51' E. Siruvani water purification plant, the main source of drinking water to Coimbatore city, is located in this area. Siruvani is easily approachable by road. River Noyyel flows closely parallel to this road on its northern side. Agricultural cultivations such as sugarcane, paddy, cotton, banana and millets are common on both sides of the road.

The underlying rock in Siruvani forest is gneiss of Archean group. The gneiss is finely foliated and is composed of quartz, felspar, horneblende and biotite (black

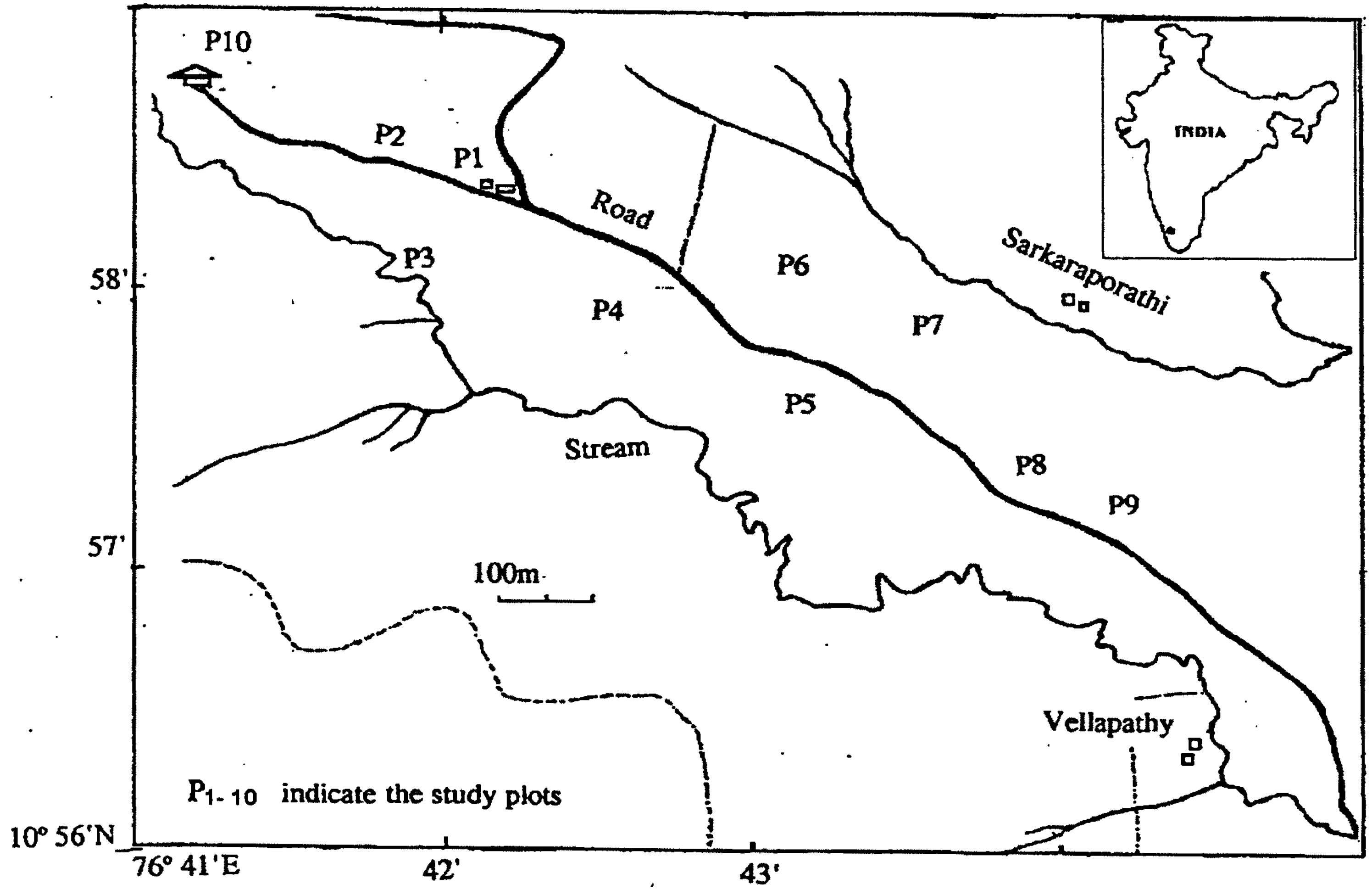

Figure 3.5 Study site at Siruvani indicating the location of study plots

mica) with an occasional admixture of garnet (Subramanyam 1959, George 1984). Laterite in pure form is not observed in the hills. Soil is reddish with yellow clay along the foothills (Subramanyam 1959). The rocks undergo a change akin to laterite metamorphosis, which results in the formation of pale yellow to red coloured soil. The soil along the banks of the river Noyyel is black, clayey alluvial and very fertile (Subramanyam 1959, Subramaniyan 1966).

March, April and May are the hottest months. Except during these months climate is cool and pleasant throughout the year. Temperature ranges from 24 to 38° C at day time and night temperature ranges from 18 to 29° C. Mean annual humidity is 75%. The area receives good rainfall during the monsoon. The area receives both south-west and north-east monsoon and the rainfall during south-west monsoon is heavy usually starting by the end of May or beginning of June and lasts up to August. North-east monsoon commences in October and continues up to December. Mean annual rainfall is 2000 mm.

Forest in Siruvani area comes under the southern tropical moist deciduous type (Champion and Seth 1968). These deciduous forests gradually merge into the southern tropical evergreen forests at higher elevations (Subramaniyan 1966). While, vegetation in the study plots was represented by elements of dry deciduous as well as moist deciduous forests, so forest in study location is considered as mixed deciduous forest.

Flora of Siruvani forest mainly consists of evergreen elements such as *Litsea floribunda*, *Macaranga peltata, Alstonia scholaris, Lagerstroemia lanceolata,* *Syzigium cumini*, deciduous trees such as *Terminalia bellerica, Terminalia paniculata, Anogeissus latifolia, Tectona grandis, Dalbergia latifolia, Cordia wallichii, Bridelia retusa, Stereospermum tetragonum* and *Albizia amara*. Shrubs include *Glycosmis pentaphylla, Grewia hirsuta, Helicteres isora, Desmodium pulchellum, Zizyphus nummularia, Chromolaena odorata* and *Lantana camara*. Climbers commonly seen, are *Ipomoea staphylina, Clematis gouriana, Dioscorea bulbifera, Dioscorea pentaphylla, Cryptolepis buchanani, Naravelia zeylanica, Zizyphus oenoplia, Toddalia asiatica, Pterolobium indicum* and *Spatholobus roxburghii.* Ground layer includes rare plants such as *Rauwolfia serpentina* and common species such as *Hemidesmus indicus, Curculigo orchioides, Sida acuta, Mimosa pudica, Stachytarpheta jamaicensis, Urena lobata, Commelina* spp. and *Phaulopsis imbricata.* Major grasses are *Cyrtococcum deccanense, Panicum* spp. and *Oplismenus compositus.*

Asian Elephant, Sambar, Barking deer, Leopard, Indian Wild dog, Nilgiri langur, Bonnet macaque, Sloth bear and Giant squirrel are common in the Siruvani forest.

Chapter IV

4 METHODOLOGY

4.1 Vegetation Sampling

The study was distinguished into two phases. The first phase involved recording trees, shrubs and herbs from designated plots in all the habitats of NBR, seasonally for two years. The second phase involved detailed study of different plots laid in Siruvani forests. Vegetation Samplings for the first phase were conducted seasonally from May 1994 to February 1996 in eleven locations in NBR. Pilot survey in all the vegetation types was conducted from June to September 1994. Vegetation samplings were conducted in winter 1 (November 1994 to February 1995), summer (March 1995 to May 1995), monsoon (June 1995 to September 1995) and winter 2 (November 1995 to February 1996).

Four transects of 1 km were laid at different sites of each forest type and one transect of 1 km was laid in each plantation to study distribution and density of weeds. On each transect, ten plots of 50m X 20m were laid at 90m interval. Number of trees, girth at breast height (GBH) and height were recorded from each plot. Four quadrats of 10m X 10m were laid within each tree plot for recording shrubs. Ten quadrats of 1m X 1m were laid randomly within each tree plot for recording herb coverage (Figure 4.1). During the same period in order to examine the relation between human disturbance and weed invasion, a survey was conducted in three habitats of Mudumalai Wildlife Sanctuary (MWS) namely, dry deciduous forest, scrub jungle and moist deciduous forest. Three transects of 1 km were laid along the disturbance gradient starting from the villages extending towards the undisturbed forests in i) dry

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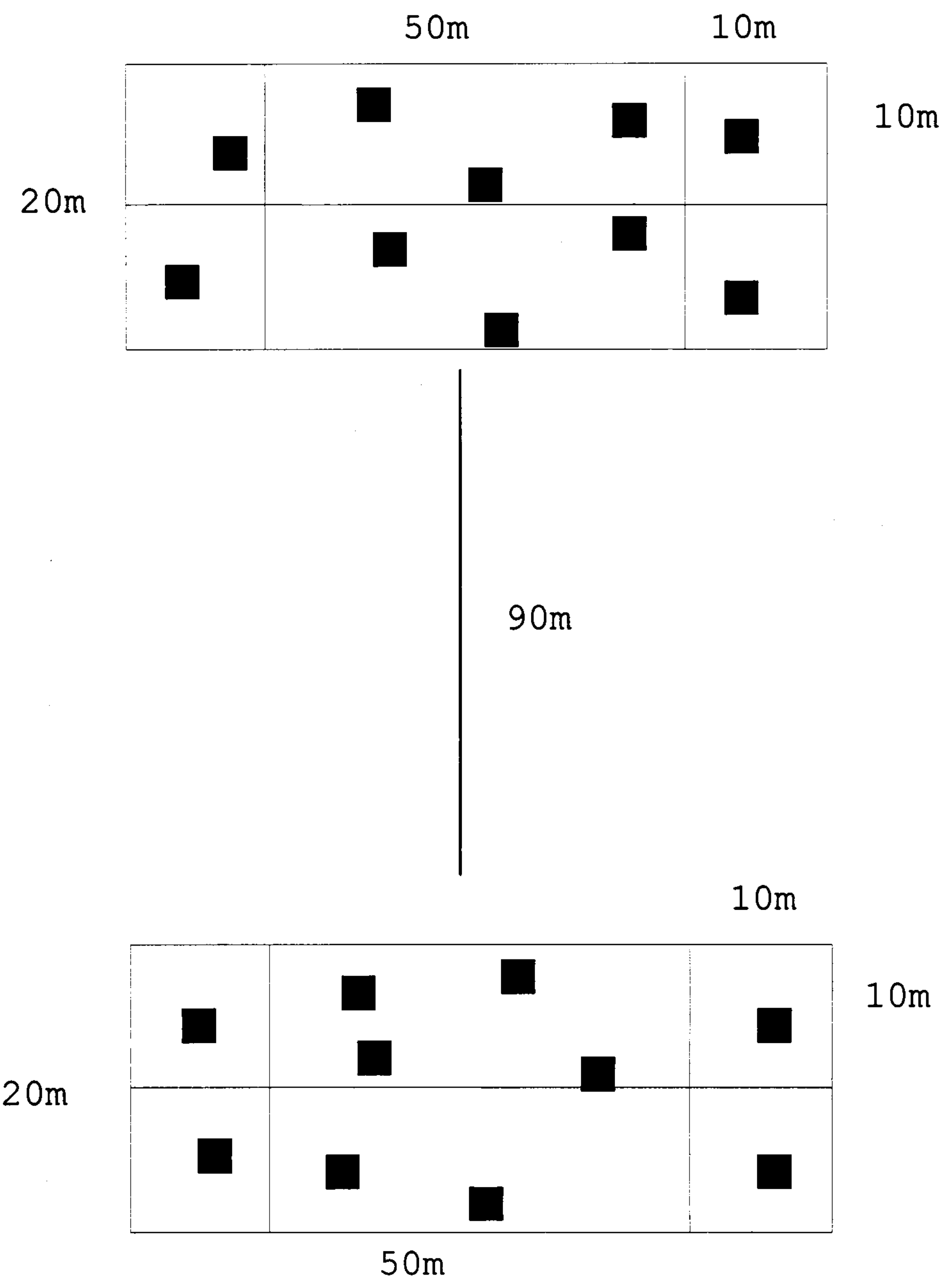
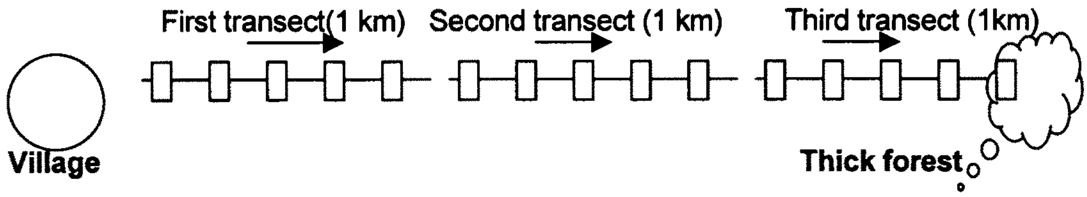
deciduous forest near Theppakadu and ii) scrub jungle near Chemmanatham (Figure 4.2). In moist deciduous forest, near Kelakooly, four transects of 500m were laid, considering the width of the forest patch.

Figure 4.1 Design of plots laid in different locations in NBR



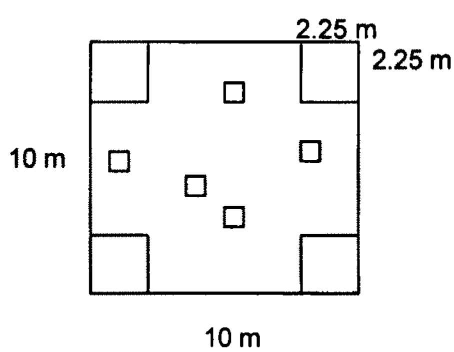
On these transects, ten plots of 20m X 10m were laid to record trees and within the plots, four 3m X 3m and five, 1m X 1m quadrats were laid for recording shrubs and herbs respectively.

Figure 4.2 Design of transects laid in Mudumalai Wildlife Sanctuary



During the second phase of the study, mixed deciduous forest at Siruvani was selected to examine various aspects of the growth and phenology of select weedy species, for further two years (1996 - 1998). Ten plots of 10m X 10m were laid randomly at different locations in Siruvani forests. In each 10m X 10m plot, four quadrats of 2.25m X 2.25m (approximately 5 m^2) were laid to record the shrubs and five 1m X 1m quadrats were laid to record the herbs. Each shrub in the 2.25m X 2.25m quadrats was labelled and plant growth was recorded by measuring the height. Number of trees, their height and GBH from all the tree quadrats, number and height of shrubs from all the shrub quadrats, and herb coverage in herb quadrats were recorded at alternate months for two years (1996 - 1998).

Figure 4.3 Design of plot in Siruvani forest



Data on phenology of selected species were collected at alternate months from each plot. Data were collected in terms of percentage of young leaves, mature leaves, flowers and fruits. Soil samples were also collected from all the plots in the same interval, to determine the pH, electrical conductivity and other nutrient status of soil. The vegetation data were quantitatively analysed for dominance, density and frequency using standard analytical and statistical methods using computer software packages (Excel, Foxpro, SPSS and Systat). The relative values of frequency, density and dominance were also estimated. These quantities were summed to derive Importance Value Index (IVI) of individual species (Curtis 1959). Species diversity was determined using Shannon-Wiener information function (H', Shannon and Wiener 1963).

$H' = -\sum[P_i \log_2 P_i]$,

$P_i = n_i/N$

Where, n_i = number of individuals of i^{th} species and N = total number of individuals of all the species in that sample area ($\sum n_i$).

Similarity based on presence and number of selected weedy species among the different vegetation types was estimated using Morisita index (Horn's similarity index). After a comparison of various similarity indices, Wolda (1981) concludes that other similarity indices are strongly dependent on sample size and diversity. Wolda (1981) recommends the use of this index to avoid complex dealings with effects of sample size and diversity. Indices such as Sorenson's do not give any role to mass variables such as frequency of species (Menon 1985) and give equal weight to all species. The formula used to calculate similarity index was,

Horn's index of similarity for samples j and k =

$$\frac{\sum(X_{ij} + X_{ik}) \log (X_{ij} + X_{ik}) - \sum (X_{ij} \log X_{ij}) - \sum (X_{ik} \log X_{ik})}{(N_J+N_K) \log (N_J+N_K) - N_J \log N_J - N_K \log N_K}$$

Where, X_{ij}, X_{ik} = number of individuals of species i in samples j and k respectively.

$N_J = \sum X_{ij}$ = Total number of individuals in sample j.

$N_k = \sum X_{ik}$ = Total number of individuals in sample k (Horn 1966).

The results were multiplied by 100 to make comparisons convenient. The maximum theoretical value according to Horn (1966) is about 'one'. In the present case since, the values were multiplied by 100 the value is about '100'.

Associations between selected weedy species from different habitats of NBR were estimated using Jaccard's index (Goodall 1973)..

$$JI = \frac{a}{(a+b+c)}$$

Where, JI = Jaccard's index.

a = number of sample units where both species A and B are present.

b = number of sample units where species A is present but B is absent..

c = number of sample units where species B is present but A is absent

The results were multiplied by 100 to make comparisons convenient.

Niche breadth is a measure of the number of different habitats the plant is found in and is abundant in. Niche breadth of all the plant species in NBR were calculated using Levin's niche breadth formula (Levin 1968).

$B = 1/\Sigma P_i^2$

$P_i = n_i/N$

Where, B = Niche breadth of an individual species i

n_i = number of individuals of species i in one habitat.

N = total number of individuals of species i in all habitats (Σn_i).

Relations among total number and species richness of herbs and weeds, different physical and chemical parameters of soil such as EC, pH, nitrogen, phosphorus, potassium and organic carbon in different plots in Siruvani mixed deciduous forest, and rainfall, were examined using Pearson's correlation coefficient and regression analysis.

4.2 Soil analysis

Soil samples were collected from 10 plots in Siruvani forest. From each plot, four samples were collected from four sites located randomly. The samples were mixed thoroughly to make a composite sample and were spread on a sheet of paper and air dried under shade. After drying, the samples were ground by light pounding with mortar and pestle in a way so that the aggregate particles are broken down to ultimate soil particles. The soil thus prepared was divided in to two parts. Of which one part was used for grain-size composition analysis. The other part was sieved through a sieve with round holes of 2mm diameter and the part below 2mm size was used for other analysis (Bose *et al.* 1988).

4.2.1 Grain size composition

Department of Agriculture (USDA) has established a soil separates classification system. (Miller *et al.* 1992, table 4.1). This system has been approved by the Soil Science Society of America and is used in the present study. From each air-dried sample, 100 gm soil was sieved through five different sieves of standard mesh size (having holes of diameter of 2 mm, 1mm, 0.5 mm, 0.25 mm and 0.05 mm). Soil separate from each sieve was collected and weighed.

Table 4.1 Soil separates and their diameter ranges in mm.

Soil separates	Size(mm)
Coarse sand	1.0 - 0.5
Medium sand	0.5 - 0.25
Fine sand	0.25 - 0.10
Very fine sand	0.10 - 0.05
Silt	0.05 - 0.002
Clay	<0.002

4.2.2 Soil pH

pH of all the samples were determined by potentiometric method. Soil solutions were prepared as 1:2 suspension in double distilled water (20 gm of soil + 40 ml water). pH of the solutions were measured using Glass electrode pH meter.

4.2.3 Electrical conductivity

The electrical conductivity is measured in terms of the resistance offered to the flow of current using a conductivity bridge. It was measured using conductivity meter. Soil solutions were prepared as 1:2 suspension in double distilled water. Soil having more than 1.0 m.mhos/cm electrical conductivity is considered injurious to plant growth (Bose *et al.* 1988, table 4.2)

Table 4.2 Rating of soil with reference to EC

Rating	EC (m. mhos/cm)
Harmless	0.0 - 1.0
Injurious	1.0 - 3.0
Critical	3.0

4.2.4 Nutrients

4.2.4.1 Nitrogen

Alkaline $KMnO_4$ method was used to estimate the available nitrogen in the soil samples (Bose *et al.* 1988). The amount of soil nitrogen released by the $KMnO_4$

oxidation of soil organic matter is estimated by distillation with NaOH. The distillate is collected in boric acid containing double indicator and titrated against standard H_2SO_4. Rating of soil with reference to available nitrogen status is given in table 4.3 (Bose *et al.* 1988).

Table 4.3 Rating of soil with reference to available nitrogen status

Rating	Nitrogen (Kg/ha)
Low	up to 280
Medium	280 to 450
High	more than 450

4.2.4.2 Phosphorus

For estimating available phosphorus in the soil, Olsen's method (using 0.5M $NaHCO_3$, Jackson 1973, Bose *et al.* 1988) was used. The CO_3^{2-} ions from $NaHCO_3$ react with Ca^{2+} and $CaCO_3$ is precipitated, thus allowing phosphates to come into solution. The amount of P extracted is determined colorimetrically. Rating of soil with reference to available phosphorus status is given in table 4.4 (Bose *et al.* 1988).

Table 4.4 Rating of soil with reference to available phosphorus status

Rating	Phosphorus (Kg/ha)
Low	Up to 11
Medium	11 to 22
High	More than 22

4.2.4.3 Potassium

Estimation of available potassium in soil samples was done by extraction with 0.1 N HNO_3. Rating of soil with reference to available potassium is given in table 4.5 (Bose *et al.* 1988).

Table 4.5 Rating of soil with reference to available potassium status

Rating	Potassium (Kg/ha)
Low	up to 118
Medium	118 to 280
High	more than 280

4.2.4.4 Organic carbon

Reaction of $K_2Cr_2O_7$ with H_2SO_4 results in oxidation of carbon in the organic matter to form CO_2. The unused chromic acid in the oxidation reaction is estimated by back titrating against standard ferrous ammonium sulphate (Jackson 1973, Bose *et al.* 1988).

Table 4.5 Rating of soil with reference to organic carbon content

Rating	Organic carbon (%)
Low	0.5
Medium	0.5 to 0.75
High	More than 0.75

4.2.4.5 Heavy metals

Soil samples were also examined for distribution of copper, manganese, lead, zinc and iron. One gram of each sample was digested in closed teflon vessels. The samples were allowed to rest overnight in a mixture of 4.5ml concentrated HNO_3 and 1.5 ml HCl at room temperature. The digestion was carried out under pressure at 150°C for 3 hours. Digested samples were cooled, quantitatively filtered with precleaned filter paper and the volume was made up to 25 ml with double distilled water. Samples were analysed using Atomic Adsorption Spectrophotometer (Model Pye-Unicam SP9) using standard reagents (Merck, Germany).

Chapter V

5 RESULTS

5.1 Observations on the flora of Nilgiri Biosphere Reserve

As mentioned earlier the vegetation types in study area were evergreen forest, shola, moist deciduous forest, dry deciduous forest, mixed deciduous forest, scrub jungle and coffee-tea, teak, eucalyptus and wattle plantations. Species diversity of trees, shrubs and herbs in different habitats are given in table 5.1.1, 5.1.2 and 5.1.3. Species diversity and richness of trees were highest in evergreen forest and lowest in wattle plantation (Table 5.1.1). Species richness (Number of species) and diversity of shrubs were highest in moist deciduous forest and lowest in teak plantation (Table 5.1.2). Species richness of herbs was highest in dry deciduous forest, while species diversity of herbs was highest in evergreen forest (Table 5.1.3). Species richness and diversity of herbs were lowest in wattle plantation.

Table 5.1.1 Diversity of tree species in the study area

Vegetation types	Sp richness	Diversity H'
Mudumalai Wildlife Sanctuary		
Dry deciduous	30	1.8
Moist deciduous	50	2.51
Scrub jungle	31	2.75
Teak plantation	8	0.37
Coffee-tea plantation	18	1.77
Silent Valley		
Evergreen	60	3.43
Upper Bhavani		
Shola	40	3.01
Wattle plantation	4	0.19
Siruvani		
Mixed deciduous	40	2.42

Table 5.1.2 Diversity of shrub species in the study area

Vegetation types	Sp richness	Diversity H'
Mudumalai Wildlife Sanctuary		
Dry deciduous	48	2.31
Moist deciduous	87	3.13
Scrub jungle	47	2.62
Teak plantation	21	0.89
Coffee-tea plantation	21	1.77
Silent Valley		
Evergreen	79	2.95
Upper Bhavani		
Shola	63	2.20
Wattle plantation	29	1.57
Siruvani		
Mixed deciduous	36	2.08

Table 5.1.3 Diversity of herbs species in the study area

Vegetation types	Sp richness	Diversity H'
Mudumalai Wildlife Sanctuary		
Dry deciduous	65	2.87
Moist deciduous	58	2.32
Scrub jungle	53	2.73
Teak plantation	37	2.39
Coffee-tea plantation	29	2.86
Silent Valley		
Evergreen	45	2.92
Upper Bhavani		
Shola	40	2.73
Wattle plantation	16	1.90
Siruvani		
Mixed deciduous	40	2.26

A comprehensive list of plant species in the study area was prepared. Total 376 species of herbs and shrubs belonging to 69 families were recorded (Table 5.1.4). Poaceae, Papilionaceae, Asteraceae, Rubiaceae, Cyperaceae and Acanthaceae were the dominant families of herbs and shrubs. Poaceae had the largest number of species of shrubs and herbs followed by Papilionaceae, Asteraceae and Rubiaceae. A total of 179 species of trees are also recorded from different habitats. (Appendix 2).

Table 5.1.4 List of families of herbs and shrubs in the study area.

Family	Number of species
Ranunculaceae	2
Menispermaceae	2
Flacourtiaceae	2
Hypericaceae	1
Theaceae	1
Ancistrocladaceae	1
Malvaceae	13
Sterculiaceae	2
Tiliaceae	4
Zygophyllaceae	1
Oxalidaceae	2
Rutaceae	6
Erythropalaceae	1
Celastraceae	3
Rhamnaceae	3
Vitaceae	1
Leeaceae	2
Sapindaceae	1
Anacardiaceae	1
Paplilionaceae	30
Caesalpiniaceae	6
Mimosaceae	6
Rosaceae	2
Myrtaceae	2
Melastomataceae	3
Onagraceae	3
Cactaceae	1
Umbelliferae	2
Rubiaceae	24
Asteraceae	26
Ericaceae	1
Myrsinaceae	1
Symplocaceae	3
Oleaceae	1
Apocynaceae	3
Asclepiadaceae	5

Gentianaceae	1
Boraginaceae	2
Convolvulaceae	5
Solanaceae	6
Scrophulariaceae	5
Orobanchaceae	2
Acanthaceae	17
Thunbergiaceae	3
Verbenaceae	4
Labiatae	14
Amaranthaceae	2
Polygonaceae	1
Aristolochiaceae	1
Piperaceae	6
Chloranthaceae	1
Elaeagnaceae	1
Euphorbiaceae	20
Urticaceae	6
Orchidaceae	4
Zingiberaceae	9
Costaceae	1
Hypoxidaceae	1
Dioscoreaceae	5
Agavaceae	1
Liliaceae	6
Smilacaceae	4
Commelinaceae	10
Arecaceae	1
Pandanaceae	1
Araceae	2
Eriocaulaceae	1
Cyperaceae	18
Poaceae	47

The dominant trees, shrubs and herbs based on Importance Value Index, in different study sites in NBR are given in the tables 5.1.5, 5.1.6 and 5.1.7.

Table 5.1.5 Dominant trees in study area

Vegetation type	Species	IVI
Mudumalai Wildlife Sanctuary		
Dry deciduous forest	*Anogeissus latifolia*	121.01
	Tectona grandis	97.84
	Terminalia tomentosa	50.07
Moist deciduous forest	*Terminalia tomentosa*	107.12
	Olea dioica	100.78
	Chionanthus mala-elengi	53.24
Scrub jungle	*Erythroxylon monogynum*	90.33
	Acacia sundra	89.33
	Chloroxylon swietenia	87.73
Teak plantation	*Tectona grandis*	129.52
	Lagerstroemia microcarpa	112.61
	Cassia fistula	41.43
Coffee-tea plantation	*Grevillea robusta*	150.54
	Terminalia tomentosa	57.50
	Lagerstroemia microcarpa	44.38
Silent Valley		
Evergreen forest	*Palaquium ellipticum*	9.78
	Syzygium cumini	9.42
	Syzygium mundagum	8.47
Upper Bhavani		
Shola	*Michelia nilagirica*	37.14
	Syzygium montanum	39.83
	Cinnamomum wightii	26.44
	Rhododendron nilagiricum	25.50
Wattle plantation	*Acacia mearnsii*	204.56
	Eucalyptus globulus	33.42
	Grevillea robusta	13.84
Siruvani		
Mixed deciduous forest	*Tectona grandis*	45.14
	Terminalia crenulata	42.32
	Pterocarpus marsupium	35.24

IVI values of dominant trees in high altitude vegetation types such as evergreen forest and shola are comparatively lower as these habitats are more diverse with reference to the trees.

Table 5.1.6 Dominant shrubs in study area.

Vegetation type	Species	IVI
Mudumalai Wildlife Sanctuary		
Dry deciduous forest	*Stachytarpheta jamaicensis*	42.37
	Chromolaena odorata	26.55
	Lantana camara	24.71
	Grewia hirsuta	20.08
Moist deciduous forest	*Chromolaena odorata*	26.63
	Lantana camara	16.82
	Helicteres isora	20.94
Scrub jungle	*Randia dumetorum*	34.57
	Lantana camara	27.31
	Grewia hirsuta	26.55
Teak plantation	*Randia dumetorum*	24.79
	Helicteres isora	20.25
	Chromolaena odorata	17.49
Coffee-tea plantation	*Camellia sinensis*	96.39
	Coffea arabica	30.04
	Lantana camara	13.18
Silent Valley		
Evergreen forest	*Thottea siliquosa*	9.78
	Eupatorium repandum	9.42
	Sarcandra chloranthoides	8.47
Upper Bhavani		
Shola	*Strobilanthes* sp.	60.16
	Strobilanthes foliosus	35.59
	Psychotria congesta	22.20
Wattle plantation	*Rubus racemosus*	16.31
	Rubus ellipticus	13.09
Siruvani		
Mixed deciduous	*Chromolaena odorata*	62.45
	Lantana camara	44.75
	Justicia betonica	35.69

Table 5.1.7 Dominant herbs in study area.

Vegetation type	Species	IVI
Mudumalai Wildlife Sanctuary		
Dry deciduous forest	*Heteropogon contortus*	83.69
	Themeda triandra	60.81
	Apluda mutica	32.15
Moist deciduous forest	*Oplismenus compositus*	66.88
	Malvastrum coromandelianum	38.38
	Arundinella ciliata	87.97

Scrub jungle	*Heteropogon contortus*	109.12
	Evolvulus alsinoides	61.72
	Leucas aspera	52.05
	Tephrosia purpurea	38.82
Teak plantation	*Oplismenus compositus*	77.46
	Mimosa pudica	49.53
	Curcuma pseudomontana	35.15
Coffee-tea plantation	*Sida acuta*	35.04
	Mimosa pudica	32.46
	Blumea virens	30.48
Silent Valley		
Evergreen forest	*Elatostemma lineolatum*	53.68
	Garnotia arundinacea	32.54
	Pennisetum hohenackeri	26.15
Upper Bhavani		
Shola	*Oplismenus compositus*	42.53
	Carex lindleyana	40.34
	Fragaria neilgherrensis	30.45
	Arundinella mesophylla	28.63
Wattle plantation	*Themeda tremula*	110.51
	Cymbopogon polyneuros	100.35
	Arundinella mesophylla	79.37
Siruvani		
Mixed deciduous	*Cyrtococcum deccanense*	73.85
	Curculigo orchioides	28.96
	Hemidesmus indicus	23.30

5.1.1. Distribution and floristic information of shrubs and herbs in different study sites in NBR.

Flora of Tamil Nadu, India (Henry *et al.* 1989, Nair et al. 1989), Excursion flora of Central Tamil Nadu India (Matthew 1991), Flora of Silent Valley tropical rainforests of India (Manilal 1988), Flora of Coimbatore (Chandrabose and Nair 1988), Flora of Palghat district including Silent Valley National Park, Kerala (Vajravelu 1990) and Flora of the presidency of Madras (Gamble 1921) were referred to write the description of shrubs and herbs observed in study area.

Family Ranunculaceae

Clematis gouriana Roxb. ex DC.

A climbing shrub with cream flowers. Found in hills above 750m, very common. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 11 - 1, fruiting - 12.

Narvelia zeylanica DC.

A climbing shrub, leaves three foliate. Flowers greenish yellow, found on hills, on cleared slopes up to 800 m, wayside, thickets or tree by forest edges. Observed in mixed deciduous forest in Siruvani.

Family Menispermaceae

Cyclea peltata (Lam.) Hook. f. & Thoms.

A climber, drupes white, flower greenish, common in hills above 800 m, often in cleared places and fallow, arable lands, occasional. Observed in mixed deciduous forest in Siruvani. Flowering 3 - 6, fruiting 1 - 12.

Cocculus hirsutus (L.) Diels.

An evergreen tomentose straggler with pale yellow flowers and reddish purple drupelets. Common in dry localities and clearings. Observed in mixed deciduous forest in Siruvani.

Family Flacourtiaceae

Casearia elliptica Willd.

Shrub, common in all plain forests and very common in waste lands, scrub jungles, banks of rivers. Capsules greenish yellow. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley. Flowering 2 - 4.

Flacourtia indica (Burm. f.) Merr.

A shrub in scrub forest and on rocky hills, very common, wood very hard. Flowers cream coloured, drupes red, globose. Observed in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 6 - 9 and 1 - 3.

Family Hypericaceae

Hypericum mysurense Heyne ex. Wight & Arn.

A large shrub on open grass slopes. Flowers yellow. Observed in grass-land in Upper Bhavani. Distribution - Coimbatore, Nilgiri and Madurai.

Family Theaceae

*** *Camellia sinensis*** (L.) Kuntze.

A glabrous, evergreen shrub, cultivated in the hills, flowers white. Observed in coffee plantation in Mudumalai Wildlife Sanctuary. Native of Southeast Asia extending north to east Asia and south to India, Rapid spread in tropical and subtropical countries during 19th century.

Family Ancistrocladaceae

Ancistrocladus heyneanus Wall.

Large, climbing shrub with hooked branches and yellow flowers. Found in moist evergreen forest in Silent Valley National Park. Not common. Flowering and fruiting 2 - 5.

Family Malvaceae

Abutilon hirtum (Lam.) Sweet.

It is a weed of wasteland. Flowers yellow. It is distributed in old world tropics, tropical America and Malaysia. Observed in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Abutilon indicum (L.) Sweet.

A shrub with yellow flowers opening in the evening. It is common in open waste place and hedges. Flowering and fruiting in all months. Found in mixed deciduous forest in Siruvani. Widely distributed through-out tropics and subtropics of both hemispheres. Aggressive colonizer on disturbed ground.

Abutilon neilgherrense Munro ex Wight

An undershrub in the hills, distributed in Coimbatore, moist deciduous and scrub jungle of Mudumalai Wildlife Sanctuary, Madurai, Nilgiri and Ramnathpuram.

Hibiscus solandra LHer.

Common herb with white flowers, in the Western Ghats. Observed in moist deciduous forest of Mudumalai Wildlife Sanctuary.

Hibiscus surattensis L.

Subshrub observed in evergreen forest of Silent Valley. Having reddish branchlets with recurved prickles. Flower bright yellow, inside base purple, common on roadside, by arable land.

Malvastrum coromandelianum (L.) Garcke

Annual herb with yellow flowers. Common weed on road sides and waste places. Observed in moist deciduous forests in Mudumalai Wildlife Sanctuary and Siruvani. Flowering - 5.

Pavonia zeylanica (L.) Cav.

An under shrub with white to rose flowers observed in Siruvani mixed deciduous forest. It is a frequent weed. Common in wasteland, abundant in disturbed soil. Gregarious. Flowering and fruiting 1 - 12.

Sida acuta Burm. f.

Much branched shrub with lanceolate leaves and yellow flowers. Distribution - Pantropical. Very common, formidable weed in places, observed in all types of forests in Mudumalai Wildlife Sanctuary and Siruvani. Flowering and fruiting 1 - 12.

Sida cordata (Burm.f.) Borssum

Commonly occur in wastelands and wayside, locally abundant in forest clearings. Flowers yellow. Observed in moist deciduous and dry deciduous forests of Mudumalai Wildlife Sanctuary. Distribution - Pantropical. Flowering and fruiting 1 - 12.

Sida cordifolia L.

A shrub with yellow flowers. Observed in moist deciduous and dry deciduous forests of Mudumalai Wildlife Sanctuary. Common by arable or fallow lands, Flowering and fruiting 1 – 12, Pantropical.

Sida rhombifolia L.

An undershrub with rhomboid leaves and yellow flowers, commonly abundant on disturbed ground, common weed, observed in moist deciduous, dry deciduous forest and teak plantation of Mudumalai Wildlife Sanctuary and Siruvani. Flowering fruiting 1 - 12. Distribution - Old and New world tropics and subtropics.

Sida spinosa L.

An under shrub with shortly tomentose branchlets and pale yellow flowers, found in hills (500 – 900m), not common, less in plains. Found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Pantropical. Flowering and fruiting 1 - 12.

Urena lobata L.

An undershrub with stellate tomentose branchlets and rose flowers. Common in waste lands, by arable land, way side. Observed in moist deciduous forest and teak plantation of Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Family Sterculiaceae

Eriolaena quinquelocularis (Wight & Arn.) Wight

Shrub or small tree with gray foliage and yellow flowers. Observed in dry deciduos forest and scrub jungle in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Madurai, Nilgiri. Flowering and fruiting 6 - 8.

Helicteres isora L.

A large shrub, common in forest under growth. Commonly found on moist deciduous slopes and by forest clearings. Flowers crimson (bluish before fading). Fruits cylindrical, spirally twisted. Seeds infinite. Common in hills. Observed in dry deciduous forest, moist deciduous forest, scrub jungle and teak plantation in Mudumalai Wildlife Sanctuary. Flowering 9 - 12, fruiting 12 - 3.

Family Tiliaceae

Triumfetta pilosa Roth.

A perennial herb, leaves lobed, flowers yellow, fruit capsule with prickles. Observed in dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Distribution - Coimbatore, Nilgiri, Madurai. Flowering 9 -12, fruiting 1 - 12.

Triumfetta rhomboidea Jacq.

A herb with rhomboid leaves, yellow flowers and having capsules with prickles. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Distribution - Pantropical. Flowering 9 - 11, fruiting 1 – 12.

Grewia hirsuta Vahl.

Straggling shrub with white flowers and red fruits, commonly found on hills (400 - 1000 m). Observed in dry deciduous forest, scrub jungle, moist deciduous forest and eucalyptus plantation in Mudumalai Wildlife Sanctuary and moist deciduous forest in Siruvani. Flowering 6 - 8, fruiting – 8.

Grewia orbiculata Rottl.

Straggler with yellow flowers. Observed in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering - 4.

Family Zygophyllaceae

Tribulus terrestris L.

A silky herb with spinescent fruits, in dry localities. Golden yellow flowers. Weed of waste land. Very common. Found in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering 1 - 4, fruiting 1 - 12.

Family Oxalidaceae

Biophytum sensitivum (L.) DC.

Herb in open places, road-sides and banks and cultivated fields. Leaves whorled apicaly on stem, even pinnate, some what sensitive to touch. Flowers yellow in axillary umbels. Flowering and fruiting 8 - 12. Common weed of tea plantation in South India. Observed in dry deciduous forest and moist deciduous forest in Mudumalai Wildlife Sanctuary and Siruvani. Distributed through-out the tropics.

Oxalis corniculata L.

A creeping herb, common weed in garden soil and moist places. Flowers yellow. Found in hills above 500 to 800 m, widely distributed. Abundant in fallow fields. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Family Rutaceae

Clausena dentata (Willd.) M. Roem.

Strongly aromatic shrub with axillary inflorescence. Leaves odd, pinnate. Flowers white. Observed in mixed deciduous forest in Siruvani. Distribution - foot hill, scrub jungle to 1400 m. Flowering 3 - 4, fruiting - 7.

Glycosmis pentaphylla (Retz.) DC.

Undergrowth in forests. Flowers small, white, crowed in small clusters. Berries globose, pinkish white or creame coloured. Observed in moist deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 2 - 4 and fruiting - 3.

Toddalia asiatica (L.) Lam.

Armed, prickly straggler, leaves trifoliate, flowers white, common along hedges, waste places. Observed in scrub jungle in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 5 - 7 fruiting 8 - 11.

Toddalia asiatica var. ***floribunda***

Liana with yellow flowers. Commonly found in hills above 1200 m. Observed in sholas in Upper Bhavani. Flowering 11 - 1 and 5 - 6, fruiting 1 - 12.

Murraya koenigii (L.) Spreng.

Deciduous shrub with pinnate leaves, flowers small, white, fragrant. Fruits - purplish black. Found on hills, 750 - 1200 m. Flowering 3 - 5 and 7 - 8, fruiting 1 - 12. Commonly cultivated, leaves used in flavoring food preparation. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary.

Murraya paniculata (L.) Jack

Evergreen large shrub. Common in under wood and especially in ravines. Flowers white, fruits red. Found in hills, 750 – 1400 m. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley. Flowering 3 - 5 and 8 - 9, fruiting 1 - 12.

Family Erythropalaceae

Erythropalum populifolium Mast.

Climbing shrub with yellow flowers. Endemic, common in forest under growth. Observed in evergreen forest in Silent Valley National Park. Flowering and fruiting 10 - 4.

Family Celastraceae

Euonymus angulatus Wight

A small tree or shrub, observed in evergreen forest in Silent Valley. Distribution - Coimbatore and Nilgiri.

Floscopa scandens Lour.

A herb with pink flowers, common in evergreen forests, along water streams. Observed in evergreen forest in Silent Valley. Flowering and fruiting 1 - 4.

Fluggea leucopyrus Willd.

Profusely branched shrub, branchlets arrested stift, thorn like, very common in scrub jungles. Observed in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowers greenish, fruiting 4 - 11.

Family Rhamnaceae

Zizyphus oenoplia (L.)Mill.

A large shrub with recurved thorn and greenish yellow flowers, generally found in dry forest and open bushy places, more common on lower slopes. Observed in dry deciduous forest, moist deciduous forest, scrub jungle, coffee plantation and eucalyptus plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 7 – 11, fruiting 10 - 1.

Zizyphus nummularia (Burm. f.) Wight & Arn.

A small straggling shrub, common in dry forest, scrub jungle. Observed in mixed deciduous forest in Siruvani. Distribution - Coimbatore.

Zizyphus rugosa Lam.

A large straggler with stout thorns. Drupes globose, white, when ripe. Common in dry forests and hills (900 -1500 m). Observed in scrub jungle and moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 3 - 6.

Family Vitaceae

Cissus glyptocarpa (Thw.) Planch.

A climbing shrub in slopes of hills at lower elevations. Flowers light yellow, berry black purple. Observed in evergreen forest in Silent Valley. Distribution - Coimbatore, Nilgiri.

Family Leeaceae

Leea indica (Burm. f.) Merr.

A large shrub in lower elevation. Flowers greenish white. Found in hills above 750 to 900 m, sholas, occasional. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary and Siruvani and evergreen forest in Silent Valley. Flowering 4 - 5 and 10 - 11, fruiting 1 - 12

Leea asiatica (L) Ridsdale.

A large undershrub, on slopes of hills. Flowers greenish white, berry globose gray. Distribution - Coimbatore, Madurai, Nilgiri.

Family Sapindaceae

Allophylus cobbe (L.) Raeusch.

A large shrub with yellowish - brown bark. Flowers small, white. Fruits, globose, red when ripe. Observed in evergreen forest in Silent Valley. Distribution - Coimbatore, Nilgiri.

Family Anacardiaceae

Buchanania axillaris (Desr.) Ramam.

Shrub, flowers greenish white. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - hills (500 – 1000 m), on the slopes. Flowering 5 - 6, fruiting 6 - 12.

Family Papilionaceae

*** *Aeschynomene indica*** L.

A slender herb with yellow to flame colored flowers. Observed in dry deciduous forest of Mudumalai Wildlife Sanctuary. Common in low lying moist places, fallow lands, bank of ponds. Native of South-east United States. Pantropical. Flowering 1 - 3, fruiting 1 - 12.

Alysicarpus rugosus (Willd.) DC.

Herb with pink to purple flowers. Found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 11 - 3 and 8 - 9, pod 1 - 12. Frequent weed.

*** *Clitoria ternatea*** L.

Vine with blue flowers. Introduced, widely cultivated in tropics. Commonly found on the waysides on thickets in scrub jungles. Abundant in forest clearings. Observed in mixed deciduous forest in Siruvani. Flowering 3 - 5, fruiting 1 - 12.

*** *Crotalaria pallida*** Dryand.

A glabrescent under shrub, flowers yellow with red stripes. Found in teak plantation and moist deciduous forest in Mudumalai Wildlife Sanctuary.

Introduced, native of Central and tropical America, widely introduced in tropical Africa, Asia, Malaysia and Queensland.

Crotalaria prostrata Rottl. ex Willd.

A perennial herb, clothed with short spreading silky yellow, brown hair. Flowers yellow, flowering and fruiting - 1. Observed in mixed deciduous forest in Siruvani.

Desmodium gyrans DC.

Undershrub with pink flowers. Rare, found in evergreen forest in Silent Valley National Park. Flowering and fruiting - 12.

Desmodium triflorum (L.) DC.

A small much branched herb among grasses, forming compact mats. Flowers, small, pink, some times white. Found in dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Flowering 12 - 2, fruiting 1 - 12.

Desmodium pulchellum (L.) Benth.

A shrub with white flowers in the under growth of dry forests. Found in dry deciduous forest and moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Nilgiri, Madurai districts of Tamil Nadu.

Desmodium gangeticum (L.) DC.

A shrub with unifoliate leaves, as forest under growth. Flowers white or violet. Common weed. Observed in Mudumalai Wildlife Sanctuary. Flowering 11 - 2, fruiting - 12.

Desmodium laxiflorum DC.

A shrub in moist places as undergrowth. Trifoliate leaves, flowers blue. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 12 - 4, fruiting - 1.

Desmodium zonatum Miq.

A slender erect undershrub with pale violet flowers. Rare, observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 10 - 2.

Derris scandens (Roxb.) Benth.

A woody straggler with imparipinnate leaves and white to pale rose flowers, seeds winged. Common in scrub jungles and along riverbank. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 7 - 8 and fruiting -8.

Flemingia bracteata (Roxb.) Wight

A shrub, with rosy or purple flowers, found in dry deciduous forest and moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Nilgiri, Madurai districts of Tamil Nadu.

Flemingia strobilifera (L.) R. Br. ex Ait.

A much branched shrub with white flowers, found in moist and dry deciduous forests of Mudumalai Wildlife Sanctuary.

Flemingia wightiana Graham. ex Wight & Arn.

A shrub with pink flowers found in moist and dry deciduous forests in Mudumalai Wildlife Sanctuary. It is distributed in Coimbatore, Nilgiri, Madurai districts of Tamil Nadu. Flowering and fruiting 11- 2.

Indigofera cassioides Rottl. ex DC.

A deciduous gray pubescent shrub with pink - red pretty flowers, found in moist deciduous forest in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 12 - 3 and fruiting - 1.

Indigofera linifolia (L. F.) Retz.

A annual herb with red to crimson flower, common in pasture lands, fallow fields, way sides, even in bare, gravely ground. Observed in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering 9 - 12, fruiting - 10.

Indigofera linnaei Ali.

A trailing profusely branched herb. Flowers pink or red, aggressive colonizer on disturbed ground, common weed. Found in scrub jungle, dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 9 -11.

Indigofera stachyodes Lindl.

A small shrub found in dry deciduous and moist deciduous forests in Mudumalai Wildlife Sanctuary and in Nilgiri district, probably cultivated. Spreading herb or vine. Flowers yellow. Flowering - 1, fruiting - 2.

Pueraria tuberosa DC.

Vine with tuberous roots. Leaves three foliate, flowers pale violet. Occasional clumps along ghats. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering - 4. Distribution - Nilgiri, Coimbatore.

Spatholobus roxburghii Benth.

Gigantic climber with creamy white flowers. Very common on forest trees. Found in mixed deciduous forest in Siruvani. Flowering 9 - 4.

Tephrosia pumila (Lam.) Pers.

Herb among grasses in waste-lands, fallow-lands, way-side. Flowers white or purplish. Observed in dry deciduous forest of Mudumalai Wildlife Sanctuary.

Tephrosia purpurea (L.) Pers.

A perennial under shrub, flowers bluish pink to purple, Gregarious in wastelands, fallow fields, even in poor soil. Observed in moist deciduous, dry deciduous forest, scrub jungle, eucalyptus plantation and coffee plantation in Mudumalai Wildlife Sanctuary and in mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Tephrosia tinctoria Pers.

Hairy herbs, flower orange to flame colored, common on bare slopes, crevices of rocks, forest borders. Found in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Tephrosia villosa (L.) Pers.

An erect hairy herb, corolla pink, common on waste land, in poor soil, Gregarious in disturbed ground. Observed in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering 11 -3, fruiting-12.

Teramnus labialis (L. F.) Spreng.

A slender twining vine, flowers pink, red, purple; fruits brown when ripe.. Found in plains from the coast to 900 m. On thickets by forest borders. Locally abundant on riverbanks. Flowering 11 - 2, fruiting – 12.

Uraria logopodioides (L.) Desv.

A herb in grass lands. Observed in dry deciduous forest and moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowers rose.

Uraria rufescens (DC.) Schind.

A straggling under shrub in dry forest. Flowers rose coloured. Observed in dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Flowering - 11, fruiting - 12.

Zornia gibbosa Span.

Much branched annual herb, common in floor of scrub jungle, fallow fields, poor gravely soils, widely distributed, occasional weed. Flowers orange or yellow with pink streaks. Observed in moist deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary. Flowering 9 - 1, fruiting 10.

Glycine javanica L.

Twining herb with reddish flowers, common in semi-evergreen forest. Found in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 11 - 2.

Family Caesalpiniaceae

Cassia absus L.

Herb, leaves with two pairs of leaflets, Flowers red, Abundant in disturbed ground. Found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 11 - 2, fruiting - 12.

Cassia hirsuta L.

A shrub with yellow flowers, common weed, found in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Cassia intermedia Sharma, Vivek. & Rathakr.

A common herb in Nilgiri district. Flowers yellow. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 4 -11.

Cassia mimosoides L.

Perennial herb with yellow flowers. Common in scrub jungles, observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 7-11.

***Cassia occidentalis** L.

An annual under shrub with yellow flowers. Observed in moist deciduous forest, dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Gregarious weed of waste land. Native of tropical America. Now pantropical. Flowering and fruiting 1 - 12.

Cassia pumila Lam.

An under shrub with yellow flowers. Common in dry sandy places. Observed in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Family Mimosaceae

Acacia caesia (L.) Willd.

Straggler (6 to 10 m.) with hooked internodal thorns. Profusely armed, extensive straggler forming impenetrable thickets, observed in moist deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowers white in globose head. Flowering 10 - 12, fruiting - 12.

Acacia torta (Roxb.) Craib

Straggler having straight internodal thorns and white flowers. Found in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 4 - 6, fruiting - 6.

Dichrostachys cinerea (L.) Wight & Arn.

Armed shrub. Flowers above yellow and pink below. Common in scrub jungles, waste-lands, along the hedges, even in poor soils. Observed in dry deciduous forest, scrub jungle, eucalyptus plantation and teak plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 4 - 7, fruiting 1 - 5.

Mimosa pudica L.

A prickly herb with sensitive leaves and purple to pale pink heads. Introduced, native of South America, now a pantropical weed. Observed in dry deciduous forest, moist deciduous forest, scrub jungle, teak plantation and coffee plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 11 - 3, fruiting 1 - 5.

Pterolobium indicum A. Rich.

Woody armed, climbing shrub with yellowish white flowers. Common in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting - 5.

Vigna trilobatus (L.) Verde.

Twining herb, flowers yellow. Leaves trifoliate. Commonly cultivated, used as fodder. Found in Mudumalai Wildlife Sanctuary. Flowering and fruiting 11 - 4.

Family Rosaceae

Fragaria indica Andr.

Perennial herb with creeping stolons. Flowers yellow, common in Western Ghats, Nilgiri hills at 1800 -2100 m. Observed in sholas in Upper Bhavani.

Fragaria neilgherrensis Schlecht. ex Gay

Perennial creeping, stout herb known as wild strawberry. Flowers white, fruits edible. Common in Western Ghats, Nilgiri hills at 1800 -2100 m. Observed in sholas in Upper Bhavani.

Family Myrtaceae

Rhodomyrtus tomentosa (Ait.) Hassk.

A bushy shrub in open forest and along the margins of sholas. Observed in sholas in Upper Bhavani. Distribution - Coimbatore, Madurai and Nilgiri.

Eugenia thwaitesii Duthie

A big shrub, common in Nilgiri and Coimbatore. Flowers white, berry crimson. Observed in evergreen forest in Silent Valley.

Family Melastomataceae

Memecylon edule Roxb.

Shrub with blue flowers. Common in evergreen forest in Silent Valley National Park. Flowering - 3, fruiting - 10.

Memecylon heyneanum Benth. ex wight and Arn.

Shrub with blue flowers. Common in evergreen forest in Silent Valley National Park. Flowering and fruiting 11 - 2.

Osbeckia gracilis Bedd.

A herb in high altitudes, drying yellowish green or dark olive green. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution -Nilgiri and Madurai.

Family Onagraceae

Ludwigia octovalvis (Jacq.) Raven

Herb densely covered with spreading pubescence, flowers yellow. Common weed in moist sandy places. Commonly found in hills above 400 m in perennially moist places like marshes, ponds, riverbanks. Observed in evergreen forest in Silent Valley. Flowering and fruiting 1 - 12.

Ludwigia parviflora Roxb. (Perennis L.)

Annual herb. Flowers yellow. Common in moist places. Occasional weed in paddy fields and moist places. Observed in evergreen forest in Silent Valley. Flowering and fruiting 1 - 12.

Microtropis stocksii Gamb.

An undershrub with broadly elliptic leaves. Flowers yellowish white. Found in evergreen forest in Silent Valley. Endemic to southern Western Ghats. Flowering and fruiting 3 - 4

Family Cactaceae

*****Opuntia dillenii*** (Ker - Gawl.) Haw.

An alien succulent shrub with yellow flowers. Leaves deciduous. Native of America, widely naturalized in India. Introduced before 1786. Found in waste places. Fruits - bright red. Run wild in waste-land. Observed in scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Family Umbelliferae

Hydrocotyle javanica Thunb.

Herb in shady places on hills above 1300 m, moist places like shola floor, stream banks and rotting wood. Flowers greenish white. Observed in mixed deciduous forest in Siruvani, evergreen forest in Silent Valley and sholas in Upper Bhavani. Flowering 10 - 1, fruiting - 11.

Pimpinella wallichiana (Miq.) Gandhi.

A tall herb with white flowers, common near stream banks, low hills, in the shade. Observed in evergreen forest in Silent Valley. Flowering and fruiting - 9. Distribution - Coimbatore, Nilgiri.

Family Rubiaceae

*** *Coffea arabica*** L.

A large shrub, cultivated. Flowers white, fragrant, fruits berry, red when ripe. Plantations at Nilgiri. Observed in coffee plantation and moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 3 - 5, fruiting - 10. Native of Ethiopia, spread to east early.

Galium asperifolium Wall. in Roxb.

A slender herb at higher elevation, found on wayside thickets. Flowers white. Flowering - 4, fruiting - 5. Observed in sholas in Upper Bhavani. Distribution - Madurai, Nilgiri.

Hedyotis nitida Wight & Arn.

An annual herb, flowers in axillary cyme. Common in Coimbatore, Nilgiri and Madurai. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 10-11.

Hedyotis pumila L. f.

A herb often found at lower level. Flowers white. Rare, observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Nilgiri. Flowering and fruiting 8 - 10.

Ixora pavetta Andr.

Slender shrub, flowers white. Very common, found in hills (300 - 900 m). Observed in mixed deciduous forest in Siruvani. Flowering 3 - 4, fruiting 1 - 2.

Knoxia sumatrensis (Retz.) DC.

Herb, common in hills (400 - 1000 m), on bare slopes, fallow fields. Flowers pale violet. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary and sholas in Upper Bhavani. Flowering 4 - 10, fruiting 9 - 12.

Lasianthus ciliatus Wight

A stout shrub with tawny brown rusty tomentum and white flowers, found in sholas at higher elevation. Observed in evergreen forest in Silent Valley. Distribution - Nilgiri. Flowering and fruiting 1 - 12.

Ophiorrhiza mungos L.

Herbs with white flowers. Common in evergreen forest in Silent Valley National Park. Flowering and fruiting 11 - 2.

Pavetta breviflora DC.

A shrub in higher elevation. Observed in sholas in Upper Bhavani. Distribution - Nilgiri.

Pavetta congesta nil

A shrub in sholas in Upper Bhavani and evergreen forest in Silent Valley.

Pavetta hispidula Wight & Arn.

A shrub with white flowers, common in evergreen forest. Observed in sholas in Upper Bhavani. Distribution - Nilgiri, Coimbatore.

Pavetta indica L.

A small shrub with pale yellow bark, leaves lanceolate, flowers white, scented, very common on shola floor. Observed in evergreen forest in Silent Valley. Flowering 5 - 8, fruiting - 6.

Pavetta tomentosa Roxb. ex J.E. Smith

Shrub, common on hills, on slopes, inside sholas. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 6 - 9, fruiting 1 - 12. Distribution - Nilgiri, Coimbatore.

Psycotria nilgiriensis (Hook. f.) Deb & Gang.

Large shrub with white flowers and blackish purple drupes. Rare, found in evergreen forest in Silent Valley National Park. Flowering and fruiting - 3.

Psycotria nigra (Gaertn.) Alston

A glabrous shrub with white flowers in damp forests. Observed in evergreen forest in Silent Valley. Flowering and fruiting 3 - 10

Randia dumetorum (Retz.) Poir.

Armed shrub, leaves clustered, flowers white turning yellow. Found in foot hill scrub jungles to lower dry deciduous slopes. Very common. Observed in all the habitats of Mudumalai Wildlife Sanctuary and Siruvani. Flowering peak in 1 and 7, fruiting 1 - 12.

Randia malabarica Lam.

Thorny shrub with white scented flowers and red berry. Observed in dry deciduous forest, scrub jungle, eucalyptus plantation and teak plantation in Mudumalai Wildlife Sanctuary.

Rubia cordifolia L.

A climbing, branched herb with white flowers. Drupes dark blue. Found in hills above 800 m on thickets. Observed in sholas in Upper Bhavani. Flowering with peak 11 - 1, fruiting - 2. Distribution - Nilgiri and Madurai.

Rubus ellipticus Sm.

A large straggling shrub with hairs and prickles. Flowers white. Fruits are orange, like raspberry, edible. Generally found in Western Ghats above 1800 m. Observed in Sholas in Upper Bhavani.

Rubus racemosus Roxb.

A straggling shrub with red flowers. Found in sholas in Nilgiri hills at high elevation.

Saprosma foetens (Wight) K. Schum.

Shrub, bad smelling when bruised. Flowers purple, drupes deep blue. Observed in sholas in Upper Bhavani and evergreen forest in Silent Valley.

Spermacoce ocymoides Burm. f.

A branched herb in hills (400 - 1400 m), on bare slopes, along the way-side in the thin layer of soil. Flowers white. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 9 - 2, fruiting 1 - 12.

Spermacoce hispida L.

A spreading hispid herb. An aggressive colonizer, abundant in fallow fields. Flowers pinkish white. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 9 - 1, fruiting 1 - 12.

Spermacoce pusilla Wall.

Slender herb with white flowers. Observed in dry deciduous, moist deciduous forests in Mudumalai Wildlife Sanctuary. Flowering and fruiting 7-11.

Family Asteraceae

*** *Ageratum conyzoides*** L.

An aromatic, introduced herb with hispid, opposite leaves and white or pinkish violet flowers. Common weed, observed in all the habitats of Mudumalai Wildlife Sanctuary, evergreen forest in Silent valley and moist deciduous forest in Siruvani.

*** *Acanthospermum hispidum*** DC.

An introduced herb. Gregarious weed of wastelands, fallow lands, aggressive colonizer, found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Disc florets yellow, ray florets yellow or cream. Flowers 1 - 6. Native of South America, widely introduced in tropics.

Anaphalis elliptica DC.

A soft, very white, woolly herb at higher altitude, observed in sholas at Upper Bhavani. Distribution - Coimbatore, Nilgiri and Madurai

Anaphalis marcescens (Wight) Clarke

A graceful small herb on banks of streams at higher altitudes, observed in sholas at Upper Bhavani.

Anaphalis neelgerryana (Sch.-Bip. ex DC.) DC.

A much branched shrub common on dry slopes and in rocky places at higher altitude. Leaves covered with cottony wool. Flowers yellow. Observed in sholas at Upper Bhavani. Distribution - Coimbatore, Nilgiri. Flowering 2 – 4.

Anaphalis wightiana (DC.) DC.

An erect herb with woody root stock in cool places and on banks of streams at higher altitude, observed in sholas at Upper Bhavani. Distribution - Nilgiri, Madurai.

*** *Bidens pilosa*** L.

An introduced stout herb, observed in teak plantation at Mudumalai Wildlife Sanctuary and evergreen forest at Silent Valley. Gregarious weed of fallow land, aggressive colonizer, Flowers white, The black achens have 3 - 4 awns with retrorse barbs that help them in getting dispersed by sticking to the skin of animals. Flowering 10 - 4. Pantropical weed.

Blepharispermum subsessile DC.

Glabrous shrub. Head 5 -10 flowered. Common in Nilgiris at 600 – 900 m altitude Observed in sholas in Upper Bhavani.

Blumea mollis (D. Don) Merr.

An aromatic herb observed in all the habitats of Mudumalai Wildlife Sanctuary, evergreen forest at Silent valley and moist deciduous forest at Siruvani. Common weed, flowers rose to pink.Flowering 1 - 4. Distribution - tropical Africa and Asia.

Blumea lacera (Burm. f.) DC.

A large strongly scented herb at lower elevation, observed in moist deciduous forest, scrub jungle and tea plantations at Mudumalai Wildlife Sanctuary. It is common in wasteland and fallow fields. Flowers pink, flowering 1 - 6, Distribution - Africa, Asia, Australia.

Blumea alata (D. Don) DC.

A stout leafy herb, disc florets pink, ray florets pale pink. Observed in moist deciduous forest, scrub jungle and tea plantations at Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Dharmapuri, Madurai and Nilgiri. Flowering and fruiting 12 - 1.

Blumea Virens Wall. ex DC.

Tall, slender, glabrescent herb in hilly forest region and fallow fields. Flowers white. Observed in moist deciduous forest, scrub jungle and tea plantations at Mudumalai Wildlife Sanctuary. Flowering -3. Distribution - Sri Lanka, India, South east Asia, Malaysia.

* ***Chromolaena odorata*** (L.) King & Robinson

Aromatic, introduced, herbaceous shrub, with bluish white flowers. Aggresive, colonising weed in disturbed forests and plantations. Observed in all the habitats of Mudumalai Wildlife Sanctuary and Silent Valley. Native of America, widely naturalized in tropical Asia. Flowering 12 - 3.

Elephantopus scaber L.

Herb with purple flowers, observed in moist deciduous forest, scrub jungle and coffee plantation. Distribution - Coimbatore, Nilgiri.

Emilia sonchifolia (L.) DC.

A soft straggling, glabrescent herb with purple flowers, observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 12 - 4.

* ***Erigeron karvinskianus*** DC.

A branched spreading weed of waysides and riverbanks, observed in sholas of Upper Bhavani. Disc yellow, rays opening white and fading pink. Distribution - Coimbatore, Madurai, Nilgiri. Native of Mexico, introduced in India. Flowering 2 - 5.

* ***Eupatorium repandum*** Willd.

Introduced herb, flowers white or pinkish white, generally found in high altitude. Observed in evergreen forest in Silent Valley and sholas and wattle plantations in Upper Bhavani.

* ***Galinsoga parviflora*** Cav.

Herb with bisexual florets, found in hills above 900 to 1200 m. Introduced. Gregarious weed of cultivation. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 12 - 4. Native of tropical America.

Glossocardia bosvallea (L.f.) DC.

A pretty herb with bipinnatisect leaves and yellow flowers, found on plains on the floor of scrub jungles and dry deciduous forest in Mudumalai Wildlife Sanctuary, stream banks or even in very poor gravely ground and dry areas. Flowering 10 - 2. Distribution - Coimbatore, Nilgiri.

* ***Gnaphallum polycaulon*** Pers.

A soft, white, woolly, annual, introduced herb. Found in sholas at Upper Bhavani. Weed of cultivation, roadside and waste places. A pantropical weed. Flowering 11 - 5.

Gynura nitida DC.

A tall sub-succulent herb with yellowish florets, observed in evergreen forest, at Silent valley. Flowering - 9, common in dry open forests in hills, on bare slopes in crevices of rocks.

*** Lagascea mollis*** Cav.

White, pubescent herb. Heads one flowered, florets white, bisexual. Common weed in plains, in fallow lands. Flowering and fruiting 1 -12. Native of tropical America, now adventative in India and Malaya. Distribution - Coimbatore, Nilgiri.

*** Parthenium hysterophorus*** L.

A poisonous, alien weed on road-sides and waste places. Heads white. Harassingly aggressive, found in scrub jungle of Mudumalai Wildlife Sanctuary. Flowering 11 - 3, Native of North America, now a pantropical weed. It causes allergy, asthma and skin diseases.

Sonchus oleraceus L.

An annual herb on road-sides. Ligules pale yellow. Usually found in gardens and cultivated fields in hills. Common weed of cultivation, fallow fields. Found in scrub jungle of Mudumalai Wildlife Sanctuary. Flowering and fruiting 12 - 4.

*** Synedrella nodiflora*** (L.) Gaertn.

An exotic, annual hairy herbs with yellow florets. Native of West Indies. Common in waste lands. Observed in moist deciduous forest in Siruvani and Mudumalai Wildlife Sanctuary. Flowering 7 - 10.

*** *Tridax procumbens*** L.

It is a procumbent, hispid, perennial herb. Wide spread and abundant weed, especially where soil has been disturbed and on roadside. Achenes are gray, densely covered with short hairs and surrounded by a ring of pappus consisting of feathery bristles. Observed in evergreen forest of Silent Valley. Flowering 1 - 12, less in summer, native of Central America, now wide spread.

Family Ericaceae

Gaultheria fragrantissima Wall.

Shrub, with white, pinkish flowers, found in sholas in Upper Bhavani.

Family Myrsinaceae

Antistrophe serratifolia (Bedd.) HooK. f.

Slender herb with rusty villous branches and white flowers. Fruits globos red. Endemic, rare, found in evergreen forest in Silent Valley National Park. Flowering and fruiting 3 - 10.

Family Symplocaceae

Symplocos pulchra Wight

A diffuse shrub in hills. Observed in sholas in Upper Bhavani.

Uraria rufescens (DC.) Schindler

A straggling under shrub in dry forest. Leaves three foliate, flowers rose. Common in hills above 150 m. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 11, fruiting 12.

Uraria logopodioides Merr.

A herb in grass lands. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Madurai, Nilgiri.

Family Oleaceae

Jasminum rottlerianum Wall. ex A. DC.

A large climbing shrub with white flowers, observed in mixed deciduous forest in Siruvani and evergreen forest in Silent Valley. Distribution - Coimbatore.

Family Apocynaceae

Carissa carandas L.

Thorny shrub with milky latex. Flowers pale pink or white, berry dark purple, edible. Endemic, observed in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting 9 - 3.

Rauvolfia serpentina (L.) Benth. ex Kurz.

A herbaceous under shrub, mostly in cleared forest area. Flowers white, tinged with violet. Cultivated for its root. Observed in mixed deciduous forest in Siruvani and teak plantation in Mudumalai Wildlife Sanctuary.

Rhynchotechum permolle (Nees) Burtt.

Herb with white flowers. Stem covered with wooly tomentose. Found in evergreen forest in Silent Valley. Flowering and fruiting 8 – 3.

Family Asclepiadaceae

Caralluma umbellata Haw.

Succulent herb. Flowers dark red inside, greenish outside. Observed in evergreen forest in Silent Valley National Park. Flowering and fruiting - 7.

Cryptolepis buchanani Roem. & Shultes.

A much branching climber in deciduous forest and on hedges, base woody, flowers greenish yellow on cleared slopes, forest borders, ready colonizer, very common. Observed in mixed deciduous forest in Siruvani. Flowering 3 - 4 (plains) 7 - 9 (hills), fruiting 1 - 12. Distribution - Coimbatore, Madurai, Nilgiri.

Hemidesmus indicus R. Br.

Straggler with milky latex and decussate leaves. Flowers yellow, purple. Found in moist deciduous and scrub forest, on slopes, very common, roots are aromatic.

Tylophora indica (Burm. F.) Merr.

A much branched climber with long fleshy roots. Leaves cordiform. Flowers pale yellow. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Common on hedges and in open forest. Flowering 2 - 4 (plain), 7 - 10 (hills); fruiting 1 - 12.

Wattakaka volubilis (L. f.) Stapf.

A woody straggler found in mixed deciduous forest in Siruvani. Bark brown with shallow vertical grooves. Flowers white. Flowering 4 -5 (hills), 7 -1 (plains); fruiting 1 - 12.

Family Gentianaceae

Canscora decussata (Roxb.) Schultes & Schultes f.

Herb in moist area and exposed slopes, flowers white. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 11 - 3, fruiting 12.

Family Boraginaceae

Cynoglossum zeylanicum (Vahl. ex Horrum.) Thunb. ex Lehm.

A herb with blue to white flowers, found on hills above 900 m, on the wayside, by riverbanks, in fallow fields, common. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 1 - 3 and 8 - 11.

Heliotropium marifolium Retz.

Herb with white flowers in racemes. Common in waste places. Observed in Mudumalai Wildlife Sanctuary. Flowering and fruiting - 7.

Family Convolvulaceae

Argyreia cuneata (Willd.) Ker-Gawl.

Bushy, pretty, silky shrub in hilly tracts, flowers purple, showy. Observed in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Distribution - Nilgiri, Coimbatore. Flowering - 8, fruiting - 11.

Evolvulus alsinoides (L.) L.

A herb with blue flowers, common on floor of scrub jungle, even in poor soil, more abundant on hills, bare exposed slopes, common weed. Observed in dry deciduous forest, moist deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12. Distribution - Tropical and subtropical regions of both hemisphere.

Ipomoea obscura (L.) Ker- Gawl.

A slender twining herb with delicate, yellow or white tinged pink flowers. Common on the hedges, arable land. Found in mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Ipomoea staphylina Roem.& Schultes

Extensive liane, flowers showy, pink with a deeper throat (funnel shaped), common and abundant in waste places over the hedges and thickets. Gregarious in heavy masses on thickets and trees. Observed in mixed deciduous forest in Siruvani and in Mudumalai Wildlife Sanctuary. Flowering 12 - 3, fruiting 1.

Ipomoea turbinata Lag. Gen.

A slender climber, common in Nilgiri. Flowers bluish purple, seeds black. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 10-12.

Family Solanaceae

* ***Capsicum frutescens*** L.

A herb extensively cultivated as vegetable, some times found as an escape. Flowers white or greenish white. Observed in mixed deciduous forest in Siruvani. Native of tropical America. Flowering 1 - 5, fruiting 1 - 12.

Solanum anguivi Lam.

A herb, armed with straight prickles, flowers violet, common along the road-sides and waste places near canals, ditches. Observed in dry deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting, 7 - 12.

Solanum viarum Dunal in DC.

Shrub with recurved prickles and white flowers. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 1 -10.

Solanum melongena L.

A perennial herb, very widely cultivated, found as an escape. Corolla campanulate, violet. Observed in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Solanum torvum Sw.

Armed shrub, prickles scattered, flowers white, scented. Often cultivated, Observed in dry deciduous forest, moist deciduous forest, scrub jungle, coffee plantation and teak plantation in Mudumalai Wildlife Sanctuary. Flowering 2 - 4 and 8 - 11, fruiting 1 - 12.

Solanum erianthum D. Don.

A large shrub, covered with yellowish or gray stellate hair. Flowers, white. Usually found in shady places. Observed in teak plantation in Mudumalai Wildlife Sanctuary.

Family Scrophulariaceae

Lindernia antipoda (L.) Alston.

Well branched herb, rooting at nodes. Flowers - bluish violet. Very common in moist areas, pasture lands, riverbanks, fallow fields, bunds of arable lands in clayey soil. Common weed in wet lands. Observed in coffee plantation in Mudumalai Wildlife Sanctuary. Flowering 11 - 2, fruiting - 12.

Lindernia ciliata (Colsm.) Pennell

Gregarious herb. Flowers white with pink throat, common along streams. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 11 - 2, fruiting - 12.

Striga asiatica (L.) Kuntze

A root parasite with rigid stem, hispid. Flowers – white or yellow (sessile), leaves sessile, common in cultivated fields, grassy places and along roadside. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Urochola panicoides Beauv.

Ascending, leafy, annual herb, common on plains and lower slopes, moist places. Spikelets green, common weed in wet land. Distribution - Coimbatore, Nilgiri.

Vetiveria lawsonii Blatt & MeC.

A tufted perennial herb. Distribution - Coimbatore and Nilgiri.

Family Orobanchaceae

Aeginetia indica L.

A parasitic, chlorophyllus herb with haustorial roots and pink flowers. Gregarious. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 9 - 10.

Aeginetia pedunculata Wall.

A parasitic herb on roots of grasses. Flowers pale blue with yellow centre. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary.

Family Acanthaceae

Andrographis serpyllifolia (Rottl. ex Vahl) Wight

Densely hispid herb, flowers white with pink tinge, flowering 6 - 9 and 1 - 3; fruiting 1 - 12, found on hills, locally abundant and widely distributed. Observed in dry deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary.

Andrographis lobelioides Wight

A much branched herb with woody root stock, corolla white streaked with red. Distribution - Nilgiri.

Barleria cristata L.

A hairy ornamental shrub with purplish pink or white flowers. Found in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering 12 - 2, fruiting 1.

Barleria mysorensis Heyne ex Roth.

A small prickly shrub with blue flowers, common weed in dry places. Observed in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Distribution - Nilgiri, Coimbatore.

Dipteracanthus prostratus (Poir.) Nees

Herb in dry places. Flowers blue, violet or white. Common in disturbed ground like forest borders, arable lands, near habitations. Found in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Justicia betonica L.

Common weed on waste land and on hedges. Corolla white, spotted with pink. Observed in evergreen forest in Silent Valley and mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Justicia simplex D.Don.

A slender branced herb found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowers in dense axillary or terminal spikes, pink.

Monothecium aristatum (Wall. ex Nees) T. And.

A branched, small herb in dry open forests. Corolla white with spots on the lower lip. Observed in mixed deciduous forest in Siruvani.

Nilgirianthus barbatus (Nees) Bremek.

A gregarious shrub with white flowers. Found in evergreen forest in Silent Valley. Distribution - Coimbatore, Nilgiri. Flowering 9 – 12.

Phaulopsis imbricata (Forssk.) Sweet

A much branched, diffuse, spreading herb in forest under growth, flowers white. Common in hills above 750 m, moist slopes, riverbanks. Observed in mixed deciduous forest in Siruvani. Flowering 12 - 3, fruiting - 1.

Rhynchosia minima (L.) DC.

A slender trailing annual with small yellow flowers, found in dry places. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Rungia parviflora (Retz.) Nees

A small soft herb in dry forests, flowers blue. Observed in mixed deciduous forest in Siruvani. Distribution - Nilgiri, Coimbatore and Madurai.

Strobilanthes foliosus T. And.

Shrub, common in sholas and evergreen forest, flowers blue.

Strobilanthes kunthiana T. Anderson ex Benth.

Shrub, flowers blue to violet, gregarious. Found in evergreen forest in Silent Valley. Flowering 11 and 1.

Strobilanthes heyneanus Nees.

Perennial subshrub with pink to pale blue flowers. Gregarious, occasional in moist deciduous and evergreen forests in Western Ghats.

Strobilanthes perrottetiana Nees.

Shrub with bluish pink or purple flowers. Found in sholas in Upper Bhavani.

Xenacanthus pulneyensis (Clarke) Bremek.

Shrub with pale blue flowers. Endemic, rare. Observed in sholas in Upper Bhavani. Flowering and fruiting 11.

Family Thunbergiaceae

Thunbergia mysorensis T. And.

An extensive glabrous climber, tubular, purple corolla expanding to yellow lobes. Found in evergreen forest in Silent Valley. Flowering 1 - 12.

* ***Thunbergia alata*** Boj. ex Sims

A slender climber, corolla yellow with purple throat, cultivated in gardens, apparently grow wild. Native of Africa, widely cultivated. Found in evergreen forest in Silent Valley and mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Thunbergia fragrans Roxb.

A slender twiner, common on thickets, fences, forest boarders and in exposed places. Flowers white, opening at day break and fading by mid morning. Observed in evergreen forest in Silent Valley. Flowering and fruiting 1 - 12.

Family Verbenaceae

Clerodendron infortunatum L.

Large, tomentose shrub with pinkish white flowers. Drupes black, in enlarged pink calyx. Observed in evergreen forest in Silent Valley. Flowering and fruiting 7 - 2.

* ***Lantana camara*** L.

Armed straggling shrub, introduced, flowers yellowish pink, red or scarlet. Drupe dark blue. Observed in all the habitats of Mudumalai Wildlife Sanctuary, Siruvani and Silent Valley. Flowering and fruiting 1 - 12, Native of tropical America, widely naturalized in tropics and subtropics. Common weed in disturbed forest, waste places and hedges.

Lantana indica Roxb.

An unarmed shrub, in hilly regions and cultivated gardens, corolla pink to red. Drupe red when ripe. Occasional. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 1 - 4 and fruiting 1 - 12. Distribution - India, South-east Asia.

Stachytarpheta jamaicensis (L.) Vahl.

A tall herb on roadsides and moist places, flowers blue or violet. Common weed of fallow land, disturbed ground and cultivation. Very wide spread. Observed in dry deciduous forest, moist deciduous forest, scrub jungle in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering 1 - 12. Flowers open in the morning and fall off in the same evening.

Family Labiatae

Coleus forskohlii Briq.

Stout aromatic herb with villous leaves and blue flowers. Common in evergreen forest in Silent Valley National Park. Flowering and fruiting 10 -12.

Coleus malabaricus Benth.

Large herb, stem purple, flowers white tinged with purple. Rare, found in evergreen forest in Silent Valley National Park. Flowering and fruiting - 10.

Gomphostemma heyneanum Wall. ex Benth.

Herb with orange, yellow flowers, occasionally found in moist deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary

Leucas aspera (Wllld.) Link

Annual herb with much branched stems with white flowers. Common wayside weed. Locally abundant in fallow lands and waste lands. Found in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering 11 - 2, fruiting 1 - 12.

Leucas biflora (Vahl) R. Br.

Slender herb, flowers white, abundant on forest clearings, forest border and hedges. Found in evergreen forest in Silent Valley. Flowering 11 - 4, fruiting 1 - 12.

Leucas ciliata Benth.

A straggling, aromatic, loosely branched herb with white flowers, distributed in Coimbatore, Nilgiri. Observed in dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 11 - 1.

Leucas indica (L.) R. Br. ex Vatke.

A slender, hairy annual herb. Flowers white. Locally abundant in unweeded farmlands. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Leucas lanceaefolia Desf.

A tall shrub with white flowers, observed in sholas in Upper Bhavani. Distribution - Coimbatore, Madurai, Nilgiri.

Leucas martinicensis (Jacq.) R. Br.

A tall stout, annual herb with white flowers, common in moist places. Locally abundant in wastelands, fallow fields or as a weed of cultivation. Found in scrub jungle and teak plantation in Mudumalai Wildlife Sanctuary. Flowering 11 - 1, fruiting 1 - 12.

Leucas marrubioides Desf.

Perennial hairy herbs in hills, flowers white, common on slopes. Found in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 8 and 11.

Ocium tenuiflorum L.

A branched, strongly aromatic subshrub, corolla - white purplish, scented. Abundant in fallow fields, sacred plant, often planted near houses and temples. Found in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering 11 - 1 and fruiting - 12.

Orthosiphon thymiflorus (Roth) Sleensen.

Aromatic herb with white flowers in dry and open places. Found in scrub jungle, dry deciduous forest, moist deciduous forest and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Common on the slopes, in cervices of rocks, arable lands. It is a colonizer along new roads. Flowering and fruiting 1 - 12.

Plectranthus japonicus (Burm. f.) Koidz.

A tall herb with pale blue flowers along forest edges, forest clearings and in scrub jungles. Found in Mudumalai Wildlife sanctuary. Flowering and fruiting 12 - 1.

Pogostemon paniculatus (Willd.) Benth.

Pubescent herb with pinkish flowers. Flowering and fruiting 12 - 2. Fairly common in semievergreen forest in Mudumalai Wildlife Sanctuary.

Family Amaranthaceae

Achyranthes aspera L.

Herb with tomentose leaves and pale greenish flowers in spikes. Fruits easily adhering to animals or clothings. Weed of waste lands. Flowering and fruiting 1 - 12. Found in mixed deciduous forest in Siruvani.

Achyranthes bidentata Blume

Herb with reddish flowers, rare, found in evergreen forest in Silent Valley National Park. Flowering and fruiting - 10.

Family Polygonaceae

Polygonum chinense L.

Glabrous undershrub with white flowers. Common in evergreen forest in Silent Valley National Park and mixed deciduous forest in Siruvani. Flowering 10 - 4.

Family Aristolochiaceae

Thottea siliquosa (Lam) Ding Hou

Finely pubescent shrub with dark purple flower in axillary cyme. Common in evergreen and semievergreen forests. Observed in evergreen forest in Silent Valley. Distribution - Nilgiri, Coimbatore, Madurai.

Family Piperaceae

Lepianthes umbellata (L.) Rafin. Sylra Tellur.

Shrub common in evergreen forest. Observed in evergreen forest in Silent Valley. Flowers bisexual, perianth absent. Flowering and fruiting 7 - 2.

Peperomia tetraphylla (Forst. f.) Hook & Arn.

An epiphytic, tufted, succulent herb found in sholas in Upper Bhavani.

Piper argyrophllum Miq.

A slender climber with slender spikes found in evergreen forests in Silent Valley and sholas in Upper Bhavani. Distribution - Coimbatore, Nilgiri, Madurai.

Piper trioicum Roxb.

Densely foliaceous vine, in evergreen forest. Found in hills above 1000 m. and on shola trees. Observed in evergreen forest in Silent Valley. Flowering 8 - 10, fruiting 4 - 5.

Piper nigrum L.

A stout climbing shrub/ Vine, in evergreen forest. Fruits globose, red when ripe. Cultivated for its fruits. Found in hills above 1200 m. Observed in sholas in Upper Bhavani. Flowering - 6, fruiting 4 (ripening).

Piper wightii Miq.

A stout climber with smooth stems, spikes slender with pale pink ting. Berry globose. Found in shola forests in Upper Bhavani. Distribution - Madurai, Nilgiri.

Family Chloranthaceae

Sarcandra chloranthoides Gard.

Glabrous shrub with greenish flowers and purplish black drupes. Observed in evergreen forest in Silent Valley National Park. Flowering and fruiting 12 - 2.

Family Elaeagnaceae

Elaeagnus kologa Schlecht.

Extensive straggler, some times thorny. Flowers cream, found in hills above 1200. Common. Flowering 1 - 12 and fruiting - 3. Observed in sholas in Upper Bhavani. Distribution - Madurai and Nilgiri.

Family Euphorbiaceae

Acalypha fruticosa Forssk.

Gregarious bushy, strong smelling shrub, generally occurs in foot hill scrub jungle, Locally abundant, Aggressive colonizer. Found in scrub jungle in Mudumalai Wildlife Sanctuary. Distribution - Tropical Africa, Arabia, Peninsula, Burma. Flowering and fruiting 8 - 10.

Acalypha indica L.

A herb generally occurs on waste-lands and in moist and shady places. Observed in scrub jungle of Mudumalai Wildlife Sanctuary. It is a common weed of waste-lands and crop lands. This is seen mostly in cold seasons.

Acalypha racemosa Heyne ex Baill.

Occasional weed, commonly found in moist and shady places, waste-lands. Observed in scrub jungle of Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

*** Croton bonplandianum*** Baill.

An introduced herb with unpleasant odour, abundant on waste lands, ready colonizer. It is a native of Paraguay in South America. Plants are often infected with virus turning the leaves yellow or streaked. Observed in Moist deciduous forest of Siruvani.

Breynia retusa (Dennst) Alston

A spreading shrub in low hills, common near forest border, floor and open slopes. Flowers greenish. Observed in Moist deciduous forest of Siruvani. Flowering 3 - 5, fruiting-4.

Breynia vitis - idaea (Burm. f.) Fischer

A large shrub commonly found in deciduous forest, scrub jungle, waste-land and hedges. Capsules globose red. Observed in Moist deciduous forest of Siruvani and Mudumalai Wildlife Sanctuary. Flowering - 2 (plains) and 4 (hills) Fruiting 1 - 12.

Euphorbia hirta L.

Herb with milky latex. Very common weed of pastureland and waste-lands, an aggressive colonizer. Observed in dry deciduous forest, scrub jungle, coffee plantation and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12, Pantropical.

Euphorbia indica Lam.

Common weed, observed in scrub jungle of Mudumalai Wildlife Sanctuary. Involucral bracts pale pinkish. Distribution - Pantropical. Flowering and fruiting 1 - 12.

* ***Euphorbia cythophora*** Murr.

An introduced herb, native of Central America, now a pantropical weed. Floral leaves, opposite, green towords the apex and scarlet crimson or rose coloured towards the base. It is a common weed of cultivated and fallow field, often gregarious, observed in dry deciduous forest of Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

*** Euphorbia chamaesyce** L.

Introduced herb, common pantropical weed, observed in scrub jungle of Mudumalai Wildlife Sanctuary.

Euphorbia rosea Retz.

A prostrate, pinkish herb. Common in scrub jungles, gravely ground and in poor soil. Involucral bracts pink. Ready colonizer in the casuarina plantations. Observed in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting 12 - 3.

Euphorbia rothiana Spreng.

Profusely branched herb in hills, colonizer, common on the new roads. Observed in sholas and wattle plantation in Upper Bhavani. Flowering and fruiting 10 - 4.

Euphorbia thymifolia L.

A hispid, reddish herb in fallow fields, ready colonizer, common along new roads. Found in scrub jungle in Mudumalai Wildlife Sanctuary. Distribution - Tropical Asia. Flowering and fruiting 12 – 3.

Jatropha curcas L.

A cultivated shrub, native of New world tropics, now planted elsewhere in tropics. Flowers yellowish green. Observed in scrub jungle and dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 4 - 7 and fruiting - 4.

Jatropha heynei Balakr.

Herb observed in dry deciduous forest of Mudumalai Wildlife Sanctuary. Flowers pale green, endemic. Flowering and fruiting 3 - 6.

Phyllanthus amarus Schum. & Thonn.

An erect herb, flowers axillary. Native of America, now pantropical. Common in arable, fallow lands and clearings. Flowering and fruiting 1 - 12.

Phyllanthus gardnerianus (Wight) Baill.

A slender under shrub in hills found in Coimbatore and Nilgiri. Flowers axillary, calyx pale green, capsule globose, three lobed. Rare, found in moist marshy habitat in Mudumalai Wildlife Sanctuary.

Phyllanthus maderaspatensis L.

Common weed in fallow fields, cleared, arable lands. Flowers axillary, male flowers small in clusters, female flowers solitary. Observed in scrub jungle of Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Phyllanthus rheedii Wight.

A slender herb, observed in moist deciduous and dry deciduous forest in Mudumalai Wildlife Sanctuary, mixed deciduous forest in Siruvani and evergreen forest in Silent valley. Distribution - Coimbatore, Nilgiri and Madurai.

Tragia involucrata L.

Twining herb, hispid with stinging hair. Male flowers - yellow, female flowers - green. Common along the hedges and in waste places. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Family Urticaceae

Debregeasia longifolia (Burm. f.) Wedd.

Dioecious shrub, found in hills above 500 to 1000 m, found in shade by stream banks. Common in disturbed forests. Fruiting perianth orange yellow. Observed in evergreen forest in Silent Valley. Flowering 11 - 1, fruiting - 12. Distribution - Coimbatore, Nilgiri, Madurai.

Pilea melastomoides (Poir.) Blume

A robust, dioecious, succulent herb in evergreen forest. Found in hills above 1200 m, sholas, often by stream banks. Locally abundant. Flowering - 10, fruiting - 12.

Elatostema lineolatum Wight.

Herb, common inside sholas, on wood rocks. Flowers dioecious. Observed in evergreen forest in Silent Valley. Flowering 3 – 5.

Laportea crenulata Gaud.

A hairy shrub with creamy yellow flowers found in evergreen forest above 700 m in Western Ghats. Observed in evergreen forest in Silent Valley. The sting of hair is very painful, may cause sneezing and fever.

Laportea interrupta (L.) Chew.

Monoecious herb, branches with stinging hair, observed in mixed deciduous forest in Siruvani. Flowering and fruiting - 12. Distribution - Coimbatore, Nilgiri and Madurai.

Pellionia heyneana Wedd.

Woody, creeping, perennial herb with pink flowers. Found in evergreen forest in Silent Valley National Park. Flowering and fruiting 5 -7.

Family Orchidaceae

Calanthe triplicata (Willem.) Ames

A shade loving herb, in humid rich moist soil, found on hills above 1300 m., common in very moist shola in deeper shade, often by streams. Observed in evergreen forest in Silent Valley and sholas in Upper Bhavani. Flowering - 8, fruiting - 9. Distribution - Coimbatore, Madurai and Nilgiri.

Calanthe masuca (D. Don.) Lindl.

A herb in evergreen forests, flowers mauve, turning to rusty colour when old. Observed in evergreen forest in Silent Valley. Distribution - Coimbatore and Nilgiri.

Nervilia plicata (Andr.) Schltr.

Tuberous herb. Flowers creamy white, streaked with violet. Rare but abundant, found in evergreen forest in Silent Valley National Park. Flowering and fruiting 7 -12.

Nervilia aragoana Gaudich. Voy. Uranie.

Herb found in evergreen forest in Silent Valley National Park. Flowers pale green veined with purple. Rare. Flowering and fruiting 10 - 1.

Family Zingiberaceae

Amomum pterocarpum Thw.

A herb at lower elevation of hills, flowers white. Observed in evergreen forest in Silent Valley. Distribution - Coimbatore.

Hedychium coronarium Koen.

A herb in moist localities. Rhizome extensive. Flowers very fragrant, yellow. Found in hills above 1000 m, marshy places. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 7 - 8.

Zingiber roseum (Roxb.) Roscoe

A tuberous herb at higher elevation. Observed in teak plantation in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley.

Curcuma pseudomontana Graham

A tuberous herb with bright yellow flowers, in higher elevations. Leaves 60 cm in length. Observed in dry deciduous forest, moist deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley. Distribution - Nilgiri, Coimbatore.

Curcuma longa L.

A tuberous herb, often cultivated, native of India, widely cultivated in the tropics. Flowers pinkish. Observed in moist deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Flowering-12.

Curcuma aromatica Salisb.

A tuberous herb, with fragrant, pale rose flowers, often cultivated for its tubers. Observed in moist deciduous forest and coffee plantation in Mudumalai Wildlife Sanctuary.

Elettaria cardamomum (L.) Maton

A perennial herb, often under cultivation, leafy shoots, flowers white, found in hills above 1200 m. Observed in evergreen forest in Silent Valley. Native of Peninsula and Sri Lanka, introduced else where.

Globba Marantina L. Mant.

A herb in moist forests, flowers yellow, rhizomes creeping, roots fleshy. Found in hills above 1000 m, in shade, near streams. Observed in evergreen forest and teak plantation. Flowering - 9.

Globba ophioglossa Wight

A herb in damp places. Flowers yellow. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Nilgiri. Flowering and fruiting 7 - 9.

Family Costaceae

Costus speciosus (Koen) J.E. Smith

A succulent herb in moist localities, flowers white, labellum white with a yellow center. Found on hills above 900 m. Gregarious by stream bank, shola floor. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 9 - 10.

Family Hypoxidaceae

Curculigo orchioides Gaertn.

A stemless herb from sea level to higher altitudes. Rhizomes elongated. Flowers yellow. Common on floors of scrub jungle and moist deciduous forests, hills and slopes above 1200 m. Abundant in disturbed ground. Observed in dry deciduous forest, moist deciduous forest, scrub jungle, coffee plantation and teak plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Family Dioscoreaceae

Dioscorea bulbifera L.

A tuberous climber, leaves ovate, suborbicular, base deeply cordate. Male flowers green or purplish, female flowers sessile. Commonly found on hills. Observed in moist deciduous forest, coffee plantation, teak plantation in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani.

Dioscorea oppositifolia L.

A tuberous vine, branchlets twinning to right with red young leaves. Flowers in spike, male flowers dense, female flowers solitary or in pairs. Common on hills, on thickets, inside forests and scrub jungles. Flowering 7 - 9 (hills), 12 - 3 (plains); fruiting 1 - 12. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary and Siruvani.

Dioscorea pentaphylla L.

A tuberous climber, branchlets twinning to left. Leaves rusty pubescent, some times prickled. Male flowers in racemes, female flowers in spike. Found in foot hills to 1000 m, on thickets, scrub jungles; less in plains. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 8 -10, fruiting 9 in pendulous masses.

Dioscorea tomentosa Koen. ex Spreng.

Vine, tuberous, leaves whitish, tomentose. Commonly found in hills up to 1400 m, on slopes and near forest borders, less in plains. Male flowers in axillary or terminal spikes. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering 7 - 10, fruiting - 8.

Dioscorea wallichii Hook. f.

A tuberous climber, leaves suborbicular, secondary nerves conspicuous. Male flowers in slender spike. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Distribution - Nilgiri.

Family Agavaceae

*** *Furcraea foetida*** (L.) Haw.

A stout plant from a perennial rhizome, cultivated. Introduced, native of South America, extensively cultivated in tropics. Found on hills above 1000 m, bare slopes, gregarious in places. Observed in eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowers greenish.

Family Liliaceae

Asparagus racemosus Willd.

Armed vine with spines, common in deciduous forest, scrub jungle and in hilly terrain. Flowers white and fruits red. Observed in all the habitats of Mudumalai Wildlife Sanctuary and Siruvani. Flowering 7 - 10 (hills) and 1 - 3 (plains); fruiting 1 - 12.

Asparagus gonoclados Baker

A climber in scrub jungle, leaves spinecent. Flowers white. Observed in dry deciduous forest, moist deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary and sholas in Upper Bhavani. Distribution - Coimbatore and Nilgiri.

Chlorophytum attenuatum (Wight) Baker

Rhizomatous herb at higher elevations. Flowers white. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Endemic. Distribution - Kanyakumari, Nilgiri.

Gloriosa superba L.

A climber herb, in shady places in deciduous forests. Rhizome medicinal. Flowers orange or scarlet to crimson. Observed in coffee plantation in Mudumalai Wildlife Sanctuary. Flowering - 10, fruiting, 1 - 12.

Ophiopogon intermedius Don.

Root stock rhizomatous, flowers bisexual, purple. Found in hills, on shola floor in Upper Bhavani. Flowering 8 - 10, fruit globose, dark blue - 10.

Scilla hyacinthina L.

Bulbous, slender herbs with pinkish green flowers. Common on grassy slopes. Found in sholas in Upper Bhavani.

Family Smilacaceae

Smilax aspera L.

A climbing shrub in evergreen forests. Observed in sholas in Upper Bhavani. Distribution - Coimbatore, Nilgiri and Madurai.

Smilax perfoliata Lour.

An armed climbing vine at higher elevation. Occasional. Flowers greenish. Observed in evergreen forest in Silent Valley. Flowering 2 - 4 and fruiting 4 - 11

Smilax prolifera Roxb.

Climbing shrub found in evergreen forest in Silent Valley.

Smilax zeylanica L.

A prickly vine with variable leaves. Found in plains and ghats. Common in hills, on thickets and shola. Flowers greenish. Observed in evergreen forest in Silent Valley. Flowering 6 - 9 and fruiting 7 - 2.

Family Commelinaceae

Commelina benghalensis L.

A slender, creeping fleshy herb with blue flowers. Rooting at lower node. Very widely distributed in scrub jungles, way sides, puddles. Common weed of arable lands. Observed in dry deciduous forest and coffee plantation in Mudumalai

Wildlife Sanctuary and mixed deciduous forest in Siruvani. Flowering and fruiting 8 - 2.

Commelina diffusa Burm. f.

Perennial, spreading herb, rooting at lower nodes, flowers blue, occasional weed, common in moist places. Observed in moist deciduous forest, scrub jungle and coffee plantation in Mudumalai Wildlife Sanctuary. Distribution - Pantropical and warm temperate regions. Flowering and fruiting 9 to 2.

Commelina ensifolia R. Br.

A spreading herb on hills, rooting at lower nodes, flowers blue, occasional weed. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 8 - 2.

Commelina hirsuta (Wight) Clarke

A herb in evergreen forest, flowers yellow. Observed in dry deciduous forest, scrub jungle in Mudumalai Wildlife Sanctuary and sholas in Upper Bhavani. Distribution - Madurai, Nilgiri.

Commelina longifolia Lam.

A slender herb with blue flowers in low hills. Observed in dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Distribution - Nilgiri, Coimbatore.

Cyanotis adscendens Dalz.

A spreading herb with tuberous roots, commonly found in scrub jungles and hills up to 800 m. Flowers purple. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Cyanotis cristata (L.) D. Don.

A fleshy herb, flowers rose to purple, generally occurs in hills above 1000 m. Observed in dry deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary.

Cyanotis fasciculata (Heyne ex Roth) Schultes & Schultes f.

A slender spreading herb with silky white hair, from low hills to high elevations. Flowers rose. Observed in dry deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary.

Cyanotis pilosa Schultes & Schultes f.

Herb with long spreading hair, gregarious, flowers pink to purple. Observed in scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary.

Murdannia spirata (L.) Brueckner

A herb with fibrous roots, from sea level to higher level. Found in fallow lands, river beds, banks. Flowers pinkish (plains) and bluish (hills). Observed in teak plantation in Mudumalai Wildlife Sanctuary.

Family Arecaceae

Calamus rotang L.

A tall slender, armed climber from plains to higher elevations. Flowers yellow. Found in plains from scrub jungles. Observed in evergreen forest in Silent Valley. Flowering 3 - 4, fruiting 1 - 12.

Family Pandanaceae

Pandanus thwaitesii Martelli

A common undershrub in evergreen forest in Silent Valley National Park with very fragrant white flowers.

Family Araceae

Arisaema leschenaultii Blume

A tuberous herb in shady places at higher elevations. Flowers light pinkish to green with small purplish spots, commonly found in hills above 1200 m. in the shade, especially on shola floor, locally abundant, gregarious. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 5 - 7, fruiting 10 - 11. After ripening red. Distribution - Nilgiri, Coimbatore.

Arisaema tortuosum (Wall.) Schott.

A herb with cream to purplish flowers. Berry orange, red in colour. Found in hills above 800 m, in shade, gregarious. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering 5 - 7, fruiting 7. Distribution - Himalaya, South India and Sri Lanka.

Family Eriocaulaceae

Eriocaulon thwaitesii Koern.

A tufted herb in hills above 1200 m. Observed in evergreen forest of Silent Valley. Flowering and fruiting 8 - 11. Distribution - Coimbatore, Nilgiri and Madurai.

Family Cyperaceae

Carex baccans Nees

A perennial herb, common in open forest, slopes and moist places. Observed in evergreen forest in Silent Valley.

Carex lindleyana Nees

A slender herb, inflorescence paniculate with crowed spikelets, common in moist places along hills. Observed in sholas in Upper Bhavani. Distribution - Coimbatore, Nilgiris.

Carex phacota Spreng.

A perennial tufted herb, found in many places at higher elevations. Distribution - Coimbatore, Nilgiris and Madurai.

Carex speciosa Kunth

A rhizomatous tufted herb, common at higher elevation. Observed in moist deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley. Distribution - Nilgiri, Salem.

Cyperus bulbosus Vahl.

Tufted herb with filiform stolons. Spikelets reddish, brown. Occasional weed, especially on sandy soils. Observed in moist deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting 9 - 11.

Cyperus cyperinus (Retz.) Valcken.

A perennial herb, in shady places. Observed in moist deciduous forest, dry deciduous forest and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Common in Coimbatore, Nilgiris and Madurai.

Cyperus distans L.f.

A perennial herb with short creeping rhizomes, spikelets purplish. Common in hills. Observed in moist deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Distribution - Tropical and Subtropical regions of both hemispheres. Flowering and fruiting 6-8.

Cyperus exaltatus Retz.

A perennial large herb in wetlands. Spikelets greenish. Common in plains less on hills. Observed in scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary.

Cyperus pangorei Rottb.

A perennial herb with creeping rhizome, common along streams and swamps. Observed in dry deciduous forest, moist deciduous forest, eucalyptus plantation in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley. Flowering and fruiting 11 - 12.

Cyperus rotundus L.

Perennial herb, stolons elongate, ending with blackish tubers. Spikelets reddish brown. Common weed in open land and cultivation. Observed in dry deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley.

Cyperus triceps (Rottb.) Endlicher

A perennial herb with short rhizome. Observed in scrub jungle and dry deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore.

Cyperus compressus L.

An annual herb with tufted stem. Spikelet 20-40 flowered, yellow when ripe. Found in open grasslands, riverbanks and fallow fields.

Fimbristylis dichotoma (L.)Vahl.

A perennial herb, common in open waste places, very variable and complex species. Observed in dry deciduous forest, moist deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 8 -11.

Fimbristylis ovata (Burm.f.) Kern

A glabrous tufted perennial herb in grasslands. Observed in dry deciduous forest, moist deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary and evergreen forest in Silent Valley. Flowering and fruiting 6-9.

Kyllinga monocephala Rottb.

Tufted herb with creeping rhizome and white subglobose spikes, very common from plains to hills. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Distribution - Pantropical. Common weed in wet land.

Kyllinga triceps Rottb.

Stem densely tufted. Common on plains, less on hills, wide spread. Found in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Scirpus juncoides Roxb.

Herb commonly found in high altitudes. Observed in sholas in Upper Bhavani.

Scleria lithosperma (L.) Sw.

A perennial tufted herb with thick woody rhizome. Pantropical. The most widely distributed species of the genus. Common on hills. Observed in moist deciduous forest in Mudumalai Wildlife Sanctuary and Siruvani.

Family Poaceae (Gramineae)

Apluda mutica L.

Perennial herb, common along roadsides, waste places and hedges. Found in moist deciduous forest, dry deciduous forest and coffee plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 9 - 12.

Aristida adscensionis L.

Slender wiry culms, densely tufted, widely distributed, more abundant on the slopes. Found in scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting 10 - 12.

Arundinella ciliata (Roxb.) Nees ex Miq.

An annual herb, culms to 50 cm. Common by rocks on thin layer of soil, gregarious, endemic to Tamil Nadu. Found in scrub jungle, moist deciduous forest and sholas in Upper Bhavani.

Arundinella purpurea Hochst. ex Steud

Erect herb, leaves linear lanceolate, yellowish green when dry. Endemic, rare, seen in sholas in Upper Bhavani. Distributed in Mysore and Nilgiri. An excellent fodder. Flowering and fruiting 10 - 12.

Arundinella holcoides Trin

Herb, found in sholas in Western Ghats. Endemic.

Arundinella leptochloa (Nees ex Steud.)

Perennial herb, endemic to south west India. Common in grasslands. Observed in sholas in Upper Bhavani. Flowering and fruiting 10 - 12

Arundinella mesophylla Nees ex steud.

Slender culms, perennial. Endemic to South India. Found in sholas in Upper Bhavani. Distribution - Western Ghats, Coimbatore, Nilgiri, Madurai. Flowering and fruiting 9 - 12.

Arundinaria wightiana Nees

An erect gregarious shrub generally found on hills of 1800 - 2500 m altitudes. Observed in sholas in Upper Bhavani.

Alloteropsis cimicina (L.) Stapf

Culms tufted. Spikelets greenish purple. Common in floor of scrub jungles, slopes of hills. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Old world tropics.

Alternenthera sessilis R. Br.

Herbs with white flowers, rooting at lower nodes. Common weed, Observed in mixed deciduous forest in Siruvani. Flowering 11 - 4. Distribution – Tropical region.

Bothriochloa pertusa (L.)A. Camus

A slender perennial herb, in open places, often in saline soil, plains and hills. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Bambusa arundinacea (Retz.) Roxb.

A long thorny bomboo up to 40 m tall. Culms thick and erect with yellowish lanceolate spikelets. Observed in moist deciduous forest, dry deciduous forest, teak plantation in Mudumalai Wildlife Sanctuary. Native of Sri Lanka, India, South-east Asia; introduced in to West Indies. Flowering and fruiting 7 – 2.

Chloris barbata Sw.

A tufted perennial herb, found in a wide variety of habitats. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Chrysopogon fulvus (Spreng.) Chiov.

A perennial herb, clums up to 60 cm, densely tufted at base, usually found in dry sandy or gravely soils. Observed in mixed deciduous forest in Siruvani.

Chrysopogon orientalis (Desv.) A. Camus

A perennial herb, densely tufted, matty at base, with a creeping rootstock. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary and sholas in Upper Bhavani.

Cymbopogon polyneuros (Steud.) Stapf

An aromatic perennial herb. Distribution - Nilgiri.

Cynodon dactylon (L.) Pers.

A perennial rhizomatous creeping herb, rooting at nodes, spikes green, compressed spikelets. Common weed, grown for lawns used as fodder for horses. Observed in scrub jungle in Mudumalai Wildlife Sanctuary and dry deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 1 - 12.

Cyrtococcum deccanense Bor.

An annual or perennial herb in hilly areas. Observed in teak plantation in Mudumalai Wildlife Sanctuary and in mixed deciduous forest in Siruvani. Flowering and fruiting 8 -12.

Cyrtococcum patens (L.) A. Camus

A tall perennial herb, forms mating on ground, common in shaded places. Observed in moist deciduous forest and teak plantation in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Nilgiri and Madurai.

Digitaria abludens (Roem. & Schultes) Veldk.

A tufted annual herb. Observed in teak plantation and dry deciduous forest in Mudumalai Wildlife Sanctuary. Common in Nilgiri and Coimbatore. Flowering and fruiting 7 - 8.

Digitaria bicornis (Lam.) Roem. & Schultes ex Loud

Ascending herb, racemes long, green, digitate. Common weed. Found in dry deciduous forest and scrub jungle in Mudumalai Wildlife Sanctuary. Flowering and fruiting 8 - 11.

Eleusine indica (L.) Gaertn.

An annual herb. Spikelets 3-6 flowered, glabrous. Common in moist places, hills and slopes. Weed in cultivated fields. Found in sholas in Upper Bhavani. Distribution - Tropical and subtropical regions throughout the world.

Eragrostis atrovirens (Desf.) Trin. ex Steud.

A perennial herb in waste places. Spikelets gray - green to pale yellow. Common on hills. Found in dry deciduous forest, moist deciduous forest, scrub jungle and coffee plantation.

Eragrostis bifaria (Vahl) Wight ex Steud.

Perennial, densely tufted herb. Spikelets green or olive gray, 15-20 flowered. Found in scrub jungle in Mudumalai Wildlife Sanctuary.

Eragrostis ciliensis Link

Annual tufted herb, usually a weed in cultivated field, Observed in dry deciduous forest, coffee plantation and teak plantation in Mudumalai Wildlife Sanctuary. Distribution - Coimbatore, Nilgiri and Madurai.

Eragrostis unioloides (Retz.) Nees ex Steud.

Common herb in dry or moist grassy places, spikelets pinkish. Found in moist deciduous forest, dry deciduous forest, scrub jungle, teak plantation and coffee plantation in Mudumalai Wildlife Sanctuary.

Garnotia arundinacea Hook. f.

A weak trailing grass, usually in shaded places in hilly areas. Found in sholas in Upper Bhavani and evergreen forest in Silent Valley. Distribution - Coimbatore and Nilgiri.

Heteropogon contortus (L.) P. Beauv. ex Roem. & Schultes

Perennial tufted herb; racemes, green spiciform. Observed in dry deciduous forest, moist deciduous forest, scrub jungle and eucalyptus plantation in Mudumalai Wildlife Sanctuary. Common weed in dry places, good fodder grass. Flowering and fruiting 8 - 12.

Impereta cylindrica (L.) Raeusch.

A tall stoloniferous perennial herb, culms 40 - 60 cm, panicles silvery white with soft hairs. Common weed, observed in moist deciduous forest in Mudumalai Wildlife Sanctuary. Flowering and fruiting 7 - 11.

Oplismenus compositus (L.) P. Beauv.

A herb with slender, creeping culms, rooting at lower nodes. Spikelets pinkish. Found on hills above 800 m, floor of forests, slopes. Common weed in moist shaded places. Observed in all the habitats of Mudumalai Wildlife Sanctuary and Siruvani. Flowering and fruiting 8 - 12.

Paspalidium flavidum (Retz.) A. Camus.

An annual or perennial herb, culms tufted. Spikelets 15 - 25 per raceme. Found in dry deciduous forest in Mudumalai Wildlife Sanctuary and mixed deciduous forest in Siruvani.

Panicum notatum Retz.

A grass culms to 2 m with woody base and ovoid spikelets. Found in dry deciduous forest, moist deciduous forest, scrub jungle and teak plantation in Mudumalai Wildlife Sanctuary.

Panicum brevifolium L.

A weak perennial herb, in moist shaded places. Observed in teak plantation in Mudumalai Wildlife Sanctuary.

Panicum trypheron Schultes

A tufted leafy annual in waste places, fallow lands, weed in cultivated field. Observed in dry deciduous forest in Mudumalai Wildlife Sanctuary.

Perotis indica (L) Kuntze

A slender, annual herb. Culms tufted, spikelets purple. Very common in wastelands, dry or wet sandy soil. Found in scrub jungle in Mudumalai Wildlife Sanctuary.

Oryza granulata Nees & Arn. ex Watt

Tall herb, found in moist deciduous forest in Mudumalai Wildlife Sanctuary.

Paspalum scrobiculatum L.

A herb in moist places, weed in a cultivated fields, spikelets 2 ranked, 30 to 70 per raceme. Found in mixed deciduous forest in Siruvani.

Pennisetum hohenackeri Hochst. ex Steud.

Densely tufted perennial herb, spikelets purple, commonly found in plains and low hills. Observed in evergreen forest in Silent Valley.

Pseudoechinolaena polystachya (H.B.K.) Stapf

Slender annual herb found in Western Ghats. Not very common. Observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 10 - 1.

Setaria pallidefusca Stapf & Hubb.

Herb with pale yellow to reddish brown panicles, a fair fodder. Observed in dry deciduous forest and moist deciduous forest in Mudumalai Wildlife Sanctuary.

Setaria palmifolia (Koen.) Stapf

A perennial herb with plicate leaves, usually occur in moist shady places and hills. Rare, observed in teak plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 8 - 11.

Setaria verticillata (L.) P. Beauv.

A leafy annual, with long, stout, prostrate ascending culms in moist places. Not common, found in scrub jungle in Mudumalai Wildlife Sanctuary.

Themeda cymbaria Hack.

A tall stout, perennial herb, commonly found in hills, slopes. Gregarious. Observed in dry deciduous forest, moist deciduous forest and coffee plantation in Mudumalai Wildlife Sanctuary. Flowering and fruiting 7 - 9.

Themeda triandra Forssk.

A densely tufted perennial herb, usually in open places, hills and slopes, Gregarious, very common, found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Distribution - Warm tropical regions of the old world. Flowering and fruiting 7 - 3.

Themeda tremula (Nees ex Steud.) Hack.

Herb in marshes and moist places. Observed in sholas in Upper Bhavani. Distribution - Coimbatore, Nilgiri, Madurai.

Tragus roxburghii Panigrahi

Perennial herb, culms tufted, glabrous, common weed. Spikelets green. Abundant in dry open places. Observed in mixed deciduous forest in Siruvani. Flowering and fruiting 1 - 12.

Tripogon bromoides Roem. & Schultes

A tufted perennial herb in hilly areas. Culms to 50 cm. Found on hills above 1000 m in shallow soil, around rocks. Rare, observed in grassland and wattle plantation in Upper Bhavani. Flowering and fruiting 10 - 12.

(* indicates introduced species; numbers 1 to 12 indicate months)

Plate 8&9. *Lantana camara*

Plate 10 *Opuntia dillenii*

Plate 11. *Chromolaena odorata*

Plate 12. *Ageratum conyzoides*

Plate 13 *Euphorbia hirta*

Plate 14 *Justicia betonica*

Plate 15. *Tephrosia purpurea*

Plate 16 *Stachytarpheta Jamaicensis*

5.2 Distribution of weeds in various vegetation types.

Of the 376 species of herbs and shrubs encountered during the study 85 are reported to be weedy species. Of these 85 weedy species, 15 namely, *Lantana camara, Chromolaena odorata, Mimosa pudica, Eupatorium repandum, Ageratum conyzoides, Cassia occidentalis, Triumfetta pilosa, Sida acuta, Euphorbia hirta, Tephrosia purpurea, Synedrella nodiflora, Barleria mysorensis, Justicia betonica, Opuntia dillenii and Stachytarpheta jamaicensis,* which are reported as aggressive weeds (Tadulingam and Venkatnarayana 1932, Chandrabose and Nair 1991, Matthew 1991) and are abundant in various vegetation types were selected for further study.

Lantana camara is a perennial, much branched, thicket-forming, bird dispersed, spiny, South American shrub. Leaves of *Lantana* have strong characteristic smell when crushed. The flowers are normally pink, orange, or red, with yellow throats. After pollination the flowers darken and lose the central yellow. Fruits are green when young and purple or black when ripe. Nectar produced by flowers of *Lantana* attracts insects such as butterflies and moths, which help in cross as well as self pollination (Dronamraju 1958, Schemske 1976, Kugler 1980). Small insects like thrips found within flowers also help in pollination (Mohanram and Mathur 1984, Mathur and Mohanram 1986). *Lantana camara* reproduces by both vegetative and sexual methods. Its seeds germinate throughout the year in favourable conditions. New shoots constantly arise from the base of the plant. Stem roots at nodes, when comes in contact with the moist soil or moist fallen logs and debris, and grows as a separate daughter plant (Parsons and Cuthbertson 1992). *Lantana* grows vigorously from buds at the base of the stem even after cutting. It does not grow at temperatures below 5° C and in dry soil. *Lantana* grows best in areas receiving constant rainfall or where the soil moisture is available throughout the year and in rich organic soil. It can tolerate poor soils and almost pure sand (Winder 1980), but can not tolerate waterlogged condition and high soil salinity (Thaman 1974).

Chromolaena odorata, native of tropical and subtropical America is commonly known as Siam weed in Asia, Communist Pacha in Kerala, Gandi Gulabi in Coorg. It has bushy habit and forms dense thickets. The flowers of *Chromoleana* are pale bluish lilac white. It is a short daylength plant (McFadyen and Skarratt 1996) and is capable of growing throughout the year (Rai 1976). *Chromolaena odorata* has a quick growing rate, thus invading forest clearings and abandoned lands very fast due to numerous seed production, easy seed dispersal by wind, perenniality, and wide adaptability and plasticity (Kushwaha *et al.* 1981, Torres and Paller 1989). The cypsella of *C. odorata* are very light and with the help of pappus float long distance. Though it is well adapted for anemochory, dispersion also proceeds by exozoochory and anthropochory (Gautier 1992). The plant is able to root where twigs come in contact with the soil, which increases the competitive ability of the plant and it can succeed in suppressing surrounding vegetation. It grows best below 1500m altitude and is more aggressive in tropical wet dry climates. It does not grow well in water logged and acidic soil (McFadyen 1995).

Mimosa pudica is an introduced prickly herb of family Mimosaceae with sensitive leaves. It is a native of South America. It is a common weed of wastelands, arable lands, riverbanks and disturbed forests. Its flowers are purple to pink heads in a cluster. *Eupatorium repandum* is an introduced herb of family Asteraceae. It is a common weed found in high altitudes. *Ageratum conyzoides,* a member of the same family, is an aromatic, introduced herb with white or pinkish violet flowers. It is a common weed of wastelands, roadsides and forest borders. *Cassia occidentalis* is an annual under shrub with yellow flowers, of family Caesalpiniaceae. It is a gregarious weed of wastelands. It flowers throughout the year. It is doubtfully a native of tropical America. *Triumfetta pilosa* is a perennial herb with yellow flowers in cyme, of family Tiliaceae. It is a common weed of wastelands.

Sida acuta is a herb of family Malvaceae. It is a very common formidable weed of wasteland, cultivated land, roadsides and forest borders. It flowers throughout the year. Flowers are yellow. *Tephrosia purpurea*, a perennial undershrub of family Papilionaceae is a gregarious weed in wasteland and fallow fields and disturbed forests. It grows even in poor sandy soil. It flowers throughout the year. Flowers are pink to purple coloured. Fruits are flat pods curved at the tip. The fruit dehisces longitudinally with a jerk and splitting noise. It resprouts from seeds as well as from the stumpy rootstocks of the previous season (Sen 1981). *Synedrella nodiflora* is an introduced herb of family Asteraceae. Flowers are yellow. It is a common weed of disturbed forest. *Barleria mysoemsis* is a shrub with blue flowers of family Acanthaceae. It is a common weed of scrub jungle and dry places.

Euphorbia hirta, a herb with milky latex, is a member of the family Euphorbiaceae. It is distributed throughout the hotter parts of the country. It is found to be growing up to a height 1200 m. It is a widely distributed, very common weed of cultivated fields, fallow lands, pastureland and roadsides. It is an aggressive coloniser and occupies a wide variety of habitats. *E. hirta* does not prefer waterlogged soil. It can tolerate low temperature of winter as well as extremely hot summer (Sen 1981). It flowers and fruits throughout the year. Seeds do not have dormancy period. They germinate in favourable condition like availability of moisture in substratum and complete the life cycle in about three months time (Sen 1981).

Justicia betonica is a shrub of family Acanthaceae. It is common on wasteland by stream banks and on hedges. Flowers are white, spotted with pink in spikes. *Opuntia dillenii* is an alien succulent shrub of family Cactaceae, with deciduous leaves, yellow flowers and bright red fruits. It is a native of America, introduced in India before 1786. It grows wild in wastelands and disturbed scrub jungle. It flowers and fruits throughout the year. *Stachytarpheta jamaicensis* is a tall herb of family Verbenaceae. It is a common weed of fallow land, disturbed moist forests and cultivation. It flowers throughout the year and the flowers are violet or blue.

Species richness of the above mentioned weeds was highest in dry deciduous habitat and scrub jungle followed by mixed deciduous habitat. It was lowest in wattle plantation followed by shola forest (Figure 5.2). Total number of individuals of these weeds was highest in dry deciduous habitat and least in sholas (Figure 5.2).

5.2.1 Area wise distribution of weeds during pilot survey

5.2.1.1 Mudumalai Wildlife Sanctuary

a) Dry deciduous forest

During pilot survey, out of fifteen weeds selected for study, eleven namely, *Lantana camara, Chromolaena odorata, Mimosa pudica, Sida acuta, Ageratum conyzoides, Stachytarpheta jamaicensis, Synedrella nodiflora, Triumfetta pilosa, Barleria mysorensis, Cassia occidentalis,* and *Euphorbia hirta* were found in dry deciduous forest in Mudumalai Wildlife Sanctuary. Total number per 0.1 ha of the select weedy species was 773.

b) Moist deciduous forest

Eight weedy species namely, *Lantana camara, Chromolaena odorata, Mimosa pudica, Sida acuta, Ageratum conyzoides, Stachytarpheta jamaicensis, Triumfetta pilosa* and *Cassia occidentalis* were observed in moist deciduous habitat in Mudumalai Wildlife Sanctuary. Total number per 0.1 ha of weedy species was 607.

c) Scrub jungle

In scrub jungle in Mudumalai Wildlife Sanctuary, eleven of the fifteen select species, namely *Lantana camara, Chromolaena odorata, Mimosa pudica, Sida acuta, Ageratum conyzoides, Triumfetta pilosa, Barleria mysorensis, Opuntia dillenii, Tephrosia purpurea, Cassia occidentalis,* and *Euphorbia hirta* were found. Total number per 0.1 ha of weedy species was 445.

d) Coffee plantation

In coffee plantation in Mudumalai Wildlife Sanctuary eight species, namely *Lantana camara, Chromolaena odorata, Mimosa pudica, Eupatorium repandum, Sida acuta, Ageratum conyzoides, Triumfetta pilosa* and *Euphorbia hirta* were observed. Total number per 0.1 ha of the species was 299.

e) Teak Plantation

In teak plantation six weedy species, namely *Lantana camara, Chromolaena odorata, Mimosa pudica, Ageratum conyzoides, Triumfetta pilosa* and *Synedrella nodiflora* were observed. The total number of the species per 0.1 ha in teak plantation was 714.

f) Eucalyptus plantation

Seven weedy species; *Lantana camara, Chromolaena odorata, Barleria mysorensis, Opuntia dillenii, Tephrosia purpurea* and *Cassia occidentalis* were found in eucalyptus plantation. In eucalyptus plantation, total number of these species per 0.1 ha was 363.

5.2.1.2 Silent Valley National Park

a) Evergreen forest

In the evergreen forest of Silent Valley, only five species of the selected fifteen, namely *Lantana camara, Chromolaena odorata, Justicia betonica, Eupatorium repandum, Ageratum conyzoides* and *Stachytarpheta jamaicensis* were found. The total number of these species per 0.1 ha was 246.

5.2.1.3 Upper Bhavani

a) Shola

In shola of Upper Bhavani, only three weedy species namely *Chromolaena odorata, Eupatorium repandum* and *Stachytarpheta jamaicensis* were found. Compared to other vegetation types, total number of weedy species was lowest (145 per 0.1 ha) in sholas.

b) Wattle plantation

Out of fifteen select weeds only one, *Eupatorium repandum* was found in Wattle plantation. The total number of *Eupatorium repandum* per 0.1 ha was 289.

5.2.1.4 Siruvani

a) Mixed deciduous forest

In the mixed deciduous forest of Siruvani 10 out of 15 selected species, namely *Lantana camara, Chromolaena odorata, Mimosa pudica, Sida acuta, Ageratum conyzoides, Stachytarpheta jamaicensis, Justicia betonica, Triumfetta pilosa, Synedrella nodiflora* and *Cassia occidentalis* were found. Their total number was 751 per 0.1 ha.

Total number of individuals of most of the weedy species, were increasing gradually during the study. In all seasons, except summer, the number was higher than the previous season. In summer, there was slight decrease in the number because of scarcity of moisture. In all the habitats of NBR, there was an increase in the total number of individuals of all weedy species in second year of the study compared to the first year.

5.2.2 Distribution of select weeds

5.2.2.1 *Lantana camara*

During pilot survey, *L. camara* was present in all the habitats of NBR, except shola and wattle plantation. Highest number of *L. camara* was observed in mixed deciduous forest followed by teak plantation, dry deciduous forest and moist deciduous forest. Evergreen forest showed least number of *L. camara* (Figure 5.2.1). Except summer in all other seasons, there was a gradual increase in the number of *L. camara*. The number of *L. camara* was higher in the second year of the study than that in the first year (Figure 5.2.16).

5.2.2.2 *Chromolaena odorata*

During pilot survey, *C. odorata* was present in all habitats of NBR, except shola and wattle plantation. Mixed deciduous forest had the highest number of *C. odorata*, followed by teak plantation, moist deciduous forest, dry deciduous forest, evergreen forest and coffee plantation. The eucalyptus plantation had least number of *C. odorata* (Figure 5.2.2). *Chromolaena* number increased gradually in all seasons except summer. During the second year the number of species was higher than that in the first year (Figure 5.2.17).

5.2.2.3 *Mimosa pudica*

Mimosa pudica was present in moist deciduous forest, teak plantation, mixed deciduous forest, coffee plantation, dry deciduous forest and scrub jungle. It was not observed in eucalyptus plantation, evergreen forest, shola and wattle plantation. Highest number was observed in teak plantation followed by moist deciduous forest, coffee plantation and mixed deciduous forest. Dry deciduous forest and scrub jungle showed least number during pilot survey (Figure 5.2.3). In all the habitats, the species showed gradual increase in number in all seasons except summer (Figure 5.2.18).

5.2.2.4 *Eupatorium repandum*

Eupatorium repandum was observed in high altitude forests such as shola, wattle plantation, evergreen forest and coffee plantation. It was not present in dry deciduous forest, eucalyptus plantation, moist deciduous forest, scrub jungle and teak plantation. Highest number was observed in wattle plantation followed by shola and evergreen forest. Coffee plantation had the least number of *Eupatorium repandum* during pilot survey (Figure 5.2.4). *E. repandum* increased in all the habitats where it had seen, in all seasons except summer. In the second year the number was higher than the first year (Figure 5.2.19).

5.2.2.5 *Ageratum conyzoides*

Ageratum conyzoides was observed in all the habitats of NBR except shola, eucalyptus and wattle plantations. Coffee plantation had highest number of *A. conyzoides* followed by evergreen forest, moist deciduous forest and teak plantation. Scrub jungle had least number of the species during pilot survey (Figure 5.2.5). Total number of *A. conyzoides* increased in all seasons in all habitats except in summer (Figure 5.2.20).

5.2.2.6 *Cassia occidentalis*

Cassia occidentalis was observed in dry deciduous forest, eucalyptus plantation, and moist deciduous forest and scrub jungle. Number of *Cassia occidentalis* was highest in dry deciduous type followed by moist and scrub types. In eucalyptus plantation, its number was least (Figure 5.2.6). In all seasons, number of *Cassia occidentalis* gradually increased except in summer. Number of *Cassia occidentalis* was higher in the second year compared to the first year (Figure 5.2.21).

5.2.2.7 *Triumfetta pilosa*

It was observed in teak plantation, scrub jungle, moist deciduous forest, mixed deciduous forest, coffee plantation and dry deciduous forest. It was not present in shola, wattle plantation, evergreen forest and eucalyptus plantation. Highest number of *Triumfetta pilosa* was observed in teak plantation followed by scrub jungle. Coffee plantation showed lowest number followed by dry deciduous forest, mixed deciduous forest and moist deciduous forest (Figure 5.2.7). *Triumfetta pilosa* number increased gradually in all seasons except summer in all the habitats in which it was present. During the second year, the number was higher than in the first year (Figure 5.2.22).

5.2.2.8 *Sida acuta*

Sida acuta was observed in dry deciduous forest, coffee plantation, mixed deciduous forest, moist deciduous forest and scrub jungle. It was not present in eucalyptus plantation, evergreen forest, shola and teak and wattle plantations. The highest number was in dry deciduous forest followed by coffee plantation, moist deciduous forest, mixed deciduous forest and scrub jungle (Figure 5.2.8). It showed increase in number in all seasons except summer. During the second year number was higher than the first year (Figure 5.2.23).

5.2.2.9 *Synedrella nodiflora*

Synedrella nodiflora, an exotic herb of Asteraceae was observed in dry deciduous forest, teak plantation and mixed deciduous forest. Its number was highest in dry deciduous forest, followed by teak plantation (Figure 5.2.9). There was a increase in number of *Synedrella* in all the habitats of its occurrence in every season except summer (Figure 5.2.24).

5.2.2.10 *Tephrosia purpurea*

It was observed in eucalyptus plantation, scrub jungle and mixed deciduous forest. Number of *Tephrosia purpurea* was highest in scrub jungle, followed by eucalyptus plantation (Figure 5.2.10). In every season, total number of *Tephrosia purpurea* increased in both habitats except summer (Figure 5.2.25).

5.2.2.11 *Euphorbia hirta*

Euphorbia hirta was observed in coffee plantation, scrub jungle, dry deciduous forest and eucalyptus plantation. Highest number of *Euphorbia hirta* was observed in coffee plantation followed by scrub jungle, and dry deciduous forest. Eucalyptus plantation showed least number (Figure 5.2.11). There was a gradual increase in number of *Euphorbia hirta* in all seasons except summer. In the second year, the number was higher than the first year (Figure 5.2.26).

5.2.2.12 *Barleria mysorensis*

Barleria mysorensis was observed in dry deciduous forest, eucalyptus plantation and scrub jungle. Highest number was observed in eucalyptus plantation followed by dry deciduous forest and scrub jungle (Figure 5.2.12). In every season, there was an increase in number except summer (Figure 5.2.27).

5.2.2.13 *Justicia betonica*

It was observed in evergreen and mixed deciduous forests. Total number of *Justicia betonica* was highest in mixed deciduous forest followed by evergreen forest (Figure 5.2.13). There was increase in number of *Justicia betonica* in every season except summer (Figure 5.2.28).

5.2.2.14 *Opuntia dillenii*

Opuntia dillenii was observed only in scrub jungle and eucalyptus plantation. Number was higher in scrub jungle than eucalyptus plantation (Figure 5.2.14). In both habitats number of *Opuntia dillenii* was higher in second year compared to first year. In summer, number of *O. dillenii* did not reduce because of its xerophytic adaptations (Figure 5.2.29).

5.2.2.15 *Stachytarpheta jamaicensis*

Stachytarpheta jamaicensis was observed in dry deciduous forest, moist deciduous forest and mixed deciduous forest. The number of the species was highest in dry deciduous forest followed by mixed deciduous and moist deciduous forests (Figure 5.2.15). In all habitats of occurrence, number of *Stachytarpheta jamaicensis* increased in every season except summer (Figure 5.2.30).

Figure 5.2 Distribution of select weeds in different habitats of NBR

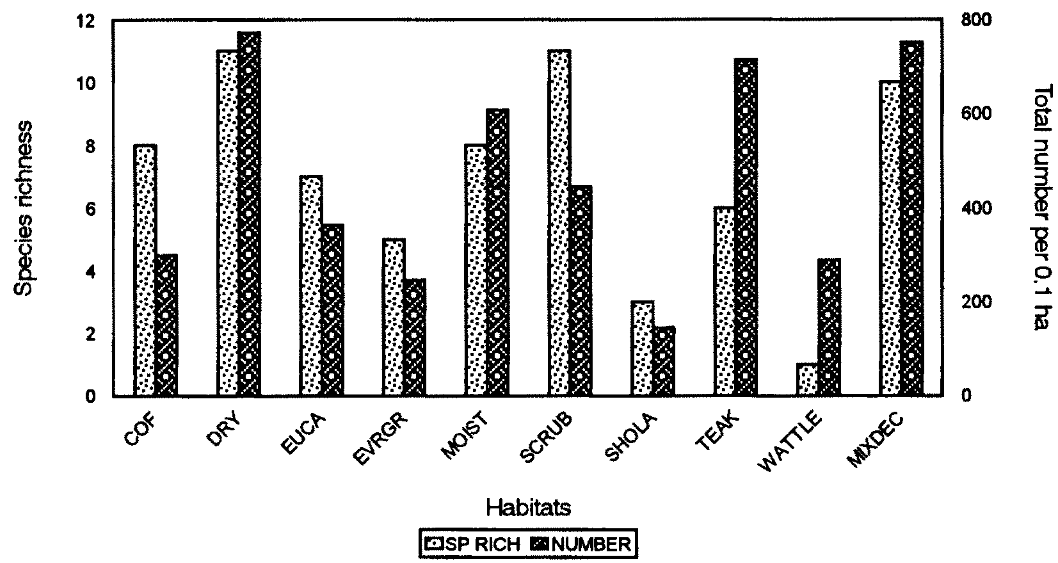


Figure 5.2.1 Total number of *Lantana camara* in different habitats of NBR

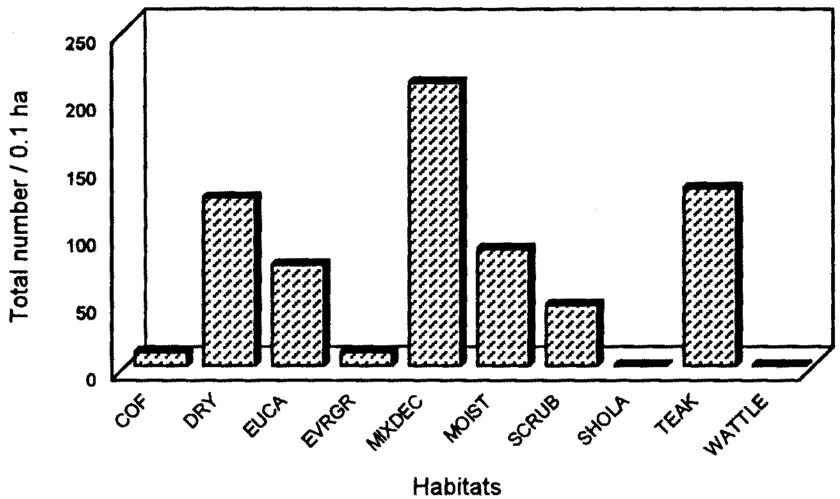


Figure 5.2.2 Total number of *Chromolaena odorata* in different habitats of NBR.

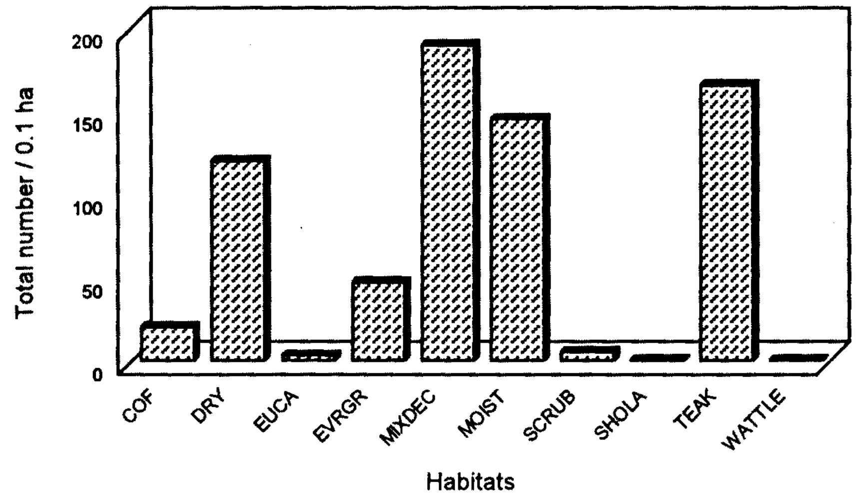


Figure 5.2.3 Total number of *Mimosa pudica* in different habitats of NBR.

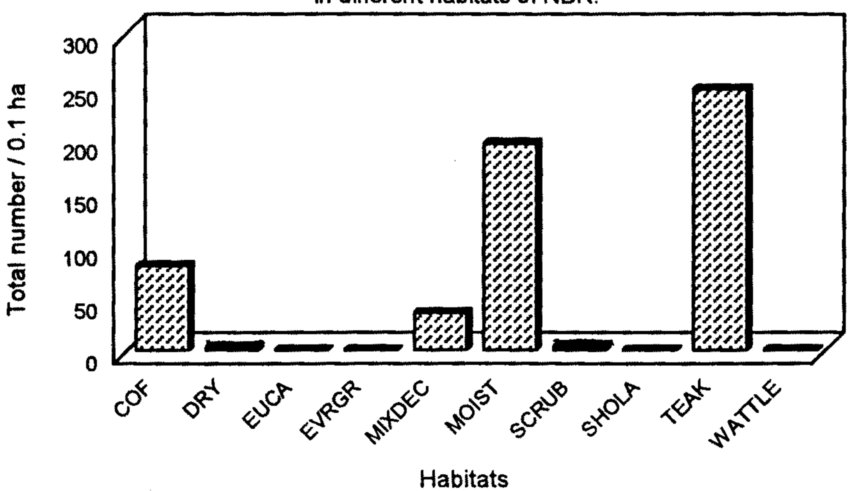


Figure 5.2.4 Total number of *Eupatorium repandum* in different habitats of NBR.

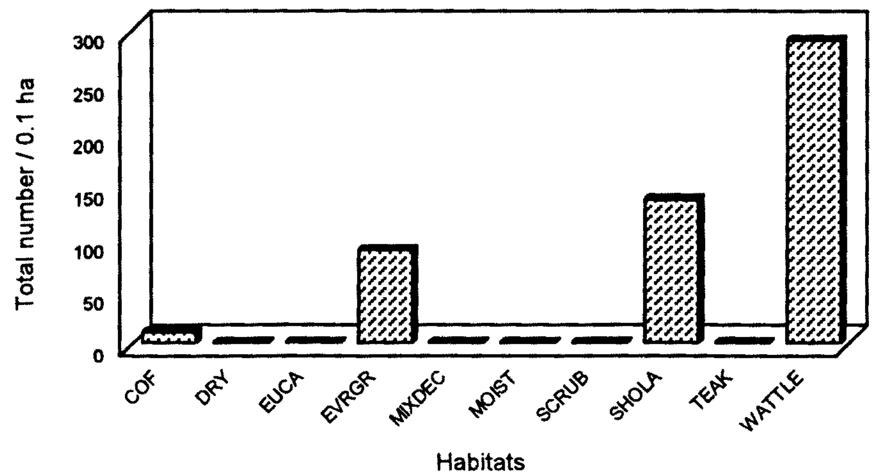


Figure 5.2.5 Total number of *Aegeratum conyzoides* in different habitats of NBR.

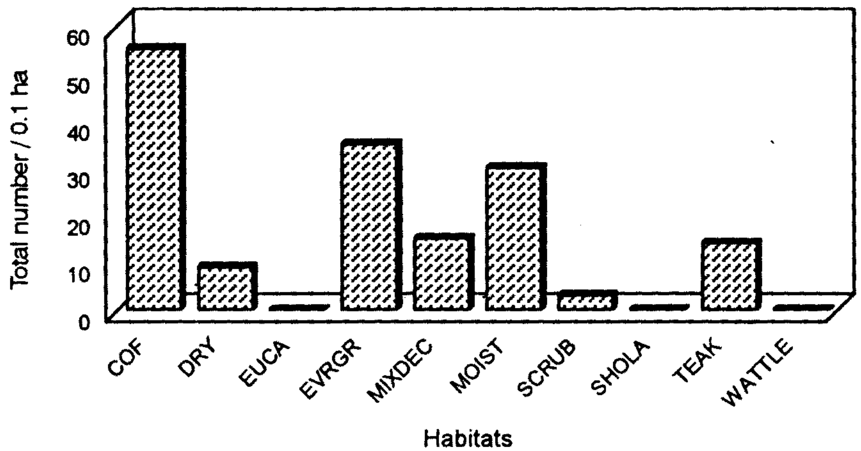


Figure 5.2.6 Total number of *Cassia occidentalis* in different habitats of NBR.

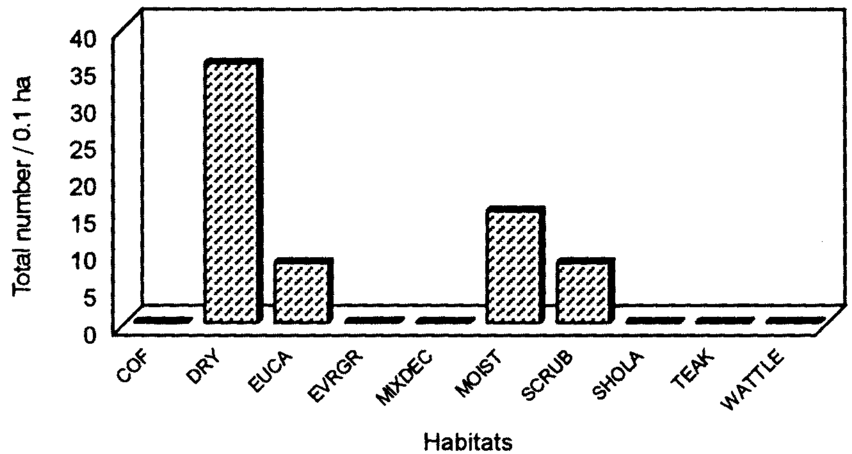


Figure 5.2.7 Total number of *Triumfetta pilosa* in different habitats of NBR.

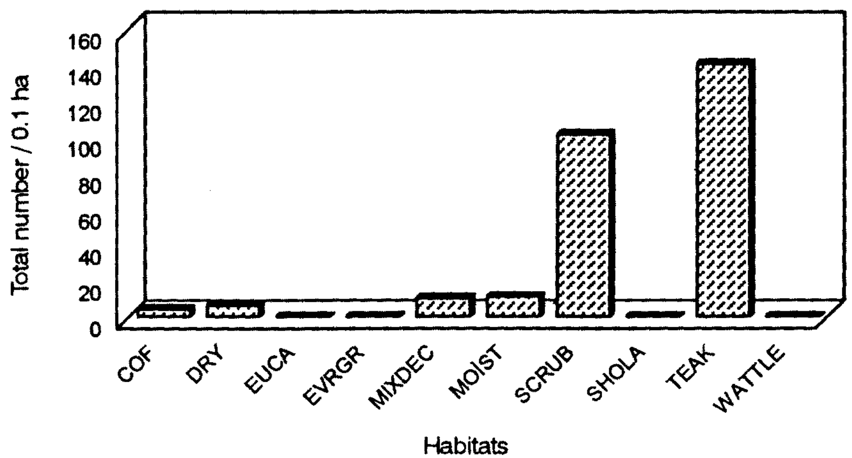


Figure 5.2.8 Total number of *Sida acuta* in different habitats of NBR.

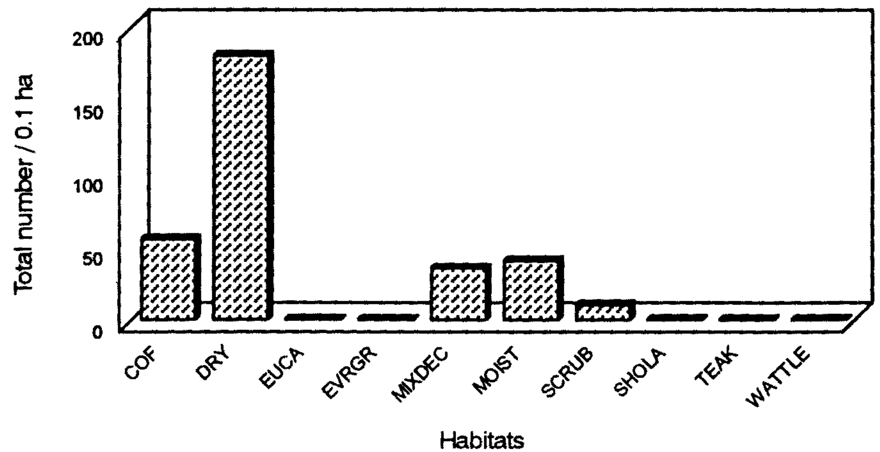


Figure 5.2.9 Total number of *Synedrella nodiflora* in different habitats of NBR.

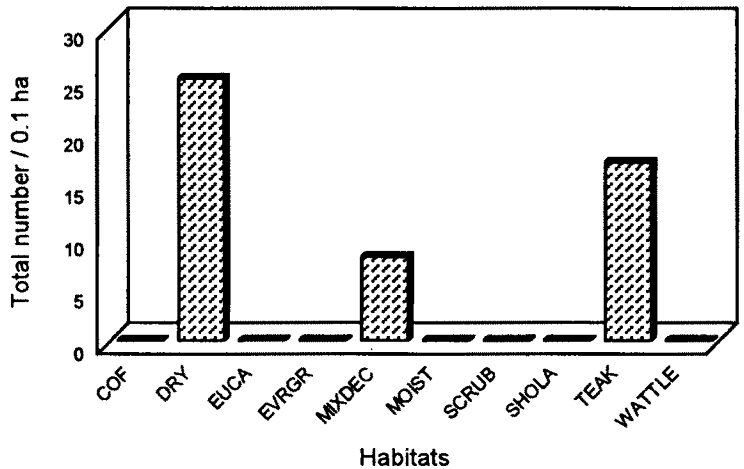


Figure 5.2.10 Total number of *Tephrosia purpurea* in different habitats of NBR.

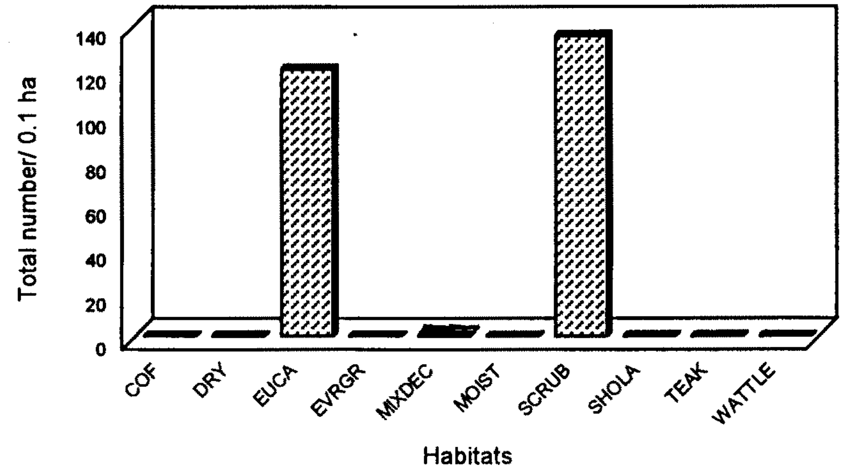


Figure 5.2.11 Total number of *Euphorbia hirta* in different habitats of NBR.

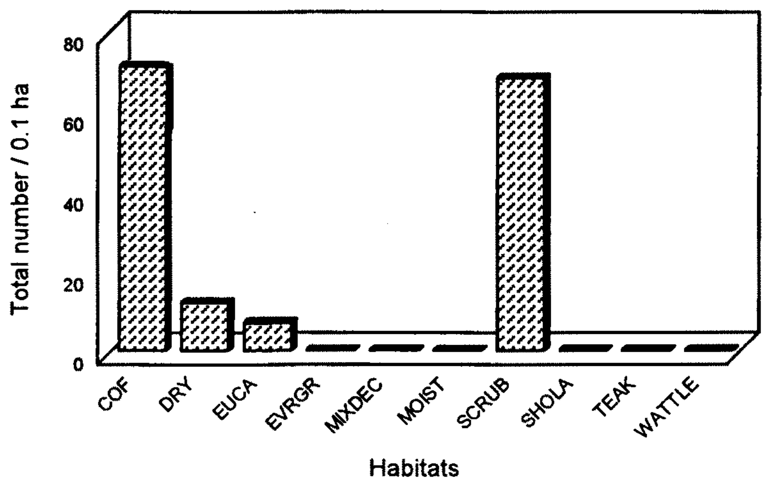


Figure 5.2.12 Total number of *Barleria mysorensis* in different habitats of NBR.

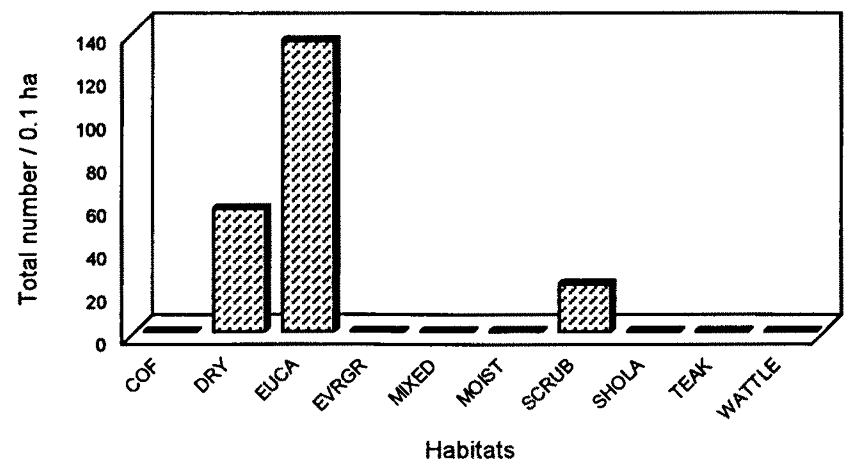


Figure 5.2.13 Total number of *Justicia betonica* in different habitats of NBR.

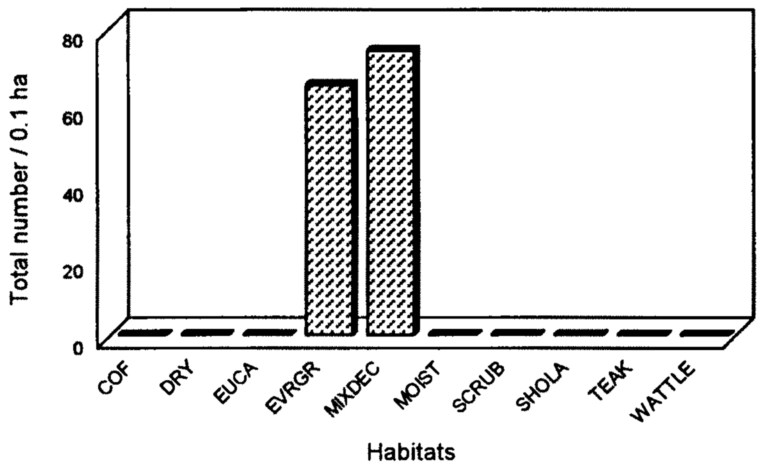


Figure 5.2.14 Total number of *Opuntia dillenii* in different habitats of NBR.

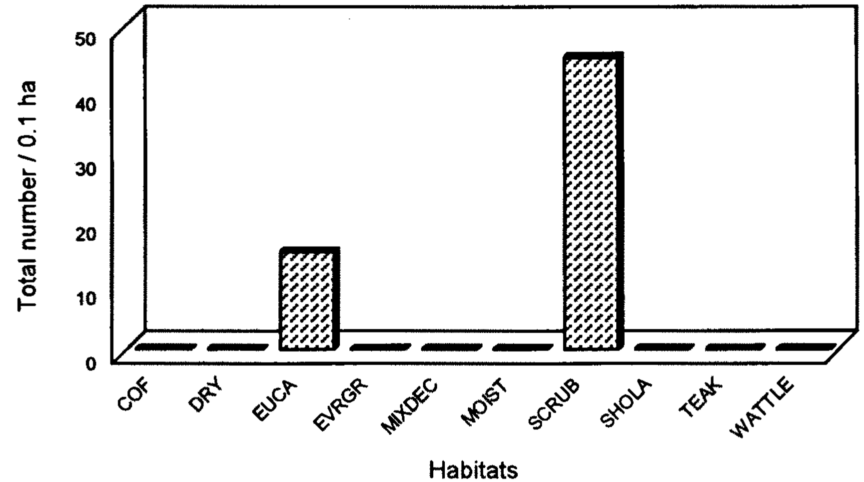


Figure 5.2.15 Total number of *Stachytarpheta jamaicensis* in different habitats of NBR.

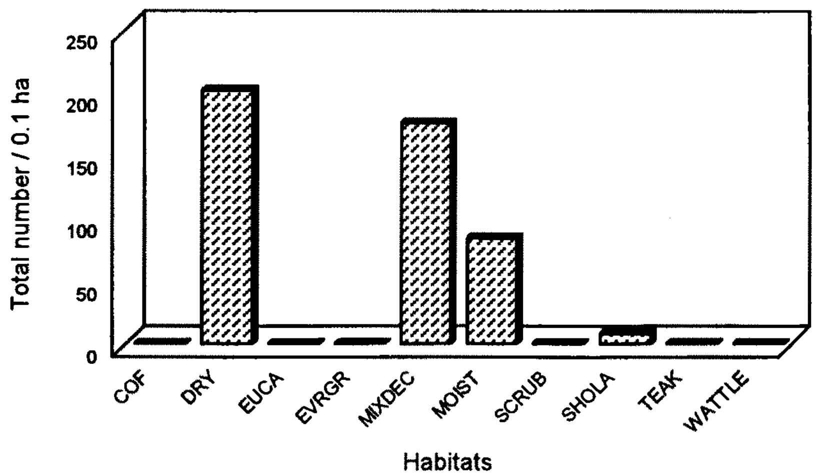


Figure. 5.2.16 Seasonal variation in number of *Lantana camara* in different habitats of NBR.

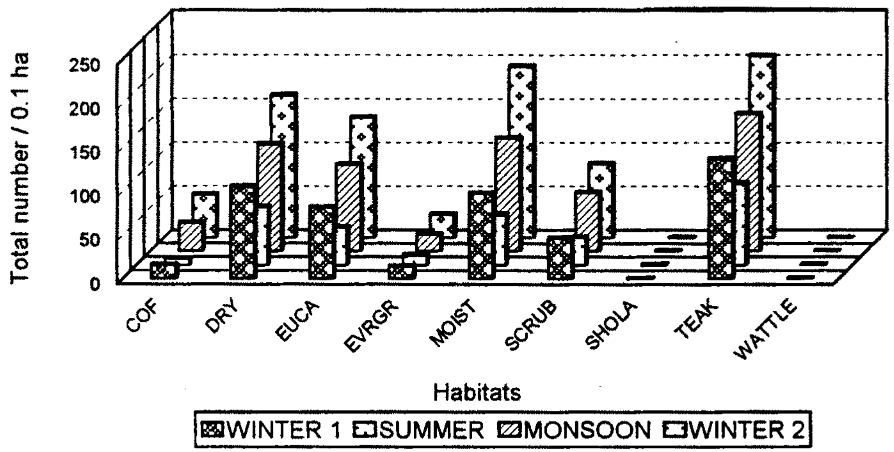


Figure 5.2.17 Seasonal variation in number of *Chromolaena odorata* in different habitats of NBR.

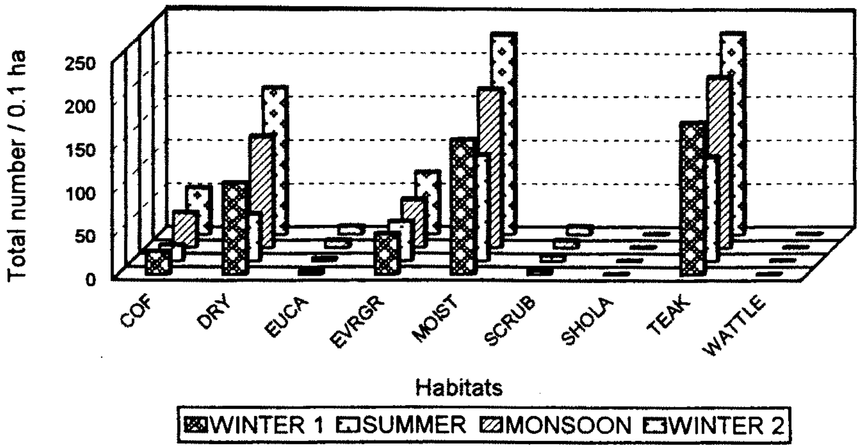


Figure 5.2.18 Seasonal variation in number of *Mimosa pudica* in different habitats of NBR.

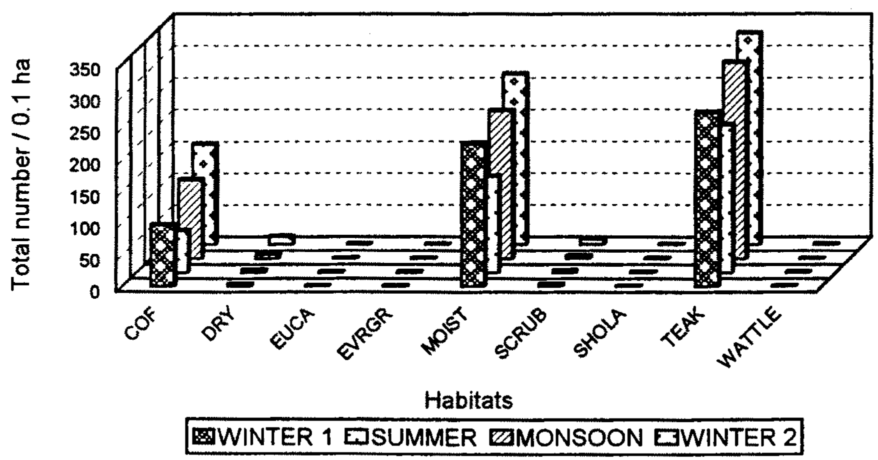


Figure 5.2.19 Seasonal variation in number of *Eupatorium repandum* in different habitats of NBR.

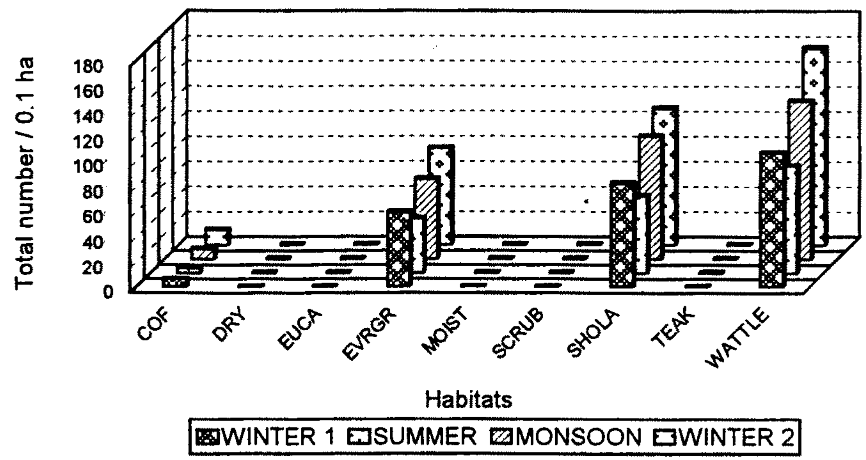


Figure 5.2.20 Seasonal variation in number of *Ageratum conyzoides* in different habitats of NBR.

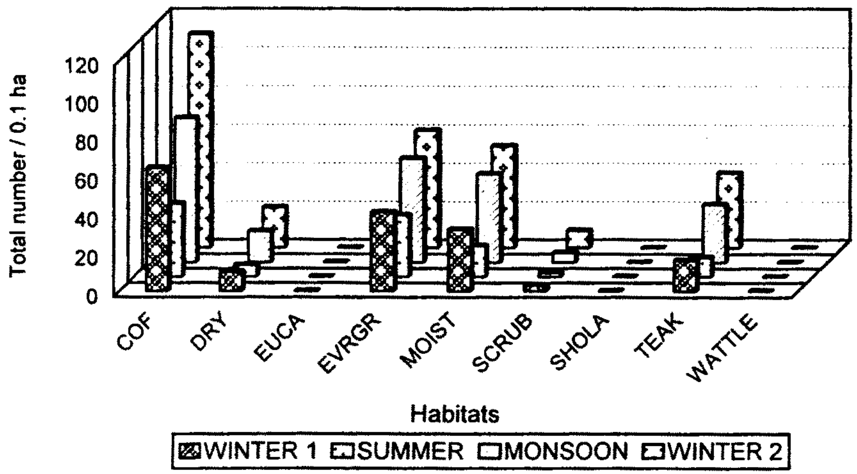


Figure 5.2. 21 Seasonal variation in number of *Cassia occidentalis* in different habitats of NBR.

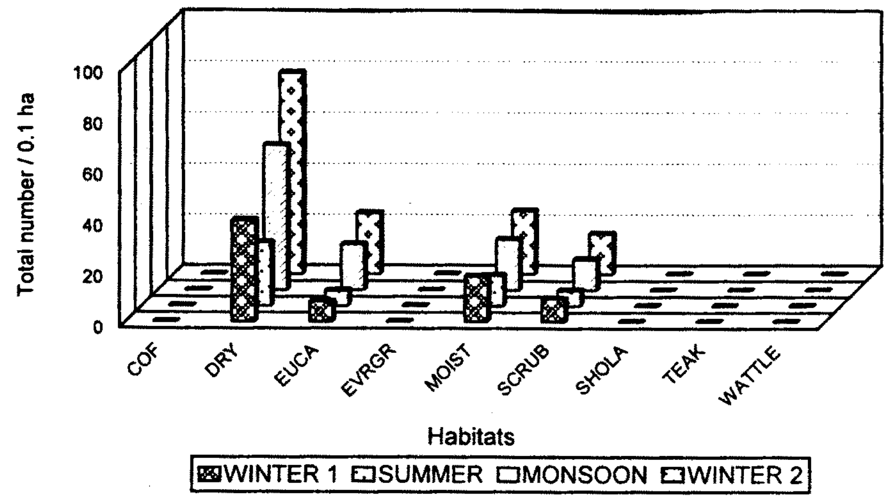


Figure 5.2.22 Seasonal variation in number of *Triumfetta pilosa* in different habitats of NBR.

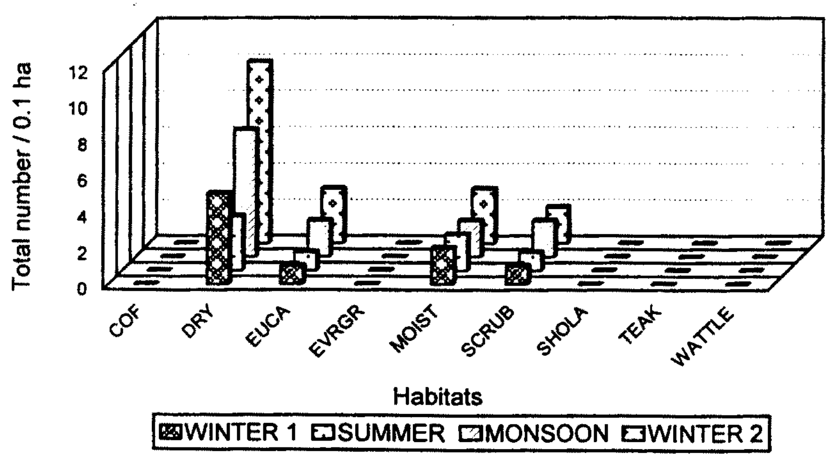


Figure 5.2.23 Seasonal variation in number of *Sida acuta* in different habitats of NBR.

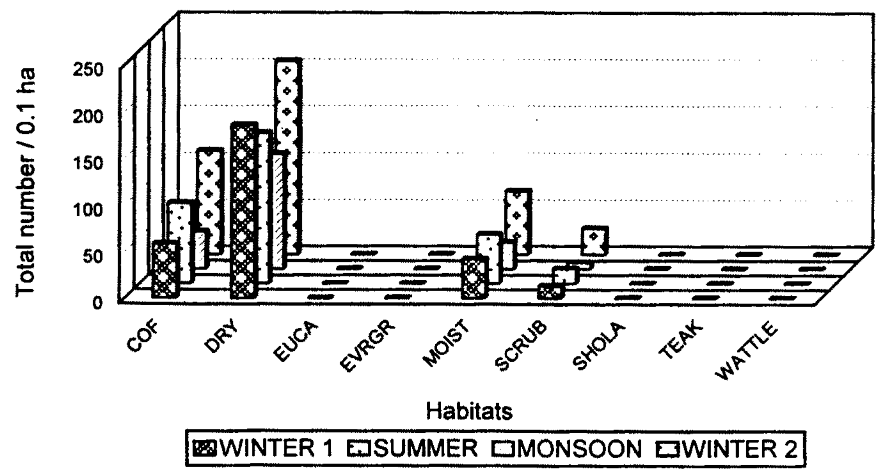


Figure 5.2.24 Seasonal variation in number of *Synedrella nodiflora* in different habitats of NBR.

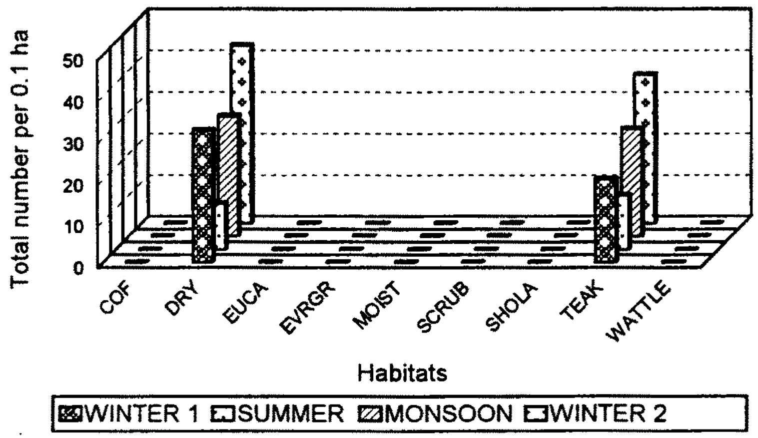


Figure 5.2.25 Seasonal variation in number of *Tephroshia purpurea* in different habitats of NBR.

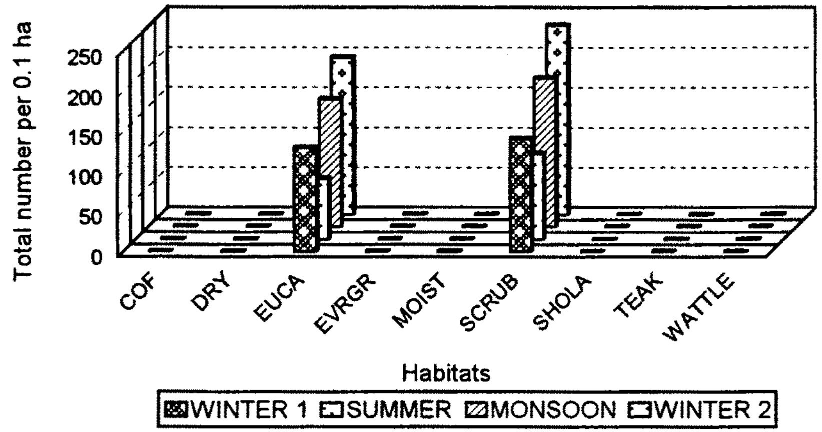


Figure 5.2.26 Seasonal variation in number of *Euphorbia hirta* in different habitats of NBR.

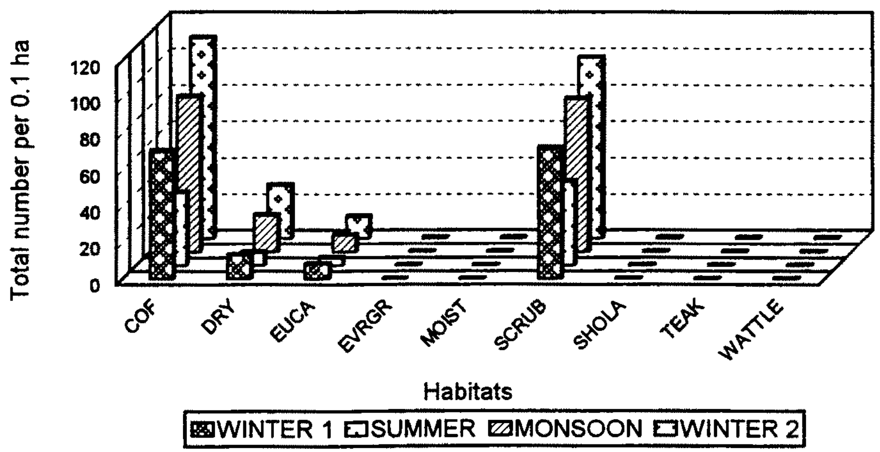


Figure 5.2.27 Seasonal variation in number of *Barleria mysorensis* in different habitats of NBR.

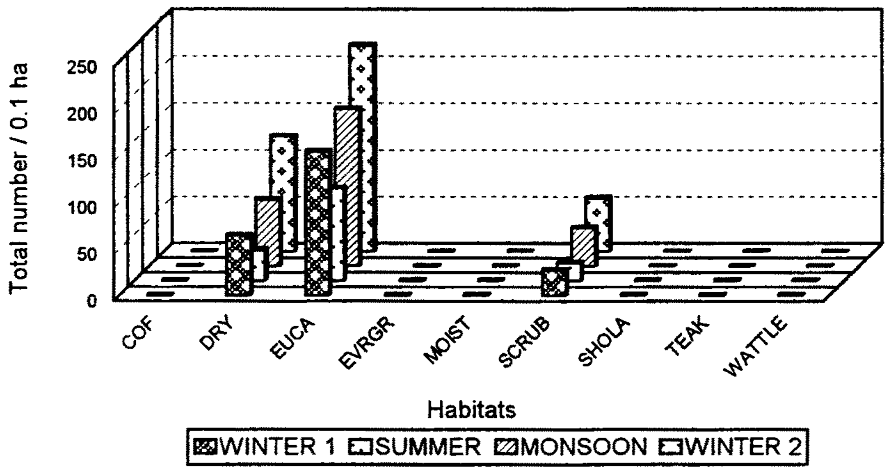


Figure 5.2.28 Seasonal variation in number of *Justicia betonica* in different habitats of NBR.

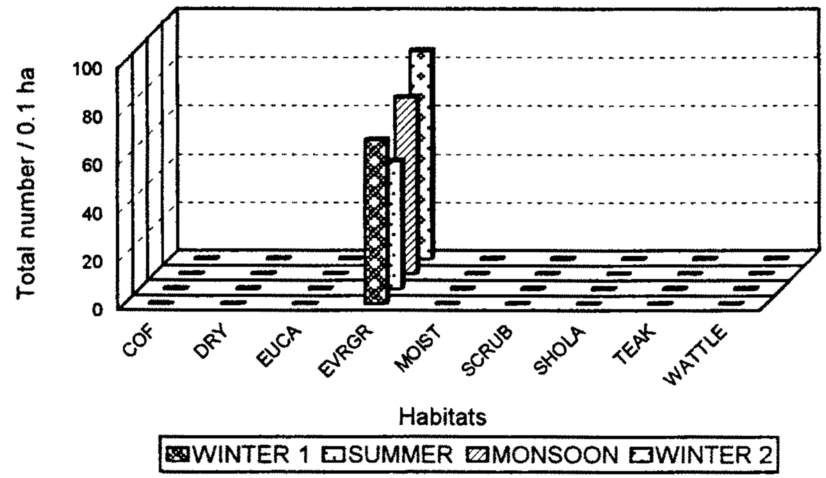


Figure 5.2.29 Seasonal variation in number of *Opuntia dillenii* in different habitats of NBR.

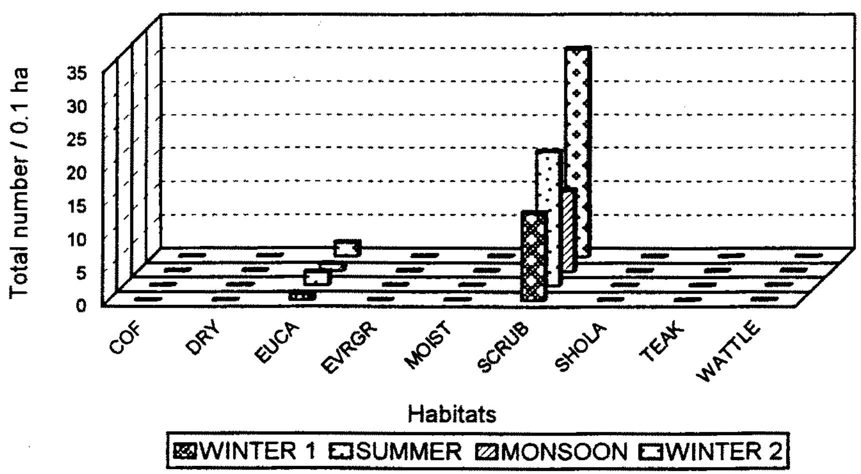
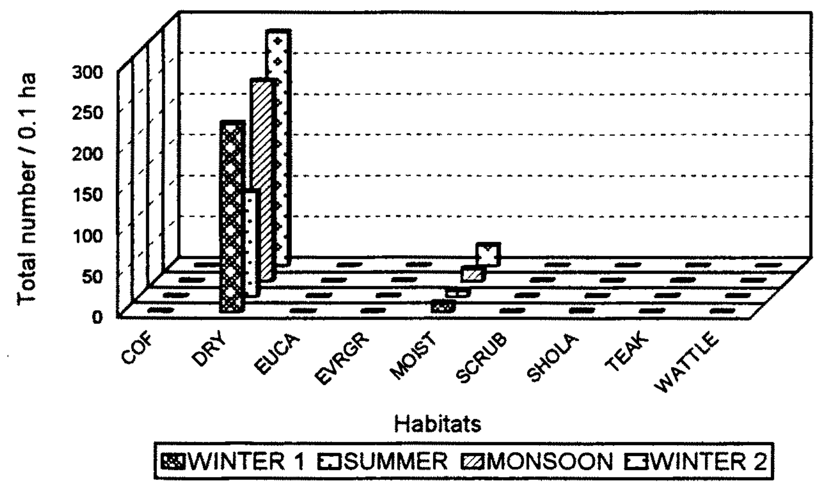


Figure 5.2.30 Seasonal variation in number of *Stachytarpheta jamaicensis* in different habitats of NBR.



5.3 Weeds in Siruvani mixed deciduous forest.

5.3.1 Species composition in different plots

Species richness as well as the total number of the individuals of plants were highest in plot 6 followed by plot 7. Species richness was lowest in plot 10. The total number of individuals of all plant species was lowest in plot 9 (Figure 5.3). List of plant species in different plots is given in appendix 3.

Table 5.3.1 Dominant shrubs in different plots in Siruvani forest

Plots	Shrubs	IVI
1	*Justicia betonica*	51.73
	Lantana camara	47.89
	Helicteres isora	25.82
	Acacia torta	23.90
2	*Randia dumetorum*	48.85
	Lantana camara	43.14
	Chromolaena odorata	26
	Acacia torta	25.57
3	*Lantana camara*	61
	Justicia betonica	35.11
4	*Lantana camara*	53.33
	Randia dumetorum	47.6
	Justicia betonica	28.57
5	*Lantana camara*	56.55
	Glycosmis pentaphylla	25.23
	Justicia betonica	28.57
6	*Chromolaena odorata*	48.15
	Lantana camara	28.42
	Glycosmis pentaphylla	22.30
7	*Chromolaena odorata*	72.00
	Desmodium pulchellum	27.14
	Stachytarpheta jamaicensis	21.21
8	*Chromolaena odorata*	96.22
	Lantana camara	26.16
	Stachytarpheta jamaicensis	23.12
9	*Chromolaena odorata*	69.92
	Lantana camara	23.05
	Bambusa arundinacea	26.56
10	*Lantana camara*	61.67
	Justicia betonica	34.47
	Glycosmis pentaphylla	18.69

Table 5.3.2 Dominant herbs in different plots in Siruvani forest

Plots	Herbs	IVI
1	*Cyrtococcum deccanense*	114.72
	Oplismenus compositus	9.7
	Panicum notatum	8.2
2	*Cyrtococcum deccanense*	87.59
	Curculigo orchioides	21.25
	Laportea interrupta	10.77
	Dioscorea bulbifera	10.77
3	*Cyrtococcum deccanense*	58.65
	Laportea interrupta	19.43
	Hemidesmus indicus	12.95
4	*Cyrtococcum deccanense*	101.54
	Panicum notatum	12.48
	Mimosa pudica	10.3
5	*Cyrtococcum deccanense*	77.85
	Phaulopsis imbricata	21.65
	Panicum notatum	19.13
6	*Cyrtococcum deccanense*	58.96
	Curculigo orchioides	23.54
	Mimosa pudica	11.77
7	*Cyrtococcum deccanense*	39.88
	Curculigo orchioides	24.40
	Hemidesmus indicus	24.40
8	*Cyrtococcum deccanense*	45.23
	Hemidesmus indicus	25.39
	Phaulopsis imbricata	20.63
9	*Cyrtococcum deccanense*	47.14
	Curculigo orchioides	46.66
	Hemidesmus indicus	30.47
10	*Cyrtococcum deccanense*	106.99
	Monothecium aristatum	12.17
	Panicum notatum	12.17

Dominant shrubs and herbs based on Importance Value Index (IVI) in all the ten plots are given in Tables 5.3.1 and 5.3.2.

In brief the dominant shrubs in the Siruvani forest were *Lantana camara, Chromolaena odorata, Glycosmis pentaphylla* and *Justicia betonica*. Herb layer in the forest was dominated by *Cyrtococcum deccanense, Panicum notatum, Hemidesmus indicus* and *Curculigo orchioides* (Tables 5.3.1 and 5.3.2).

5.3.2 Seasonality of weeds

When, 'one way anova' was used to test the significance of difference in the total number of individuals of all the select species among different plots, the ten plots did not differ significantly among them.

5.3.2.1 Lantana camara

Total number of *Lantana* was highest in plot 3, while it was lowest in Plot 8. Total height of individuals of *Lantana* was highest in plot 10 followed by plots 3 and 5. In plot 9 total height of *Lantana* was lowest.

Considering the whole two years of study, the total number of individuals of *L. camara* was highest in January of the second year. Total height of *Lantana* individuals also was highest in the same month (Figure 5.3.1.1 and 5.3.2.1). Rainy and winter seasons (July, September, November and January) of both years showed higher number of *Lantana* compared to summer (March, May). *Lantana* was lowest in number in May 1996 (Figure 5.3.1.1). Total number of individuals of *L. camara* in all plots in July, September and January of the second year were significantly higher than respective months of the previous year (paired test, $p < 0.05$). Total height of individuals of *Lantana* in all plots in January, July, September and November of the second year were significantly higher than that of the first year ($p < 0.05$).

5.3.2.2 Chromolaena odorata

Total number of *Chromolaena odorata* was highest in plot 8. Plot 10 and 4 had the lowest number. Total height of the species was highest in plot 8 and least in plot 4.

Number and total height of *C. odorata* were highest in January of second year (Figure 5.3.1.2 and 5.3.2.2). Rainy and winter seasons (July, September, November and January) of both the years showed higher number of *Chromolaena odorata* compared to summer (March, May). The species was seen least in number in March of second year. Total number of individuals of *C. odorata* was significantly higher in January of second year compared to first year. Although, total height of the species in September, November and January of the second year were higher than the respective months of the first year, difference was not significant.

5.3.2.3 Ageratum conyzoides

Ageratum conyzoides was absent in plots 2, 3, 4, 5, 7 and 10. Among the rest of the plots the highest number of the species was present in plot 8. The same plot had the highest total height of the species.

In March and May of the first year *Ageratum conyzoides* was not observed. Number of *A. conyzoides* increased gradually with the advent of the rain. It was highest in January in both years. In January of the second year number and height of *A. conyzoides* were highest (Figure 5.3.1.3 and 5.3.2.3). Total number and height of *A. conyzoides* in the second year, although were higher than the first year, did not differ significantly from the respective months of the previous year.

5.3.2.4. *Mimosa pudica*

Mimosa pudica was observed only in plots 5, 6, 7, 8 and 9 in Siruvani forest. Of these, the plot 6 had the highest value of total number of the species and its height, and plot 5 had the lowest.

Among the various months of the two years of the study the total number and total height of *Mimosa pudica* were highest in January of the second year. They were the lowest in May of the first year (Figure 5.3.1.4 and 5.3.2.4). Total number of *Mimosa pudica* in all the months of the second year were higher than respective months of the previous year but difference was not significant. Total height of *M. pudica* in March, July, September, November and January of second year were significantly higher than respective months of the previous year.

5.3.2.5 *Justicia betonica*

Justicia betonica was absent in plots 2, 6, 7, 8 and 9. Among the plots where it was seen, the total number of individuals of the species was highest in plot 5 followed by 10, 3, 1 and 4. Total height of *J. betonica* was highest in the plot 5. Plot 4 had the lowest total height of the species.

The total number of individuals of *J. betonica* was highest in January of the 2nd year (Figure 5.3.1.5). Total height of individuals of the species also was highest in the January of the second year (Figure 5.3.2.5). Rainy and winter seasons (July, September, November and January) of both the years had higher number of the species compared to summer (March, May). Number of *J. betonica* was least in May of the first year (Figure 5.3.1.5). Total number of individuals of the species in January, July and November of the second year were significantly higher than respective months of the previous year. Total height of individuals of *J. betonica* was significantly higher in March, July and September of the second year ($p < 0.05$) compared to respective months of the first year.

5.3.2.6 Stachytarpheta jamaicensis

Stachytarpheta jamaicensis was present only in plot 6, 7 and 8. Plot 7 showed the highest number followed by the plots 8 and 6. Total height was highest in plot 7 followed by 8 and 6. In plot 6, *S. jamaicensis* was absent in March and May of the first year but July onwards it was seen in all the months.

The total number of individuals and height of *S. jamaicensis* were highest in January of the second year (Figure 5.3.1.6 and 5.3.2.6). The number of *S. jamaicensis* was least in March of the first year. Rainy and winter seasons (July, September, November and January) of both the years had higher number of the species compared to summer (March, May). Total number and height of individuals of the species in the different months of second year were higher than the respective months of first year, but difference was not significant.

5.3.2.7 *Triumfetta pilosa*

Triumfetta pilosa was absent in plot 2, 3, 4, 5, 8, 9 and 10 and it was seen only in plot 6, 7 and 1. In plot 6 and 7 in March and May of both the years *Triumfetta* was absent. In plot 1, in the first year, it was absent and it came up in the plot, first time only in September of the second year. Highest number was observed in plot 6 followed by 7. Plot 1 showed least number of *T. pilosa*. In both the years in summer *T. pilosa* was not observed in study plots. However, with the advent of monsoon *T. pilosa* increased in number.

The total number of the species was highest in November of the second year and least in July of the first year (Figure. 5.3.1.7). Total height was highest in January of the second year and least in July of the first year (Figure 5.3.2.7). Although total number and height of the species was higher during different months of the second year than corresponding months of the first year, difference was not significant.

5.3.2.8 *Sida acuta*

Total number and height of *Sida acuta* were highest in Plot 3 and were lowest in Plot 6. Total number of individuals of *Sida acuta* was highest in November of second year. In both the years, in summer, number and total height of *S. acuta* were very low. It gradually increased in rainy season (July, September and November) and reached a maximum in November (Figure 5.3.1.8 and 5.3.2.8). Total number of *S. acuta* was significantly higher in July of the second year than corresponding month of the first year. Total height in July, September and

November of the second year were significantly higher than that of the first year ($p < 0.05$).

5.3.2.9 *Sida rhombifolia*

Sida rhombifolia was observed in plots 2, 4, 6 and 10. In all plots in March and May of both the years it was absent because of lack of moisture. In plot 10, in July of the first year also it was absent. In plot 2, in the first year *S. rhombifolia* was not present and it was observed only in July of the second year. Total number and height were highest in plot 4 followed by 10 and 6. In plot 2, total number and total height of *S. rhombifolia* were lowest.

In both the years in summer, *Sida rhombifolia* was absent. In rainy season, the species showed a gradual increase in total number and total height. *S. rhombifolia* was found highest in number during the first year in November (Figure 5.3.1.9). However, its total height was highest in the month of January (5.3.2.9). In the second year, total number and total height were highest in January (Figure 5.3.1.9 and 5.3.2.9). Although total number and height of the species were higher during different months of the second year than corresponding months of the first year, difference was not significant.

5.3.3 Impact of weeds on native plant species

The number of most of the weedy species gradually increased at every season except summer. During the second year, number of most weedy species was higher compared to the first year. On the other hand, the total number of other native plants decreased during the second year (Figure 5.3.3.1). Probably because of the rapid growth and colonisation by weeds, number of other native plants as well as their species richness reduced during the second year (Figure 5.3.3.1 and 5.3.3.2).

Figure 5.3 Species richness and total number of plant species in different plots in Siruvani forest

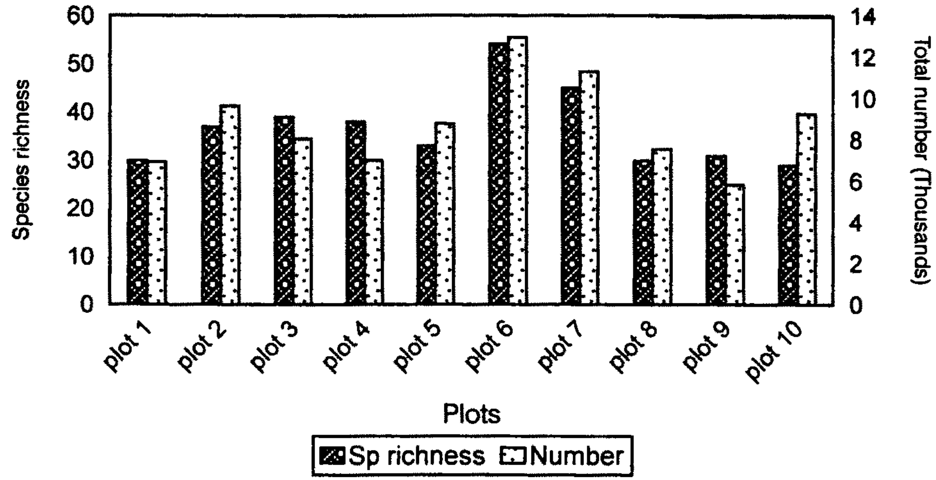


Figure 5.3.1.1 Annual variations in number of *Lantana camara*

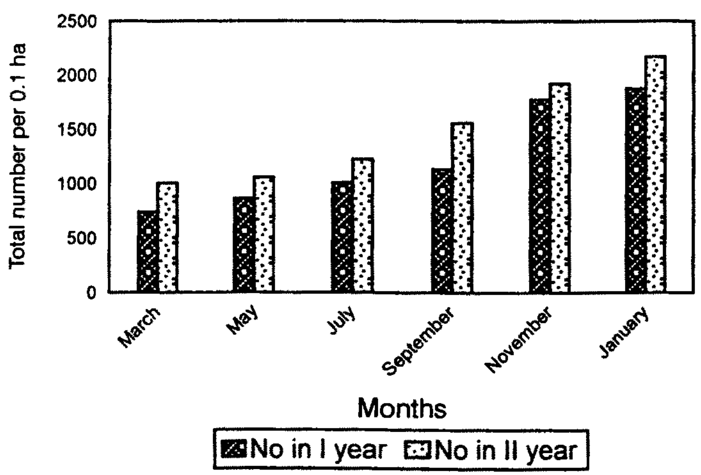


Figure 5.3.2.1 Annual variations in height of *Lantana camara*

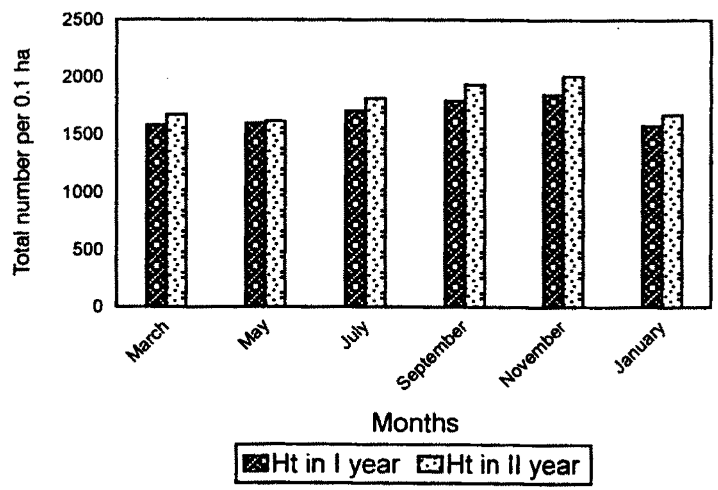


Figure 5.3.1.2 Annual variations in number of *Chromolaena odorata*

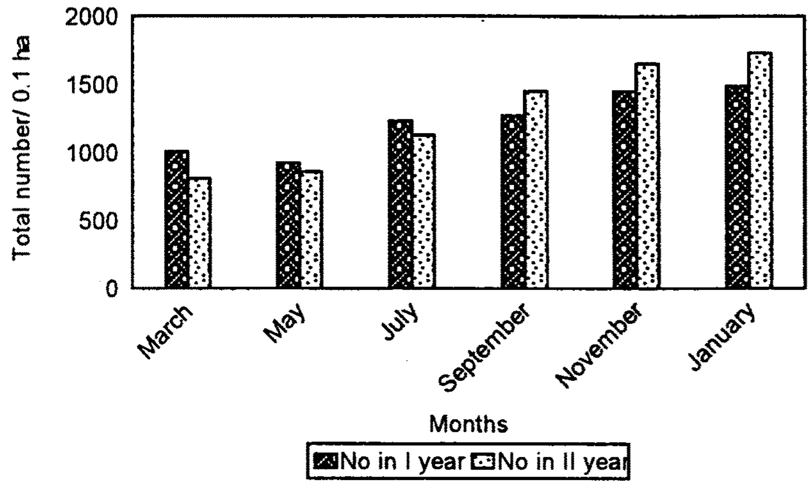


Figure 5.3.1.3 Annual variations in number of *Ageratum conyzoides*

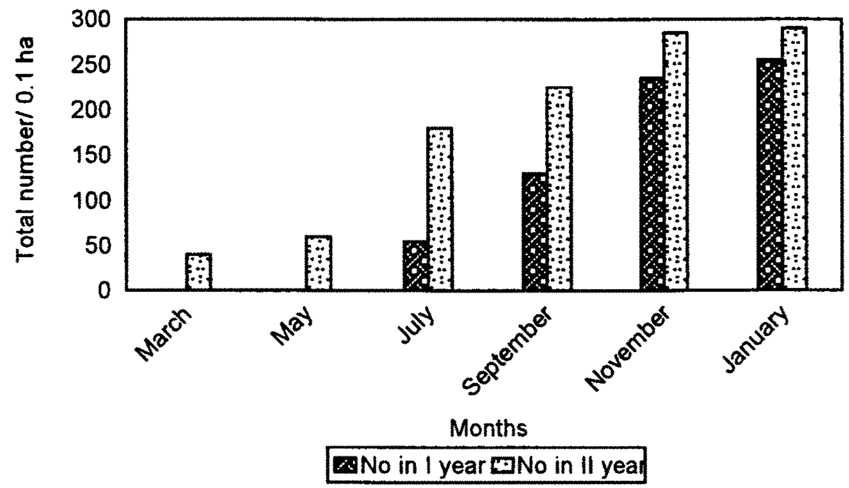


Figure 5.3.1.4 Annual variations in number of *Mimosa pudica*

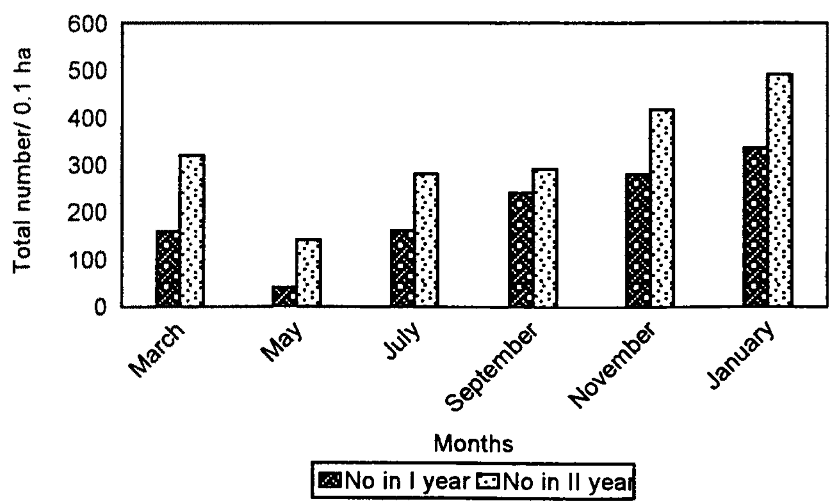


Figure 5.3.1.5 Annual variations in number of *Juticia betonica*

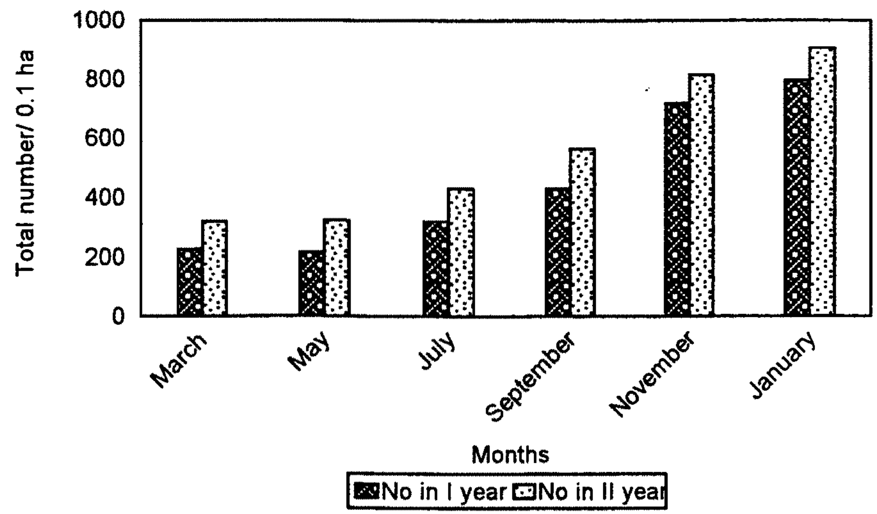


Figure 5.3.1.6 Annual variations in number of *Stachytarpheta jamaicensis*

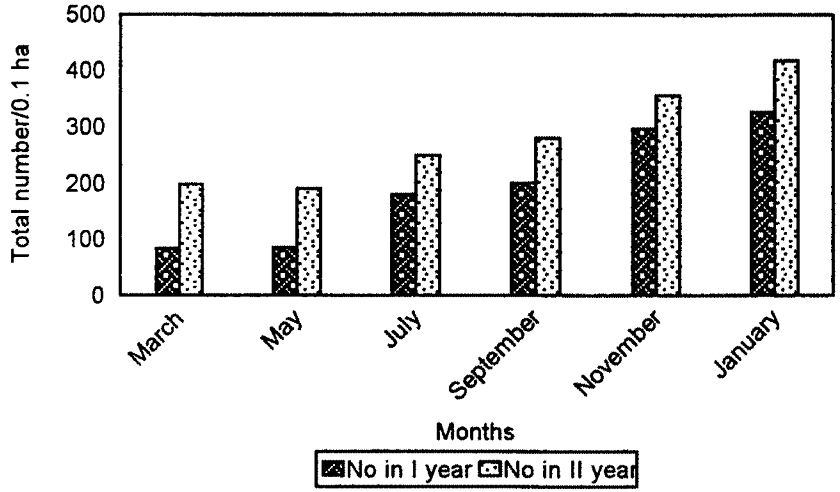


Figure 5.3.1.7 Annual variations in number of *Triumfetta pilosa*

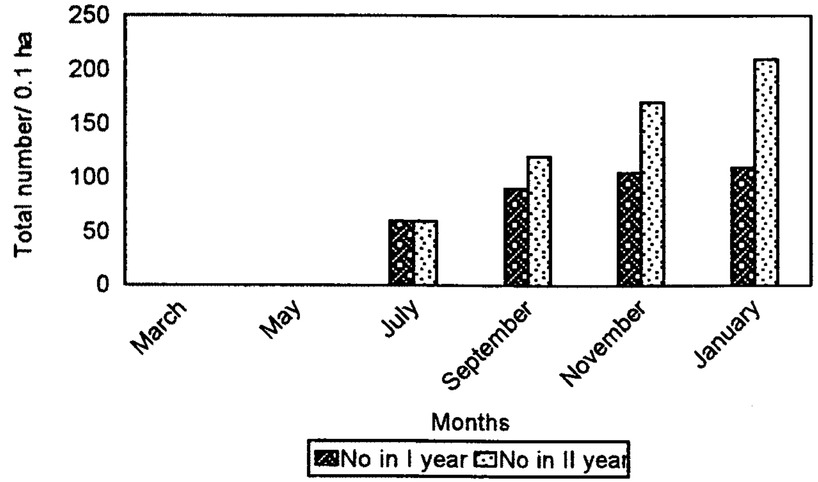


Figure 5.3.1.8 Annual variations in number of *Sida acuta*

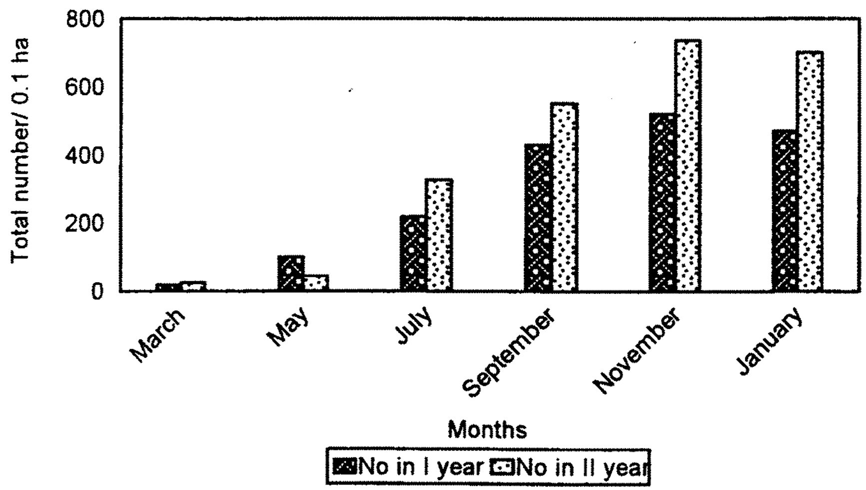


Figure 5.3.1.9 Annual variations in number of *Sida rhombifolia*

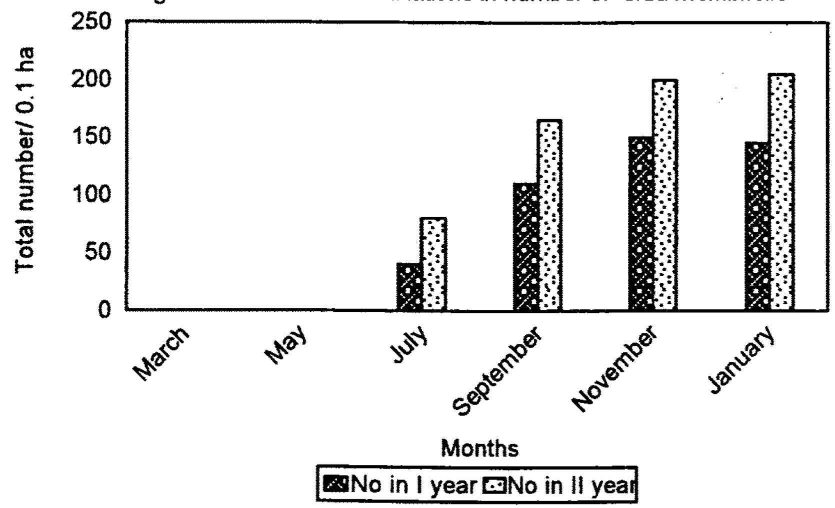


Figure. 5.3.2.2 Annual variations in height of *Chromolaena odorata*

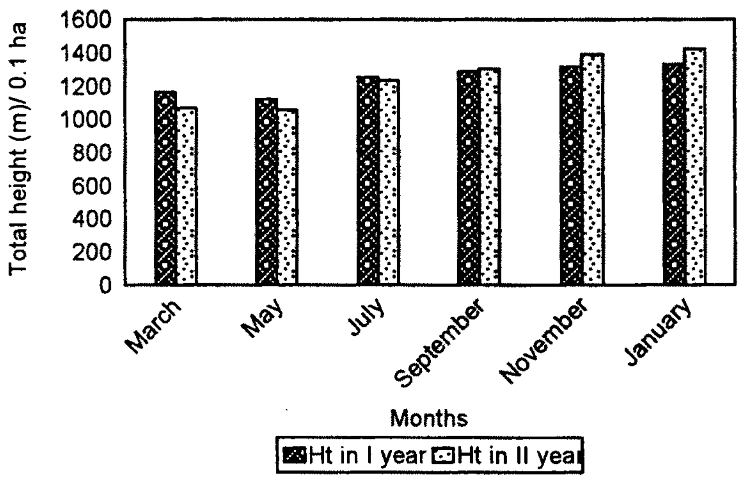


Figure 5.3.2.3 Annuall variations in height of *Ageratum conyzoides*

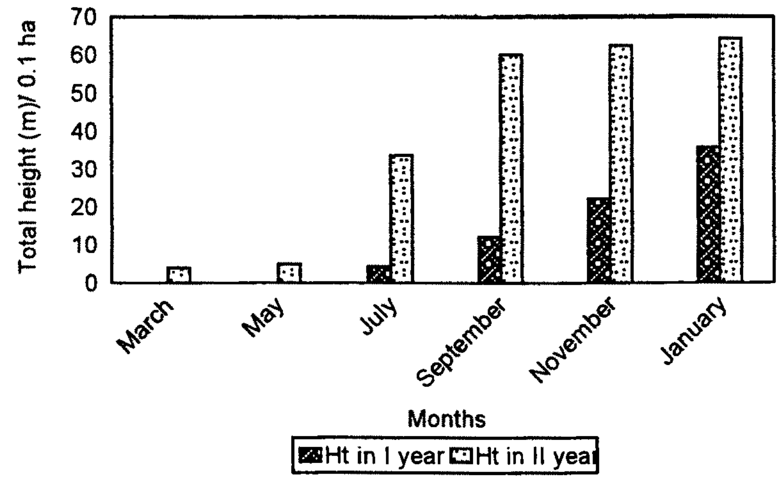


Figure 5.3.2.4 Annual variations in height of *Mimosa pudica*

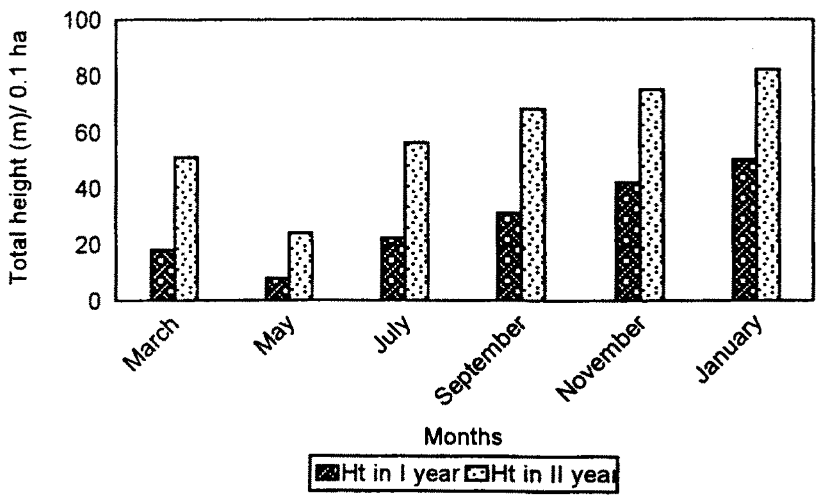


Figure 5.3.2.5 Annual variations in height of *Justicia betonica*

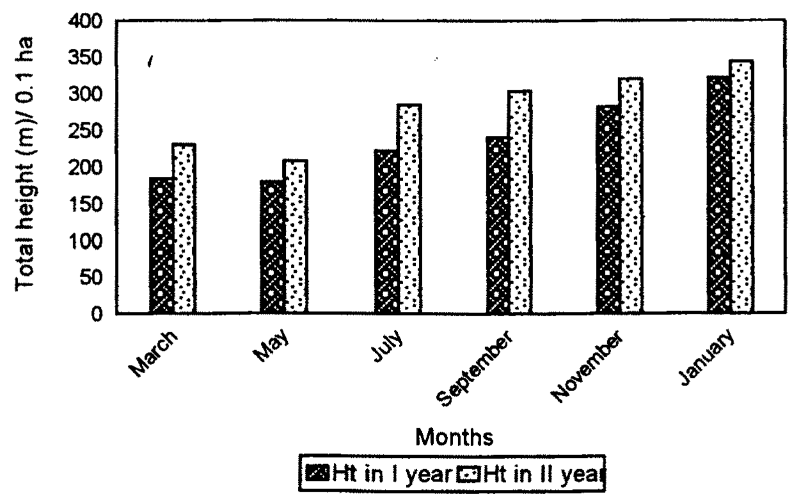


Figure 5.3.2.6 Annual variations in height of *Stachytarpheta jamaicensis*

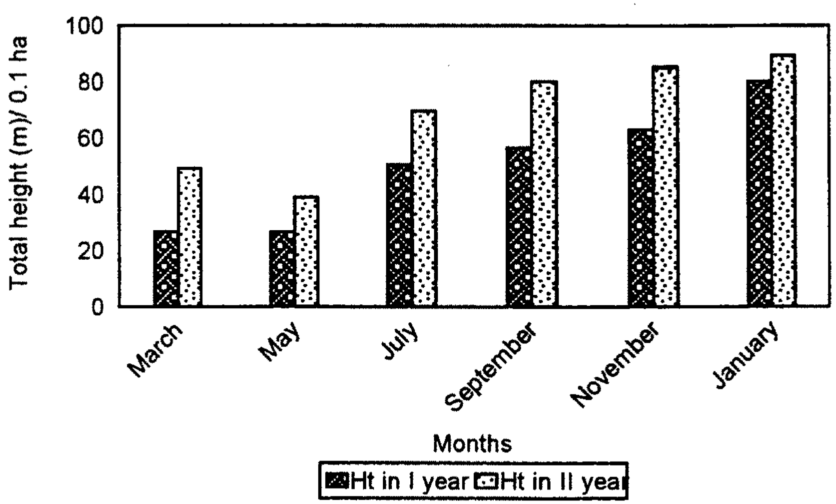


Figure 5.3.2.7 Annual variations in height of *Triumfetta pilosa*

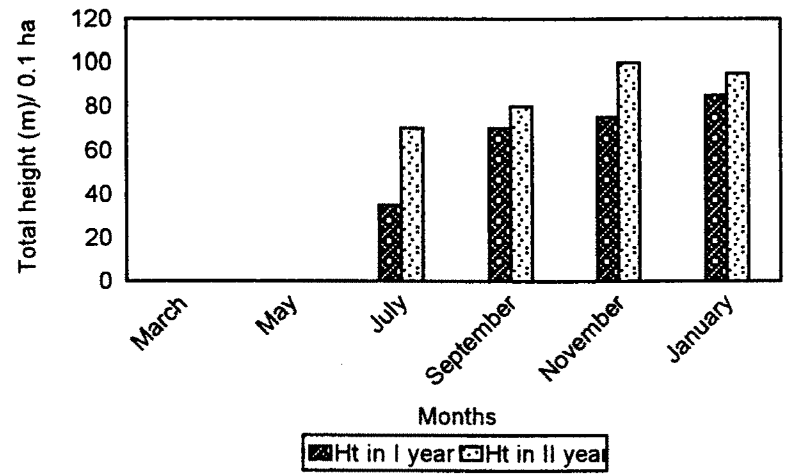


Figure 5.3.2.8 Annual variations in height of *Sida acuta*

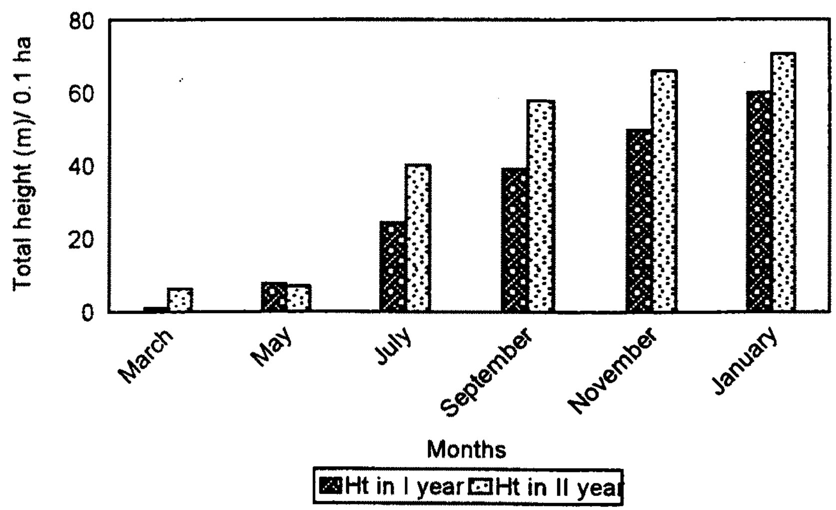
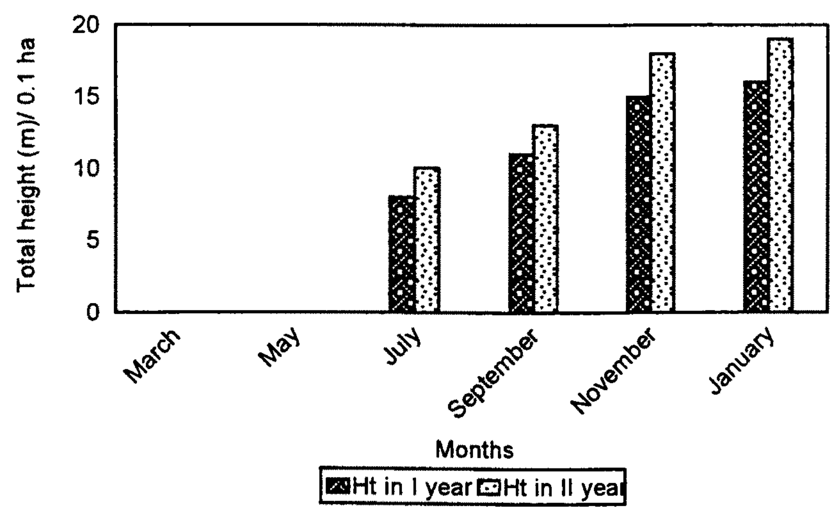


Figure 5.3.2.9 Annual variations in height of *Sida rhombifolia*



Total number of plant species = Total number of individuals of all plant species
Species richness of plant species = Number of species of plants

Figure 5.3.3.1 Annual variations in total number of plant species excluding weeds in Siruvani forest

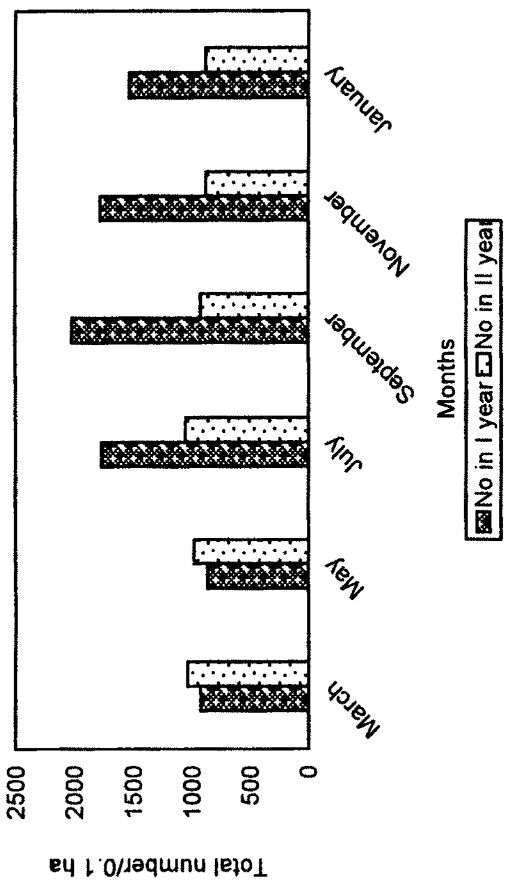
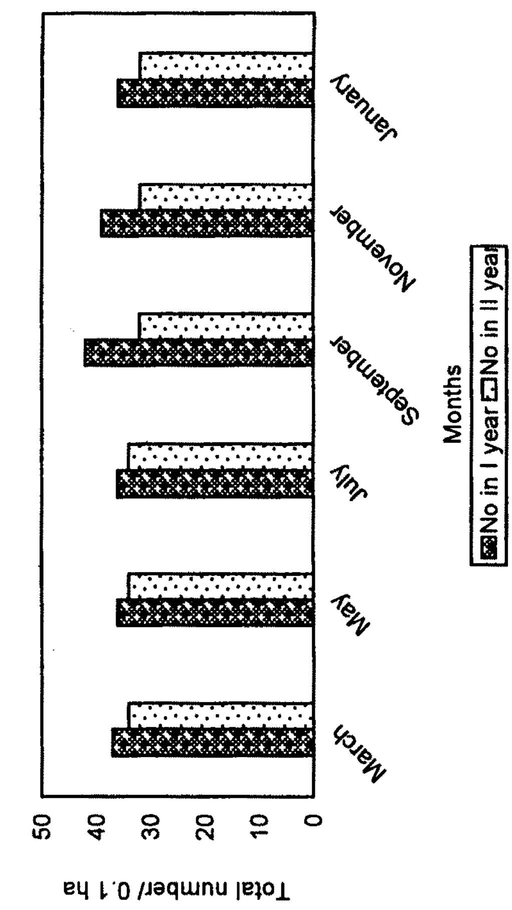


Figure 5.3.3.2 Annual variations in species richness of plant species excluding weeds in Siruvani forest



5.4 Phenological studies on select weeds in Siruvani Forest

Phenology of nine select weeds from Siruvani forest, namely *Lantana camara, Chromolaena odorata, Mimosa pudica, Ageratum conyzoides, Sida acuta, Sida rhombifolia, Triumfetta pilosa, Justicia betonica* and *Stachytarpheta jamaicensis* is discussed below, as other weeds selected for the first phase of the study were absent in Siruvani.

5.4.1 *Lantana camara*

Young leaves of *L. camara* were observed in all seasons. Percentage of young leaves was highest in July, September and November (15%), followed by March, May and January (10%). Mature leaves were also observed in all the seasons. Percentage of mature leaves was higher in the months of January, March and May (60%). In July, September and November percentage of mature leaves was 50. Flowering was observed in all the seasons. Flowering was highest in July (25%), followed by May (20%). Fifteen percent flowering was observed in March, September and November. In January, percentage of flowering was lowest. Fruiting was present in all the seasons. Fruiting was highest in September, November and January (20%), followed by March (15%). In May and July 10% fruiting was observed (Figure 5.4.1).

5.4.2 *Chromolaena odorata*

Young leaves of *Chromolaena odorata* were observed in all the seasons. Percentage of young leaves was highest in September (30%), followed by March, May and July (10%). In January, percentage of young leaves was least (5%). Mature leaves were present in all seasons. Percentage of mature leaves was highest in May and July because of absence of flowering and fruiting in these months. Flowering was present from November to January. Maximum flowering was observed in November (40%). Fruiting was seen from November to March. Maximum fruiting was observed in November (40%), followed by January (35%, Figure 5.4.2).

5.4.3 *Mimosa pudica*

Young leaves of *Mimosa pudica* were observed in all seasons except summer (March to May). Young leaves were highest in September (20%) and lowest in January (5%). Mature leaves were present throughout the year. Percentage of mature leaves was maximum in July (85%), followed by September (80%) and May (75%). In November percentage of mature leaves was 70% and in March and January 65% mature leaves was observed. Flowering was observed from November to March. In all these months flowering was about 20%. Fruiting was from January to May. In May percentage of fruiting was maximum (25%), followed by March (15%) and January (10%, Figure 5.4.3).

5.4.4 *Ageratum conyzoides*

Young leaves of *Ageratum conyzoides* were observed in all the seasons except summer (March and May). In September percentage of young leaves was highest (20%) followed by November (15%). The percentage of young leaves was lowest in July and January. Mature leaves were observed throughout the year. In July, percentage of mature leaves was maximum (90%) followed by November (85%). In March, May and September percentage of mature leaves was 80 and in January it was lowest (70%). Flowering was observed from

January to March. In January, percentage of flowering was highest (20%). Fruiting was observed in March and May and it was highest in May (20%, Figure 5.4.4).

5.4.5 *Sida acuta*

Young leaves of *Sida acuta* were present in all the seasons except summer (March to May). In July and September percentage of young leaves was highest (15%) followed by November and January (10%). Mature leaves were observed throughout the year. Maximum percentage of mature leaves was observed in May (90%), followed by July (85%) and March (75%). In January, percentage of mature leaves was lowest (60%). Flowering was observed from September to March. Maximum percentage of flowering was observed from September to November. In March, percentage of flowering was 10%. Fruiting was observed in January to May. January and March showed 15% fruiting. In May, fruiting was only 10%. (Figure 5.4.5).

5.4.6 *Sida rhombifolia*

Young leaves of *Sida rhombifolia* were present throughout the year except in summer. Maximum percentage was observed in July and September (20%) followed by November (10%). Mature leaves were present throughout the year. In May young leaves, fruits and flowers were absent and the plant was full of mature leaves. In September and November lowest percentage of mature leaves were observed (60%). Flowering was observed from September to January. Maximum flowering was in September and November (20%), followed by January (15%). Fruiting was present from November to March. Maximum fruiting was in March (20%, Figure 5.4.6).

5.4.7 *Triumfetta pilosa*

Except March and May young leaves were present throughout the year. Maximum percentage of young leaves was present in July (20%) followed by September and November (10%). In January, percentage of young leaves was lowest (5%). Mature leaves were present in all seasons. Maximum percentage of mature leaves was in July (85%). Percentage of mature leaves was least in November and January (65%). Flowering was observed from September to January. Maximum flowering was in November (25%), followed by September and January (20%). Fruiting was observed from January to May. Maximum fruiting was present in May (25%), followed by March (20%). In January, percentage of fruiting was least (10%, Figure 5.4.7).

5.4.8 *Justicia betonica*

Young leaves of *Justicia betonica* were present throughout the year except March. Maximum young leaves were present in September and November (20%), followed by July and January. In May, the percentage of young leaves was least (5%). Mature leaves were observed throughout the year. Of which, maximum percentage was in July, September and January (80%). In March, 70% of mature leaves were observed. Flowering was present from March to July. In May maximum flowering was observed (20%) followed by March and July (10%). Fruiting was present from September to May. In March and May percentage of fruiting was maximum (20%) followed by January (10%). In September and November, fruiting was only 5% (Figure 5.4.8).

5.4.9 *Stachytarpheta jamaicensis*

Young leaves of *Stachytarpheta jamaicensis* were not observed in March. But in January and May, 5% young leaves was present due to few showers of rain. In September and November percentage of young leaves was maximum (20%) followed by July (10%). Mature leaves were present all through the year. Highest percentage of mature leaves was in January. In March percentage of mature leaves was 70. Flowering was observed from March to July. Maximum flowering was in May (20%), followed by March and July (10%). Fruiting was observed from September to May. In March and May percentage of fruiting was maximum (20%), followed by January (10%). In September and November 5% fruiting was observed (Figure 5.4.9).

Figure 5.4.1 Phenology of
Lantana camara

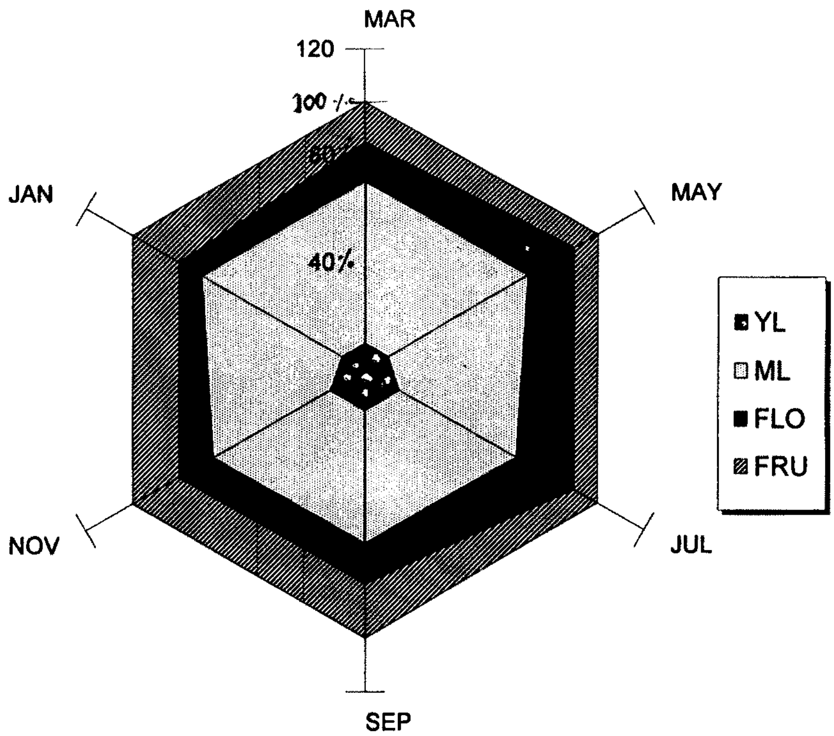


Figure 5.4.2 Phenology of
Chromolaena odorata

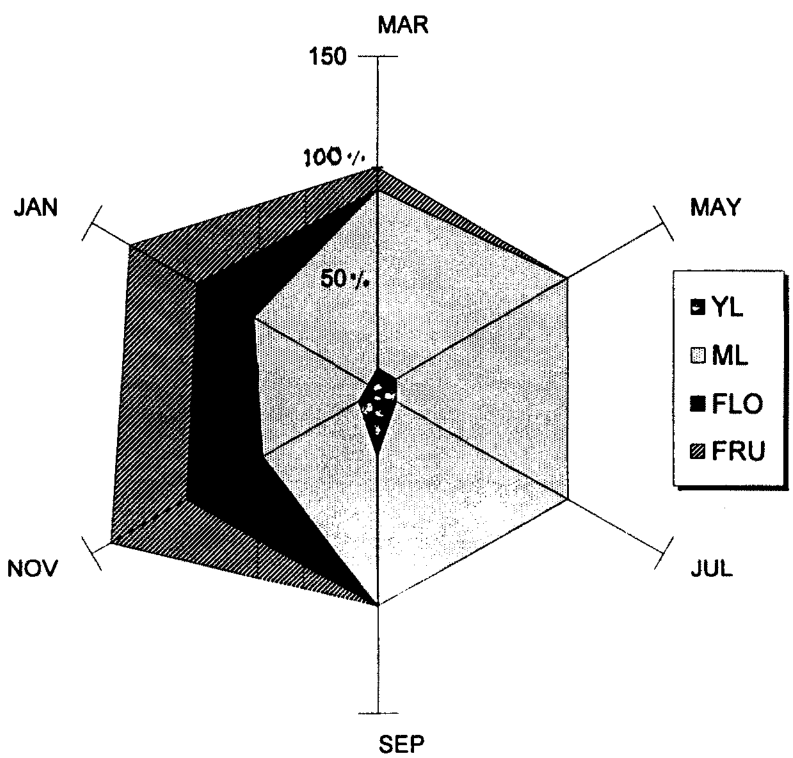


Figure 5.4.3 Phenology of
Mimosa pudica

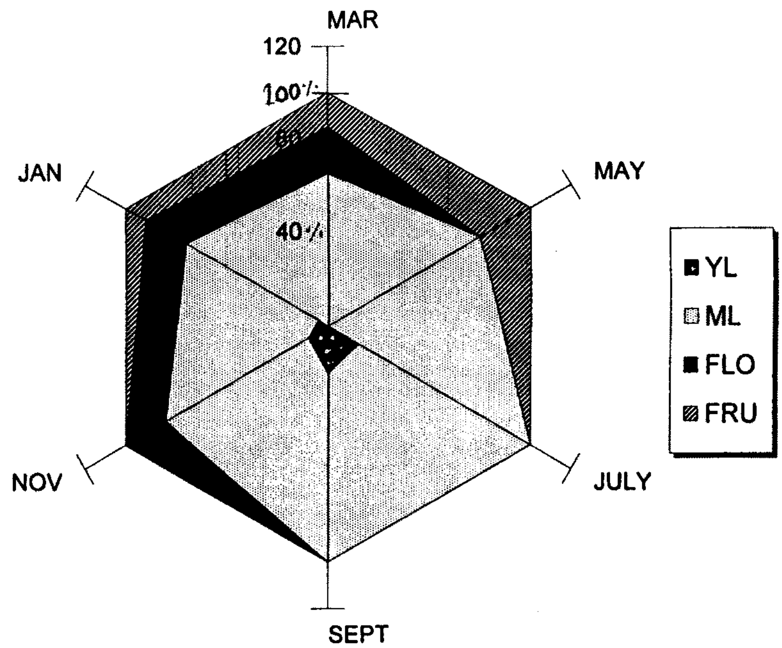


Figure 5.4.4 Phenology of
Ageratum conyzoides

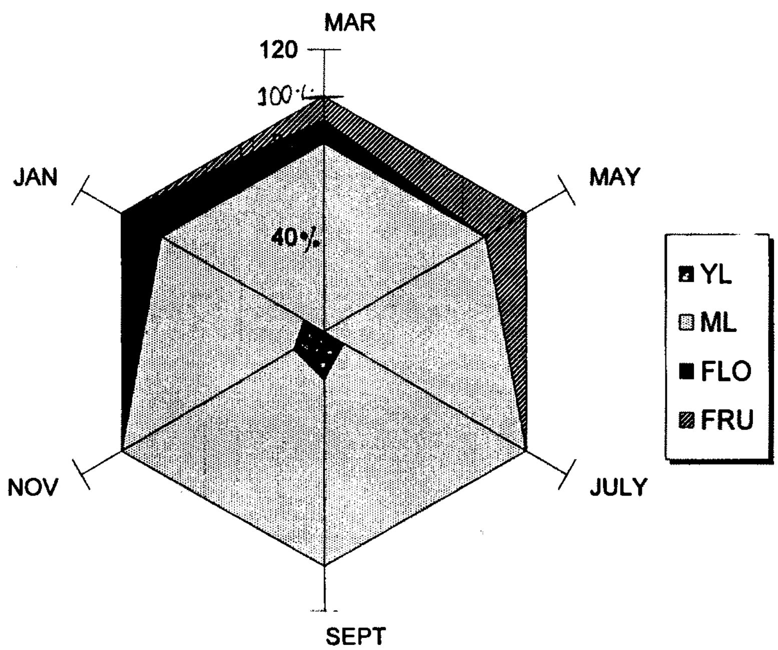


Figure 5.4.5 Phenology of
Sida acuta

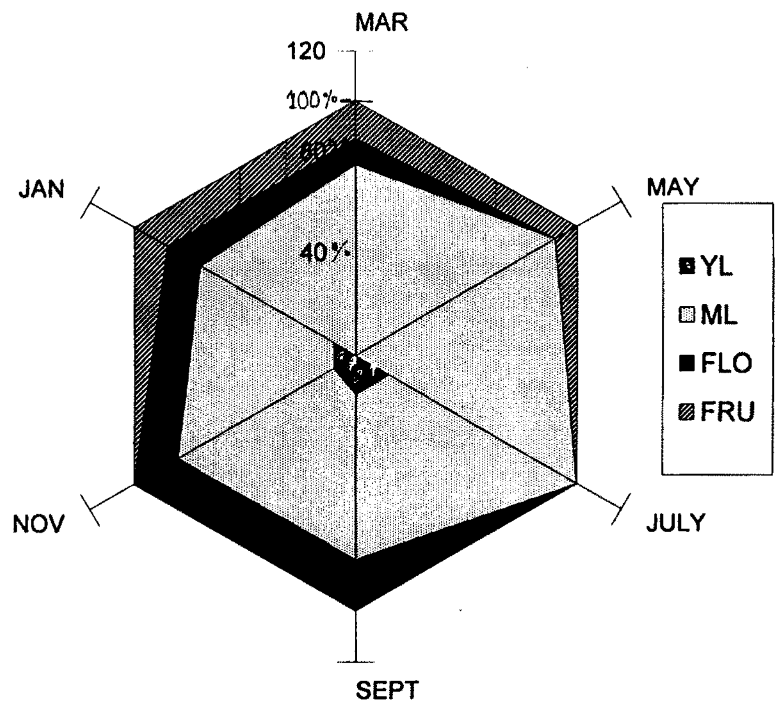


Figure 5.4.6 Phenology of
Sida rhombifolia

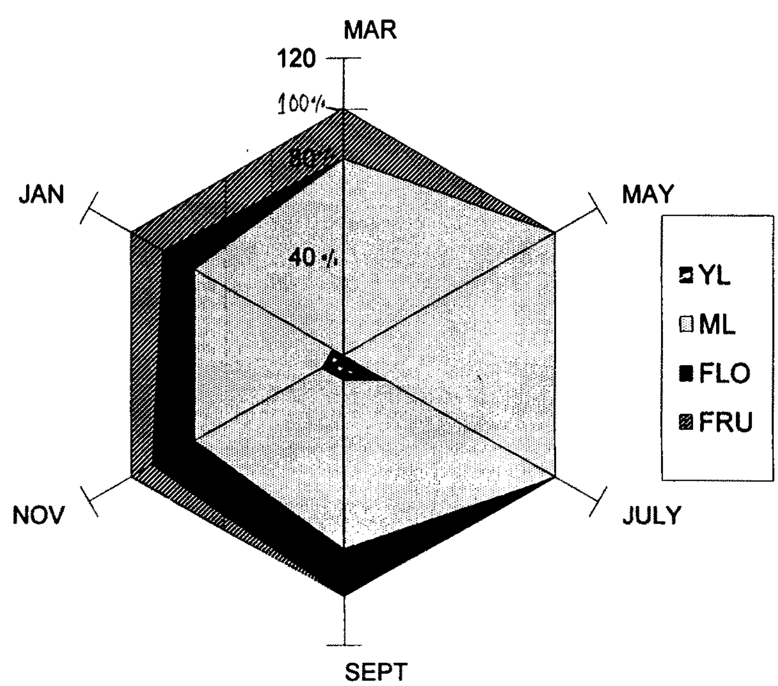


Figure 5.4.7 Phenology of
Triumfetta pilosa

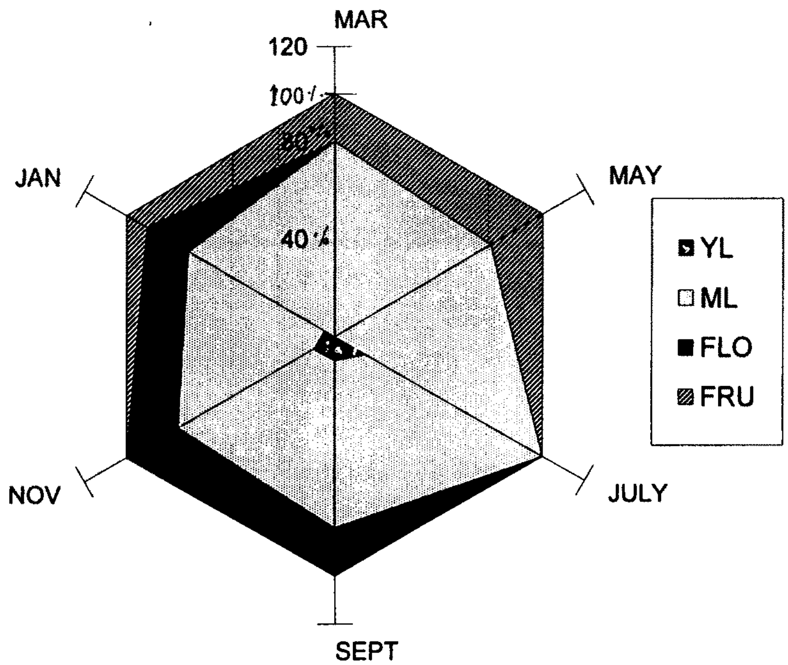


Figure 5.4.8 Phenology of
Justicia betonica

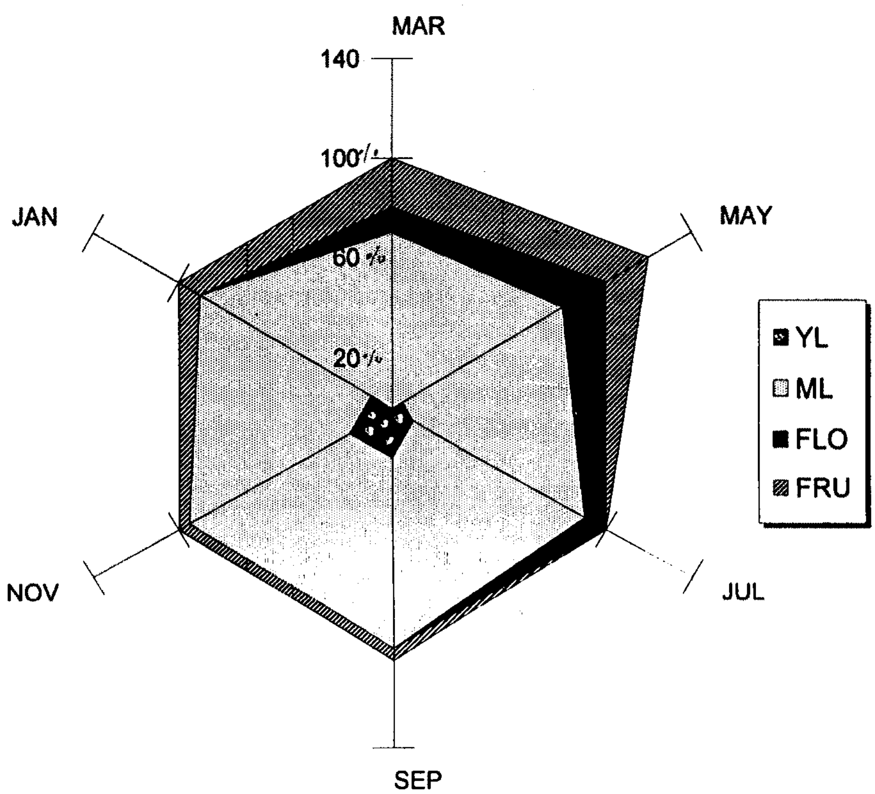
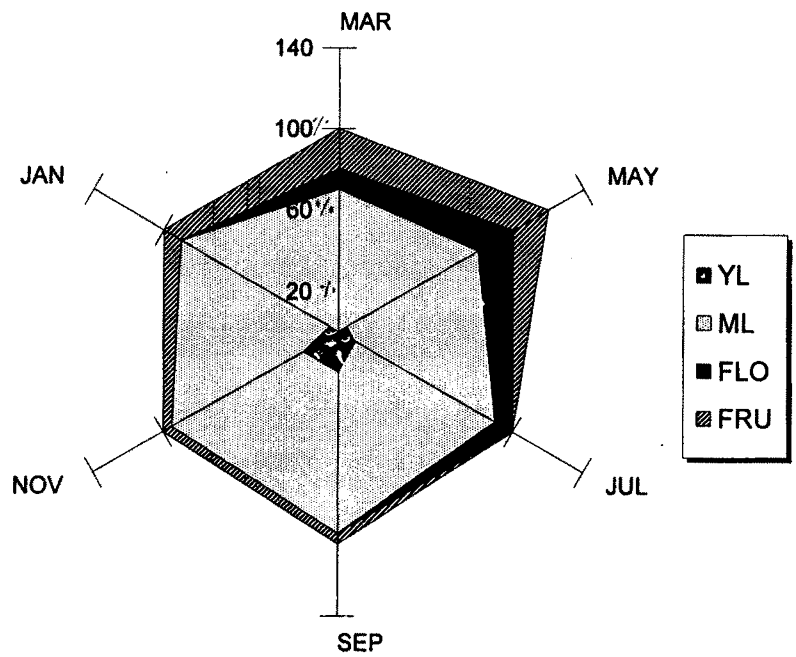


Figure 5.4.9 Phenology of
Stachytarpheta indica



5.5 Similarity

5.5.1 Similarity among the different vegetation types of Nilgiri Biosphere Reserve based on weed flora.

Similarity among the different vegetation types of Nilgiri Biosphere Reserve was estimated using Morisita (Horn's) index. For calculating Horn's similarity index, presence and number of selected, coloniser weedy species were taken as a criterion of similarity.

Similarity was highest between wattle plantation and evergreen forest (83%). Moist deciduous forest showed 75% similarity with coffee plantation, 65% similarity with teak plantation and 61% similarity with mixed deciduous forest. Mixed deciduous forest showed 67% similarity with teak plantation. Shola forest showed 65% similarity with wattle plantation.

Table 5.5.1 Percentage Similarity (Horn's similarity index) among the different habitats in the study area

HABITAT	COF	DRY	EUCLY	EVEGR	MIXED	MOIST	SCRUB	SHOLA	TEAK	WATTLE
COF	100									
DRY	34	100								
EUCLY	9	43	100							
EVEGR	21	16	7	100						
MIXDEC	39	58	22	37	100					
MOIST	75	42	16	20	61	100				
SCRUB	29	45	70	6	19	30	100			
SHOLA	3	1	1	53	2	1	1	100		
TEAK	45	37	15	22	67	65	23	1	100	
WATTLE	6	2	2	83	2	2	2	65	2	100

(Note: COF = Coffee tea plantation, DRY = Dry deciduous forest, EUCLY = Eucalyptus plantation, EVEGR =Evergreen forest, MIXDEC = Mixed deciduous forest, MOIST = Moist deciduous forest, SCRUB = Scrub jungle, SHOLA = Shola forest, TEAK = Teak plantation, WATTLE = Wattle plantation)

Shola forest was the most dissimilar vegetation with dry deciduous forest, eucalyptus plantation, moist deciduous forest, scrub jungle and teak plantation.

Evergreen forest showed only 16% similarity with dry deciduous forest and scrub jungle showed only 19% similarity with mixed deciduous forest. Wattle plantation was distinct in terms of similarity with dry deciduous forest, eucalyptus plantation, mixed deciduous forest, moist deciduous forest, scrub jungle and teak plantation (Table 5.5.1).

5.5.2 Species association

When association among the selected weedy species in different habitats was estimated using Jaccard's index, ***Chromolaena odorata*** was found to have highest association with *Lantana camara* (89%) and more than 65% association with *Ageratum conyzoides, Mimosa pudica, Sida acuta* and *Triumfetta pilosa* in the order of decrease.

Similarly, ***Lantana camara*** showed highest association with *Chromolaena odorata,* more than 65% association with *Ageratum conyzoides, Mimosa pudica, Sida acuta and Triumfetta pilosa.* It showed 50% association with *Evolvulus alsinoides, Opuntia dillenii* and *Malvastrum coromandelianum*

In the case of ***Mimosa pudica,*** highest association was seen with *Lantana camara* followed by *Chromolaena odorata* and *Orthosiphon thymiflorus.* It showed 50% association with *Tribulus terrestris, Tephrosia purpurea* and *Parthenium hysterophorus.* ***Sida acuta*** was highly associated with *Lantana camara* (75%) and *Sida rhombifolia* (75%). It also showed more than 50%

association with *Chromolaena odorata, Desmodium triflorum, Triumfetta pilosa and Synedrella nodiflora.*

Sida rhombifolia showed more than 65% association with *Sida acuta, Malvastrum coromandelianum* and *Justicia betonica. Stachytarpheta jamaicensis* showed high association with *Justicia betonica* (83%).

Opuntia dillenii showed highest association with *Tephrosia purpurea* (75%) followed by *Urena lobata*. In the case of ***Synedrella nodiflora*** associated (more than 70% association) species were *Sida cordata* and *Desmodium triflorum.* ***Cassia occidentalis*** showed 75% association with *Orthosiphon thymiflorus* and *Barleria mysorensis.*

Ageratum conyzoides was highly associated with *Lantana camara* (88%) followed by *Sida acuta* (86%), *Mimosa pudica* (86%) and *Chromolaena odorata* (78%). ***Triumfetta pilosa*** was highly associated with *Malvastrum coromandelianum, Justicia betonica* and *Sida cordata.* It also showed association with *Ageratum conyzoides, Lantana camara* and *Chromolaena odorata.*

Barleria mysorensis showed 75% association with *Leucas aspera, Evolvulus alsinoides, Cassia occidentalis, Euphorbia hirta* and *Tephrosia purpurea.* ***Tephrosia purpurea*** was associated with *Opuntia dillenii, Barleria mysorensis, Leucas aspera* and *Mimosa pudica* (Appendix 5).

5.6 Niche breadth

Most of the weeds have wide distribution and are seen in high population. In order to study the distribution of weed species compared to other species, niche breadth of all the plant species distributed in different habitats of NBR were calculated using Levin's niche breadth formula (Levin 1968). Most of the weedy species are found to have wider niche breadth. *Chromolaena odorata, Lantana camara, Mimosa pudica, Sida rhombifolia, Sida acuta, Ageratum conyzoides, Eupatorium repandum* and *Barleria mysorensis* have niche breadth greater than 2.6 (Table 5.6.1). Out of 407 plant species studied, 191 have least niche breadth i.e. one (Appendix 4).

Table 5.6.1. Niche breadth of herbs and shrubs (> 2.5 Niche breadth) in different vegetation types of Nilgiri Biosphere reserve

Species	Niche breadth
Oplismenus compositus	5.370
Chromolaena odorata	5.240
Asparagus racemosus	5.150
Asparagus gonoclados	5.120
Lantana camara	4.610
Curculigo orchioides	4.480
Grewia hirsuta	4.410
Flacourtia indica	4.110
Panicum notatum	4.090
Blumea virens	3.750
Leucas aspera	3.680
Fimbristylis dichotoma	3.460
Cassia occidentalis	3.400
Bambusa arundinacea	3.310
Commelina hirsuta	3.260
Solanum melongena	3.190
Apluda mutica	3.160
Cyanotis tuberosa	3.160
Curcuma pseudomonta	3.100
Mimosa pudica	3.090
Commelina benghalensis	3.050
Evolvulus alsinoides	3.040
Solanum torvum	3.000
Arundinella mesophylla	2.960
Sida rhombifolia	2.940

Sida acuta	2.920
Fimbristylis ovata	2.850
Orthosiphon thymiflorus	2.840
Pterolobium indicum	2.840
Eragrostis unioloides	2.810
Ageratum conyzoides	2.730
Eupatorium repandum	2.730
Heteropogon contortus	2.710
Strobilanthes foliosus	2.650
Cyperus cyperinus	2.650
Barleria mysorensis	2.610
Sida cordata	2.610
Anaphalis elliptica	2.600
Blumea alata	2.570
Cyperus pangorei	2.540

5.7 Human disturbance and weeds.

Preliminary surveys in NBR indicated that Mudumalai Wildlife Sanctuary was highly disturbed by tourism, human settlements and cattle. Apart from 29 tribal settlements, many villages are present inside and around the sanctuary. Tribals as well as most of the villagers are dependent on forest resources such as firewood, fruits, honey and timber, and for cattle grazing. Silori and Mishra (1995) estimated that villagers removed 1800 tonnes of fuel wood and 800 tonnes of grass during their study period. The studies also document that 90% of families did not have regular income and are exclusively dependent on firewood for fuel (Silori and Mishra 1995). In order to study the relationship between human disturbance and weed population, three transects of one kilometres were laid in scrub jungle and dry deciduous forest in the sanctuary, placed along the disturbance gradient, starting from villages and ending in deep forest.

5.7.1 Scrub jungle

Along the first transect, which was located close to villages, high population of weedy species such as *Acalypha fruticosa*, *Lantana camara*, *Opuntia dillenii*, *Tephrosia purpurea*, *Ageratum conyzoides*, *Evolvulus alsinoides*, *Sida acuta* and *Barleria mysorensis* were observed. Total number of individuals of all the above species except *Lantana* was low in the second transect.In third transect, which was laid deep inside the forest away from human habitations, *Lantana camara, Ageratum conyzoides, Sida acuta* and *Barleria mysorensis* were absent. There was also a reduction in total number of weedy species such as *Acalypha fruticosa*, *Opuntia dillenii, Tephrosia purpurea* and *Evolvulus alsinoides* (Table 5.7.1 and Figure 5.7.1).

Table 5.7.1 Density of weeds along the disturbance gradient in scrub jungle

Weeds	Number/0.1 ha		
	Transect 1	Transect 2	Transect 3
Acalypha fruticosa	130	115	95
Lantana camara	190	265	0
Opuntia dillenii	525	495	415
Tephrosia purpurea	2380	1300	80
Ageratum conyzoides	300	300	0
Evolvulus alsinoides	4300	4200	1400
Sida acuta	400	400	0
Barleria mysorensis	200	100	0

5.7.2 Dry deciduous forest

In the first transect which was laid near village weedy species such as *Lantana camara, Chromolaena odorata, Ageratum conyzoides, Sida acuta, Sida rhombifolia, Triumfetta pilosa* and *Synedrella nodiflora*, and *Evolvulus alsinoides* were present in high numbers. In the second transect *Triumfetta pilosa* and *Synedrella nodiflora* were absent, numbers of *Lantana camara, Chromolaena odoratum, Sida acuta, Sida rhombifolia* and *Evolvulus alsinoides* were lower but that of *Ageratum conyzoides* was slightly higher. In the third transect, laid deep inside the forest, *Triumfetta pilosa, Sida acuta* and *Synedrella nodiflora* were absent and all other weed species were lower in number compared to that in the first and second transects (Table 5.7.2 and Figure 5.7.2).

Table 5.7.2 Density of weeds along the disturbance gradient in dry deciduous forest

Weeds	Number/0.1 ha		
	Transect 1	Transect 2	Transect 3
Lantana camara	200	40	25
Chromolaena odorata	220	190	75
Ageratum conyzoides	40	60	10
Sida acuta	70	75	0
Sida rhombifolia	75	85	20
Triumfetta pilosa	30	0	0
Synedrella nodiflora	20	0	0
Evolvulus alsinoides	40	15	25

5.7.3 Moist deciduous forest

In the case of the moist deciduous forest near Kelakooly, the first and the last transect were laid near the two different villages present in the area. Hence, effect of human interference was intense in the first and last transects. In the first transect, weedy species such as *Lantana camara, Chromolaena odorata, Ageratum conyzoides, Mimosa pudica, Sida rhombifolia, Triumfetta pilosa* were present in large numbers. In the second transect *Mimosa pudica* and *Sida rhombifolia* were absent and number of all other weedy species, except *Ageratum conyzoides* were reduced. In the third transect *Mimosa pudica* was absent and total number of other weedy species except *Chromolaena odorata* got decreased. In the fourth transect, which was near another village, all the weedy plant species seen in transect one were present in higher number than the first, the second and the third transects. The number of *Lantana camara* in the fourth transect was higher than that in the third but was lower than that in the first and the second transect. Highest number of *Lantana camara* was observed in transect 1 followed by transect 2 (Table 5.7.3 and Figure 5.7.3).

Table 5.7.3. Density of weeds along the disturbance gradient in moist deciduous forest

Weeds	**Number/0.1 ha**			
	Transect 1	Transect 2	Transect 3	Transect 4
Lantana camara	640	360	40	280
Chromolaena odorata	230	80	200	240
Ageratum conyzoides	50	90	20	110
Mimosa pudica	50	0	0	150
Sida rhombifolia	30	0	30	40
Triumfetta pilosa	140	110	30	180

In all the three habitats studied, weed population as well as their species richness were higher in transects near the villages, and they decreased towards the undisturbed deep forest (Figure 5.7.4, 5.7.5 and 5.7.6).

Figure 5.7.1 Density of weeds along the disturbance gradient in scrub jungle

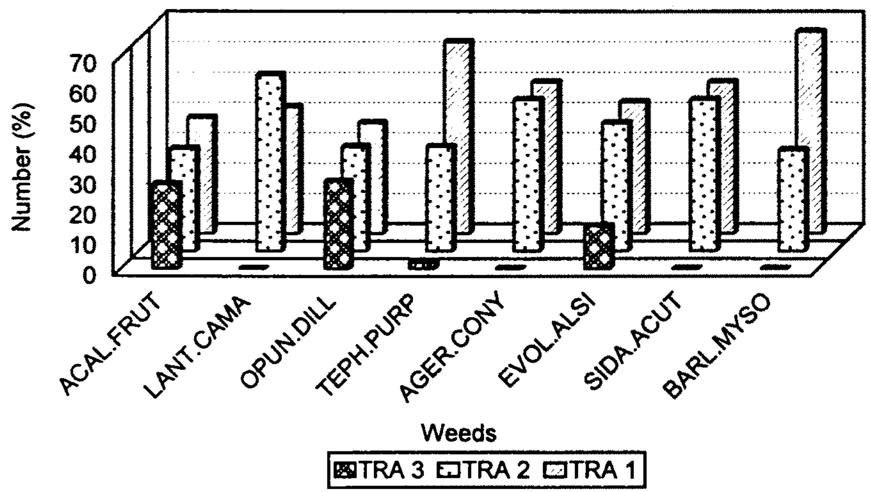


Figure 5.7.2 Density of weeds along the disturbance gradient in dry deciduous forest

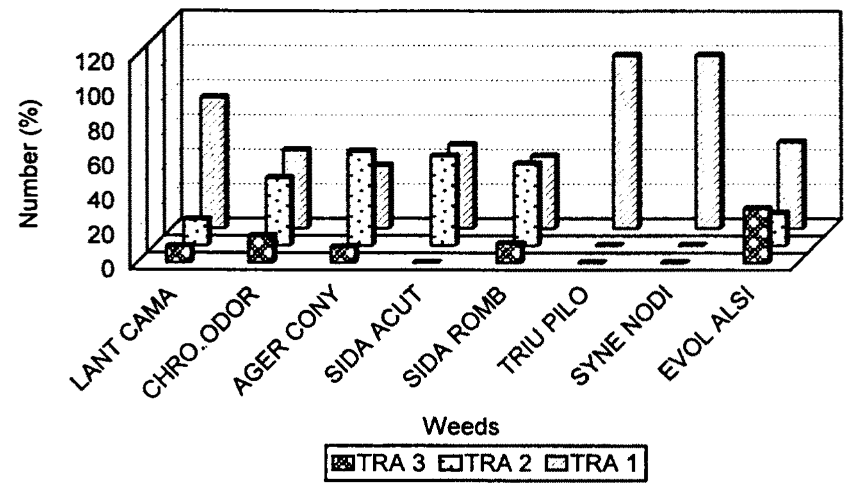


Figure 5.7.3 Density of weeds along the disturbance gradient in moist deciduous forest

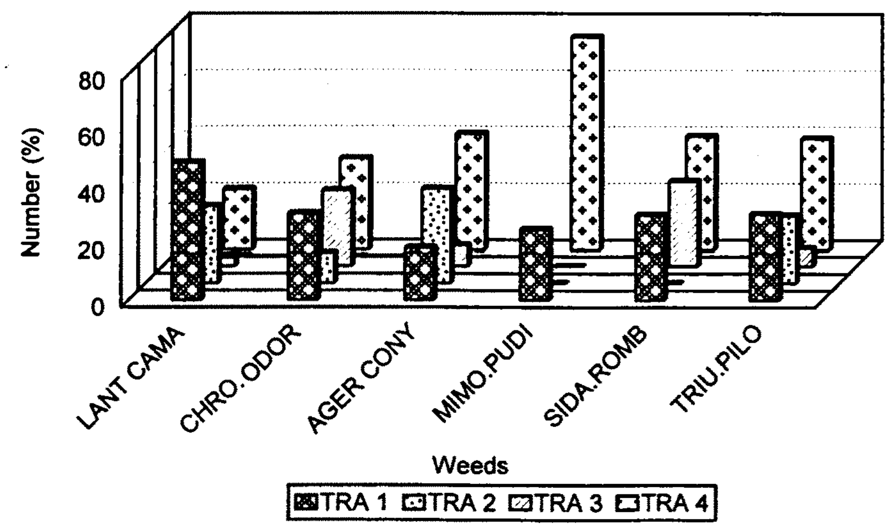


Figure 5.7.4 Species richness and total number of weeds along the disturbance gradient in scrub jungle

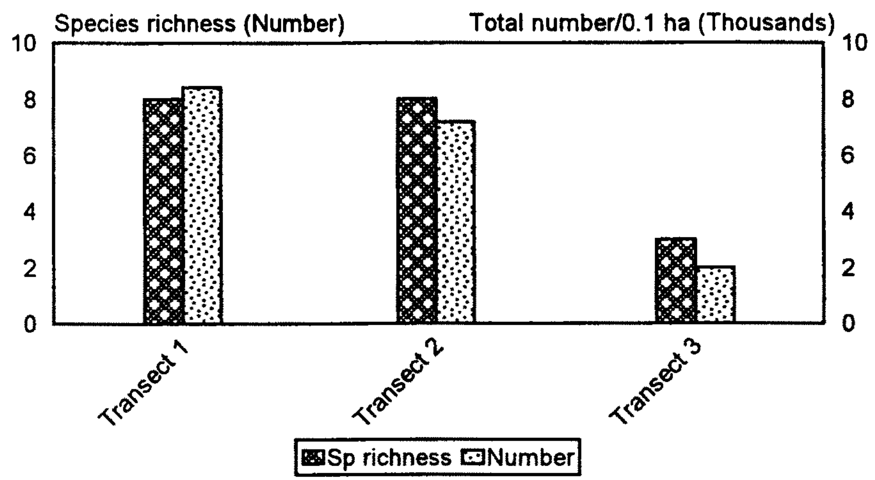


Figure 5.7.5 Species richness and total number of weeds along the disturbance gradient in dry deciduous forest

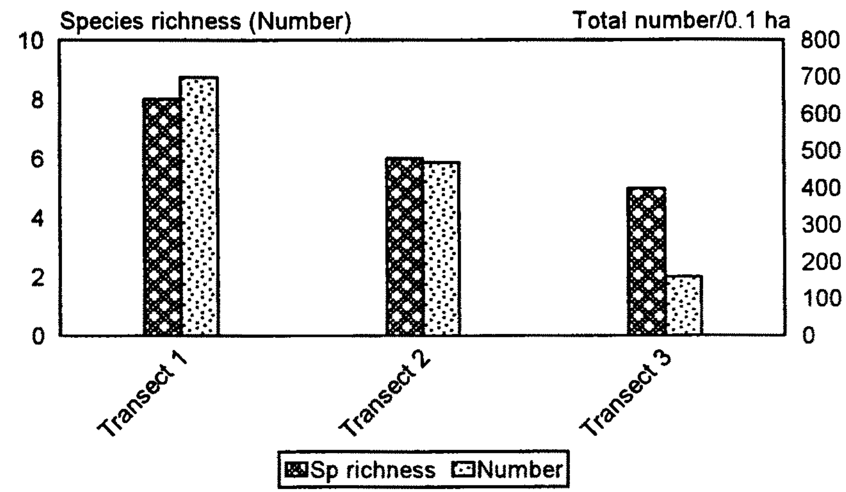
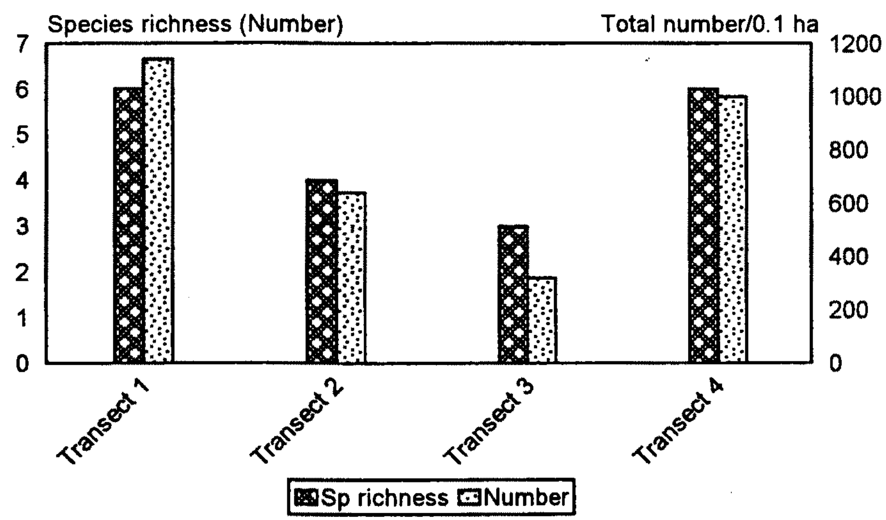


Figure 5.7.6 Species richness and total number of weeds along the disturbance gradient in moist deciduous forest



5.8 Influence of soil characteristics on weeds in Siruvani mixed deciduous forest.

Seasonally collected soil samples, from different plots in Siruvani mixed deciduous forest were investigated for selected physical and chemical characters namely, grain size composition, pH, electrical conductivity, available nitrogen, phosphorus, potassium and organic carbon.

5.8.1 Soil characteristics

5.8.1.1 Grain size composition

Soil in the study area was loamy sand. Average percentage of sand in different plots at Siruvani mixed deciduous forest was more than 87% and that of silt and clay was less than 13%.

Table. 5.8.1 Average grain size of soil samples in different plots in Siruvan forest.

Grain size	Average percentage
Gravel (> 2.0 mm.)	2.18
Very Coarse sand (2.0 - 1.0 mm.)	7.72
Coarse sand (1.0 - 0.5 mm.)	19.90
Medium sand (0.5 - 0.25 mm.)	34.60
Fine sand (0.25 - 0.10 mm.)	25.70
Very fine sand and Silt & Clay (< 0.1 mm.)	9.62

5.8.1.2 pH

Average pH of all seasons in different plots ranged from 5.42 to 8.26. The highest average pH of all seasons was in plot 1 and lowest in plot 9. There was an increase in pH in rainy seasons of both the years. Highest average pH of all plots was observed in July of the second year and lowest in January of the first year (Figure 5.8.1.1). There was significant difference between average pH in all plots, among most of the seasons in both the years.

5.8.1.3 Electrical conductivity

Average EC of all seasons in different plots were in the range from 0.18 to 0.25 m.mhos/cm. The highest average EC during all seasons was in plot 1 and lowest in plot 2 (Figure 5.8.2.2). EC in May of second year was significantly higher than May of the first year. Other months of the first year and the second year did not significantly differ in EC (Figure 5.8.2.1).

5.8.1.4 Available nitrogen

Average available nitrogen in all seasons in different plots ranged from 108 to 120 kg/ha. Average available nitrogen in all seasons was higher in plot 3, 4 and 5 compared to other plots (Figure 5.8.3.2). Average available nitrogen of all plots was highest in January of the first year and lowest in September of the first year (Figure 5.8.3.1). In rainy season, nitrogen was lower than in summer season. This may be because of leaching of soil nitrogen due to high rainfall. In most cases, there was a significant difference between nitrogen in similar months of the first and second year.

5.8.1.5 Available phosphorus

Average available phosphorus of all seasons in different plots ranged from 4.67 to 5.58 kg/ha. Average available phosphorus of all seasons was highest in plot 10 and lowest was in plot 8 (Figure 5.8.4.2). Average available phosphorus of all plots in different seasons was highest in January of second year and lowest in July of the first year (Figure 5.8.4.1). Except March, all other months of first year and the second year were significantly different in phosphorus.

5.8.1.6 Available potassium

Average available potassium of all seasons in different plots, were ranging from 154.31 to 251.83 kg/ha. Highest average available potassium of all seasons was in plot 1 and lowest in plot 6 (Figure 5.8.5.2). Highest average available potassium of all plots was observed in March of the second year and lowest in July of the first year (Figure 5.8.5.1). Available potassium in the same months except March, of the first and second year, did not differ significantly.

5.8.1.7 Organic Carbon

Average organic carbon of all seasons in different plots were ranging from 1.31 to 1.76%. Highest average organic carbon of all seasons was observed in plot 5 and lowest in plot 7 (Figure 5.8.6.2). Highest average OC of all plots was observed in January of the second year and lowest was observed in July of the first year (Figure 5.8.6.1). OC in same months of the first year and the second year, except January, did not differ significantly. OC in January of the first year was significantly lower than OC in January of the second year. OC in January of the second year was significantly higher than all other months in both the years.

When Pearson's correlation coefficients were calculated, to assess correlation among different soil parameters, available nitrogen, potassium, phosphorus and EC were negatively correlated with rainfall. Available potassium, phosphorus, pH and EC were positively correlated with organic carbon. Available phosphorus showed significant positive correlation with EC, pH and available nitrogen. Available nitrogen was positively correlated with available phosphorus and EC and negatively correlated with pH (Table 5.8.5).

5.8.1.8 Heavy metals

Soil samples were also investigated to examine the distribution of Cu, Zn, Pb, Mn and Fe in the soil of mixed deciduous forest in Siruvani.

Table 5.8.2 Metal concentrations (mg/kg) in the study area

Metals in Samples	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Average
Average Cu	24.58	19.17	14.17	15.00	15.00	19.17	14.58	16.25	14.58	16.25	16.88
Average Mn	369.17	623.75	285.42	418.75	411.67	283.33	257.92	433.33	484.17	404.17	397.17
Average Pb	48.92	91.25	67.54	44.29	13.88	86.21	14.08	43.46	10.92	66.17	48.67
Average Zn	45.75	36.38	30.79	35.46	35.75	40.13	35.13	37.08	35.46	131.29	46.32
Average Fe	12440	11927	10084	9747	10767	11826	10997	9903	10941	11899	11053.

Table 5.8.3 Range of heavy metals (mg/kg) in normal and polluted soils

Metals	Range of HM in various soils	Critical range (possibility for toxicity)	Range in Sewage sludge	Slight contamination in soil	Heavy contamination in soil
Cu	2-250	60-75	50-8000	100-200	500-2500
Mn	20-10000	1500-3000	60-3900	500-1000	2000-10000
Pb	2-300	100-400	29-3600	500-1000	2000-10000
Zn	1-900	70-400	91-4100	250-500	1000-2000

(Kabata-Pendias and Pendias 1984, Department of the Environment 1980)

Copper

The distribution of copper in study area varied between 5 - 28 mg/kg of soil with an average of 16.8 mg Cu/kg. The samples from plot 1 recorded higher concentration of copper compared to the rest of the plots (Table 5.8.2).

Manganese

Soil samples contained manganese in the range between 15 mg /kg and 658 mg/kg with an average of 397 mg/kg (Table 5.8.2). Plot 2 recorded higher Mn concentrations in all seasons (605 - 650 mg/kg) which falls under a category classified as "slightly contaminated zone " (Table 5.8.3).

Lead

Lead in soils ranged between 4 to 376 mg/kg with an average distribution of 48 mg/kg (Table 5.8.2).

Zinc

The estimated values of Zn in soils of Siruvani forest ranged from 13 to 190 mg/kg, with an average of 46.3 mg/kg (Table 5.8.2). A comparatively high Zn concentration was observed in plot 10 in all seasons.

Iron

The investigation showed an average concentration of 11053 mg/kg (Table 5.8.2), of iron with highest values in plot 1 samples (11965 - 12683 mg/kg).

As per their respective concentration in the soil, the heavy metals in Siruvani soils were in the order Fe>Mn>Zn>Pb>Cu (Table 5.8.2).

Correlation attempted among metals investigated in the study area, did not yield any significant relationship, except copper having a considerable degree of positive correlation with iron (r = 0.55, Table 5.8.4)

Table 5.8.4 Pearson's correlation co-efficient

	Cu	Mn	Pb	Zn	Fe	pH	OC	Phosph	Nitroge	Potass
Cu	1.00									
Mn	0.27	1.00								
Pb	0.17	0.17	1.00							
Zn	0.04	0.03	0.07	1.00						
Fe	**0.55***	0.02	-0.06	0.21	1.00					
pH	0.09	0.17	0.34	-0.02	-0.19	1.00				
OC	-0.09	0.12	0.09	0.09	0.08	0.10	1.00			
Phosphorus	0.02	0.15	-0.23	0.11	-0.10	-0.14	0.20	1.00		
Nitrogen	-0.01	-0.13	-0.10	-0.04	0.03	-0.36	0.14	0.11	1.00	
Potassium	0.30	0.28	0.00	0.21	0.16	-0.05	0.10	0.21	0.04	1.00

5.8.2 Similarity among the plots based on soil characteristics and species composition.

Hierarchical cluster analysis was used to study the similarity among different plots laid in Siruvani forest, based on species composition and their number in 0.1 ha area. The result, as dendrogram, is given in Figure (5.8.7). Two clusters were formed in the dendrogram. Plots 4, 5, 1, 3, 2 and 10 were similar and formed the first cluster. The other cluster was formed by plots 7, 8, 9, and 6. Hierarchical cluster analysis was also used to study similarity among different plots based on different physical and chemical soil characteristics discussed earlier. Two clusters were resulted. One cluster was formed by plots 4, 5, 1, 10 and 2 and plots 7, 9, 8, 3 and 6 formed second cluster (Figure 5.8.8)

Based on species composition, number as well as soil characteristics; plots 1, 2, 4, 5 and 10 showed similarity among them and plots 6, 7, 8 and 9 were similar with each other (Figure 5.8.7 and 5.8.8). While, plot 3 was similar with first group (Plot 1, 2, 4, 5 and 10) based on species composition and number but based on soil characteristics it showed similarity with second group (Plot 6, 7, 8 and 9).

5.8.3 Correlation among species richness and number of herbs and soil parameters.

The Pearson's correlation coefficients were calculated to assess correlation among total number of herbs, species richness, and physical and chemical parameters of soil such as EC, pH, available nitrogen, phosphorus, potassium; organic carbon and rainfall. Total number of herbs showed significant positive correlation with soil pH and rainfall, and negative correlation with EC and available nitrogen ($p < 0.05$). Species richness of herbs showed significant positive correlation with pH and rainfall, and negative correlation with EC, available nitrogen and potassium ($p < 0.05$, Table 5.8.5).

Multiple regression analysis (step-wise method), when attempted to check the relation among, total number of herbs, species richness and soil characteristics and rainfall (Figure 5.8.9.1 and 5.8.9.2), the following equations were obtained.

$N_H = (-26.389 \pm 16.633) + [pH \times (11.134 \pm 2.595) + R_F \times (0.039 \pm 0.008)]$..........[1]

(R Square = 0.40137, P< 0.001)

$S_H = (9.787 \pm 1.863) + [EC \times (-15.903 \pm 7.702) + R_F \times (0.071 \pm 0.0012)]$.......... [2]

(R Square = 0.36680, P<0.001)

(Where, N_H = Total number of herbs, pH = pH, R_F = Rainfall, EC = Electrical conductivity, S_H = Species richness of herbs)

As suggested by the Pearson's correlation, the total number of herbs was positively correlated with rainfall. It also showed significant positive correlation with pH (equation 1). Species richness of herbs was positively correlated with rainfall, while it was negatively correlated with EC (equation 2.)

5.8.4 Correlation among the total number and species richness of select weeds and soil characteristics.

The Pearson's correlation coefficients were calculated to estimate correlation among total number, species richness of select weeds, and physical and chemical parameters of soil and rainfall. Total number of weeds was positively correlated with pH ($p < 0.05$) and negatively correlated with potassium ($p < 0.01$). Species richness of weeds was positively correlated with pH and rainfall ($p < 0.01$) and negatively correlated with EC, available nitrogen ($p < 0.05$) and potassium ($p < 0.01$, Table 5.8.5).

The following equations were generated when multiple regression analysis (step-wise method) was attempted to study the relation among, total number, species richness of select weeds, and soil characteristics and rainfall (Figure 5.8.9.3 and 5.8.9.4).

$N_W = (675.445 \pm 76.7) + [P_T \times (-1.646 \pm 0.313) + P_S \times (21.878 \pm 7.152)]$........[3]

(R Square = 0.203, P<0.000)

$S_W = 6.299 \pm 0.611 + [P_T \times (-0.00092 \pm 0.002) + pH \times (0.456 \pm 0.132)]$.........[4]

(R Square = 0.179, P<0.000)

(Where N_W = Total number of weeds, P_T = Potassium, P_S = Phosphorus, pH= pH, S_W = Species richness of weeds)

Total number of weeds was positively correlated with available phosphorus and negatively correlated with available potassium (equation 3). Species richness of weeds was positively correlated with pH and negatively correlated with available potassium (equation 4).

Table 5.8.5 Pearson's correlation among soil characteristics, weeds and herbs in study plots in Siruvani forest

	Total no of herbs	Total herb species	Total no of weeds	Total weed species	Nitrogen	Potassium	EC	pH	Organic carbon	Phospho-rus	Rainfall
Total no of herbs	1	0.719**	0.421**	0.486**	-0.29**	-0.075	-0.274**	0.532**	0.058	0.084	0.554**
Total herb species	0.719**	1	0.411**	0.497**	-0.265**	-0.209*	-0.402**	0.367**	-0.113	-0.148	0.586**
Total no of weeds	0.421**	0.411**	1	0.632**	-0.019	-0.392**	-0.118	0.187*	-0.037	0.178	0.092
Total weed species	0.486**	0.497**	0.632**	1	-0.195*	-0.308**	-0.201	0.293**	-0.116	0.159	0.279**
Nitrogen	-0.29**	-0.265**	-0.019	-0.195*	1	0.023	0.21	-0.391**	0.049	0.192*	-0.28**
Potassium	-0.075	-0.209*	-0.392**	-0.308**	0.023	1	0.183	-0.013	0.209*	0.174	-0.21*
EC	-0.274**	-0.402**	-0.118	-0.201*	0.21*	0.183*	1	-0.125	0.181*	0.261**	-0.455**
PH	0.532**	0.367**	0.187*	0.293**	-0.391**	-0.013	-0.125	1	0.216*	0.238**	0.472**
Org carbon	0.058	-0.113	-0.037	-0.116	0.049	0.209*	0.181	0.216*	1	0.379**	-0.155
Phosphorus	0.084	-0.148	0.178	0.159	0.192*	0.174	0.261**	0.238**	0.379**	1	-0.245**
Rainfall	0.554**	0.586**	0.092	0.279**	-0.28**	-0.21*	-0.455**	0.472**	-0.155	-0.245**	1
Significance (2-tailed)											
Total no of herbs	0	0	0	0.001	0.414	0.002	0	0.529	0.364	0	
Total herb species	0	.	0	0	0.003	0.022	0	0	0.219	0.107	0
Total no of weeds	0	0	.	0	0.839	0	0.2	0.041	0.689	0.051	0.319
Total weed species	0	0	0	.	0.033	0.001	0.028	0.001	0.207	0.083	0.002
Nitrogen	0.001	0.003	0.839	0.033	.	0.804	0.021	0	0.593	0.035	0.002
Potassium	0.414	0.022	0	0.001	0.804	.	0.045	0.888	0.022	0.057	0.021
EC	0.002	0	0.2	0.028	0.021	0.045	.	0.174	0.048	0.004	0
PH	0	0	0.041	0.001	0	0.888	0.174	.	0.018	0.009	0
Org carbon	0.529	0.219	0.689	0.207	0.593	0.022	0.048	0.018	.	0	0.09
Phosphorus	0.364	0.107	0.051	0.083	0.035	0.057	0.004	0.009	0	.	0.007
Rainfall	0	0	0.319	0.002	0.002	0.021	0	0	0.09	0.007	.

(N = 120, ** Correlation is significant at P<0.001, * Correlartion is significant at P<0.005)

Figure 5.8.1.1 Soil pH in different seasons in Siruvani forest

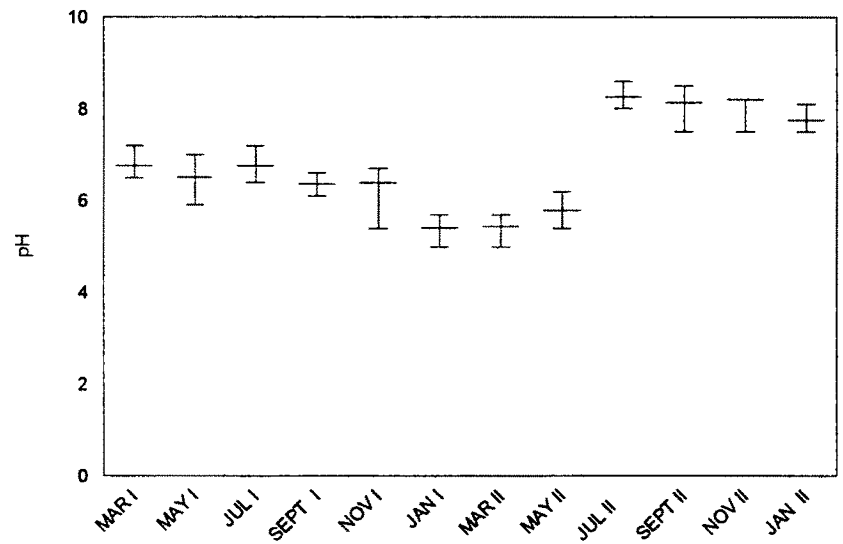


Figure 5.8.1.2 Soil pH in different plots in Siruvani forest

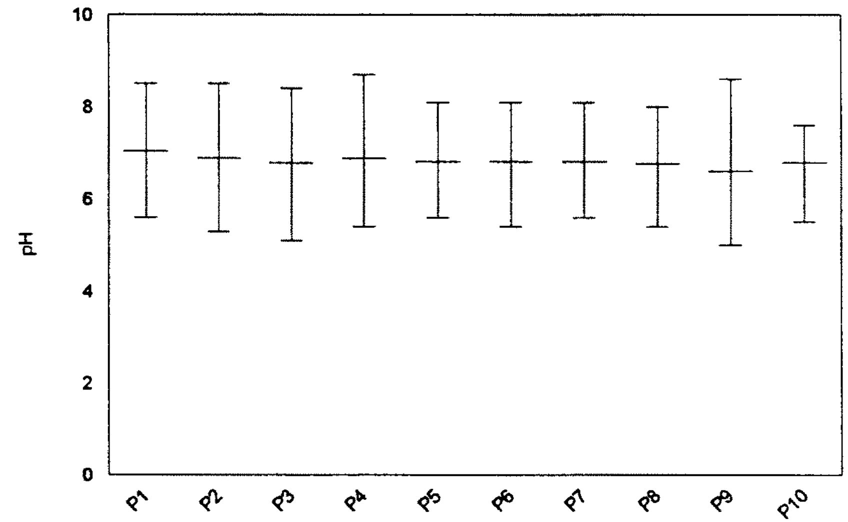


Figure 5.8.2.1 EC of soil in different seasons in Siruvani forest

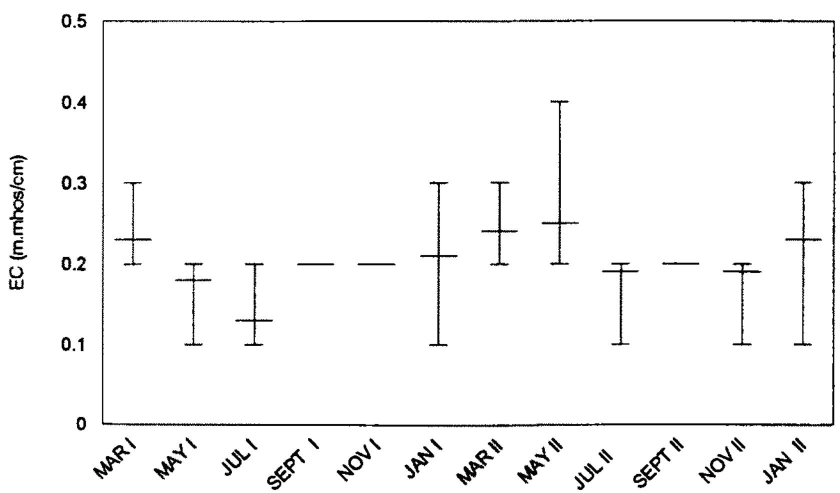


Figure 5.8.2.2 EC of soil in different plots in Siruvani forest

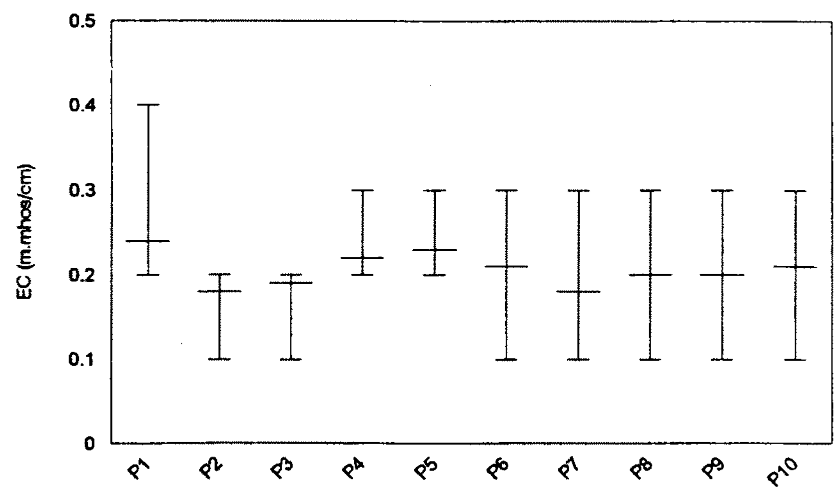


Figure 5.8.3.1 Nitrogen in soil in different seasons in Siruvani forests.

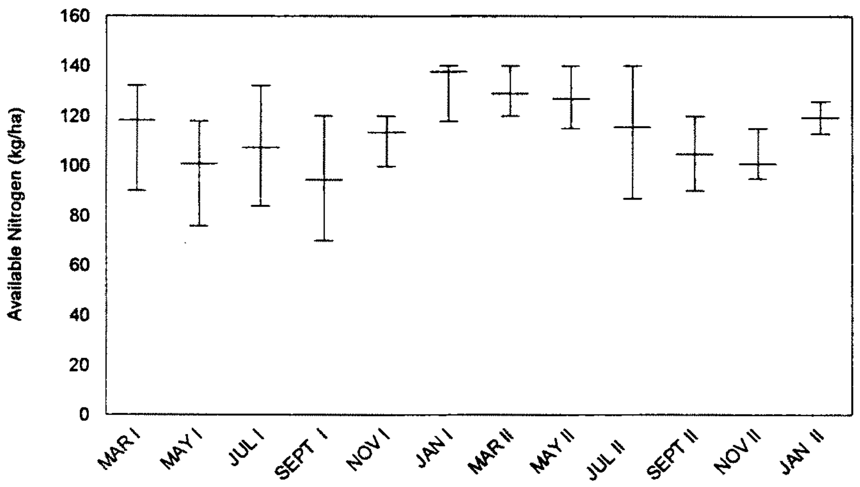


Figure 5.8.3.2 Nitrogen in soil in different plots in Siruvani forests

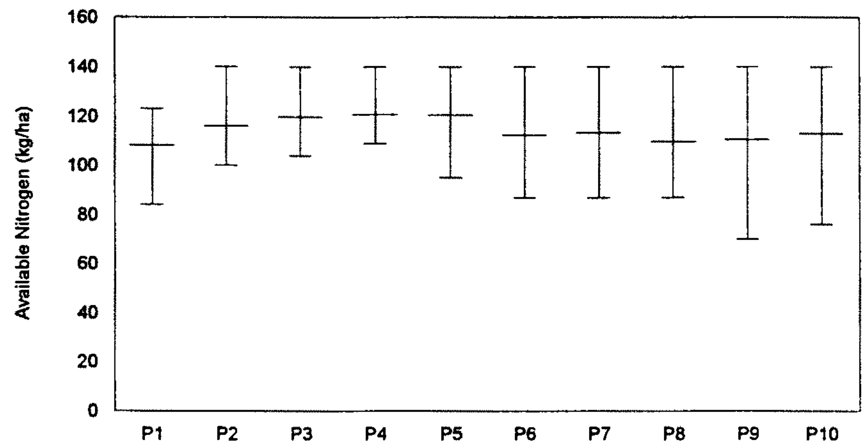


Figure 5.8.4.1 Phosphorus in soil in different seasons in Siruvani forests

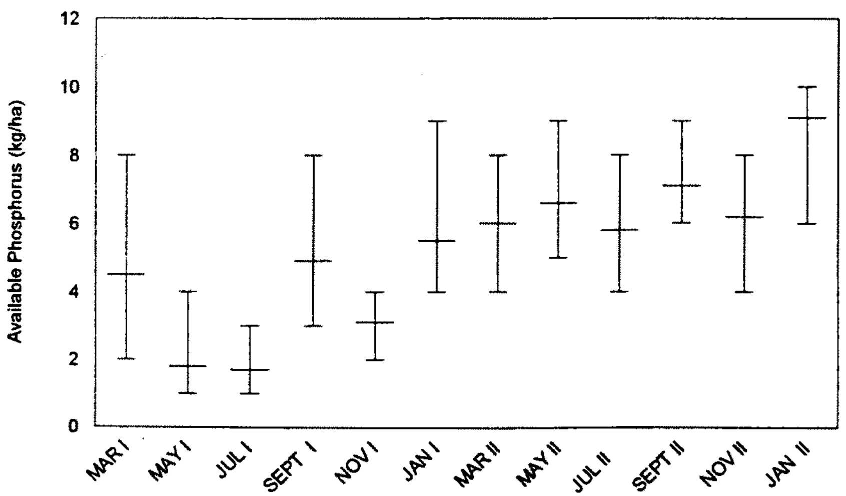


Figure 5.8.4.2 Phosphorus in soil in different plots in Siruvani forests

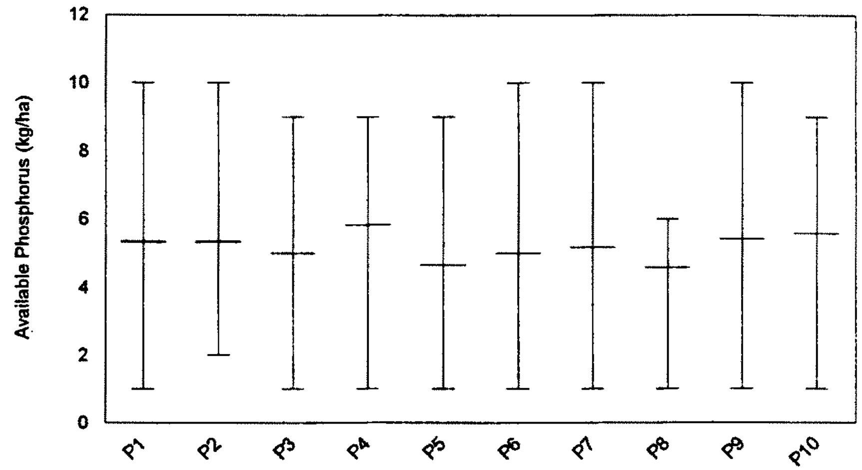


Figure 5.8.5.1 Potassium in soil in different seasons in Siruvani forest

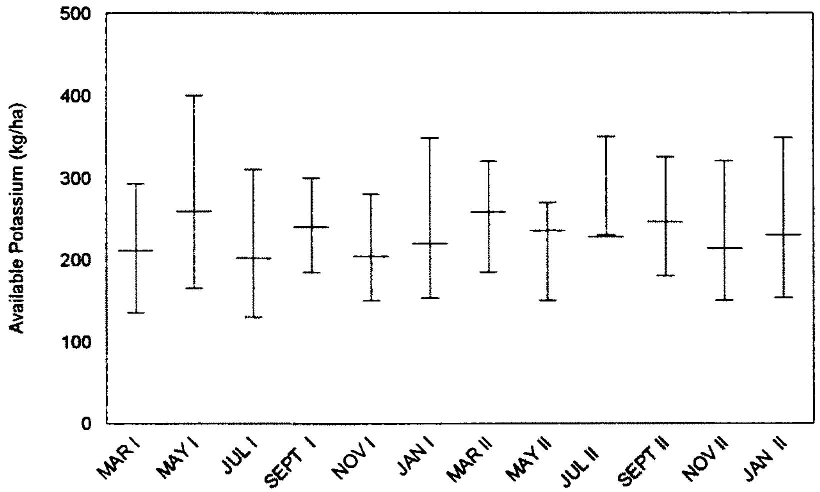


Figure 5.8.5.2 Potassium in soil in different plots in Siruvani forest

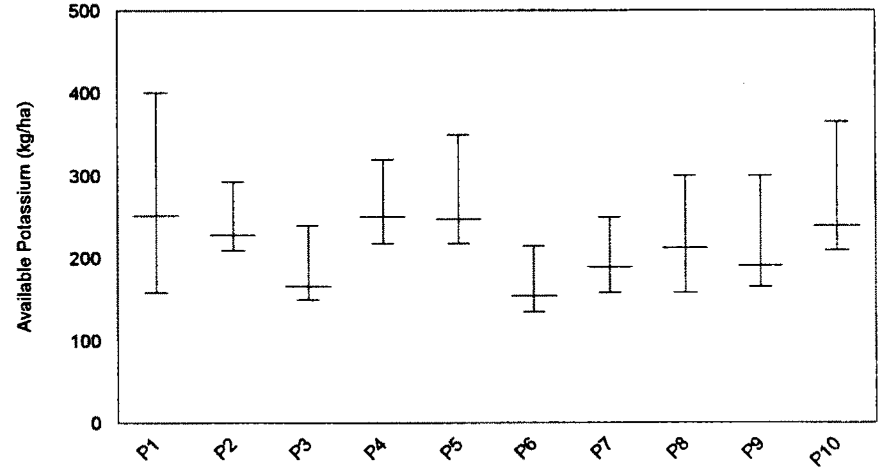


Figure 5.8.6.1 Organic carbon in soil in different seasons in Siruvani forest

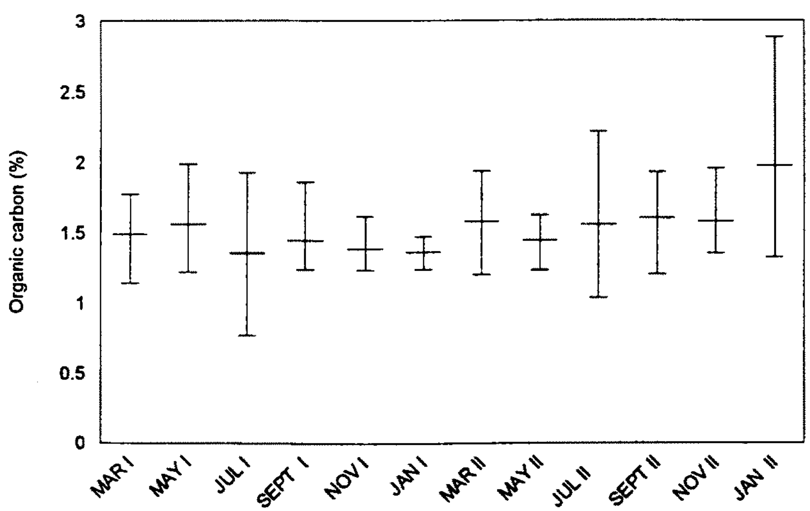


Figure 5.8.6.2 Organic carbon in soil in different plots in Siruvani forest

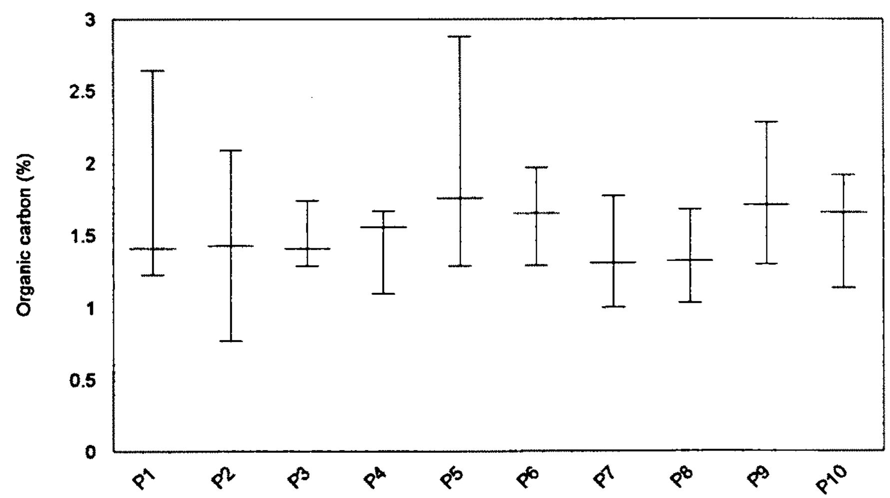


Figure 5.8.7 Cluster analysis based on species composition and number in different plots in Siruvani forest

```
                 0         5        10        15        20        25
                 +---------+---------+---------+---------+---------+

p4         4     -+-+
p5         5     -+ +-----+
p1         1     ---+     +---+
p3         3     ---------+   +---+
p2         2     -------------+   +-------------------------------+
p10       10     -----------------+                               I
p7         7     -----+---------+                                 I
p8         8     -----+         +-------+                         I
p9         9     ---------------+       +-------------------------+
p6         6     -----------------------+
```

Figure 5.8.8 Cluster analysis based on soil characteristics in different plots in Siruvani forest

```
                 0         5        10        15        20        25
                 +---------+---------+---------+---------+---------+

P7         7     -+-----+
P9         9     -+     +-------------+
P8         8     -------+             +----------------------------+
P3         3     ---+-----------------+                            I
P6         6     ---+                                              I
P4         4     -+---+                                            I
P5         5     -+   +--------------------------------------------+
P1         1     -+   I
P10       10     -+---+
P2         2     -+
```

Figure 5.8.9.1 Fitness of the multiple regression among total number of herbs, soil characteristics and rainfall

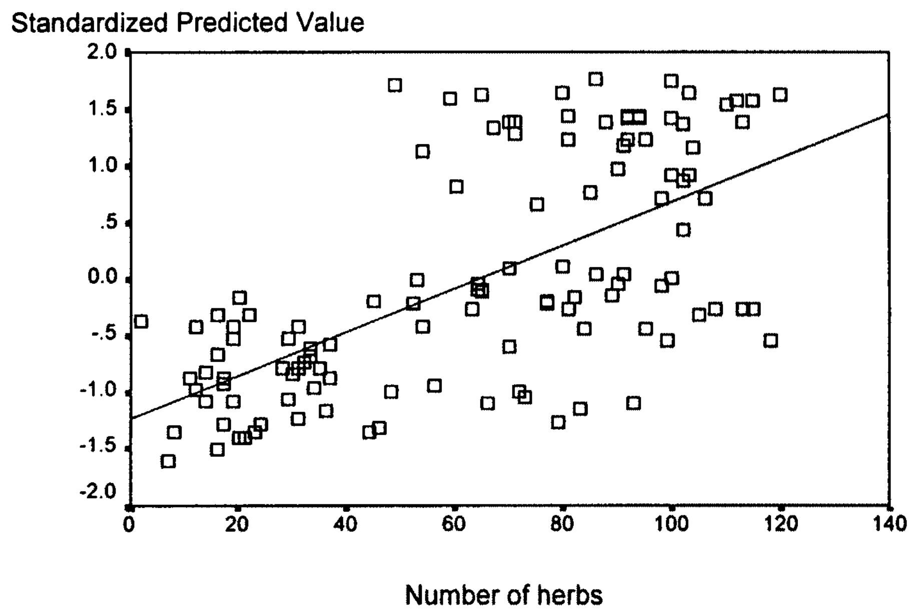


Figure 5.8.9.2 Fitness of the multiple regression among species richness of herbs, soil characteristics and rainfall

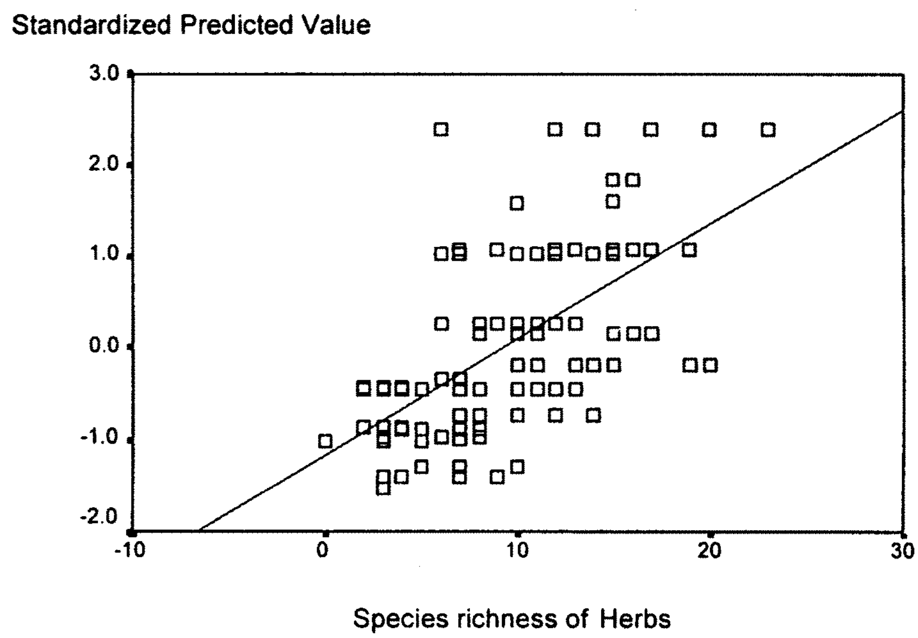


Figure 5.8.9.3 Fitness of the multiple regression among total number of weeds, soil characteristics and rainfall

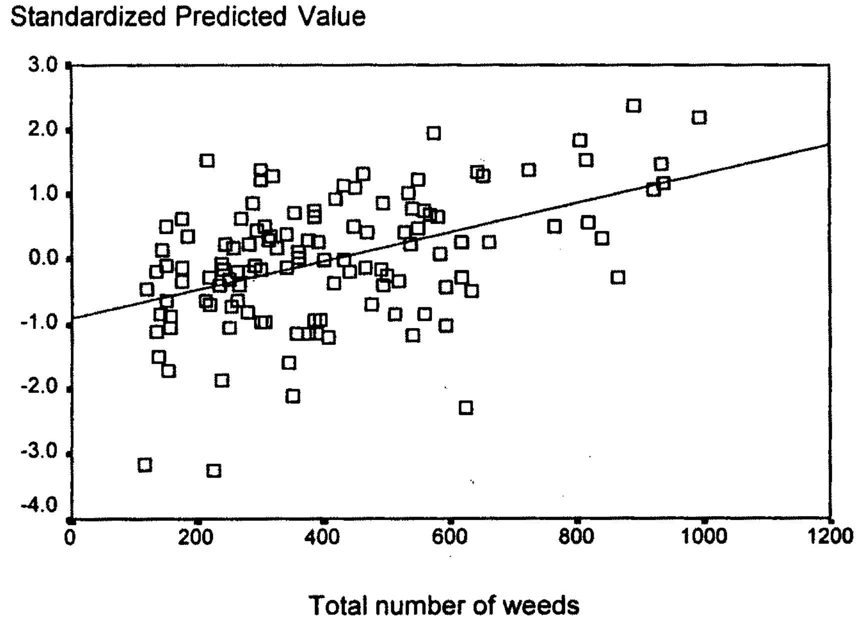
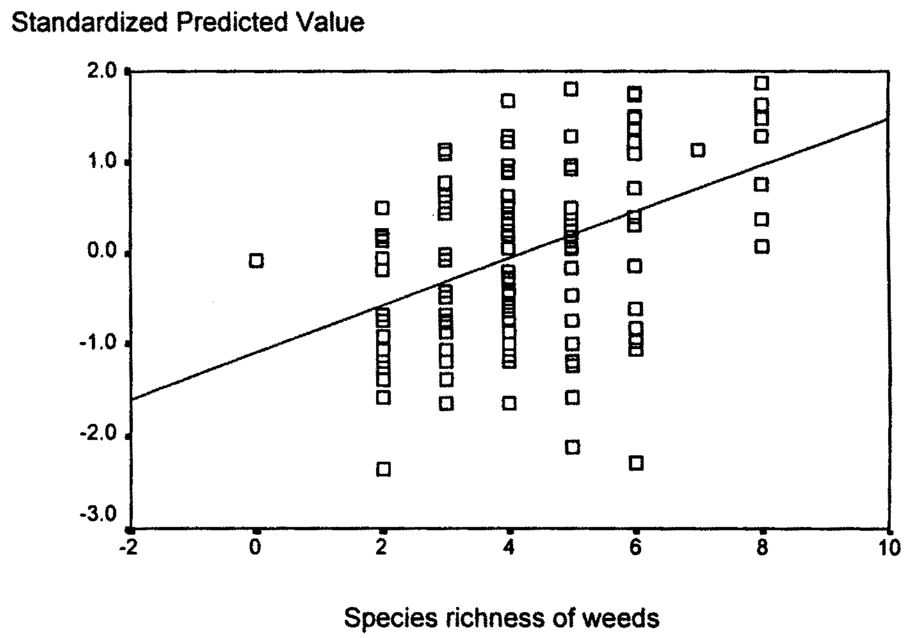


Figure 5.8.9.4 Fitness of the multiple regression among species richness of weeds, soil characteristics and rainfall



Chapter VI

6 DISCUSSION

6.1 Observations on the flora of the study area

The Nilgiri Biosphere Reserve, the biosphere reserve, which extends to three states of south India, namely Karnataka, Kerala and Tamil Nadu,has almost all types of vegetation recorded in the Southern Peninsular India within its boundaries. The biosphere reserve is a very rich repository of biodiversity (Daniels 1993) with probably a lion share of which is still remaining undocumented. The present study conducted in NBR followed a strategy of examining select major types of vegetation with respect to weedy plant species. In the study area, nine vegetation types at different locations were identified. These locations differed widely in climatic, altitudinal and physiognamic characteristics. The sampling strategy involved laying transects and quadrats in the demarcated locations and recording the species present in the quadrats.

A total of 376 species of herbs and shrubs belonging to 69 families were recorded. The number of trees recorded were 179. The family Poaceae had the largest number of species of herbs and shrubs, followed by Papilionaceae, Asteraceae, Rubiaceae and Euphorbiaceae.

Dry deciduous forest in Mudumalai Wildlife Sanctuary (MWS) was dominated by trees such as *Anogeissus latifolia, Tectona grandis* and *Terminalia* *tomentosa* (Stephen 1994). Dominant shrubs included *Stachytarpheta jamaicensis, Lantana camara, Grewia hirsuta* and *Chromolaena odorata*. The ground layer was dominated by *Themeda triandra, Heteropogon contortus, Sida acuta, Apluda mutica* and *Curculigo orchioides*. In moist deciduous forest in MWS, dominant trees were *Terminalia tomentosa, Olea dioica* and *Chionanthus mala-elengi*. The dominant shrubs in this forest type included *Chromolaena odorata, Lantana camara* and *Helicteres isora*. Ground layer in moist deciduous forest was dominated by *Arundinella ciliata, Oplismenus compositus, Malvastrum coromandelianum, Cyrtococcum deccanense* and *Curcuma pseudomontana*. The trees dominating the scrub jungle in Mudumalai Wildlife Sanctuary were *Erythroxylon monogynum, Acacia sundra, Chloroxylon swietenia*, and *Zizyphus* spp. The dominant shrubs here were *Lantana camara, Randia dumetorum* and *Grewia hirsuta*. Ground layer included *Heteropogon contortus, Euphorbia hirta, Evolvulus alsinoides, Leucas aspera* and *Tephrosia purpurea*. Almost similar observations were made by Sharma *et al.* (1978), Stephen (1994) and Suresh *et al.* (1996) on the flora of MWS.

In teak plantation in the MWS, the dominant trees were *Tectona grandis, Lagerstroemia microcarpa* and *Cassia fistula;* dominant shrubs were *Randia dumetorum, Helicteres isora* and *Chromolaena odorata*. Ground layer was dominated by *Oplismenus compositus, Mimosa pudica* and *Curcuma pseudomontana*. Coffee plantation was dominated by trees such as *Grevillea robusta, Terminalia tomentosa* and *Lagerstroemia microcarpa* and shrubs such as *Camellia sinensis*, *Coffea arabica* and *Lantana camara*. Dominant herbs included *Blumea virens, Apluda mutica, Mimosa pudica* and *Sida acuta*. In eucalyptus plantation in Mudumalai Wildlife Sanctuary, dominant trees were *Eucalyptus globulus, Acacia sundra* and *Naringi crenulata*. Dominant shrubs were *Barleria mysorensis*, *Randia dumetorum* and *Gymnosporia montana*. Herb layer in eucalyptus plantation was dominated by *Heteropogon contortus, Cyanotis tuberosa, Evolvulus alsinoides* and *Tephrosia purpurea*.

The evergreen forest in the Silent Valley was dominated by trees such as *Palaquium ellipticum*, *Syzygium mundagum, Syzygium cumini, Mesua ferrea* and *Vernonia arborea* and shrubs such as *Sarcandra chloranthoides, Thottea siliquosa, Strobilanthes* spp. and *Eupatorium repandum*. Herb layer was dominated by *Elatostemma lineolatum, Garnotia arundinacea* and *Pennisetum hohenackeri*. Manilal (1988) and Vajravelu (1990) also observed similar species composition in Silent Valley National Park.

Shola forest in Upper Bhavani was dominated by trees such as *Michelia nilagirica, Syzygium montanum, Cinnamomum wightii, Rhododendron nilagiricum* (Sukumar *et al.* 1995) and *Cryptocarya lawsoni* and shrubs such as *Strobilanthes* spp., *Psychotria congesta* and *Eupatorium repandum.* Ground layer included *Fragaria* spp., *Arundinella mesophylla*, *Oplismenus compositus* and *Carex lindleyana*. Wattle plantation in Upper Bhavani, was dominated by trees such as *Acacia mearnsii, Eucalyptus globulus* and

Grevillea robusta. Dominant shrubs seen were *Rubus racemosus* and *R. ellipticus*. Herb layer included *Themeda tremula, Cymbopogon polyneuros* and *Arundinella mesophylla*. In mixed deciduous forest in Siruvani, dominant trees were *Tectona grandis, Anogeissus latifolia, Dalbergia latifolia* and *Cordia wallichii*. Dominant shrubs were *Lantana camara, Chromalaena odorata, Glycosmis pentaphylla* and *Helicteres isora*, *Cyrtococcum deccanense, Oplismenus compositus* and *Panicum* spp. were dominant grasses. Subramanyam (1959) and Subramaniyan (1966) recorded almost similar species composition from Siruvani forest. However *Chromalaena odorata* was not reported by them.

6.2 Distribution of weeds in the study area

Of the 376 species of herbs and shrubs observed during the study, 85 have been recognized as weedy species by various authors (Tadulingam and Venkatnarayana 1932, Chandrabose and Nair 1990, Matthew 1991). Colonizing weedy species are those which are capable of invading parts of the world where they were not native, or of increasing enormously in abundance under the influence of man where they were native (Grubb 1987). Out of the 85 weedy species, 15 species, namely *Lantana camara, Chromolaena odorata, Mimosa pudica, Eupatorium repandum, Ageratum conyzoides, Cassia occidentalis, Triumfetta pilosa, Sida acuta, Euphorbia hirta, Tephrosia purpurea, Synedrella nodiflora, Barleria mysorensis, Justicia betonica, Opuntia dillenii* and *Stachytarpheta jamaicensis* have been found colonizing with higher number and wider distribution (Matthew 1991). Hence, these species were selected for examination in the present study.

Similarity in soils and climate between humid tropics of Asia and Africa, and Latin American home of species such as *L. camara* and *C. odorata,* is one of the reasons of successful invasion and colonisation of these species in many sites of these two continents (Nye and Greenland 1960, Bennett and Rao 1970, Toky and Ramakrishnan 1983, Mishra and Ramakrishnan 1983, Azeez *et al.* 1999). The lack of other controlling factors such as pests, which are present in their original locations, also contribute to their successful invasion (Randall 1996). *L. camara* is a serious invader in the disturbed and undisturbed tropical rain forests (Humphries *et al.* 1991), creating serious problems in forest management. Distribution of *Lantana camara* in India was studied by Rao in 1916. It is a very serious weed in Coorg, Wynad, West coast, Travancore, Cochin, Yercaud, Coimbatore, and up to 5000 ft altitude in the Nilgiris (Tadulingam and Venkatanarayana 1932). It is well adapted to the tropical and sub tropical climatic conditions and to semi arid to humid regions (Gujaral and Vasudevan 1983). It occurs along the roadsides, fences, waste lands and becomes dominant under-storey in disturbed forests, pastures and tropical tree plantations (Rao 1920, Thaman 1974, Sivaramakrishnan 1976, Gujaral and Vasudevan 1983, Waterhouse and Norris 1987, Angiras *et al.* 1988, Parsons and Cuthbertson 1992 and Ojha *et al.* 1994). In the present study, the species was observed in all the vegetation types of NBR except high altitude forest

En. 8. 6

types such as shola forest and wattle plantation. Chandrashekara (1999) also observed that *Lantana*, a dominant shrub in dry deciduous forest in Chinnar Wildlife Sanctuary, Kerala was absent in high altitudes in the same Sanctuary. *Lantana* was observed in all the forest types in the Mudumalai Wildlife Sanctuary, where it was not recorded prior to 1978 (Sharma *et al.* 1978).

Since World War II, *Chromolaena odorata* has replaced the *Lantana camara* in many areas of the western parts of the Western Ghats. *Lantana* is quite common in the eastern parts of the Western Ghats where *Chromolaena odorata* is rare (Muniappan and Viraktamath 1993). *C. odorata* is a serious weed of plantations of tea, coffee, teak, cardamom and citrus (Tripathi 1985, Mukhtar 1991, Gautier 1996). Studies have reported that it can rapidly occupy forest gaps generated due to disturbances (Chandrashekhara 1999). It occurs abundantly on the wasteland, cultivated fields, along roadsides, fences, and forest clearings, where it successfully colonizes and becomes dominant (Tripathi 1985, Gautier 1993, Doddamani *et al.* 1999). *C. odorata* is a colonizer in the moist deciduous, semi evergreen and evergreen forests of the Western Ghats of India (Muniappan and Viraktamath 1993, Doddamani *et al.* 1999). *C. odorata* was observed in all the vegetation types of NBR except shola and wattle plantation.

Mimosa pudica was present in moist deciduous forest, teak plantation, mixed deciduous forest, coffee plantation; dry deciduous forest and scrub jungle.

Eupatorium repandum was seen in high altitude forests such as shola, evergreen forest, coffee plantation and wattle plantation. In thickly vegetated area, the species is mostly seen along the waysides and gaps. *Ageratum conyzoides* was seen in all the habitats except eucalyptus plantation, shola and wattle plantation. *Cassia occidentalis* was observed in dry deciduous forest, eucalyptus plantation, moist deciduous forest and scrub jungle. *Triumfetta pilosa* was observed in teak plantation, scrub jungle, moist deciduous forest, mixed deciduous forest, coffee plantation and dry deciduous forest. *Sida acuta* was present in dry deciduous forest, coffee plantation, mixed deciduous forest, moist deciduous forest and scrub jungle. *Synedrella nodiflora* was observed in dry deciduous forest, teak plantation and mixed deciduous forest. *Tephrosia purpurea* was observed in eucalyptus plantation, scrub jungle and mixed deciduous forest. *Euphorbia hirta* was seen in coffee plantation, scrub jungle, dry deciduous forest and eucalyptus plantation. *Barleria mysorensis* was observed in dry deciduous forest, eucalyptus plantation and scrub jungle. *Justicia betonica* was observed in evergreen forest and mixed deciduous forest. *Opuntia dillenii* was seen in scrub jungle and eucalyptus plantation. *Stachytarpheta jamaicensis* was observed in dry deciduous forest, moist deciduous forest and mixed deciduous forest. Species like *L. camara* and *C. odorata* can colonise in areas with wider altitudinal variations because of their higher physiological plasticity. On the other hand some weedy species prefer specific habitat and are narrow in their distributions. For example, *Eupatorium repandum* is seen mostly in higher altitudes and *Opuntia dillenii* prefer mostly scrub jungles and drier areas.

Among the various locations under study, the species richness as well as the total number of individuals of the above weedy species varied widely. Species richness and numbers of individuals were highest in dry deciduous forest. Dry deciduous forest, teak plantation, mixed deciduous forest, moist deciduous forest and scrub jungle were affected more by weed invasion compared to high altitude forests, such as shola, evergreen forest and wattle plantation. Most of the weedy species prefer more light. Weed growth is comparatively less in high altitude forest types, which may be because of dense shade due to thick canopy cover and many weedy species can not tolerate extreme cold conditions in high altitude forests.

The number and species richness of weeds, decreased more or less with the decrease in thickness of vegetation. In case of coffee plantation the weeds were low in species richness and number because of the regular weeding, and below the coffee plants, the growth of herbs is probably inhibited because of the thick crown.

Total numbers of most of the weeds were higher in every season than the preceding season except summer. In summer, weeds were low in number, because, many of them complete their life cycle prior to the onset of the monsoon. With the onset of monsoon, the seeds, which were dormant in summer, germinate and start next cycle. Total numbers of all the select weeds were higher in second year than the first year, indicating that the weed population and their invasion are on the rise in NBR. This may be due to increasing pressure of human disturbance on habitats in NBR.

6.3 Weeds in Siruvani forest

In Siruvani forest, *Chromolaena odorata* was not reported up to 1984 (Subramanyam 1959, Subramaniyan 1966, George and Varghese 1984). While, during the study (1996-1998), *C. odorata* was one of the most dominant shrubs in study plots. Out of the ten plots,in four, *Chromolaena odorata* was the most dominant species having the highest Importance Value Index. Similar to the situation elsewhere in the study area, in Siruvani forest also, total number and height of most of the select weeds gradually increased at every succeeding season except summer. During most of the seasons in second year, total number and total height of most of the select weeds were comparatively higher than respective seasons of first year. In contrast, the total number as well as species richness of other native plant species were lower during most of the months of second year than corresponding months of the previous year. This decrease in the number of non-weedy, native species is likely to be caused by competition with fast growing, aggressive weedy species (Mooney and Drake 1986). A number of studies reported elsewhere, (MacDonald *et al.* 1991, Randall 1996, Mauchamp 1997 and Mauchamp *et al.* 1998) indicate the similar impacts of weeds on other species. Gentle and Duggin (1997a) observed that *L. camara* interrupted regeneration of native plants due to its aggressiveness. It decreased their germination, reduced growth rates and increased mortality, which lead to the disruption of community development. Fensham (1994) observed overall decline in the species richness with increase in the density of *L. camara* in the rainforest in Forty-mile Scrub National Park in North

Queensland. Mauchamp *et al.* (1998) suggested that *Lantana camara* invasion is responsible for extinction of many species in Galapagos. Tripathi (1985) observed a net gain of nine plants of *C. odorata* per square meter over a period of one year in north-east India. According to Yadav and Tripathi (1981), if invasive-weed population in natural forests continues to grow it may suppress and even eliminate many important elements of the native flora.

6.4 Phenology of selected weeds in Siruvani forest

In the present study *Lantana* was flowering and fruiting throughout the year as reported earlier by Matthew (1991) and Manilal (1988). According to Thakur *et al.* (1992), it flowers throughout the year, but uncommonly in winter in northern India. *Lantana* flowers whenever soil moisture is available, temperature, and humidity are high, resulting in continuous flowering and fruiting (Swarbrick *et al.* 1995).

In the present study *C. odorata* was found flowering from November to January. Maximum flowering was in November. Fruiting was present from November to March. Maximum fruiting was observed in November. According to Muniappan and Viraktamath (1993), *C. odorata* shows active vegetative growth during July - October. It flowers during November and December. Fruiting is at its maximum in January (Tripathi 1985). Matthew (1991) observed flowering in *C. odorata* from December to March in central Tamil Nadu. Manilal (1988) observed flowering in *C. odorata* from April to June in

Silent Valley. *Mimosa pudica* was found flowering from November to March and fruiting from January to May in the present study. Maximum fruiting was observed in May. Matthew (1991) also observed flowering and fruiting in *M. pudica* in the same season. Chandrabose and Nair (1988) observed flowering and fruiting in *M. pudica*, from October to March in Coimbatore. According to Manilal (1988) *M. pudica* was flowering from June to December in Silent Valley.

Ageratum conyzoides was flowering from January to March and fruiting between March and May. Flowering was maximum in January and fruiting in May. Chandrabose and Nair (1988) observed flowering and fruiting of *A. conyzoides* throughout the year. *Sida acuta* was flowering from September to March. Maximum flowering was observed from September to November. Fruiting in *Sida acuta* was observed in January to May. Matthew (1991) reported that *Sida acuta* was flowering and fruiting throughout the year. Chandrabose and Nair (1988) observed flowering and fruiting in *S. acuta* from August to February in Coimbatore. According to Manilal (1988) *S. acuta* was flowering from March to October in Silent Valley. In *Sida rhombifolia* flowering was observed from September to January and fruiting was present from November to March. Maximum flowering in *Sida rhombifolia* was present in September and November and maximum fruiting was seen in March. Matthew (1991) observed that *S. rhombifolia* was flowering and fruiting throughout the year. Chandrabose and Nair (1988) observed flowering and fruiting in *S. rhombifolia* from October to March in Coimbatore. According to Manilal (1988) *S. rhombifolia* was flowering from September to December in Silent Valley.

Triumfetta pilosa was flowering from September to January and fruiting from January to May. Maximum flowering in *T. pilosa* was in November and maximum fruiting in May. Matthew (1991) observed flowering in *T. pilosa* from September to December and fruiting throughout the year. Manilal (1988) observed flowering in *T. pilosa* from October to February in Silent Valley. *Justicia betonica* was flowering from March to July and fruiting from September to May. Maximum flowering in *J. betonica* was observed in May and maximum fruiting in March and May. Chandrabose and Nair (1988) also observed flowering and fruiting in *J. betonica* in the same seasons (from April to November) in Coimbatore. According to Matthew (1991) and Manilal (1988) *J. betonica* flowers and fruits throughout the year.

Stachytarpheta jamaicensis was flowering from March to July and fruiting from September to May. Maximum flowering was in May. Fruiting was maximum in March and May. Matthew (1991) reported flowering in *S. jamaicensis* from December to March in plains and throughout the year in the hills. Chandrabose and Nair (1988) observed flowering and fruiting in *S. jamaicensis* throughout the year.

In general, it may be stated that the weedy species show variation in the period of flowering and fruiting according to area. They flower and fruit in the most conductive period. Many weeds like *L. camara* flowers and fruits throughout the year, which helps them to regenerate more frequently and successfully than other plants.

6.5 Similarity among the different vegetation types in NBR.

When similarity in terms of the presence and number of weedy species was assessed using Horn's similarity index, wattle plantation and evergreen forest showed maximum similarity. Shola forest showed 65% similarity with wattle plantation. These three habitats have fewer weedy species compared to other habitats. These habitats are similar to each other for their high altitude. Moist deciduous forest showed 75% similarity with coffee plantation, 65% similarity with teak plantation and 61% similarity with mixed deciduous forest. Mixed deciduous forest showed 67% similarity with teak plantation, which may be because natural moist deciduous forests were converted into plantations in earlier days.

6.6 Association among select weeds in NBR

An attempt was made to evaluate the associations among selected weedy species in different habitats of Nilgiri Biosphere Reserve using Jaccard's index.

Chromolaena odorata and *Lantana camara* were highly associated. *Lantana camara* also showed association with *Ageratum conyzoides, Mimosa pudica, Sida acuta* and *Triumfetta pilosa*. *Mimosa pudica* had highest association with *Lantana camara* followed by *Chromolaena odorata* and *Orthosiphon thymiflorus*. *Sida acuta* was highly associated with *Lantana camara* and *Sida rhombifolia*. *Sida rhombifolia* showed association with *Sida acuta*, *Malvastrum coromandelianum* and *Justicia betonica*. *Stachytarpheta jamaicensis* showed high association with *Justicia betonica*. *Justicia betonica* was associated with *Triumfetta pilosa*, *Stachytarpheta jamaicensis*, *Sida rhombifolia* and *Synedrella nodiflora*.

Opuntia dillenii was highly associated with *Tephrosia purpurea*. *Synedrella nodiflora* was associated with *Sida cordata* and *Desmodium triflorum*. *Cassia occidentalis* showed high association with *Orthosiphon thymiflorus* and *Barleria mysorensis*. *Ageratum conyzoides* was highly associated with *Lantana camara*, *Sida acuta, Mimosa pudica* and *Chromolaena odorata*. *Evolvulus alsinoides* was highly associated with *Barleria mysorensis* and *Orthosiphon thymiflorus*. *Triumfetta pilosa* had high association with *Malvastrum coromandelianum, Justicia betonica and Sida cordata*. *Barleria mysorensis* was highly associated with *Leucas aspera, Evolvulus alsinoides, Cassia occidentalis, Euphorbia hirta* and *Tephrosia purpurea*. *Tephrosia purpurea* was associated with *Opuntia dillenii*, *Barleria mysorensis*, *Leucas aspera* and *Mimosa pudica*. The association observed among the species can be interpreted as; a) species having similar resource demands show strong association, b) they are strongly associated because of their wide ecological plasticity.

6.7 Niche breadth of weeds in NBR

Most of the weedy species such as *Lantana camara*, *Chromolaena odorata*, *Mimosa pudica*, *Sida acuta*, *Sida rhombifolia*, *Cassia occidentalis*, *Ageratum conyzoides* and *Barleria mysorensis* have wide niche breadth. These weeds invade different habitats successfully as they have adaptive attributes such as fast growth, stress tolerance, competitive strategies, greater reproductive potential, various morphological adaptations and high efficiency for nutrient uptake (Newsome and Noble 1986, Heywood 1989).

Species such as *Chromolaena odorata* and *Lantana camara* have remarkable plasticity and adaptability to environmental extremes probably except extreme cold conditions. *Lantana camara* can multiply by sexual and rarely by asexual methods. It has high efficiency of nutrient extraction and retranslocation of nutrients from senescing leaves (Rawat *et al.* 1994) enabling it to grow in nutrient poor sites. It also exhibits high foliar nitrogen concentration, even on nutrient poor sites. The species combines nutrient conserving strategies with capacity for higher circulation and low retention of nutrients, rapid decomposition and faster nutrient turnover rate making it able to expand rapidly (Rawat *et al.* 1994). *Lantana camara* shows ecotypic and phenotypic plasticity and extends up and covers an altitudinal range up to 2000m in the

Palni Hills in South India (Matthew 1972). Weeds belonging to Asteraceae, such as *Chromolaena odorata, Ageratum conyzoides, Blumea virens, Parthenium hysterophorus* and *Eupatorium repandum* have higher reproductive capacity than other species. This high reproduction potential is achieved by large number of minute; light and wind dispersed seeds (Saxena and Ramakrishnan 1982).

6.8 Human disturbance and weeds

When the weed distribution was examined with respect to human habitations, in all the three habitats namely dry deciduous forest, scrub jungle and moist deciduous forest, species richness as well as number of weeds were highest near villages and were found decreasing towards the undisturbed forests. The natural ecosystems disrupted by large scale, intense and frequent disturbances are known to be prone to weed invasion (Saxena 1991). A disturbance is an interrupted event or series of events that kill or damage existing organisms, directly or indirectly increase resource availability and create an opportunity for new individuals to become established (Sousa 1984). Slobodkin (1980) observed that the establishment of an invader implies the availability of an approachable vacant niche. Thompson (1988) has reported the preponderance of plant invasions in disturbed habitats and their rarity in the mature communities in the tropics. *Lantana* and other weedy species are less common in undisturbed thick forests than in those that have been disturbed by plantations, cultivations, grazing, road work, trails, cutting and logging, in which their dominance is seen (Saxena 1991, Swarbrick *et al.* 1995). *Lantana camara* has invaded microsites created by heavy grazing pressure (Singh 1976, Sinha 1976, Sawarkar 1984, Duggin and Gentle 1998).

In highly disturbed areas *Chromolaena odorata* dominates the herbaceous community, and increases to serious proportions (Saxena and Ramakrishnan 1984, Swamy and Ramakrishnan 1987). The species is found to occupy specifically selection-felled gaps (Chandrashekara and Ramakrishnan 1994), possibly due to disturbances caused by selection felling. The gaps developed by selection felling are in many orders more ecologically disturbing than those formed naturally. Invasive-plant colonisation is more successful in open habitats created by high degree of disturbance (Ramakrishnan 1991, Gentle and Duggin 1997b).

6.9 Influence of soil characteristics on vegetation

6.9.1 Physical characteristics of soil

Texture of soil indicates proportion of sand, silt and clay in it. The soil texture controls water intake rates, water storage in the soil, aeration, root penetration, soil fertility and also some chemical properties (Miller 1992). Soil in the Siruvani mixed deciduous forest is loamy sand in nature. It contains more than 87% sand. Prasad *et al.* (1985) has reported slightly lower level (71.8%) of sand in Siruvani natural forest.

pH indicates the acidity or alkalinity of the soil solution. Average pH of soil in all plots in study area ranged from 6.48 to 6.90. More or less similar range in pH (6.38 to 6.92) was reported by Prasad *et al.* (1985) in the same area. In rainy season of both years (1997,1998) pH was higher compared to dry season, may be due to dissolution effect of the rain on soil minerals. The availability of micronutrients as well as several other inorganic constituents to plants depends upon the pH of the soil. The low pH may inhibit the nitrogen fixing activity of *Rhizobium* on plant roots causing, nitrogen deficient legumes (Barber 1984). Baker (1990) concluded that if pH is not maintained in desirable range (6-7), the availability of Zn, Cu, Mn, and other essential micronutrients to plants is likely to be a problem.

Electrical conductivity is a measure of soluble salts in solution. Soil having more than 1 m.mhos/cm EC is considered as harmful as it contains high concentration of soluable salts, which may be toxic to many plants (Bose *et al.* 1988). Average EC of soil in all plots ranged from 0.18 to 0.25 m.mhos/cm.

6.9.2 Chemical characteristics of soil

Nitrogen is a key nutrient in plant growth. It is a constituent of plant proteins, chlorophyll, nucleic acid and other plant substances. Nitrogen deficiency causes poor plant yield. Adequate nitrogen often produces thinner cell walls, which results in more tender, succulent and larger plants (Miller *et al.* 1992). Healthy soil should have more than 280 kg/ha of available nitrogen (Bose *et al.*

1988). Average available nitrogen in soil in all plots in study area ranged little low (94.4 to 137.9 kg/ha). Study plots were dominated by species like *Lantana camara*, which have high nitrogen uptake efficiency. Fast growing species use more nutrients. This may be one of the reasons for low nitrogen in soil in the study sites. Available nitrogen in rainy season was lower than summer, which may be because of leaching effect of rains.

Phosphorus, a key plant nutrient is an essential part of nucleoproteins in the cell nuclei, which controls cell division and growth. It is also present in deoxyribonucleic acid (DNA) molecules. It plays a major role in stimulation of early root growth, hastening plant maturity, energy transformation within the cells, fruiting and seed production. Healthy soil should have more than 11 kg/ha available phosphorus (Bose *et al.* 1988). Average phosphorus in soil in all plots in different seasons were ranging from 1.8 to 9.1 kg/ha. This is lower than the recommended (Bose *et al.* 1988).

Potassium is an important nutrient for plant growth. Potassium deficiencies are most common in leached soils. Healthy soil should have more than 118 kg/ha available potassium (Bose *et al.* 1988). Average potassium in soil in all plots in different seasons were ranging from 201 to 258 kg/ha, indicating that soil in study area had sufficient available potassium for plant growth.

Soil in study area is very rich in organic carbon (more than 0.75%, Bose *et al.* 1988). Average organic carbon in soil in all plots in different seasons were ranging from 1.35% to 1.96%. Organic carbon in January of the second year was significantly higher than all other seasons in both the years. Prasad *et al.* (1985) has reported organic carbon ranging from 1.4% to 1.7% in soil of different depths in Siruvani natural forest.

6.9.3 Heavy metals

Heavy metals occur naturally in soils, usually at relatively very low concentrations, as a result of the weathering and other pedogenic process acting on the rock fragments from which the soil is formed. Considerable variations occur between the normal concentration ranges of different elements, from Au (0.001 - 0.02 mg/kg) to Mn (20 -10000 mg/kg). From the soil, plants accumulate heavy metals, a primary means by which heavy metals enter the biotic components of ecosystem. The bioavailability of heavy metals in soils is determined by factors such as pH of soil, concentration and speciation of metals in soils, redox reactions, competition in absorption by other metal ions and absorptive area of root. The absorbed metals are translocated at various rates depending on the metal concerned. Chanery and Giordano (1977) classified Mn, Zn, Cd, Be, Mo and Se as elements which were readily translocated to the plant tops, Ni, Co, and Cu intermediate, and Cr, Pb and Hg the least extent. The bio-essential trace elements are frequently referred as micronutrients and its inadequate supply adversely affects the plants growth.

On the other hand an excessive supply will cause varying degrees of toxicity (Kabata – Pendias and Pendias 1984).

Soil samples from Siruvani forest contained copper in the range 5-28 mg/kg. Copper is an essential micronutrient for plants and it functions as a part of prosthetic group of many enzyme systems and as a facultative activator of enzymes (Baker 1990). Lindsay (1979) reported 70 mg/Kg Cu as average lithosphere composition and chose 30 mg/kg as an average value for soils. McLaren and Crawford (1973) investigated effect of pH on Cu adsorption by various soil components and found that as pH increases more was adsorbed.

Distribution of Mn in the study site varied between 15 and 658 mg/kg. Mn is essential for plants for a number of important functions. While at higher level it causes toxicity. Symptoms of Mn toxicity is found in wide range of crops including soybean, cotton, tobacco and other species of plants, in soils of Mn concentrations 80-5000 mg/kg (Hannam and Okhi 1988). Walker and Barber (1960) analysed 12 Indian soils and found total manganese concentrations ranging from 640 mg/kg to 1320 mg/kg for a soil developed from residued limestone.

Lead in the Siruvani forest soils ranged between 4 to 376 mg/kg with an average distribution of 48 mg/kg. Higher lead concentrations seen in certain samples of post monsoon seasons may be due to high lead associated with suspended particulate matter in atmosphere. The southwest and northeast monsoons, which bring heavy rains in the study area, might be a source for Pb. Lindberg and Harris (1989) measured atmospheric deposition of lead in a deciduous forest, in eastern Tennessee, USA, and found that deposition rate in upper canopy ranged from 3 to 15 ug/m^2/day. There are several well-recognised major sources of the metal of which mining, and smelting activities, sewage sludge and vehicle exhaust (120 to 700ug/g in highways) are important. Lead in uncontaminated soils has been reported as 17 ug/g (Nriagu 1978) and 29 ug/g (Ure and Berrow 1982). The Ministry of Agriculture and Food, London (1982) recommended a maximum accumulation of 550 ug/g in soils. Lead on its entry into food chain gives varying degrees of toxicity depending on organism and mode of entry into it.

Zinc in soils of Siruvani forest ranged from 13 mg/kg to 190 mg/kg. Zinc is an essential micronutrient for higher plants, which acts as a metal component of enzymes or as a functional, structural or regulatory cofactor of enzymes. The most permanent symptoms of Zn deficiency are interveinal chlorosis, stunted growth, malformation of stems and leaves. In general Zn concentrations in soils can be classified as deficient if less than 10 mg/kg, normal if between 25 and 150 mg /kg, excessive or toxic if more than 400 mg/kg (Kiekens 1990). The soils of the study area has normal concentration of Zn. Dolar and Keeney (1971) reported 7.4 to 90 mg/kg of Zn with an average of 35 mg/kg for 36 cultivated soils and found that exchangeable zinc decreased with increase in pH.

Average concentration of Iron in study area was 11053 mg/kg. In spite of higher concentration, only very low quantity of iron is required for plant growth. Plant roots absorb Fe^{2+} and transport it in that form to the junction of protoxylem and metaxylem, where it is oxidised back into Fe^{3+} (Brown 1978). It is then chelated with citrate and moved into the xylem for transport to the shoot. There was no correlation among heavy metals investigated in the study area except copper which showed positive correlation with iron ($r = 0.55$, Table 5.8.7.3.). Schuhmacher *et al* (1994) observed a positive correlation between copper and zinc content in rice ($r = .7065$, $P < .0001$) and soil ($r = 0.4546$, $P < .015$).

It is obvious from the present study that metal concentrations in the study area are well within the safe limits, exceptions being Mn and Pb in one or two plots, which needed attention to identify the source of high concentrations.

6.9.4 Correlation among different soil characteristics, rainfall, herb and weed composition.

Available nitrogen, potassium, phosphorus and EC were negatively correlated with rainfall, may be because of leaching effect of rain. Available potassium, phosphorus, pH and EC were positively correlated with organic carbon. Kaushal *et al.* (1997) and Pal and Mukhopadhyay (1992) also reported positive correlation between available potassium and organic carbon. Available phosphorus showed significant positive correlation with EC (Kaushal *et al.* 1997), pH and available nitrogen. Available nitrogen was positively correlated with available phosphorus and EC and negatively correlated with pH.

Total number of herbs was positively correlated with soil pH, rainfall, and negatively correlated with available nitrogen and EC. Rainfall also showed positive correlation with pH. Total number of herbs might have increased due to availability of sufficient water with increase in rainfall. pH also might have increased with rainfall due to dissolution of soil minerals, carbonates, hydroxides and borates. A decrease in available nitrogen with increase in herb number may be because high numbers of herbs require more available-nitrogen. Species richness of herbs showed significant positive correlation with pH, rainfall, available phosphorus and negative correlation with EC, available nitrogen and available potassium.

Total number of weeds was positively correlated with pH and negatively correlated with available potassium. Species richness of weeds was positively correlated with pH and rainfall and negatively correlated with EC, available nitrogen and available potassium. By multiple regression analysis, total number of weeds was found positively correlated with available phosphorus and negatively correlated with available potassium. Species richness of weeds was positively correlated with pH and negatively correlated with available potassium.

6.9.5 Similarity among the different plots, based on species composition and soil characteristics

By hierarchical cluster analysis (using euclidean distance matrix) based on species composition, their numbers as well as soil characteristics; plots 1, 2, 4, 5 and 10, which were dominated by *Lantana camara* clustered together. Plots 6, 7, 8 and 9, which were dominated by *Chromolaena odorata* formed another cluster. This may be because the dominating species present in the ecosystem regulates the physico-chemical properties of the soil (Singh et al. 1995).

7 CONCLUSIONS

Studies on distribution, seasonal variation in number and growth and phenology of select weeds, in relation to associated vegetation, soil conditions and human disturbance indicate that weeds are particularly successful in disturbed habitats. However, weeds given a chance can equally invade other areas also (Wiser *et al.* 1998, Azeez *et al.* 1999). As the weedy species are aggressive and exhibit many adaptive strategies, they spread fast and may pose serious threat to certain useful elements of native flora. The usual pattern of invasion includes an initial phase of establishment, then slow spread which consists limited population in few locations, followed by a logistic growth phase enabling rapid range expansion of the population, and a final phase of limited expansion (Salisbury 1953, Mack 1981, Auld *et al.* 1983). The population of invaders may become stabilised in course of time, but during the process there is a risk of suppression and even elimination of many native species. The present study indicates that NBR, probably like any other similar area in the country, is facing a serious threat from invading species of plants.

The invaded areas in Nilgiri Biosphere Reserve need immediate attention to arrest further invasion and colonisation by weeds. Because of aggressiveness of weeds, it is difficult to control them by exclusively mechanical, biological or chemical method. An integrated management strategy is essential for a successful control. It is felt that emphasis need to be placed on early detection, prevention of new weeds from becoming established and elimination of incipient invasions. Further, investigations in-to the ecology of weeds to identify species likely to invade the various communities and their possible long-term effects need to be undertaken.

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(* Originals not referred)

APPENDIX 1

Common weeds in South India

Species	Family
Argemone mexicana	Papaveraceae
Nasturtium indicum	Cruciferae
Cleome gynandra	Cleomaceae
Cleome viscosa	Cleomaceae
Cleome chelidonii	Cleomaceae
Ionidium suffruticosum	Violaceae
Polygala chinensis	Polygalaceae
Portulaca oleracea	Polygalaceae
Bergia ammannioides	Elatinaceae
Malvastrum coromandelianum	Malvaceae
Sida spinosa	Malvaceae
Sida glutinosa	Malvaceae
Sida cordifolia	Malvaceae
Sida acuta	Malvaceae
Abutilon indicum	Malvaceae
Pavonia procumbens	Malvaceae
Pavonia coxii	Malvaceae
Pavonia zeylanica	Malvaceae
Hibiscus micranthus	Malvaceae
Hibiscus panduraeformis	Malvaceae
Hibiscus vitifolius	Malvaceae
Hibiscus ficuneus	Malvaceae
Corchorus olitorius	Tiliaceae
Corchorus trilocularis	Tiliaceae
Triumfetta rotundifolia	Tiliaceae
Triumfetta pilosa	Tiliaceae
Tribulus terrestris	Zygophyllaceae
Crotalaria verrucosa	Papilionaceae
Indigofera enneaphylla	Papilionaceae
Tephrosia purpurea	Papilionaceae
Tephrosia spinosa	Papilionaceae
Alysicarpus rugosus	Papilionaceae
Alysicarpus monilifer	Papilionaceae
Phaseolus trilobus	Papilionaceae
Phaseolus aconitifolius	Papilionaceae
Clitoria ternatea	Papilionaceae
Rhynchosia minima	Papilionaceae
Rothia trifoliata	Papilionaceae
Desmodium triflorum	Papilionaceae
Cassia occidentalis	Caesalpiniaceae
Cassia tora	Caesalpiniaceae
Mimosa pudica	Mimosaceae
Rotala densiflora	Lythraceae
Ammania baccifera	Lythraceae
Ammania octandra	Lythraceae
Ludwigia parviflora	Onagraceae
Coccinia indica	Cucurbitaceae
Cucumis trigonus	Cucurbitaceae
Citrullus colocynthis	Cucurbitaceae
Opuntia dillenii	Cactaceae
Trianthema portulacastrum	Aizoaceae

Trianthema triquetra	Aizoaceae
Trianthema decandra	Aizoaceae
Mollugo lotoides	Aizoaceae
Mollugo oppositifolia	Aizoaceae
Mollugo pentaphylla	Aizoaceae
Centella asiatica	Umbelliferae
Oldenlandia umbellata	Rubiaceae
Oldenlandia aspera	Rubiaceae
Oldenlandia corymbosa	Rubiaceae
Oldenlandia herbacea	Rubiaceae
Borreria hispida	Rubiaceae
Dentella repens	Rubiaceae
Xanthium strumarium	Asteraceae
Lagascea mollis	Asteraceae
Acanthospermum hispidium	Asteraceae
Eclipta alba	Asteraceae
Blainvillea rhomboidea	Asteraceae
Tridax procumbens	Asteraceae
Flaveria australasica	Asteraceae
Voluturella divaricata	Asteraceae
Lactuca runcinata	Asteraceae
Sonchus oleraceus	Asteraceae
Vernonia cinerea	Asteraceae
Erigeron asteroides	Asteraceae
Blumea wightiana	Asteraceae
Blumea lacera	Asteraceae
Sphaeranthus indicus	Asteraceae
Bidens pilosa	Asteraceae
Lochnera pusilla	Apocynaceae
Calotropis gigantea	Asclepiadaceae
Leptadenia reticulata	Asclepiadaceae
Pentatropis microphylla	Asclepiadaceae
Heliotropium ovalifolium	Boraginaceae
Heliotropium scabrum	Boraginaceae
Trichodesma indicum	Boraginaceae
Coldenia procumbens	Boraginaceae
Evolvulus alsinoides	Convolvulaceae
Convolvulus arvensis	Convolvulaceae
Merremia emarginata	Convolvulaceae
Ipomoea hispida	Convolvulaceae
Ipomoea reptans	Convolvulaceae
Ipomoea sepiaria	Convolvulaceae
Solanum xanthocarpum	Solanaceae
Solanum nigrum	Solanaceae
Physalis minima	Solanaceae
Datura fastuosa	Solanaceae
Withania somnifera	Solanaceae
Stemodia viscosa	Solanaceae
Moniera cuneifolia	Scrophulariaceae
Striga lutea	Scrophulariaceae
Striga euphrasioides	Scrophulariaceae
Dopatrium junceum	Scrophulariaceae
Ilysanthes parviflora	Scrophulariaceae
Ilysanthes veronicaefolia	Scrophulariaceae
Scoparia dulcis	Scrophulariaceae
Orobanche ceruna	Orobanchaceae

Martynia annua	Pedaliaceae
Pedalium murex	Pedaliaceae
Blepharis molluginifolia	Acanthaceae
Asteracantha longifolia	Acanthaceae
Rungia repens	Acanthaceae
Ruellia prostrata	Acanthaceae
Ruellia patula	Acanthaceae
Dyschoriste depressa	Acanthaceae
Andrographis echioides	Acanthaceae
Barleria mysorensis	Acanthaceae
Asystasia gangetica	Acanthaceae
Justicia prostrata	Acanthaceae
Peristrophe bicalyculata	Acanthaceae
Priva leptostachya	Verbenaceae
Lantana camara	Verbenaceae
Lippia nodiflora	Verbenaceae
Stachytarpheta jamaicensis	Verbenaceae
Clerodendron phlomidis	Verbenaceae
Ocimum canum	Labiatae
Ocimum adscendens	Labiatae
Leucas aspera	Labiatae
Leucas urticaefolia	Labiatae
Orthosiphon pallidus	Labiatae
Moschosma polystachyum	Labiatae
Anisomeles indica	Labiatae
Boerhaavia diffusa	Nyctaginaceae
Boerhaavia repanda	Amaranthaceae
Celosia argentea	Amaranthaceae
Celosia polygonoides	Amaranthaceae
Digera arvensis	Amaranthaceae
Amaranthus spinosus	Amaranthaceae
Amaranthus viridis	Amaranthaceae
Amaranthus polygamus	Amaranthaceae
Achyranthes aspera	Amaranthaceae
Aerva tomentosa	Amaranthaceae
Aerva lanata	Amaranthaceae
Alternanthera echinata	Amaranthaceae
Gomphrena decumbens	Amaranthaceae
Pupalia atropurpurea	Amaranthaceae
Pupalia lappacea	Amaranthaceae
Alternanthera triandra	Amaranthaceae
Polygonum plebejum	Polygonaceae
Aristolochia bracteata	Polygonaceae
Euphorbia hirta	Euphorbiaceae
Euphorbia prostrata	Euphorbiaceae
Euphorbia thymifolia	Euphorbiaceae
Euphorbia dracunculoides	Euphorbiaceae
Phyllanthus maderaspatensis	Euphorbiaceae
Phyllanthus niruri	Euphorbiaceae
Croton bonplandianum	Euphorbiaceae
Chrozophora rottleri	Euphorbiaceae
Acalypha indica	Euphorbiaceae
Jatropha gossypifolia	Euphorbiaceae
Jatropha glandulifera	Euphorbiaceae
Micrococca mercurialis	Euphorbiaceae
Tragia involucrata	Euphorbiaceae

Tragia cannabina	Euphorbiaceae
Cyanotis cucullata	Commelinaceae
Cyanotis axillaris	Commelinaceae
Commelina benghalensis	Commelinaceae
Commelina jacobi	Commelinaceae
Aneilema spiratum	Commelinaceae
Cyperus bulbosus	Cyperaceae
Cyperus rotundus	Cyperaceae
Cyperus difformis	Cyperaceae
Cyperus haspan	Cyperaceae
Cyperus flavidus	Cyperaceae
Stenophyllus barbatus	Cyperaceae
Eleocharis atropurpurea	Cyperaceae
Fimbristylis miliacea	Cyperaceae
Cynodon dactylon	Poaceae
Panicum repens	Poaceae
Panicum isachne	Poaceae
Panicum crus - galli	Poaceae
Panicum stagninum	Poaceae
Panicum colonum	Poaceae
Tragus racemosus	Poaceae
Coix lacryma - jobi	Poaceae
Imperata arundinacea	Poaceae
Ischaemum pilosum	Poaceae
Aristida adscencionis	Poaceae
Sporobolus coromandelianus	Poaceae
Chloris barbata	Poaceae
Eleusine aegyptiaca	Poaceae
Dinebra arabica	Poaceae
Ergrostis interrupta	Poaceae
Eichhornia crassipes	Pontederiaceae

APPENDIX 2

List of trees in study sites in NBR

Acacia catechu
Acacia ferruginea
Acacia leucophloea
Acacia mearnsii
Acacia sundra
Actinodaphne malabarica
Adina cordifolia
Aglaia elaeagnoidea
Agrostistachys borneensis
Ailanthus triphysa
Albizia amara
Albizia lebbeck
Amoora rohituka
Anogeissus latifolia
Antidesma menasu
Artocarpus heterophyllus
Bauhinia racemosa
Bischofia javanica
Bombax ceiba
Bridelia retusa
Buchanania axillaris
Butea monosperma
Callicarpa tomentosa
Calophyllum elatum
Calophyllum polyanthum
Canarium strictum
Careya arborea
Casearia esculenta
Cassia fistula
Celtis philippensis
Chionanthus mala-elengi
Chloroxylon swietenia
Cinnamomum keralense
Cinnamomum malabatrum
Cinnamomum perrotetii
Cinnamomum sulphuratum
Cinnamomum wightii
Citrus medica
Cordia domestica
Cordia monoica
Cordia myxa
Cordia wallichi
Cryptocarya lawsoni
Cryptocarya neilgherrensis
Cullenia exarillata
Dalbergia latifolia
Dalbergia paniculata
Daphniphyllum neilgherrens
Debregeasia longifolia
Derris scandens
Dichrostachys cinerea
Diospyros melanoxylon
Diospyros montona
Dolichandrone arcuata

Dolichandrone falcata
Elaeagnus kologa
Elaeocarpus munroii
Elaeocarpus serratus
Elaeocarpus tuberculatus
Elaeodendron glaucum
Erythrina indica
Erythrina stricta
Erythroxylon monogynum
Eucalyptus globulus
Euodia lunu-ankenda
Euonymus angulatus
Euonymus crenulatus
Euphorbia trigona
Ficus beddomei
Ficus benghalensis
Ficus exasperata
Ficus hispida
Ficus sp.
Ficus tjakela
Garcinia papilla
Garcinia morella
Gardenia gummigutta
Givotia rottleriformis
Glochidion arboreum
Glochidion ellipticum
Glochidian neilgherrense
Gmelina arborea
Gomphostemma coriacea
Gomphostemma paniculata
Grevillea robusta
Grewia robusta
Grewia tiliaefolia
Gymnosporia montana
Isonandra lanceolata
Jatropha curcas
Kydia calycina
Lagerstroemia microcarpa
Lagerstroemia parviflora
Lannea coromandelica
Limonia alata
Litsea coriacea
Litsea deccanensis
Litsea floribunda
Litsea insignis
Litsea oleoides
Litsea zeylanica
Macaranga indica
Macaranga peltata
Maesa perrotetiana
Maesopsis eminii
Mahonia leschenaultii
Mallotus philippensis
Mallotus tetracocus
Mangifera indica
Manilkara roxburghiana
Mastixia arborea
Melia arborea
Meliosma arnottiana
Meliosma wightii

Mesua ferrea
Michelia nilagirica
Microtropis ovalifolia
Mitragyna parvifolia
Myristica dactyloides
Naringi crenulata
Neolitsea zeylanica
Nephelium longana
Nothapodytes nimmoniana
Olea dioica
Olea polygama
Palaquium ellipticum
Pavetta hispidula
Persea macrantha
Phoebe wightii
Phyllanthus emblica
Plectronia didyma
Poeciloneuron indicum
Polyalthia fragrans
Premna tomentosa
Prunus avium
Prunus ceylanica
Pterocarpus marsupium
Radermacheria xylocarpa
Randia dumetorum
Randia sp.
Rapanea wightiana
Rhododendron nilagiricum
Sapindus emarginatus
Schrebera swietenioides
Schleichera oleosa
Scolopia crenata
Stereospermum colais
Stereospermum sp.
Strychnos potatorum
Swietenia mahagoni
Symplocos sp.
Symplocos cochinchinensis
Symplocos foliosa
Symplocos pulchra
Symplocos racemosa
Syzygium arnottianum
Syzygium calophyllifolium
Syzygium cumini
Syzygium laetum
Syzygium montanum
Syzygium mundagam
Tamarindus indica
Tectona grandis
Terminalia arjuna
Terminalia bellerica
Terminalia chebula
Terminalia paniculata
Terminalia tomentosa
Turpinia malabarica
Turpinia nepalensis
Vernonia arborea
Viburnum hebanthum
Vitex altissima
Vitex leucoxylon

Vitex pubescens
Xylosma sp
Ziziphus mauritiana
Ziziphus rugosa
Ziziphus xylopyrus

APPENDIX 3

Species composition in different plots in Siruvani forest

Plots	P 1	P 2	P 3	P 4	P 5	P 6	P 7	P 8	P 9	P 10
Abutilon hirtum	-	-	-	-	-	-	+	-	-	-
Acacia intsia	+	+	-	-	-	-	-	-	-	+
Acacia torta	+	+	-	-	-	+	+	-	-	-
Acalypha paniculata	+	+	-	+	+	-	+	-	-	-
Albizia amara	-	+	-	-	-	-	-	-	+	-
Alternanthera sessilis	-	-	-	-	-	+	-	-	-	-
Argyreia cuneata	-	-	-	-	-	-	+	-	-	-
Aristida sp.	-	-	-	+	-	-	-	-	-	-
Asparagus racemosus	-	-	-	-	-	+	+	-	-	-
Azadirachta indica	-	-	-	-	+	-	-	-	-	-
Bambusa arundinacea	-	-	-	-	-	-	-	-	+	-
Bauhinia malabarica	-	-	-	+	-	-	-	-	-	+
Bauhinia racemosa	-	+	-	-	-	-	-	-	+	+
Ageratum conyzoides	+	+	-	-	-	-	-	+	+	-
Bombax malabaricum	-	-	-	-	-	-	+	-	-	+
Breynia vitis-idaea	-	-	+	-	+	-	-	-	-	+
Canthium dicoccum	-	+	-	+	-	+	+	+	+	-
Capsicum fruticanes	-	-	+	+	+	-	-	-	-	-
Carex sp.	-	-	-	+	-	-	-	+	-	-
Carex speciosa	-	-	-	-	-	+	+	-	-	-
Cassia fistula	-	-	-	-	-	+	+	-	+	-
Cassia occidentalis	-	-	-	+	-	-	-	-	+	-
Chlorophytum attenuatum	-	-	+	-	-	-	-	-	-	-
Chromolaena odorata	+	+	+	+	+	+	+	+	+	-
Chrysopogon fulvus	-	-	-	+	-	-	-	-	-	-
Clausena dentata	-	-	-	-	+	-	-	-	-	-
Clematis gouriana	-	-	+	-	-	-	-	+	-	-
Clitoria sp.	-	-	-	+	-	-	-	-	-	-
Cocculus hirsutus	-	-	-	+	+	+	+	+	-	-
Commelina benghalensis	-	-	+	-	-	-	+	+	+	-
Commelina longifolia	-	-	+	-	-	-	-	-	-	-
Cordia wallichii	+	-	-	-	-	-	-	-	-	+
Cryptolepis buchanani	+	+	+	+	+	+	+	+	-	+
Curculigo orchioides	-	+	+	+	+	+	+	+	+	-
Cyclea peltata	-	+	+	+	-	-	-	-	-	+
Cyrtococcum deccanense	+	+	+	+	+	+	+	+	+	+
Dalbergia latifolia	+	-	-	-	-	-	-	-	-	-
Dalbergia sissoides	-	-	-	-	-	+	-	-	-	-
Dipteracanthus prostratus	-	+	+	+	+	-	+	-	+	-
Desmodium gyrans	-	-	-	-	-	+	+	+	+	-
Desmodium pulchellum	-	-	-	-	-	-	+	+	-	-
Desmodium triflorum	-	-	-	-	-	-	+	+	-	-
Dichrostachys cinerea	+	+	-	-	-	-	+	-	-	-
Digitaria abludens	-	-	-	-	-	+	-	-	-	-
Dioscorea bulbifera	-	+	+	-	-	+	-	-	-	+
Dioscorea oppositifolia	-	-	-	-	-	+	-	-	-	-
Dioscorea pentaphylla	-	+	-	-	-	-	-	-	-	-
Dioscorea tomentosa	-	-	-	-	-	-	-	-	-	+
Dioscorea wallichii	-	+	-	-	-	+	-	-	-	-
Eleusine indica	-	-	-	-	-	+	-	-	-	-
Eucalyptus globulus	-	-	-	-	-	-	+	-	+	-

Fimbristylis ovata	-	-	-	-	-	+	+	+	+	-
Flacourtia indica	-	+	+	-	+	-	-	-	-	+
Fluggea leucopyrus	-	-	-	-	-	-	-	-	+	-
Glycosmis pentaphylla	+	-	+	+	+	+	+	+	+	+
Grewia hirsuta	+	-	+	-	-	+	+	-	-	-
Grewia tiliaefolia	+	+	-	+	+	-	-	-	-	+
Helicteres isora	+	+	+	+	+	+	+	+	+	+
Ipomoea staphylina	-	-	-	-	-	+	-	-	-	-
Ipomoea turbinata	+	-	+	-	+	-	-	+	-	+
Ixora pavetta	-	-	-	+	-	-	-	-	-	-
Jasminum rottlerianum	-	-	+	-	-	+	+	-	+	-
Justicia betonica	+	-	+	+	+	-	-	+	-	+
Justicia simplex	-	-	-	-	-	+	-	-	-	-
Justicia sp.	-	-	-	-	-	-	+	+	+	-
Lagerstroemia microcarpa	-	-	-	-	-	-	-	-	-	+
Lantana camara	+	+	+	+	+	+	+	+	+	+
Laportea interrupta	-	+	+	-	-	-	-	-	-	-
Litsea floribunda	-	-	+	-	-	-	-	-	-	+
Mimosa pudica	-	-	-	+	+	+	+	+	+	-
Monothecium aristatum	+	+	+	+	+	+	-	-	-	+
Moringa citrifolia	-	-	+	-	-	+	+	-	+	-
Naringi crenulata	-	-	-	-	-	+	-	-	-	-
Naravelia zeylanica	+	+	+	+	-	-	-	-	-	-
Olea dioica	-	-	+	-	+	+	-	-	-	-
Oplismenus compositus	+	+	+	+	+	+	+	-	-	-
Oxalis corniculata	-	+	-	-	-	+	+	-	+	-
Panicum notatum	+	+	+	+	+	+	+	+	-	+
Paspalum flavidum	-	-	-	-	-	+	-	-	-	-
Paspalum scrobiculatum	-	-	-	-	-	+	-	-	-	-
Pavonia zeylanica	-	-	-	-	-	-	-	-	+	-
Phaulopsis imbricata	+	+	+	+	+	+	-	+	-	-
Phyllanthus amarus	-	+	+	+	+	+	+	+	+	+
Phyllanthus emblica	-	-	-	-	-	+	-	-	-	-
Phyllanthus rheedii	-	-	+	+	-	-	-	-	-	+
Plectranthus japonicus	-	+	-	-	+	+	-	-	-	-
Polygonum chinense	-	-	-	-	-	+	+	-	-	-
Pteridium indicum	+	-	-	-	-	-	-	-	-	-
Pterocarpus marsupium	-	-	-	-	+	-	+	-	-	+
Randia dumetorum	-	+	+	+	+	+	-	+	+	-
Randia malabarica	-	-	-	+	-	-	-	-	-	-
Rauvolfia serpentina	-	-	-	-	+	-	+	-	-	-
Rungia parviflora	-	-	+	+	-	-	-	-	-	-
Sapindus emarginatus	-	-	-	+	+	-	-	-	-	+
Scleria lithosperma	-	-	-	-	-	+	-	-	-	-
Sida acuta	+	+	+	+	+	+	+	+	+	+
Sida rhombifolia	-	+	-	+	-	+	-	-	-	-
Smilax zeylanica	-	-	+	-	-	-	-	-	-	-
Spatholobus roxburghii	+	+	-	-	-	-	-	-	-	-
Stachytarpheta jamaicensis	-	-	-	-	-	+	+	+	-	-
Synedrella nodiflora	+	-	+	+	-	-	-	-	-	-
Tamarindus indica	-	-	-	-	-	+	-	-	-	+
Tectona grandis	-	-	+	-	-	-	+	+	+	-
Tephrosia purpurea	-	-	-	-	-	-	-	-	-	+
Terminalia bellerica	+	+	+	-	+	+	+	-	-	-
Terminalia paniculata	+	+	-	-	-	-	+	-	-	-

Terminalia tomentosa	-	-	-	-	-	+	-	-	-	-
Themeda tremula	-	-	-	-	-	-	-	-	+	-
Thunbergia alata	+	-	-	-	+	-	-	-	-	-
Toddalia asiatica	-	-	-	-	-	+	-	-	+	-
Tragus roxburghii	-	-	-	-	-	-	+	-	-	-
Triumfetta pilosa	+	-	-	-	-	+	+	-	-	-
Wattakaka volubilis	-	-	+	-	-	-	-	-	-	-
Wrightia tinctoria	-	-	-	-	-	-	-	-	-	+
Ziziphus nummularia	-	-	-	-	-	-	-	+	-	-
Ziziphus oenoplia	-	+	-	+	+	+	+	+	-	-
Ziziphus xylopyrus	-	-	-	-	-	+	+	+	+	-

APPENDIX 4

Niche breadth of all plant species in different study sites in NBR

Species	Niche breadth
Abutilon hirtum	1.30
Abutilon indicum	1.60
Abutilon neilgherense	1.00
Acacia ferruginea	2.32
Acacia intsia	3.00
Acacia leucophloea	1.61
Acacia mearnsii	1.01
Acacia sp.	1.00
Acacia sundra	2.52
Acacia torta	1.00
Acalypha indica	1.00
Acalypha paniculata	1.00
Achyranthes bidentata	1.80
Adiantum incisum	1.77
Adiantum lunulatum	1.00
Adiantum sp.	1.00
Aerides crispum	1.00
Aeschynomene indica	1.00
Ageratum conyzoides	2.73
Allophylus cobbe	1.00
Alysicarpus rugosus	1.00
Amomum pterocarpum	1.00
Anaphalis elliptica	2.60
Anaphalis marcescens	1.00
Anaphalis neelghrryana	2.13
Anaphalis wightiana	1.00
Ancistrocladus heyneanus	2.00
Andrographis lobelioides	1.00
Andrographis serpyllifolia	1.40
Anemone rivularis	1.64
Angiopteris sp.	1.00
Antistrophe serratifolia	1.71
Apluda mutica	3.16
Ardisia souchifolia	1.00
Argyreia cuneata	1.57
Arisaema leschenaultii	1.00
Arisaema tortuosum	1.00
Aristida adscencionis	1.00
Arndinella mesophylla	2.96
Arundinella ciliata	1.95
Arundinella holcoides	2.01
Arundinella lawsoni	1.00
Arundinaria wightiana	1.00
Asparagus gonoclados	5.12
Asparagus racemosus	5.15
Asplenium sp.	1.36

Bambusa arundinacea	3.31
Barleria cristata	1.53
Barleria hirsuta	1.00
Barleria mysorensis	2.61
Bidens pilosa	1.47
Blepharispermum subsessile	1.00
Blumea alata	2.57
Blumea lacera	1.30
Blumea mollis	1.53
Blumea virens	3.75
Breynia patens	1.26
Breynia rhamnoides	1.00
Breynia sp.	1.00
Buchanania axillaris	1.00
Calanthe masuca	1.99
Calanthe triplicata	1.02
Calmus rotung	1.96
Camellia sinensis	1.00
Canthium dicoccum	1.00
Capparis sepiaria	1.63
Capsicum frutescens	1.00
Caralluma umbellata	1.00
Carex baccans	1.92
Carex lindleyana	2.17
Carex pedusula	1.00
Carex speciosa	1.83
Careya arborea	1.00
Caryota sp.	1.00
Caryota urens	1.38
Casearia esculenta	1.08
Cassia absus	1.00
Cassia fistula	6.01
Cassia hirsuta	1.00
Cassia intermedia	1.00
Cassia occidentalis	3.40
Cassia siamea	1.00
Cassia sp.	1.00
Chlorophytum attenuatum	1.00
Chrysopogon orientalis	1.72
Cinnamomum malabatrum	1.04
Cinnamomum perrottetii	1.00
Cinnamomum zeylanicum	1.80
Cissus discolor	1.00
Cissus glyptocarpa	1.00
Clausina dentata	1.00
Clematis gouriana	1.00
Clerodendron infortunatum	1.89
Cocculus hirsutus	1.00
Coffea arabica	1.02
Coleus forskholli	1.00

Coleus malabaricus	1.00
Commelina benghalensis	3.05
Commelina cristata	1.80
Commelina diffusa	2.21
Commelina ensifolia	1.00
Commelina hirsuta	3.26
Commelina longifolia	1.31
Costus speciosus	1.00
Crotalaria pallida	1.00
Cryptolepis buchanani	2.00
Curcuma pseudomonta	3.10
Curculigo orchioides	4.48
Curcuma aromatica	2.00
Curcuma longa	1.80
Cyanodon dactylon	1.00
Cyanoglosum furcatum	1.00
Cyanotis cristata	2.45
Cyanotis fasciculata	1.78
Cyanotis pilosa	1.28
Cyanotis tuberosa	3.16
Cyclea peltata	1.86
Cymbopogon polyneuros	1.21
Cynodon dactylon	1.02
Cyperus bulbosus	1.80
Cyperus cyperinus	2.65
Cyperus distans	1.68
Cyperus exaltatus	1.37
Cyperus pangorei	2.54
Cyperus rotundus	1.06
Cyperus triceps	1.27
Cyrtococcum deccanense	1.19
Cyrtococcum patens	1.03
Debregeasia longifolia	1.00
Derris scandens	1.68
Desmodium gyrans	1.63
Desmodium pulchellum	2.26
Desmodium triflorum	1.04
Dichrostachys cinerea	3.08
Digitaria bicornis	1.57
Digitaria abludens	1.10
Dioscorea bulbifera	1.18
Dioscorea oppositifolia	1.00
Dioscorea pentaphylla	1.00
Dioscorea tomentosa	1.00
Dioscorea trifolia	1.00
Dioscorea wallichii	1.00
Elettaria cardomomum	1.02
Elatostemma lineolatum	1.39
Eleusine indica	1.00
Eragrostis cilianensis	1.63

Eragrostis sp.	1.00
Eragrostis unioloides	2.81
Eragrostis atrovirens	1.31
Erigeron mucronatus	1.36
Eriocaulon thwaitesii	1.00
Eriolaena quinquelocularis	1.00
Erythrina indica	2.00
Erythropalum populifolium	1.66
Euonymus angulatus	1.00
Euonymus dichotomus	1.00
Chromolaena odorata	5.24
Eupatorium repandum	2.73
Euphorbia heterophylla	1.00
Euphorbia hirta	1.94
Euphorbia indica	1.00
Euphorbia prostrata	1.00
Euphorbia rosea	1.00
Euphorbia rothiana	1.19
Euphorbia thymifolia	1.00
Evolvulus alsinoides	3.04
Fimbristylis dichotoma	3.46
Fimbristylis ovata	2.85
Flacourtia indica	4.11
Flemingia strobilifera	1.00
Flemingia wightiana	1.14
Floscopa scandens	1.00
Fluggea leucopyrus	2.29
Fragaria indica	1.66
Fragaria nilgherrensis	1.14
Furcraea foetida	1.00
Garcinia combogia	1.00
Garnotia arundinacea	1.93
Gaultheria fragrantissima	1.77
Givotia rottleriformis	1.00
Globba bulbifera	1.92
Glycine javanica	1.47
Glycosmis pentaphylla	2.45
Gnaphalium indicum	1.60
Gomphostemma heyneanum	1.00
Grevillea robusta	1.71
Grewia hirsuta	4.41
Grewia orbiculata	1.00
Grewia tiliaefolia	1.55
Gymnosporia montana	1.66
Gynura nitida	1.00
Heckeria subpeltata	1.00
Hedyotis stylosa	1.00
Helicteres isora	2.41
Hemidesmus indicus	2.03
Heteropogon contortus	2.71

Hibiscus solandra	1.00
Hibiscus surattensis	1.00
Hybernum sp.	1.00
Hydrocotyle javanica	1.57
Indigofera cassioides	1.61
Indigofera linnaei	2.08
Ipomoea staphylina	1.00
Ipomoea turbinata	1.00
Jasminum rottlerianum	1.00
Jasminum sp.	1.00
Jatropha curcas	1.44
Jatropha heterophylla	1.00
Justicia betonica	1.06
Justicia simplex	1.00
Knoxia sumatrensis	1.63
Kydia calycina	2.31
Kyllinga monocephalla	1.00
Kyllinga triceps	1.00
Lannea coromandelica	1.00
Lantana camara	4.61
Lantana indica	1.00
Laportea crenulata	1.94
Laportea interrupta	1.00
Lasianthus ciliatus	2.47
Lasianthus coffeoides	1.00
Lasianthus jackianus	1.03
Lasianthus venulosus	1.00
Leea indica	1.94
Leucas aspera	3.68
Leucas ciliata	1.20
Leucas indica	1.00
Leucas lanceaefolia	1.98
Leucas martinicensis	1.92
Leucas marrubioides	1.00
Limonia alata	2.88
Lindernia antipoda	1.00
Lindernia ciliata	1.32
Lindernia sp.	1.35
Litsea coriacea	2.00
Litsea deccanensis	1.00
Litsea zeylanica	1.41
Litsea floribunda	1.00
Ludwigia octavalvis	1.00
Ludwigia parviflora	1.00
Lygodium microphylla	1.65
Maesa indica	1.32
Mahonia leschenaultii	2.64
Malvastrum coromandelianum	2.32
Meliosma wightii	1.96
Memecylon edule	1.00

Memecylon heyneanum	1.00
Memecylon umbellatum	1.00
Michelia nilagirica	1.00
Microtropis ovalifolia	1.00
Microtropis stocksii	1.00
Mimosa pudica	3.09
Monothecium aristatum	1.00
Moringa citrifolioa	1.00
Murdannia spirata	1.00
Murraya konigii	1.00
Murraya paniculata	1.00
Naringi crenulata	3.31
Naravelia zeylanica	1.00
Nephrolepis cordifolia	1.00
Nervilia aragoana	1.00
Nervilia plicata	1.00
Nilgirianthus barbatus	1.00
Nothapodytes nimmoniana	1.00
Ochlandra travancorica	1.00
Ocimum sanctum	1.00
Olea dioica	3.21
Oogeinia oujeinensis	1.00
Ophiopogon intermedius	1.42
Ophiorrhiza sp.	1.00
Oplismenus compositus	5.37
Opuntia dillenii	1.73
Orthosiphon thymiflorus	2.84
Oryza granulata	1.00
Osbeckia lineolata	1.00
Osmunda rugalis	1.00
Oxalis corniculata	1.31
Panicum brevifolium	1.00
Panicum notatum	4.09
Pandanus thwaitesii	1.63
Parthenium hysterophorus	1.00
Paspaladium sp.	1.00
Paspaladium flavidum	1.00
Pavetta breviflora	1.00
Pavetta congesta	1.32
Pavetta hispidula	1.22
Pavetta indica	1.13
Pavetta tomentosa	1.00
Pavonia zeylanica	1.00
Pellionia sp.	1.12
Pennisetum hohenackeri	1.00
Peperomia tetraphylla	1.90
Perotis indica	1.00
Phaulopsis imbricata	1.00
Phoenix sylvestris	1.00
Phyllanthus amarus	1.03

Phyllanthus emblica	1.69
Phyllanthus gardenerianus	1.65
Phyllanthus maderaspatensis	1.12
Phyllanthus rheedii	1.88
Phyllanthus sp.	1.00
Piper argyrophyllum	1.75
Piper attenuatum	1.57
Piper wightii	1.38
Plectranthus japonicus	1.00
Plectronia didyma	1.00
Pogostemon paniculatus	1.00
Polyalthia squarosus	1.94
Polygonum chinense	1.34
Polystichum sp.	2.74
Pseudechinolaena polystachya	1.58
Psychotria congesta	2.03
Psychotria nigra	1.84
Pteris pellucida	1.92
Pteris quadriurita	1.80
Pteris sp.	1.00
Pterocarpus marsupium	1.00
Pterolobium indicum	2.84
Radermacheria xylocarpa	1.00
Randia sp.	2.37
Rauwolfia serpentina	1.00
Rhodomyrtus tomentosa	1.25
Rhynchosia minima	1.00
Rhynchotechum permolle	1.00
Rubia cordifolia	1.86
Rubus ellipticus	1.74
Rubus racemosus	1.15
Saprosma ceylanicum	1.86
Sarcandra chloranthoides	1.60
Schleichera oleosa	1.00
Scilla indica	1.00
Scirpus erectus	1.02
Scolopia crenata	1.00
Selaginella sp.	1.14
Semecarpus anacardium	1.00
Senecio neelgherryanus	1.00
Setaria palmifolia	1.00
Sida acuta	2.92
Sida cordata	2.61
Sida cordifolia	1.00
Sida rhombifolia	2.94
Sida spinosa	1.00
Smilax aspera	1.47
Smilax lancaefolia	1.00
Smilax perfoliata	1.56
Smilax prolifera	1.73

Smilax zeylanica	1.24
Solanum ferox	1.00
Solanum indicum	1.05
Solanum melongena	3.19
Solanum torvum	3.00
Solanum verbascifolium	1.00
Spatholobus roxburghii	1.06
Spermacoce ocymoides	1.00
Spilanthes calva	1.00
Stachytarpheta jamaicensis	1.25
Stereospermum colais	1.38
Strobilanthes foliosus	2.65
Strobilanthes heyneanus	1.82
Strobilanthes kunthianus	1.00
Strobilanthes micranthus	1.00
Strobilanthes sp.	1.00
Strobilanthes perrotettetianus	1.00
Strychnos potatorum	1.00
Symplocos cochinchinensis	2.00
Symplocos foliosus	1.95
Symplocos pulchra	1.00
Synedrella nodiflora	1.00
Syzygium arnottianum	1.00
Syzygium laetum	1.00
Syzygium montanum	2.14
Tephrosia pulcherrima	1.00
Tephrosia pumila	1.00
Tephrosia purpurea	1.28
Tephrosia tinctoria	2.23
Teramnus labialis	1.00
Terminalia tomentosa	1.77
Themeda cymbaria	1.83
Themeda tremula	2.25
Themeda triandra	1.23
Thottea siliquosa	1.90
Thunbergia alata	1.00
Thunbergia fragrans	1.00
Thunbergia mysorensis	1.46
Toddalia asiatica	2.34
Toddalia asiatica var floribunda	1.36
Tragia involucrata	1.00
Tribulus terrestris	1.50
Tridax procumbens	1.00
Tripogon bromoides	2.05
Triumfetta pilosa	2.34
Triumfetta rhomboidea	1.00
Tylophora indica	1.00
Uraria lagopodioides	1.00
Uraria rufescens	1.00
Urena lobata	1.88

Urochloa panicoides	1.00
Vernonia sp.	1.00
Vetiveria lawsoni	1.00
Viburnum hebanthum	1.00
Viburnum punctatum	1.50
Wattakaka volubilis	1.00
Wrightia tinctoria	1.07
Xenecanthus pulneyensis	1.00
Zingiber roseum	1.00
Ziziphus oenoplia	4.16
Ziziphus rugosa	1.00

Appendix 5. Species association (Jaccard's index X 100) among select weedy species in NBR

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42
1 *Acalypha fruticosa*	100																																									
2 *Acanthospermum hispidum*	0	100																																								
3 *Achyranthes aspera*	100	0	100																																							
4 *Alysicarpus rugosus*	0	100	0	100																																						
5 *Apluda mutica*	25	25	25	25	100																																					
6 *Barleria mysorensis*	33	33	33	33	40	100																																				
7 *Bidens pilosa*	0	0	0	0	0	0	100																																			
8 *Biophytum sensitivum*	0	0	0	0	20	0	33	100																																		
9 *Blumea lacera*	0	0	0	0	50	0	0	33	100																																	
10 *Ageratum conyzoides*	14	14	14	14	57	25	29	29	29	100																																
11 *Blumea virens*	25	0	25	0	60	17	20	50	50	57	100																															
12 *Cassia occidentalis*	25	25	25	25	60	75	0	20	20	38	33	100																														
13 *Croton bonplandianum*	0	100	0	100	25	33	0	0	0	14	0	25	100																													
14 *Desmodium triflorum*	0	25	0	25	33	17	20	50	20	57	33	33	25	100																												
15 *Eupatorium odoratum*	11	11	11	11	44	33	22	22	22	78	44	44	11	44	100																											
16 *Eupatorium repandum*	0	0	0	0	29	0	17	17	40	33	29	13	0	13	40	100																										
17 *Euphorbia hirta*	25	25	25	25	60	75	0	0	20	38	33	60	25	14	44	13	100																									
18 *Euphorbia rothiana*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	40	0	100																								
19 *Evolvulus alsinoides*	25	25	25	25	60	75	0	20	20	38	33	100	25	33	44	13	60	0	100																							
20 *Justicia betonica*	0	0	0	0	0	0	33	0	0	29	0	0	0	20	22	17	0	0	0	100																						
21 *Lantana camara*	13	13	13	13	50	38	25	25	25	88	50	50	13	50	89	30	50	0	50	25	100																					
22 *Leucas aspera*	25	25	25	25	60	75	0	20	20	38	33	100	25	33	44	13	60	0	100	0	50	100																				
23 *Leucas lancefolia*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	40	0	100	0	0	0	0	100																			
24 *Malvastrum coromandelianum*	20	20	20	20	80	33	17	17	40	71	60	60	20	29	56	43	50	0	50	17	63	50	0	100																		
25 *Mimosa pudica*	17	17	17	17	67	29	14	33	33	86	67	43	17	67	67	22	43	0	43	14	75	43	0	57	100																	
26 *Opuntia dillenii*	50	0	50	0	20	67	0	0	0	13	20	50	0	0	22	0	50	0	50	0	25	50	0	17	14	100																
27 *Orthosiphon thymiflorus*	33	33	33	33	40	100	0	0	0	25	17	75	33	17	33	0	75	0	75	0	38	75	0	33	29	67	100															
28 *Parthenium hysterophorus*	100	0	100	0	25	33	0	0	0	14	25	25	0	0	11	0	25	0	25	0	13	25	0	20	17	50	33	100														
29 *Rungia parviflora*	0	0	0	0	50	0	0	33	100	29	50	20	0	20	22	40	20	0	20	0	25	20	0	40	33	0	0	0	100													
30 *Sida acuta*	17	17	17	17	67	29	14	33	33	86	67	43	17	67	67	22	43	0	43	14	75	43	0	57	100	14	29	17	33	100												
31 *Sida cordata*	0	33	0	33	40	20	25	67	25	43	40	40	33	75	33	14	17	0	40	0	38	40	0	33	50	0	20	0	25	50	100											
32 *Sida rhombifolia*	0	25	0	25	33	17	20	50	20	57	33	33	25	100	44	13	14	0	33	20	50	33	0	29	67	0	17	0	20	67	75	100										
33 *Stachytarpheta jamaicensis*	25	25	25	25	60	40	0	20	20	57	33	60	25	60	44	13	33	0	60	20	50	60	0	50	67	20	40	25	20	67	40	60	100									
34 *Strobilanthes foliosus*	0	0	0	0	0	0	25	0	0	11	0	0	0	0	20	60	0	67	0	25	10	0	67	14	0	0	0	0	0	0	0	0	0	100								
35 *Synedrella nodiflora*	0	33	0	33	17	20	25	25	0	43	17	17	33	75	33	0	17	0	17	25	38	17	0	14	50	0	20	0	0	50	50	75	40	0	100							
36 *Tephrosia pumila*	0	100	0	100	25	33	0	0	0	14	0	25	100	25	11	0	25	0	25	0	13	25	0	20	17	0	33	0	0	17	33	25	25	0	33	100						
37 *Tephrosia purpurea*	25	25	25	25	33	75	0	0	0	38	14	60	25	33	44	0	60	0	60	20	50	60	0	29	43	50	75	25	0	43	17	33	60	0	40	25	100					
38 *Tribulus terrestris*	100	0	100	0	25	33	0	0	0	14	25	25	0	0	11	0	25	0	25	0	13	25	0	20	17	50	33	100	0	17	0	0	25	0	0	0	25	100				
39 *Tridax procumbens*	0	0	0	0	0	0	50	0	0	14	0	0	0	0	11	20	0	0	0	50	13	0	0	20	0	0	0	0	0	0	0	0	0	33	0	0	0	0	100			
40 *Triumfetta pilosa*	0	20	0	20	60	14	17	40	40	71	60	29	20	80	56	25	29	0	29	17	83	29	0	43	83	0	14	0	40	83	60	80	50	0	60	20	29	0	0	100		
41 *Triumfetta rhomboidea*	0	0	0	0	0	0	100	33	0	29	20	0	0	20	22	17	0	0	0	33	25	0	0	17	14	0	0	0	0	14	25	20	0	25	25	0	0	0	50	17	100	
42 *Urena lobata*	0	0	0	0	40	0	25	67	67	43	75	17	0	40	33	33	17	0	17	0	38	17	0	33	50	0	0	0	67	50	50	40	17	0	20	0	0	0	0	60	25	100

Appendix 6

Bajara (Bajra)	= *Pennisetum typhoides*
Crore	= Ten million
EC	= Electical conductivity
IVI	= Importance Value Index
MWS	= Mudumalai Wildlife Sanctuary
NBR	= Nilgiri Biosphere Reserve
Shola	= Southern montane temperate forest (Stunted evergreen forest)
Species richness	= Number of species
Total number	= Total number of individuals