KUVEMPU UNIVERSITY

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Project Title

A study on ecology of herbaceous plant communities in montane grasslands of Kemmannugundi and Bababudangiri areas of Karnataka

Annexure - IX

Project Completion Report

Submitted to

UNIVERSITY GRANT COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI

Submitted by

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Annexure – IX

UNIVERSITY GRANTS COMMISSION
BAHADUR SHAH ZAFAR MARG
NEW DELHI – 110 002.

Final Report of the work done on the Major Research Project

1.	Title of the Project	A study on ecology of herbaceous plant communities in montane grasslands of Kemmannugundi and Bababudangiri areas of Karnataka
2.	NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR	Dr. Y.L. Krishnamurthy Department PG studies and Research in Applied Botany, Jnana sahyadri, Kuvempu University, Shankaraghatta-577451
3.	NAME AND ADDRESS OF THE INSTITUTION	Department PG studies and Research in Applied Botany, Jnana sahyadri, Kuvempu Universty, Shankaraghatta-577451
4.	UGC APPROVAL LETTER NO. AND DATE	F.No.41-388/2012(SR) 16-7-12
5.	DATE OF IMPLEMENTATION	1st July 2012
6.	TENURE OF THE PROJECT.	Three years
7.	TOTAL GRANT ALLOCATED	Rs. 8,42,284/-
8.	TOTAL GRANT RECEIVED	Rs.7,79,336/-
9	FINAL EXPENDITURE	Rs. 7,79,336/-
10	TITLE OF THE PROJECT	**A study on ecology of herbaceous plant communities in montane grasslands of Kemmannugundi and Bababudangiri areas of Karnataka**
11	OBJECTIVES OF THE PROJECT	•To make a study on diversity of herbs and grasses of Kemmannugundi and Bababudengiri shola ecosystem •To study the population biology of herbs and grass communities •To analyze the pattern of distribution of herbs and grasses in sholas
12	WHETHER OBJECTIVES WERE ACHIEVED (GIVE DETAILS)	YES
13	ACHIEVEMENTS FROM THE PROJECT.	Details included in Report
14	SUMMARY OF THE FINDINGS.	• A database of plants has been prepared, montane grasslands are rich in herbs diversity a total of 242 plant species were recorded. Of

		these, 170 species of herbaceous plants belonging to 152 genera and 45 families and 72 species of grasses belonging to 43 genera placed in two families. • Two permanent small-scale plots (10 ×10m) which have been established for population dynamics studies provided a base line for life cycle of the herbs. • The study on population biology showed that there is a slight variation in the plant communities between Kammannugundi and Bababudangiri. The Bababudangiri harbours most of the ephemerals they complete their life cycle in favourable season very slight changes in climatic conditions may influence on these communities. Whereas, in Kemmannugundi which is dominated by tall grass, variation in climate may does not much effect on these plant communities. • Study on distribution of herbaceous plant communities in different habitats showed the plants are adopted to different microhabitat. • Studies on distribution of herbs in relation to different altitude showed that more number of species are distributed at higher altitude whereas in lower and middle elevations weed plants were found due to some of the anthropogenic activities.
15	CONTRIBUTION TO THE SOCIETY	Details included in Report
16	WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT	YES
17	NO. OF PUBLICATIONS OUT OF THE PROJECT	2

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1.0. Introduction

1.0. Biodiversity

Life on earth depends on the components of biological diversity. Biological diversity is defined as 'the total variability of life on earth' (Heywood *et al*., 1995). Biologists generally have the choice conveniently defining *Diversity* as 'number of species'. A species is in comparatively 'A population whose members are able to interbreed freely under natural conditions' (Simpson, 2002). It includes all forms of terrestrial and aquatic plants, animals, microorganisms by which mainly refers to the differences in genetic makeup between distinct species (genetic diversity), variety of species with a region (species diversity) and to the variety of habitats, biotic communities and ecological processes (ecosystem diversity) (McNeely *et al*., 1990).

1.1. Importance of floristic studies

Complexity and diversity are the two new frontiers of science. Ecologists over the past four decades have devoted considerable energy to the explanation of patterns of diversity in ecological systems. The diversity of any community is in large part of function of the total number of species it may contain (species richness) but also of the distribution of individuals between those number of species. Tropical forests are known for being most species rich ecosystem on earth (Gentry, 1992). Rapid depletion of biodiversity due to deforestation is a major global concern (Ghate *et al.,* 1998). Various anthropogenic activities are threatening the natural balance intern causing increase in the rate of species extinction. Loss of the plant wealth comes at a tragic time when our knowledge of their structure and dynamics are inadequate. Several attempts to prevent this damage have often remained insufficient (Sukumar *et al*., 1992). Species disappearance at an estimated rate of 0.8 to 2 per cent annually from these forests has raised the importance of effective forest management of tropical regions (May and Stumpf, 2000). Though the research on the forests have the history of many decades the ecology of these forests are yet to be analyzed precisely. The lack of

quantitative information has been the major drawback in accessing the heterogeneity of the forests.

1.2. Biodiversity of Karnataka

Karnataka is one of the southern states of India having 3.83 million ha of recorded forest area, which is around 20 per cent of its geographical area (Prajapati, 2010). The state is a part of biodiversity rich regions in India. Physiographically the state can be divided into two distinct regions *viz*., 'Malnad' and 'Maidan'. The malnad is the hilly area comprising the portion of the Western Ghats. It includes the districts of Uttara Kannada, Shivamogga, Dakshina Kannada, Kodagu, Hassan, Chikkamagaluru and extended to some parts of the Dharawada and Belgaum. The Western Ghats in Karnataka is one of the mega diversity centers of the world. Sixty per cent of the Western Ghats are located in Karnataka. The highest peak of this hill range in Karnataka rise to 1925.4 m is Mulayyanagiri in Chikkamagaluru district. The forest types found are tropical evergreen, moist and dry deciduous, high altitude sholas, savannas and scrubs (Champion and Seth, 1968). The Western Ghats is one of the oldest mountain ranges harbor numerous elements of flora and fauna. There are over 4500 species of flowering plants (38 per cent), 330 butterflies (11 per cent), 156 reptiles (62 per cent), 508 species of birds (4 per cent), 150 mammals (12 per cent), 289 fishes (41 per cent), 135 amphibians (75 per cent) are the known biodiversity of the Western Ghats of Karnataka (Prajapati, 2010). The Western Ghats has some of the important protected areas such as Nagarahole, Bandipura, Kuduremukh National Parks, Dandeli, Bhadra, Pushpagiri, Brahmagiri and Talakaveri wildlife sanctuaries.

1.3. The Western Ghats

The Western Ghats or 'Sahyadri mountains' form a chain of mountains that runs north to south parallel to the western coastline of the Indian peninsula from 8° N to 22° N. Almost

extending from Tapti river to Kanyakumari, covering a total area of about 1,600 km. It lies border of the states of south Gujarat, Maharashtra, Karnataka, Tamil Nadu and Kerala. The mountains of the Western Ghats is no snow-peaked Himalayas. Nevertheless, what they lack in height they make up for in biodiversity, harboring a striking array of India's wildlife. This range is classified as a distinct biogeographic zone of India and a biodiversity hot spot along with Sri Lanka (Rodgers and Panwar 1988, Myers *et al*., 2000). The Western Ghats, largely controls the ecology and biogeography of peninsular India. The climatic and altitudinal gradient has resulted in a variety of vegetation types, from evergreen to semi-evergreen and from moist deciduous to dry deciduous formations. In the higher hills stunted montane communities have also developed. Four major forest types and 23 different forest sub types recognized in the Western Ghats based on ecological factors and floristic composition (Rao, 1997). The forest types found in the Western Ghats are (i) the dry scrub vegetation (ii) the dry deciduous forests (iii) moist deciduous forests (iv) the semi-evergreen forests (v) the evergreen forests (vi) the sholas and (vii) the high altitude grasslands. Due to high species endemism, the Western Ghats listed in the 35 'Biodiversity hotspots' of the world (Anon., 2005). Key Biodiversity areas are nationally identified sites of global significance. In India, the identification of key Biodiversity Areas in the Western Ghats initiated in 2003 (Anon., 2014). Almost 27 per cent of the total plant species in India have been recorded from the Western Ghats (Nayar, 1996). Peninsular India has highest number of endemic species available along the Western Ghats only next to the Himalayan region (Jain and Sastry, 1983). Nearly 1500 endemic plant species estimated from the Western Ghats (MacKinnon and MacKinnon, 1986).

1.4. Shola-grassland ecosystem

The high altitude ecosystem differs from all other ecosystems constituting a unique habitat. The montane ecosystems around the world usually endowed with a distinct natural

communities and high levels of endemism (Gentry, 1992). Among different forest types, montane forests are unique with their rich biodiversity and prominent ecological services (Doumenge *et al*., 1995). Montane forests covering 7 to 9 per cent of total forest area occur in the Himalayan, northeastern and southern parts of the India (Lal, 1989). The montane regions (> 1800 m MSL) of the Western Ghats in southern India are commonly called shola forest (Ranganathan, 1938). The Mountaintops have rocky outcrops and ephemeral flush communities and covered by mist (Karunakaran *et al*., 1998). Down to the rock, face there are spreads of grasslands interspersed with small and large islands of dark green stunted forests, namely the 'sholas'. These are found mainly in sheltered valleys, depressions and ravines. 'Shola' might have come from the Malayalam word 'chola', which means the dark shades of the thick stunted forest. As the altitude increases, the trees become more stunted and the branches of neighbouring trees covered by epiphytes (Bunyan, 2009), because of these hilltops exposed to the high velocity of wind during southwest monsoon harbor stunted trees in the middle of grassy pastures (Sharma *et al.*, 1984). The forests are largely restricted to the shielded folds of the mountains and stream courses, while the grasslands cover the hill slopes. Shola forests in the Western Ghats is a highly threatened community today. These forests are isolated dense evergreen patches composed of stunted trees with crooked branches, covered with mosses, lichens, and epiphytic orchids, where moisture content is very high in this forest. Sholas are commonly known as Persistent cloud cover areas they can be categorized as lower montane cloud forest or upper montane cloud forest depending on elevation (Bunyan, 2009). Primary scientific reports on the shola-grassland ecosystem defined that it is a dual climax means the grasslands are the climatic climax equivalent to the shola (forest), climatic factor sustained this ecosystem, frost, that prevents it's further movement towards forest (Ranganathan, 1938). Bor (1938) stated that these grasslands are 'sub-climax', stable under the influence of regular fires. Some of the followers of the single

climax concept (Clements, 1936) argued that the forests was a biotic (Noble, 1967) or edaphic climax (Jose *et al.*, 1994). Sharpe ecotone between the shola and grassland structure has been recognized to occurrence of forest fire. This ecotone region between forest and grassland is maintained by a combination of frost, fire (Meher- Homji, 1984) or grazing (Ranganathan, 1938). Due to climatic changes these montane forest and grasslands have expanded and contracted, by this process species turnover also occurs (Sukumar *et al*., 1993).

Champion and Seth (1968) considered the shola to be a single type of vegetation belonging to the southern montane wet forests. According to Shanker (1997), the virtual extents of the sholas and the grasslands have varied over geological time. In fact, during higher temperature periods, the sholas have been more widespread and during the ice ages, they have contracted. The species diversity is remarkably high in this forest. Some dominant species are *Pithecellobium subcoriaceum, Ixora notoniana, Syzygium arnottianum, Ilex denticulata, I. wightiana, Michaelia nilagirica, Elaeocarpus recurvatus, Microtropis ramiflora, Actinodaphne bourdellonii* and *Symplocos pendula*. Trees such as, *Ternstroemia japonica, Ligustrum perrottettii, Turpinia cochinchinensis, Berberis tinctoria, Vacciniumneil gherrense* mark the edges of the shola or ecotone region. Herbs, shrubs include *Moonia heterophylla, Jasminum bignoneacium, Smithia blanda, Valeriana hookeriana* and a few species of *Strobilanthes*. The hill top flora is somewhat varied from that of the Nilgiri hill which owed to the low altitude and lacks alpine species as *Rhododendron, Rhodomyrtus, Gaultheria* and *Mahonia* (Sharma *et al*., 1984).

The undergrowth in the shola is represented by *Strobilanthes* sp., *Impatiens phoenicea, I. coelotropis, Psychotria congesta, Viola patrinii, V. serpens, Arundinaria densifolia. Aerides ringens, Coelogyne nervosa, C. mossiae, Eria dalzelli, E. pauciflora,* and *Schoenorchis filiformis*. The common climbers are *Piper schmidtii, Rubia cordifolia,* and

Connarus wightii. Rapanea capillata, Vaccinium leschenaultii, Impatiens tangachee, Sonerila grandiflora, Osmunda regalis and *Eurya japonica* are usually found along streams.

The species diversity of shola forests is only analogous to that of moist deciduous or semi-evergreen forests and never reaches closer to that of evergreen forests (Swarupanandan *et al.*, 1998). The members of the family Lauraceae, Rubiaceae, Symplocaceae, Myrtaceae, Myrsinaceae and Oleaceae are dominated in the Overstory species, while Asteraceae, Fabaceae, Acanthaceae are dominated forest floor species (Davidar *et al.,* 2007; Swarupanandan *et al*., 2001). Dominant monocot species in this region include members of Poaceae, Orchidaceae and Cyperaceae (Swarupanandan *et al*., 2001). Species were found along the edge-interior gradients of shola are extensively influenced by soil moisture (overstory and understory) and soil nitrogen (understory only) (Bunyan, 2009).

1.4.1. Montane grassland

Grasses are the fourth largest group of flowering plants, globally represented by 10,550 species under 715 genera (Pathak, 2013). India is having 240 genera and 1,200 species growing which shows highly valuable grass diversity in India (Parmar *et al.,* 2012). Grassland ecosystems dominated by graminoids (i.e., grasses and sedges) that perform ecological functions including the maintenance of biodiversity (Tyagi *et al.,* 2010). Graminoids are divided into three families, *viz*., Poaceae or Gramineae commonly known as 'true grasses', Cyperaceae 'sedges' and Juncaceae 'rushes'. They are cosmopolitan and main components of most degraded land and grassland ecosystems. The grasslands commonly called the prairies, the steppes, savannas, savanna woodlands (Swarupanandan, 1998). Grasses play a very important role in ecosystem, used as forage for domesticated animal and soil conservation, many of the cereal grasses considered as the staple food for human beings, grass like *Cymbopogon* sp., *Cyanodon* sp. are used to cure many diseases (Ahmad *et al.,* 2009). Based on these uses these landscapes are very significant and valuable.

The montane grasslands in the Western Ghats are placed on the high plateau (above 1800 m) of the Nilgiri's, Annamali, Palni's, Bababudangiris and Caradomum hill ranges and are composed of *Imperata cylindrica, Arundinella setosa, Chrysopogon hackelii, Eulalia trispicata, Themeda triandra* and *Jansenella griffithiana*. Angiospermic herbs and shrubs like *Hypericum japonicum, Osbeckia leschenaultiana, Gaultheria fragrantissima, Rhusfair holmianus, Phlebophyllum kunthianus, Anaphalis aristata, Strobilanthes kunthianus, Rumex nepalensis, Exacum bicolor, Lilium neilgherrense, Lobelia nicotianaefolia, Polygala siberica, Striga asiatica, Walhenbergia gracilis, Crotolaria notonii, Knoxia mollis, Indigofera pedicellata* and several Acanthaceae and Lamiaceae members. Another characteristic species growing in these grasslands is *Phoenix humilis* (Rao, 1997). The stunted evergreen forest juxtaposed with grasslands forms a vegetation creates a landscape of interest to ecologist and biologists (Nagendra and Utkarsh, 2003). The soil depth is very less in grasslands and it is somewhat more in the valley than in slopes (Sringeshwar *et al*., 2006). Soil inside the shola forest holds twofold moisture than that of the surrounding grasslands (Thomas and Sankar, 2001). The availability of nutrition is differed in shola and grasslands. Macronutrients like N, P, K are more in shola forest, (Bunyan, 2009). The soil is calcium deficient in grasslands, which is derived from the parental rock *viz*., Gnesis, charnockites and schists (Ranganathan, 1938; Sukumar *et al.*, 1993). The wind velocity is very high in these areas. The association between mean annual temperatures and monsoon may have serious effects on the grasslands in the face of global warming (Sukumar *et al.*, 1993). Grassland works exactly opposite to the forest. In forest plants grow in deep shade, grassland plants do not need shade. In forest, leaves decompose quickly, whereas grassland plants decompose slowly. The fire destroys the forest, which helps to maintain the structure of grasslands. Both systems are interdependent on fire in different manner (Bond and Parr, 2010).

The important mountain peaks in the Western Ghats of Karnataka are Mullayyanagiri, Bababudangiri, Kemmannugundi, Kudremukh, Pushpagiri and Brahmagiri. This region has 325 globally threatened species available (Prajapati, 2010).

1.4.2. Community composition of the montane grasslands

Shola-grassland ecosystem are ironic store houses of biodiversity and home to wildlife. Plant species in these grasslands community compositions influenced by the environmental and soil factors like depth of soil, presence or absence of rocks and boulders, grazing and burnt condition, forest edges, rocky and non-rocky slopes, edaphic factors, microclimatic conditions, rainfall also determines the vegetation composition (Pemadasa, 1990; Lekhak and Yadav, 2012; Thomas and Palmer, 2007). The members of Asteraceae are dominant in the grasslands of the hilltops, genera like *Anaphalis, Conyza, Gnaphalium, Gynura, Artimesia* and *Senicio* are limited to the high altitude grasslands (Kunhikrishnan, 1995). Most of the earlier botanist classified these grasslands based on dominance of certain grass *viz*., *Eulalia, Phaeothrix* and *Dicanthium polyptychum* dominated grasslands (Thomas and Palmer, 2007). There has not yet been a thorough account of the plant species of the montane grasslands, some of the surveys made by (Shetty and Vivekanadan, 1971) explore a number of endemic species. The grasslands are a conservation priority, because of high endemism and harbors ephemeral plants associated with the sky island conditions of mountaintops (Karunakaran *et al*., 1998). Plant species are adapted to with stand extreme environmental conditions as they show adaptation to live on a substrate for water accumulation such as succulence and carnivore because of lack of nutrients like nitrogen, in the soil; some shows modification in roots (tubers, bulbs, runners). These plants also show

high metal tolerance, which are called as metallophytes (Jacobi *et al*., 2007). They have a very restricted geographic distribution and usually rare and endemic.

1.4.3. Phytogeography of shola and grassland species

The phytogeographic study of forest- grassland ecosystem, by Meher-Homji (1967) found that in montane forest the species in the shola originated from tropical regions, whereas in grasslands the species are of temperate or subtropical origin. Frost-induced stress explained the distributional patterns in these biomes. Ground frost avoids tropical species establishing in open grasslands but some succeed in establishing are the temperate frost adopted species (Meher-Homji, 1967). The biogeographic study shows that grasslands' species of the Western Ghats show more biogeographic resemblance with Western Himalayan species than Sri Lankan montane forest species (Karunakaran *et al*., 1998).

1.5. Threats and status of conservation

Grasslands all over the world are among the most threatened ecosystems due to translation for cropland, habitat degradation often from overgrazing, exotic species invasions, and woody encroachment (John *et al.,* 2011). The increase in the intensity of land use has resulted in several threats to the biodiversity of the Western Ghats (Pramod *et al*., 1997). Most of these grasslands transformed into summer holiday resorts with an unconstrained and blooming tourism industry (Dharmalingam, 2004) and the frequency of forest fires has increased threefold (Karunakaran *et al.,* 1998; Rawat *et al.,* 2000). The grassland ecosystems has been subjected to particularly intense pressure for the upcoming tourism activities, so current extinction rates of grassland species are expected to remain high or even increase.

These montane grasslands of Karnataka are exposed to threatening conditions due to encroachment, ecotourism, construction activity, grazing, and firing, home stays and various

other activities. These grasslands have very valuable medicinal plants, taxonomically important herbs and grass species. Due to the above-mentioned activities montane grassland communities becoming rare due to anthropogenic activities, many of these are endemic to this habitat. Hence, present research work has been carried out to explore the herbaceous plants and grass species communities present in sholas of central Western Ghats of Karnataka.

AIMS AND OBJECTIVES

Research on diversity and distribution of herbaceous plant communities that lie in montane grasslands scantly worked out in the Western Ghats. As these studies investigate diversity of plant species and their distribution, understanding the community patterns is essential to know the functions of ecosystem and management of resources. The principal aim of the present research work is to explore and document the information on diversity, distribution and dynamics of wild herbaceous flora in grasslands of Bababudangiri and Kemmannugundi shola vegetation in central Western Ghats, Karnataka. Hence, the present study was undertaken with the following objectives:

- To make a study on diversity of herbs and grasses of Kemmannugundi and Bababudengiri shola ecosystem
- To study the population biology of herbs and grass communities
- To analyze the pattern of distribution of herbs and grasses in sholas

2.0. Review of Literature

2.0. Studies on biodiversity

The term 'biodiversity' is a simple contraction of 'biological diversity' which comprises a broad spectrum of biotic variation, from genes to ecosystem variation (Purvis and Hector, 2000). Species diversity seems to be the most straight forward concept of the constituents of biodiversity than the other two constituents *viz*., genetic and community diversity (Palmer, 1995). The biological diversity is the variability among living organisms from all sources and the ecological complexes of which they are part and includes diversity within species or between species of ecosystems (Anon., 2002). Biodiversity reveals at three levels Species diversity, genetic diversity and ecosystem diversity (Anon., 2007). Biodiversity supports life on the earth and contributes in numerous ways to our existence.

Biodiversity hotspots are defined as areas including exceptional concentrations of endemic species and facing exceptional loss of habitat. Myers (1988) identified ten areas based on certain characters like high level of endemism, experiencing rapid rate of depletion. Threatened hot spots in tropical forests contain at least half of the earth's species. They are depleted faster than any other biome. India is the chief hotspot in terms of endemics. Tropical forests in India are restricted to the Southern Himalayan region and the Western Ghats. The Western Ghats are considered as one of the 18 mega biodiversity center of the world and one of the biological 'Hot spots' of the world along with Srilanka. These forests are unique ecosystem due to their rich plant and animal diversity (Myers *et al*., 2000).

The 25 hotspots of the world have been reorganised to 34 hotspots with the list of nine new hotspots in the great range of the Himalayas and recently the island nation of Japan. Among 34 hot spots, four are present in India. Eastern Himalaya, Indo-Burma, Western Ghats and Sri Lanka and Sundaland located in Nicobar Island. These 'Hot Spots' together

have about 5330 endemic species including flowering plants, mammals, reptiles, amphibians and butterflies (Khandekar and Srivastava, 2014)**.**

2.1. Floristic studies

Champion and Seth (1968) categorized the forests of India into 16 types. Three mega centres of endemic plants in India are (i) Eastern Himalaya (ii) The Western Ghats and (iii) Western Himalayas. They considered the Shola to be a unique type of vegetation belonging to the southern montane wet forests. Singh and Misra (1969) have studied the diversity dominance, stability and net productivity in the grasslands at Varanasi and speculated that, in the ecosystem, species diversity increases productive efficiency and makes the system stable. Rao (1978) analysed the floristic patterns along the Western Ghats of India, They selected eight areas along 1200 km from north to south. The forest changes from increase evergreen to reduction in deciduous forest. They observed various floristic patterns along with high rate of endemism in these areas. Raghavan (1981) classified the vegetational types of Agumbe forests into three types depending upon altitudinal range namely forest from the foot of the Ghat (100 m) to crest (400 m) Ghat crest region from 400 to 750 m sparely clad grasses hill tops (750 to 900 m). He also described the horizontal distribution of the forest, aquatic and semi aquatic flora, lianas, orchids in Agumbe region of Karnataka.

Gentry (1988) worked on changes in plant community diversity and floristic composition on environmental and geographical gradients. They found that forests on the three continents are similar in plants species richness and floristic composition but they are differing in structure. The floristic composition and diversity of tropical forest plant communities seems to be strong and evidence that these communities are at ecological and evolutionary equilibrium.

Floristic composition and distribution in the Western Ghats region was analysed by Pascal (1991). Three main climatic gradients leading the Western Ghats region, these climatic gradients effects on the distribution of the evergreen forest types. They studied the distribution of species in different forest types with reference to their relative importance and relative importance of the families. They compared the species richness with other tropical rainforests and also mentioned about the percentage of endemism.

Rao (1997) worked on the vegetational diversity of ten biogeographic zones of India. Fifteen thousand species of flowering plants were estimated out of 5000 species were endemic. Phytogeographical features of India have contributed to the diverse floristic composition.

Bhatt and Ghate (2000) studied on herb species diversity of the Western Ghats of Karnataka in different forests. They carried out sampling of herb species diversity from nine different vegetation types (both manmade and natural). They enumerated all herb species and individuals in equidistant quadrats placed alternatively on both sides of the 60m long line measuring the quadrat size of 1×1 m. They found the higher species richness in the semi-evergreen forest while lowest in deciduous forest.

Higher plant species endemism in the Subansiri Indian hotspot in eastern Himalayan region was investigated by Behera (2002). He has regularly sampled the various forest types to map bio rich areas. The species was observed to be evaluated for their endemic status in one of the important hotspot regions of the world. A total of 122 plots sampled randomly in various forest types and 764 plant species recorded and 59 endemic species were mentioned.

Joshi and Janarthanam (2004) carried out the floristic survey of endemic plants of the Western Ghats, they have reported 113 endemic species. Life-form analysis reveals that

herbaceous plant were the most dominant followed by trees, shrubs and climbers. They also observed the flowering phenology of the endemics and correlated the factors that affecting phenology.

Rao *et al.* (2005) documented about 232 species of herbs, shrubs, climber and other smaller plants among different habitats of Sharavathi river basin in Shivamogga. The study observed high rate of endemism in grasslands, evergreen and semi evergreen forests in and around various water shed areas due to anthropogenic pressures resulting in loss of the valuable endemic species.

Sringeswara *et al.* (2006) studied the floristic diversity of Kudremukha National Park. The study accounted that a total of 897 species including 12 sub species and 34 varieties belonging to 125 families. The Fabaceae is the dominant family in the study area which represented 38 genera, followed by Orchidaceae and Rubiaceae. Herbs were the dominant forms with 316 species followed by trees (277 species), climbers and creepers (127 species).

Behera and Misra (2006) have investigated that the floristic and structure of herbaceous plant communities in four vegetations of recovering forest in Eastern India by lying fifteen 1×1 m quadrats randomly placed at each stand for analysis. They recorded 87 species belonging to 71 genera and 32 families. Study revealed that more number of species found in 2 year recovering stands.

Davidar *et al.* (2007) investigated the floristic study of woody plants in a tropical montane forest in the Palani hills of the Western Ghats. They placed twenty 30 × 30 m plots for vegetation sampling. The sampling was sufficiently conducted for the species diversity in shola forest. A total of 2279 stems belonging to 83 species were inventoried, of which 16 species belongs to lianas. Thirty per cent of the species were endemic to the Western Ghats.

They proposed that montane evergreen forests are unique to higher elevation of the Western Ghats.

The Western Ghats of India and Sri Lanka shared the biogeographical history and considered as a one unit. Certain faunal components are particularly found in the wet zone. Gunawardene *et al.* (2007) studied the brief history of the Western Ghats and Sri Lanka biodiversity hot spot. They collected the existing information regarding species richness and endemicity of species in both the regions.

Bhatt and Purohith (2009) analysed the floristic structure and phytodiversity along the elevational gradient in temperate Himalayan forest region. Tree species richness decreased from lower to higher whereas species diversity and dominance inversely related each other. They collected 177 species, where herbs were dominant than the other groups.

Bond and Parr (2010) had examined that the ecological diversity and conservation of the grass biomes. They have observed that high biodiversity value for grassy biome in contrast to tropical forests. The study also illustrated that importance of fire in maintaining the shola grasslands systems and also discussed about major threats to biodiversity in these regions including land clearance and consequences of elevated CO_2 for forest expansion.

Ram *et al.* (2010) worked on ecology of medicinal plants in Uttarkhand, Himalaya. The ecology and biodiversity of medicinal plants were analysed in six different sites. These forests were mainly dominated with Oak. Herb layer was studied for species richness and other vegetational parameters. Twenty 1×1 m quadrats were laid down for vegetational analysis. They enumerated 95 herbs in different sites. The higher species richness was found in Oak-pine mixed forest and minimum in Oak dominated mixed forest.

Irwin and Narasimhan (2011) reviewed the endemic genera of angiosperms in India. They have resolved that only 49 genera are endemic to India, which are specific to that locality. Peninsular India harbours the high concentration of endemic genera. Seventy one per cent of the genera are herbaceous and their concentration is more in wet evergreen forests and grasslands. They have recommended that there is an urgent need for a taxation based on current IUCN criteria.

Plant diversity and regeneration in response to anthropogenic disturbance along altitudinal and horizontal transect in the scared forest of Vaishno Devi hills of Jammu and Kashmir (Koul *et al.,* 2013). Based on altitudinal gradient they divided the study area into three stands. Sampling was done by systematic stratified sampling with uniform spacing both vertically and horizontally. They found that highest species density by increase in altitude and lowest in lower altitude. Anthropogenic disturbance level decrease with increases altitudinal gradient.

Kensa and Pramila (2014) studied on floristic structure, phenological and life form analysis of Vilathivilai and Pazhavilai. Sampling was done in monthly intervals. A total of 60 plant species belonging to 32 families were documented. Life form spectrum discovered that therophytes were more dominant followed by chameophytes, geophytes, phenorophytes and hemicryptophytes. Therophytes were higher than the normal biological spectrum which indicated that study area under biotic pressure. Phenological events occur during the post summer season and in the early monsoon. The phytosociological study on grasslands of Rajasthan was conducted (Krishna *et al.,* 2014). Sampling was done by stratified random sampling method by laying 515 plots and collected 375 species.

2.2. Earlier exploration on floristic diversity of Karnataka

Earliest published report on the floristic diversity of Karnataka was by Gamble in his Flora of Presidency Madras (1915-36). Raghavan (1970, 1983) has systematically studied the Flora of Agumbe-Thirthahalli region which form a part of Western Ghats range. Studies on vegetation of many districts and establishment of local floras were conducted by Ramaswamy and Razi (1973) published the flora of Bangalore district. Flora of Hassan district was demonstrated by Saldanha and Nicolson (1976). Yoganarasimhan *et al.* (1982) published the flora of Chikkamagaluru district. Saldhana (1984) accounted the Flora of Karnataka. Sharma (1984) analysed the flora of Karnataka analysis. Ramaswamy *et al.* (2001) published the Flora of Shivamogga district. Flora of Udupi was explored by Bhat (2003). Gowda (2004) has check listed the plant wealth of Sringeri in Vanaspathi Kosha. Ramachandra *et al.* (2005) studied cumulative impact assessment in the Sharavathi river basin and reported about 215 species of herbs, 143 lichen species, 134 butterfly species, 84 ant species and 140 avian species. Dewakar and Singh (2009) identified *Canscora sanjappae* (Gentianaceae) a new species from Mookambika Wild Life Sanctuary, Karnataka, India. During the course of floristic studies in the Mookambika Wild Life Sanctuary they collected specimen of *Canscora* Linn., from Hadangundi forest. Sukumar and Shankar (2010) have prepared a study report on biodiversity of the proposed Gundia Hydro Electric Project, Karnataka and enumerated the number of species, endemic flora and fauna also recorded. Malpure (2010) has contributed the flora of Belgaum district-Dicots and Chandroe (2010) has Flora of Belgaum district - Monocot. Punekar and Lakshminarasimhan (2011) published the flora of Anshi National Park. Biodiversity study of Kodachadri hills was studied by Bhat and Prasad (2013). They enumerated the flora, fauna, amphibians and reptiles from the shola forest of Kodachadri. Flora of South Kanara by Bhat (2014) includes the plant collections from Udupi and Dakshina Kannada.

There are very less botanical explorations carried out in Chikkamagaluru, Shivamogga and Coorg. Lawson and Enres (1888), Meebold (1911) and Rottler (1749-1836) made a very few collection around Bababudangiri mountain. Buchanan (1800-01) visited the some parts of the Kodagu and his observations were published in 'A journey from Madras through the countries of Mysore' in 1807. Law and stock not only explored the Uttara Kannada and Belgaum and explored the Bababudan range also. Talbot (1882-1896) made collection from Bababudan range.

Mukhopadhyay *et al.* (1997) studied the structures in the banded iron formation of the South eastern Bababudan hills, Karnataka. The study displayed the macroscopic synformal bend with in these area forms the horse shoe shaped regional folds which encompasses the entire Bababudan range. The quartz layer appears to be more competent than ferruginous layer in this area. Ramachandra *et al.* (2013) have explored the status of forest in Shivamogga district, Karnataka. They discussed about vegetational types and mentioned a few species occur here.

2.3. Studies on shola forests and montane grasslands

The Western Ghat mountain range, that runs north-south parallel to the western coastline of the Indian Peninsula. The range is classified (based on species distributions) as a distinct bio- geographic zone of India (Rodgers and Panwar, 1988). The montane grasslands and adjacent evergreen tropical forests of the Western Ghats form a distinctive vegetation mosaic. Grassland and forest habitat forms a natural complex (Suresh and Sukumar, 1999). These forests are wet evergreen montane forests and are categorized as southern montane wet temperate forests (Nair and Khanduri, 2001).

The floristic studies of the Shola are very scanty or limited data available from the earlier floristic investigations *viz*., Wight's (1835-1853) Icones Plantarum Indiae Orientalis, Hooker's (1872-1897) Flora of British India, Gamble (1915-1936) Flora of the Presidency of Madras and other regional and local Floras. At first, Fyson (1932) has studied floristic account on the shola forests of South Indian hill stations. The grasslands of the Western Ghats represent contrasting conditions of topography, climate, soil and vegetation. Due to the influence of fire and grazing these grasslands forms secondary serial stages which may be very stable pre-climax (Bharucha and Shankaranarayan, 1958). They studied the grassland associations and successional study and the results revealed the climatic climaxes, major associations, ecological factors of the soil which manages plant associations and the factor which brings succession. Later, the flora and vegetation of the shola forests of the Palinis near Kodikanal and were studied by Gupta (1962). The flora of Nilgiris was made by Sharma *et al.* (1977). Floristic account of the shola forests of Kerala is due to the innovative studies of Sebastine and Vivekananthan (1967). Endemic and endangered plants of high ranges were studied by Shetty and Vivekananthan (1991).

Montane grasslands are placed on the high plateau covering the tops of hills. The valleys of hills have forest with stunted evergreen trees. The co-occurrence of two distinct vegetation types creates a landscape of interest. They are resistant to frost. Ecotone species supported the establishment of fire tolerant species in the interior of the forest (Ranganathan, 1938). Frost and soil factors have been the important determinants in maintaining and stabilizing the swampy upland Savanna of Sandynallah (Vasanthy, 1988).

Phytogeographical studies of the shola ecosystem was studied by Meher-Homji (1967). Shola species shows two principle floristic elements: tropical and temperate. The species of shola were originated from tropical regions, woody species along the border of

shola are originated from subtropical to temperate origins. The distribution pattern was mainly explained by the forest induced stress.

Shola grasslands are classified into communities based on dominant of certain grass (Gupta, 1967). Blasco (1971) gave an account of flora and ecology of sholas of the Western Ghats. Grassland is related to environmental and soil factors, like depth of soil, presence and absence of rocks, grazed and burnt condition, edge effect, rocky slops (Karunakaran *et al.*, 1998). Based on these characters grasslands harbours the number of endemic species studied by Shetty and Vivekananthan (1971). Tanner (1977) has carried out quantitative characterization of floristic and other ecological attributes in four montane rain forests of Jamaica.

Pemadasa and Dombois (1979) have conducted the ordination study of montane grasslands in Sri Lanka. The ordinations were made by reciprocal of higher plant and soil microfungal data reaffirmed. Ordination of species showed the ecological affinities of both higher plants and soil micro fungal characteristic different sholas.

The study on comparative ecology, structure, dynamics and productivity of grasslands in Asia and highlighting on those of Sri Lanka and Indian tropical grasslands was evaluated by Pemadasa (1990). According to this study tropical grasslands of Asia are maintained because of continued biotic pressure, differences in major nutrients, seasonality of rainfall. These may prevent the development of woody vegetation.

Floristic composition and structural features of tropical montane rain forest were surveyed along latitudinal gradients in South and East Asia. Gradual changes in floristic composition and structure along both altitudinal and latitudinal was observed by Ohsawa (1991). Similar results were observed by Binu *et al.* (2011) in Mannavan shola forest in southern India. The species diversity greater in the low altitudinal gradient, followed by the

middle. The similarity index revealed that the middle and higher altitudes have more similar species than lower 20 per cent of species are unique to shola and are endemic to southern Western Ghats of Kerala.

Sukumar *et al.* (1995) have studied on climate change and its impact on tropical ecosystem in southern India. The association between mean annual temperature and monsoon may have serious effects for the grasslands in the face of global warming and also expected that increase in temperatures would favour C_3 Plants and enhances the photosynthetic rates. Higher temperature decreases the colonize of C_3 plants.

Chandrashekara (2004) assessed vulnerability and climate change impact on the vegetation structure and composition in wet evergreen and shola forests of Kerala part of the Western Ghats. The effect of plant diversity on ecosystem functioning in montane European grassland was explored by Kahmen *et al.* (2005), they selected 78 sites and tested the effect of various measures of diversity and plant community composition on productivity. The study illustrated that simple measure of biodiversity such as species richness was the weak predictors for productivity in these grasslands than environmental variables and management parameters.

Sholas (tropical montane forest) exhibit high endemism and several species are restricted to slight elevational bands (Ricketts, 2005). The pollen analytical investigation of hanging peat bogs in the Soummit zone of south east Poland was studied by Ralska *et al.* (2006). There is an absence of upper montane spruce zone in the Bieszczady mountains it shows that last millennium or earlier days were stable. The formation of the montane grasslands in these mountains was due to the effect of human activities (Holowkiewicz, 1885).

Shola grassland forests are affected by climatic changes. Forests expanded and contracted in response to climatic fluctuation. In the drier period grasslands are expanded from 30 to 18 kyBp, where as in more humid period 10 kyBp, the adjacent forest expansion was occurred between 18 to 10 (Caner *et al.,* 2007). Expanded shola preferred to gather more number of species due to area effect, therefore species diversity also increases. These forests covered by limited habitat so and hence measured high level of endemism. Island biogeography predicts that species extinctions could also be higher in insular montane forest patches (MacArthur and Wilson, 1967).

Thomas and Plamer (2007) reviewed some of earlier works *i.e.,* habitat heterogeneity, landscape configuration, natural disturbance, grazing and productivity in maintaining the grasslands. They mainly concentrated grasslands part of sholas and did not trace upon forests or varied taxa residing them. The biogeographic evaluation indicated that montane grasslands in the Western Ghats are similar to Western Himalayan region.

Ecology of a montane grassland on five hill sides in the Sri Lanka was investigated by Pemadasa and Amarasinghe (1982). They used association analysis and reciprocal averaging ordination for this investigation. They found that vegetational and environmental diversity within the grassland is considerable but in different hillsides diversity was distinct and primarily depends on the elevation, altitude, climate, soil and degree of human interference.

Bunyan (2009) studied that the edge effects in a forest-grassland ecosystem mosaic in Southern India. In the floristic structure and diversity of a tropical montane evergreen forest of the Nilgiri mountains, southern India was studied by Davidar *et al.* (2009) in 19 montane evergreen forests (Shola's) 30 × 30 m plots randomly. They recorded 87 species most of the species are commonly distributed in these sholas. It shows the same biogeographical tradition. These sholas are in endangered and need to be conserved.

Mohandass and Davidar (2010) investigated the relationship between area and vegetation structure and diversity in montane forest patch in Southern India. They are patchy and closely put next to grasslands. They have tested the expansion phase of sholas and recorded non-climbing plants from 18 sholas. Species richness, basal area and proportion of large trees increased with shola size.

Bera *et al*. (2012) investigated that the evidence of degradation of shola forest in south Indian montane hills through palynological studies. Sedimentary profiles from Annamalai hills was documented through retrieved pollen from sediments and modern surface samples like moss cushion. Pollen diagram shows that around 1500 years BP. The land was covered by treeless but the presence of non-arboreals like *Strobilanthus, Impatiens, Senecio* and *Heracleum.* These species were closely associated with existing forest in Southern India. The study demonstrated the existence of shola woods under arid climate during the period and also occurrence of fungal spores indicated the biological degradation of microbiota during the time of deposition.

The living fossil shola plant community is under threat in upper Nilgiris was studied by Jose (2012). Nilgiris are the component of the Western Ghats range in India. They are one of the hotspot of world, harbours the rare and endemic species. Sholas are non-regenerating and fast disappearing and are dying community so they are called as living fossil.

The review on the shola (tropical montane forest) - Grassland ecosystem mosaic of peninsular India was done by Bunyan *et al.* (2012), they examined the structural, functional and distributional aspects of shola forests of peninsular India. The species present along the edge of the shola are called as ecotone species. Edge effect may influence on small fragments and make them completely susceptible to collapse.

Saravanan *et al.* (2014) studied the influence of forest fire on floral diversity of the degraded shola forest ecosystem. The chemical, biological and physical properties of soil were altered by the fire and also it inducing the vegetation pattern. The effect of fire on the plant diversity of the area in different periods after fire and after monsoon was studied using quadrate method. They analysed that severe effects of fire on the trees in the vegetation than herbs and shrubs. After the monsoon, herbs and shrubs regenerated in burned areas and regular influence of fire seriously affect the vegetation.

2.4. Seasonal variation in herbaceous plants

Burbanck and Platt (1964) evaluated the granite out crops where they found 76 species of plants from 40 islands. The flora present in those communities was distinct from surrounding vegetation. Pattern of seasonal succession in a small isolated rock ground in Nigeria was studied by weekly intervals and species was estimated by counting all individuals.

Singh and Yadav (1974) studied the variation in composition, plant biomass and net productivity in tropical grassland at Kurukshetra. The phytosociological values of the species were studied in monthly intervals. Most of the species were found to be evenly distributed. The distribution of above ground mass and individual species showed that different species dominated in different months and seasons. The net productivity of above ground mass found to be maximum during rainy season and below ground in winter season.

During the initiation Island was covered by ephemeral plant species latter it was replaced by perennials (Isichei and Longe, 1984). Herbaceous plant occurs on granite, limestone, dolomite, sand stone, chert, rhyolite and other rocks types are endemic taxa. These are restricted because of availability of chemical, biological, physical element found in these rocks, not elsewhere (Baskin and Baskin, 1988).

Krieger *et al*. (2003) have worked on species turnover of ephemeral plant communities in seasonal rock pools in Ivorian inselbergs. They observed 200 rock pools between 1990 to1999. Mean turnover rate was found to be 0.19 (17%). Species turn over increases with soil depth and area. No correlation was observed between turn over and number of species in a pool, climatic disturbances influences on the community dynamics. Ephemeral pools are isolated habitats which are dry landscape matrix and are characterized by extremely variable conditions like fast desiccation, rehydration, long dry season, high temperature, nutrient shortage and highly adopted to stress full condition. Plants show anatomical physiological and biochemical adaptations (Heilmeier *et al.*, 2005).

Species composition of ephemeral flush communities on pleotropical rock outcrops was observed by granitic and gneissic inselbergs and ferricretes are characterized by extreme environmental conditions, these inselbergs are differs from surrounding vegetation. They harbour the different plant communities. Ephemeral flush communities are prominent, highly seasonal and are specialized annual species. Plant communities in this region are indicators of nutrient poor and seasonal wet localities (Porembski *et al.*, 2005).

Jacobi *et al.* (2007) made studies on the plant communities on iron out crops which are present in diverse and endangered Brazilian ecosystem. They were collected 234 plant species belongs to 64 families. These areas are rich with dicots, some of these species play an important role in community organising and most of the plants communities are related to the micro habitats depend on the amount of soil and moisture retention topographies.

Muller (2007) has studied the herbaceous vegetation of seasonally wet habitats on inselbergs and lateritic crusts, their vegetation is fairly uniform and differs from surrounding vegetation. The study shows that slight variation in ecological situations resulted in a variety

of plant communities. Evolution from herbaceous carpets to woody vegetation in tropical inselbergs was not adapted by slope but it was by successional (Sarthou *et al.*, 2009).

A geographical study of wild flowers on Kas plateau (Satara district) was done by Anita and Awati (2011). They explored rich biodiversity of Kas and undertook several field trips to Kas plateau in rainy season from June to September and observed number of wild flowers from shrub, climber and they mentioned that shrinking of Kas plateau is due to human activities like ranching, herding and tourist arrivals. They suggested that an urgent need to conserve biodiversity of this region. Also, angiosperm diversity of Kas reservoir from Maharashtra was explored by Panwar and Sonawane (2012) they observed 94 plant families and assessed that dicot families dominate over monocotyledons.

Bhattarai *et al.* (2012) studied the endemic plant diversity on the Kas plateau of Western Ghats. They surveyed the floristic diversity of Kas plateau by conducting several field trips during the monsoon seasons. They divided the plateau into two types *viz.*, mesoscale and microscale distributions, where they recorded the major ecological zones and seasonal habitat defined by hydro geomorphic content. They also found that 100 phytogeographically significant plant species on the plateau top, comprised in 43 genera from 26 families.

Rocky plateaus in the northern Western Ghats and Konkan ranges are specialized habitats. These plateau harbours the microhabitats with characteristic assemblage of species. The distribution of plant species is dependent on microclimate and edaphic features. They show high species richness and diversity. They also harbour the large number of endemic flora and fauna (Watve, 2013).

2.5. Studies on grass exploration

Grasses are the fourth largest group of flowering plants, 10,550 species were globally represented under 715 genera. In India 1334 species with 261 genera were recorded (Pathak,

2013). Bahadur (1921) prepared a guide to study the grass of South Indian hills. He collected hundred grass species which are wide distributed in the plains of South India. Augustine *et al.* (1998) estimated 163 species of grasses including bamboos from Periyar Tiger Reserve. Vasanthakumari *et al.* (2010) have enumerated 67 grass species belonging to 48 genera and nine tribes from Bhadra Wild Life Sanctuary, Karnataka. Gad (2007) studied the family Poaceae and explored 155 species and five varieties of grasses for the state of Goa. Assessment of grass diversity in the Mizoram was also carried out (Lalchhuanawma and Lalramnghinglova, 2010). A total of 22 species under 19 genera were collected from disturbed sites, where as in undisturbed sites four species belongs to three genera were reported. Tyagi *et al.* (2010) studied the floristic diversity of grasses and associated vegetation from three grasslands of Gujarat.

Quantification of grass cover and species composition of herbaceous plant and weed abundance was studied in grasslands of Corbett Tiger Reserve by laying 50 × 50 cm quadrats (Rawat, 1997). They observed that the highest numbers of species were found in forest grassland edge followed by degraded lands. Parmar *et al.* (2012) assembled 286 species of grasses form different authentic floras of India. Rao *et al.* (2012) explored the grasses of Anshi National Park. They reported 116 flowering plant species belonging to 109 genera and 36 families. They found that Poaceae was the dominant family followed by Scrophulariaceae and Asteraceae.

2.6. Population biology studies

Population biology of the herb *Allium ursinum* L. in northern Germany was observed by Ernst (1979). Population structure and population dynamics were analyzed by investigating germination, flowering, fruiting and number of ovules and mature embryo, seed production, leaf area, bulb growth and number of individuals. Dynamics of undisturbed sub

populations were analyzed by counting number of flowering and non-flowering individuals in three permanents 1 m^2 plot per study area.

Population biology of the genus Viola was studied by Solbrig *et al.* (1980), based on the density of the species. 1 × 1 m or 1 × 0.5 m quadrat was laid. Twenty plants were selected and marked and their features were recorded at weekly intervals. The study showed fluctuation in population size was small compared to the number of individual plants gained and lost in the population.

Jeeshna and Paulsamy (2011) analyzed the phenology of *Exacum bicolor*, where they examined the four variants of *Exacum* on the basis of leaf blade shape in the grasslands of Kannur and Wayanad districts. They observed various phenophases such as vegetative growth, leaf flushing, flowering, with fruit development and fruiting and seed dispersal in monthly intervals during high activity periods observations were made weekly.

Wang *et al.* (2002) studied the distribution pattern, species diversity and life form spectra of plant communities along an altitudinal gradient in the northern slopes of China. They divided eight major plant communities to collect data and laid 75 plots. For the enumeration of herbs 1 × 1 m^2 plot was laid and for shrubs and trees were plotted in 10 × 10 m^2. They found that species diversity and species richness of both grassland and forest are peaked at middle elevational gradient and β diversity indicates that species turnover decreases with increase in elevational gradient.

Fenner (1998) reviewed the phenology of growth and reproduction in plants. They discussed about biotic and abiotic factors and concluded that each stages or phases are a compromise between variety of selective pressure with the presence of pollinators, predators and seed dispersion.

Pushpakaran and Gupta (2014) have showed the new distributional records for the family Cyperaceae in the seasonal water-logged grassland in Madumalai Tiger Reserve. They reported 33 species belonging to 11 genera and described two new distributional records of species Pycreus, in Kerala.

Martinkova *et al.* (2000) described the changes in the phenological patterns of grassland species in relation to the ecological and morphological traits. They found that recorded species cover was probably dependent on species phenological stage and also graminoides and forbs differ significantly between the positions of phenological peaks.

Effect of temperature and precipitation on advanced flowering phenology in semi-arid grassland was evaluated by Lesica and Kittelson (2010). They collected first flowering data for herbaceous broad-leaved species from 1995 to 2008 along an existing permanent transect. The results revealed that flowering phenology may be changing faster and precipitation play a more important role in semi-arid grasslands than humid temperate system.

2.7. Threats to shola ecosystem

Shanker (1997) investigated the causes for depletion of montane ecosystem. Due to numerous human activities and suggested some conservation methods regarding the ecosystem. Swarupanandan *et al.* (1998) studied the shola forest of Kerala. Anthropogenic pressure on structure and composition of a shola forest in Kerala was studied by Chandrashekara (2005). The increasing anthropogenic activities restricted into threat of the montane grasslands and adjacent forest (Pramod *et al.*, 1997). These studies revealed that main force behind the disturbance and degradation of forests is increased human activities.

Exotic and invasive plants may effect on the native forest, due to the allelopathic action of the *Eucalyptus* and *Pinus* inhibits the growth of the understory plants (Jeeva and

Ramakrishnan, 1997). The diversity of exotic plants in this park decreases with increase in the altitude due to severity of climatic conditions (Jhonston and Pickering, 2001). Bear *et al.* (2006) studied on diversity and distribution of exotic plant species in Kosciuszko National Park in south-eastern Australia and they surveyed 18 vegetation areas and collected 154 taxa belonging to 23 families in the mountain zones. All these species were related with anthropogenic disturbance. These species were recorded in disturbed and naturalised areas.

Invasion of native grasslands by exotic woody plants is recognised as a global problem, Srinivasan (2012) studied the exotic shrub invasion in a montane grasslands and the role of fire as a renewal tool for ecosystem function. He established the two paired plots in *Cytisuss coparius* un-invaded and invaded plots, both the plots were burned or unburned by an unplanned wildfire event. Estimation of plant communities was done by placing 1×1 m gridded frame in this plot. He suggested that invasion negatively impacted on the grassland community but did not alter the ecosystem function and fire is an effective tool for controlling the *Cytisuss coparius*.

It is evident from the review of literature that explorations for herbaceous plants and grass species in montane grasslands of Karnataka is very scant. In view of recent changes in landscape and present ecological problems it is highly needed to catalogue and present the status of diversity of herbs in grass lands of montane forest lands. Hence, present research work “Diversity and distribution of herbaceous plant species in montane grass lands of Karnataka” has been carried out. Methods adopted and results are presented in successive chapters.

3.0. Materials and Methods

3.0. Study area

The present investigation has been under taken to study diversity, distribution, population dynamics and status of seasonal variation of herbaceous species in montane grasslands. The materials and methodologies adopted in the present study are detailed here under.

3.1. Description of the study area

This study has been carried out at montane forest areas of Karnataka state. The area is having varied topographs and climate with stunted evergreen forest and grassland ecosystem at Bababudangiri, Kemmannugundi, (Table 3.1 and Fig. 3.1). The altitude varies from 1800-2200 MSL and rainfall here is around 850-900 mm per year. Such areas composed 80 per cent valley forest and 20 per cent of grasslands are referred as shola forests. They are commonly known as montane forest or sky Islands (Plate 1), which are naturally juxtaposed with grasslands. Most of these sholas are considered as a climax type. Montane forest in Western Ghats has high number of endemics and also home for many highly threatened species. These mountains are highly pressurized due to ecotourism or pilgrimage activities.

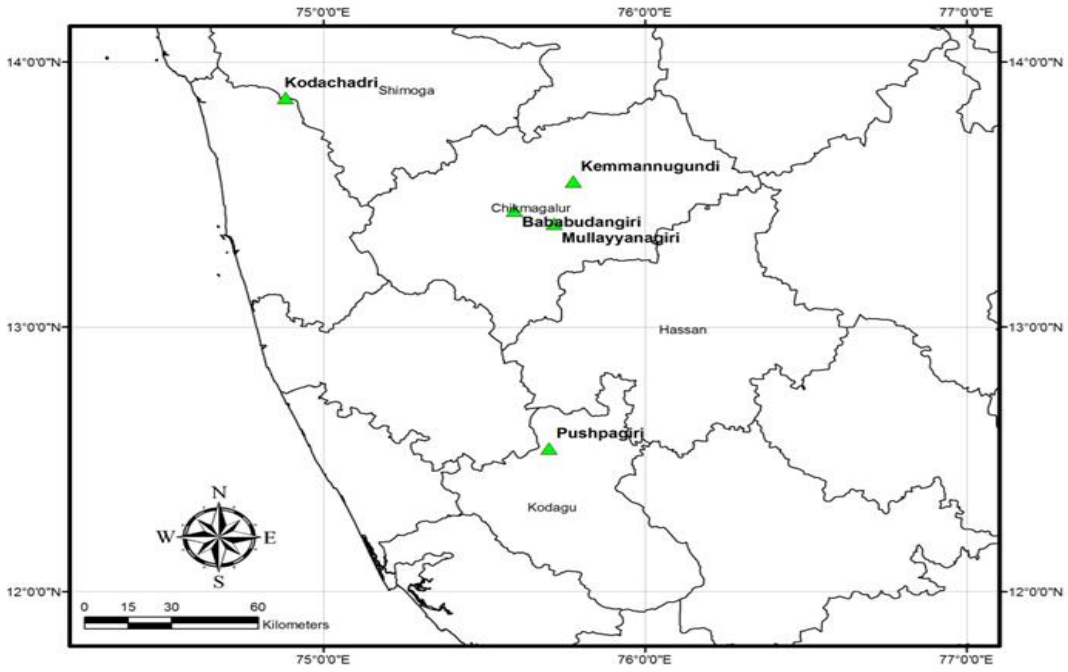

Fig. 3.1. Map showing study areas in montane grasslands of Karnataka.

3.1.1. Topography

The study areas are located in the highland region of Karnataka. Bababudan hill ranges look like crescent shape so the place is known as 'Chandradrona Parvatha'. The topography of this area consists of a chain of mountains with altitude ranging from 750-2100 m. The mountain has the normal elevation of 1000-1700 m. The highest peak in Karnataka and also the second highest in south India called Mullayyanagiri (1900 m) is located in Chikkamagaluru district. The shola forests are of high ecological significance in protecting the headwaters of rivers and has given birth to many perennial rivers.

Table 3.1. Study sites of montane grasslands of Karnataka

Place	District	Latitude	Longitude	Altitude (ft)
Bababudangiri	Chikkamagaluru	13° 25" 41' 47	75° 45" 33' 09	6011-6028
Kemmannugundi	Chikkamagaluru	13° 33" 13' 87	75° 45" 46' 39	4676-4872

3.1.2. Climate

The Western Ghats enjoys a special tropical montane bioclimate. The greater part of Chikkamagaluru district harbors the hilly terrain and this districts is situated in the south interior part of Karnataka, generally affords a pleasantly cool and fairly healthy climate throughout the year. The autumn begins in June and lasts till October. The coldest month is December with mean minimum temperature of 13°C. This minimum temperature occasionally dips below 10°C in high altitude areas. Strong winds, prolonged mist and cloud cover increases the atmospheric humidity and precipitation. Humidity is highest during rainy season-June to October and moderate during summer.

3.1.3. Weather parameters

Chikkamagaluru, districts is the wettest district in the state having an annual rain fall of 98 to 104 rainy days in a year. Heavy and continuous rainfall from June to September is experienced in some years. Highest rains were received by south-west monsoons. Rainfall data of last 10 years (from 2004 to 2013) for this district is collected from Hydronet division, New Delhi, India and Meteorological Department (Fig. 3.2).

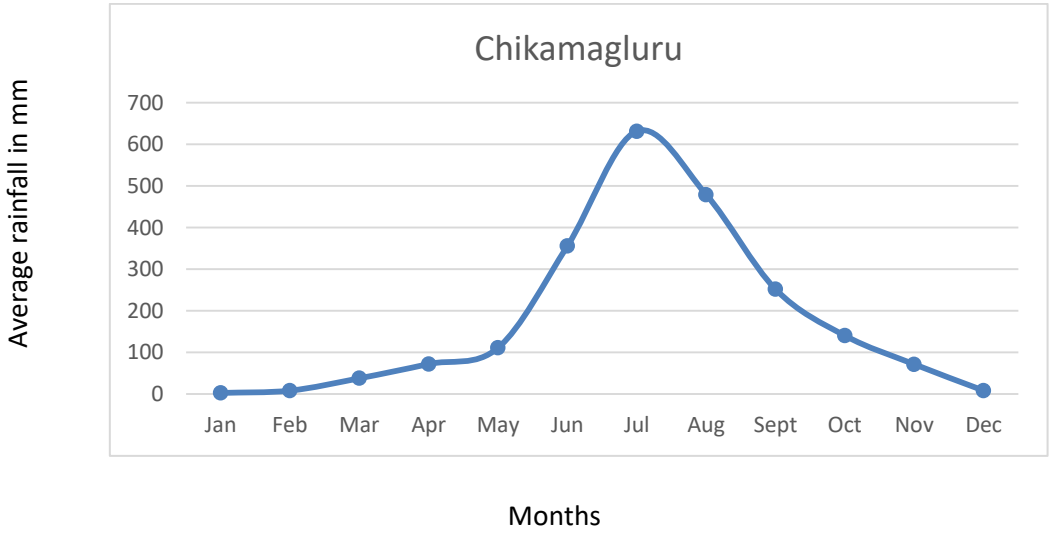

Fig. 3.2. Month-wise average rainfall data from 2004 to 2013 (10 years) of Chikkamagluru district.

3.1.4. Geomorphology

The Dharwar schists occurs in well-defined hill belts of montane grasslands, these schists have iron ores, consists of dark hornblendic rocks, which are associated with ferruginous quartzite and hematite bands. Iron is in the form of banded iron formations, which is limonite (Saldanha, 1984).

3.2. Studies on floristic diversity

Sholas and grassland normally interpose at the higher elevations of 1200 m and above, Champion and Sheth (1968) designated these forest as semi-evergreen forests of type '2A C2' which are commonly called 'Shola forests'. The vegetation includes both tropical and sub temperate mixed together, which comprise conspicuous trees and shrubs such as *Litsea wightiana, L. floribanda, Cinnamomum zeylanicum, Cinnamomum* sp. and climbers like *Piper hookeri* and *Jasminum malabaricum*. The dwarf trees along with bushes of *Strobilanthes, Pteris* and *Potentilla* forms the ecotone region. The dwarfing of the trees looks to be an adaptation to the high winds, isolation and insufficient soil in these regions.

The region above 1500 meters covered by bare hill tops consists of grass, runners and tuberous plants which serve to bind the soil and send up offshoots at short intervals. Species like *Habenaria longicorniculata, H. heyneana, Satyrium nepalense, Launea acaulis, Hypoxis aurea* and *Curculigo orchiodes* are the important herbaceous plants. Some of the important grass species are *Arundinella pumila, Themeda triandra, Chrysopogon hackelii* and *Eulalia trispicata*.

3.2.1. Study on the vegetation composition of the montane grasslands

3.2.1.1. Field survey for studying diversity of herbs

A thorough survey has been conducted to assess species diversity and distribution of herbaceous plants in Bababudangiri and Kemmannugundi shola grasslands of Karnataka during the period of October 2012 to March 2015 in selected study sites. All the herbaceous plants and grass species were recorded with in the representative quadrats. Similarly, the

plants found along the marshy areas, forest edge, on rocks that could not occur within the regular quadrat area were randomly observed, recorded and included arbitrarily.

According to Bhatt and Ghate (2000), enumeration of herbaceous plant species in the Shola grasslands were done by laying, 60 m long transects with five 1 × 1 m quadrat alternating with an interval of 10 m (Fig. 3.3). All herb species and grasses have been recorded. Representative specimens were collected from the quadrats. These plants were identified using standard floras (Gamble, 1935; Yoganarasimhan and Razi, 1982; Bahadur, 1992; Ramaswamy *et al.*, 2001; Bhat, 2003; Gowda, 2004; Inghalhalikar, 2007; Singh 2007). For quantitative assessment of grasses, random sampling method was followed, later based on ordination scale (Jongman *et al.,* 1987), grasses were ranked. The voucher specimens are deposited at Department of Applied Botany, Kuvempu University, Shankaraghatta, Shivamogga, Karnataka.

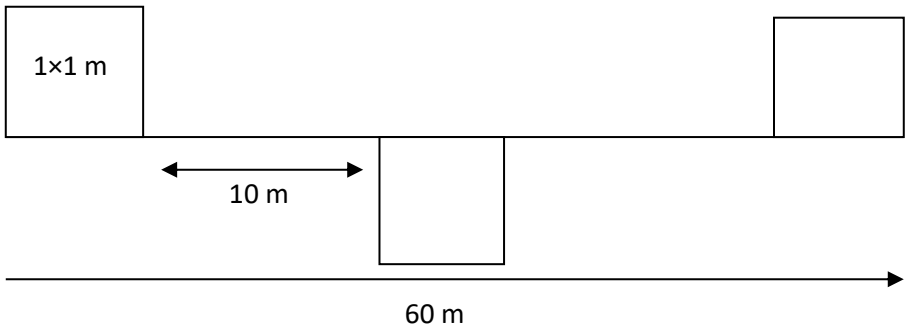

Fig. 3.3. Line transect adopted in this study.

3.3. Population biology studies

3.3.1 Studies on the population biology in small scale permanent plots

It is difficult to determine, how diversity has changed at local scales. For the measuring of how species diversity has changed is essential to distinguish how many species are present with in a specific area at some point in the past and present scenario. Two

permanent plots were established to find out the population biology at Bababudangiri and Kemmannugundi for two years from January 2013 to December 2014.

Study area

A. Bababudangiri permanent plot

The study site is located in Bababudangiri about 25 km north to the Chikkamagaluru town at 13° 25.7' northern latitude to 75° 45.5' eastern longitude at an altitude of 6011 to 6028 ft. The study site receives mean rainfall of 1900 to 2000 mm during June to September. The plot is gradually sloppy characterized by rocky plateaus and rock rifts. Plant species are adopted to with stand extreme environmental conditions as they show adaptation because of lack of nutrients like nitrogen in the soil. These plots show a series of stressful characteristics such as UV exposure, wind, high evapotranspiration, low water retention and acidic soil. The plot is dominated by species which are showing morphological adaptations. Some of the dominant species are *Cyanotis tuberosa, Chlorophytum tuberosum, Impatiens inconspicua, Habenaria heyneana, Hypoxis aurea* and *Parnassia mysorensis* (Plate-16). Land use in this area is constantly changing due to environmental factors, such as anthropogenic and grazing, fire disturbances have made few path lets inside the study site.

B. Kemmannugundi permanent plot

The study site in Kemmannugundi is located in 13° 33' northern latitude and 75° 45' eastern longitude, the altitudes is around 4695 ft. The site receives an annual rainfall about 1900 to 2000 mm spread from May to October. This site is mainly characterised by soil rich area and tall grasses. The site is slightly differ from that of Bababudangiri because of lack of rocky plateau, but feels the same stressful characters like exposure to UV light, high evapotranspiration, and high precipitation. The site is mainly composed of plants like

Strobilanthes kunthianus, Tephrosia tinctoria, Swertia corymbosa, Wahlenbergia erecta and *Neanotis* species. The dominant grasses are *Arundinella purpurea, Eulalia trispicata, Tripogon bromoides* and *Heteropogon contortus* (Plate-21).

In these two study sites one permanent plots of 10 × 10 m quadrats was established. The quadrat is further divided into 1 × 1 m sub quadrat in each corner. In each of such quadrats events of phenology like vegetative phase, reproductive phase and dispersion phase were observed at once in a month and recorded from January 2013 to December 2014 two year continuously for all the species in the field. Phenology data was tabulated on monthly basis in excel spread sheet. During this period frequent visits were made fortnightly to collect, identify and catalogue the plant population in study sites. The data was collected by selecting 30 individuals from each species in all the two study sites. Phenological observations were marked in about 10 per cent of individual under observation and considered it as initiated and peaked when it occurred in more than 80 per cent of individuals (Jeeshna and Paulsamy, 2011).

3.4. Patterns of distribution

3.4.1. Study on seasonal turnover and distribution of herbaceous plants in relation to habitat

The study was conducted in Kemmannugundi and Bababudangiri region to understand seasonal turnover of herbaceous plant species and their adaptation to different habitats, both places comes under same chain of hills called Chandradrona Parvatha. Three prominent weather seasons are prevailed such as rainy season (June to October), winter season (November to February) and summer season (March to May) in a year. This region usually receives annual rainfall of 1900-2000mm, the temperature in winter falls to 15-16°C, in summer 28-30°C. It is a cool place, hence, attracts more tourists. Extensive and regular

field survey was carried out from September 2012 to March 2015, with an interval of fortnight at these study sites to cover all the seasons of the year. A random block design has been adapted to collect the information of herbs. Community compositions of plant species in these grasslands are influenced by environmental and soil factors like depth of soil, presence or absence of rock and boulders, grazing and burnt conditions, forest edges, rocky and non-rocky slopes, edaphic factors, microclimatic conditions rainfall also determines the vegetation composition. Plants in this region are adapted to various habitats. Each habitat has prominent edaphic features, the common habitats types observed in this area are explained below according to categorization for rocky plateau outcrops. At each habitat the plants were randomly collected and identified. Along with habitat characters, flowering, fruiting and recruitment seasons were also noted down.

3.4.2. Distribution of herbaceous species in relation to altitude

Spatial distribution of the herbaceous species across altitudinal range in Bababudangiri and Kemmannugundi areas were selected. On the basis of altitude the study area was divided into three different altitudinal habitats according to Koul *et al*. (2013), Verma and Kapoor (2013) i.e., (1) lower attitude, (2) middle attitude and (3) higher attitude. At each study point, herbs and grass were enumerated by random stratified method. The species encountered in these areas were noted down and the results were tabulated.

3.5. Statistical analysis

Communities are frequently classified based on species dominance in the area or vegetation. The dominant species are also assumed to have important functional role in regulating the energy production or flow of nutrients. The data were analyzed for Abundance (Ab), Density (D) and Frequency (F) by following the method of Curtis and McIntosh (1950).

3.5.1. Dominance

The dominant species in a community are those assumed to be most important ecologically. They may be most numerous or high frequency of occurrence. Quadrat data obtained was summarized according to the standard protocols. Density, frequency and abundance and their relative measure for each species have been calculated.

4.0. Results and Discussion

4.0. Study on floristic diversity

Vegetation composition studies of non-woody angiosperms carried out to prepare a database of the montane grasslands, which resulted in a total of 242 herbaceous plant species. Of these, 170 species of herbaceous plants belonging to 152 genera (45 families) and 72 species of grasses belonging to 43 genera of two families (Appendix 1 and 2). Families with largest number of genera were Poaceae, Asteraceae and Fabaceae (Table 4.2). Poaceae is the dominant generic family followed by Asteraceae and Orchidaceae in Southern Western Maharastra (Lekhak, 2015). Similarly most specious family found in these grasslands were Poaceae, Asteraceae, Cyperaceae and Fabaceae (Table 4.3). Poaceae is the dominant family along lateritic Plateau in South Western Maharastra is followed by Orchidaceae and Asteraceae (Lekhak,). *Impatiens, Isachne,* and *Murdannia* are the largest genera, which is represented by five species (Table 4.4), followed by *Neanotis, Swertia* and *Ergostis* represented with four species each, whereas, *Eriocaulon, Habenaria Plectranths* and *Oldenlandia* represents three species.

Highest number of herb species were collected from Bababudangiri (57), and the highest number of grass species were collected from Kemmannugundi (71), (Table 4.1).

Table 4.1. Site-wise total number of herbs and grass enumerated in montane grasslands of Karnataka

Sl. No.	Study sites	Total number of Herbs and grass species	
		Herbs	Grasses
1	Bababudangiri	57	41
2	Kemmannugundi	50	71

Table 4.2. Top ten Families with highest genera in the study area

Sl. No.	Family	Genera
1	Poaceae	43
2	Asteraceae	19
3	Fabaceae	9
4	Cyperaceae	8
5	Rubiaceae	7
6	Orchidaceae	6
7	Acanthaceae	6
8	Scrophulariaceae	5
9	Gentianaceae	3
10	Commelinaceae	2

Table 4.3. Ten top most specious families in the study area

Sl. No.	Family	Species
1	Poaceae	57
2	Asteraceae	22
3	Cyperaceae	14
4	Fabaceae	14
5	Rubiaceae	12
6	Acanthaceae	10
7	Lamiaceae	8
8	Commelinaceae	8
9	Orchidaceae	7
10	Gentianaceae	7

Table 4.4. Top ten most specious genera in the study area

Sl. No.	Genus	Species
1	*Impatiens*	5
2	*Isachne*	5
3	*Murdannia*	5
4	*Neoanotis*	4
5	*swertia*	4
6	*Eragrostis*	4
7	*Eriocaulon*	3
8	*Habenaria*	3
9	*Plectranthus*	3
10	*Oldenlandia*	3

Species composition in Bababudangiri grasslands of Chikkamagaluru

In Bababudangiri *Anaphalis lawii*, *Curcuma pseudomontana*, *Drosera peltata*, *Impatiens inconspicua, Leucas marrubioides*, *Murdannia semiteres*, *Oldenlandia dichotoma*, *O. prainiana, O. stocksii*, *Parnassia mysorensis, Polygonum chinense* and *Utricularia arcuata* occurred in all quadrats (F = 1). *Gynura nitida* and *Sonerila rheedii* were less frequent with the frequency of 0.05 (Table 4.5). *Oldenlandia dichotoma* (61. 20) had the higher density, the other species having the higher density were *O. prainiana*, *Murdannia semiteres* (31.40, 18.85 respectively). *Seneceio ed goworthi* and *Swertia minor* (D = 0.05) were less dense species. The higher relative density was recorded for *Oldenlandia dichotoma* i.e., 13.87 (Fig. 4.1). *O. dichotoma, O. prainiana, Murdannia semiteres* and *Utricularia striatula* were the most abundant species with abundance of 61.20, 31.40, 18.85 and 18.26 respectively. *Oldenlandia dichotoma* had the maximum percentage of occurrence (11.74)

which is shown in Figure 4.3. *Oldenlandia dichotoma* was the most dominant with highest IVI value (Fig. 4.2).

Table 4.5. Frequency, density, abundance and IVI value of herbs in grasslands of Bababudangiri

Species name	F	D	Ab	IVI
Achyranthes bidentata	0.10	0.15	1.50	0.86
Alysicarpus racemosus	0.15	0.25	1.67	1.12
Anaphalis lawii	1.00	2.80	2.80	5.37
Campanula fulgens	0.10	0.25	2.50	1.22
Calceolaria mexicana	0.20	1.30	6.50	3.23
Cerastium glomeratum	0.20	1.00	5.00	2.64
Chlorophytum tuberosum	0.45	1.00	2.22	2.61
Conyza stricta	0.35	0.90	2.57	2.34
Crotalaria nana	0.65	1.45	2.23	3.46
Curcuma neligherrensis	0.15	0.40	2.67	1.50
Curculigo orchioides	0.65	2.40	3.69	4.31
Curcuma pseudomontana	1.00	2.45	2.45	5.11
Cyanotis tuberosa	0.35	0.95	2.71	2.41
Cynoglossum zeylanicum	0.15	0.20	1.33	1.00
Dichrocephala integrifolia	0.30	0.70	2.33	2.02
Drosera peltata	1.00	5.25	5.25	7.15
Emilia flammea	0.05	0.20	4.00	1.50
Gentiana quadrifaria	0.90	3.40	3.78	5.59
Gynura nitida	0.05	0.10	2.00	0.83
Habenaria grandifloriformis	0.80	1.25	1.56	3.67
H. heyneana	0.80	2.15	2.69	4.40
Heracleum candolleanum	0.20	0.50	2.50	1.65
Hypoxis aurea	0.55	4.65	8.45	6.40
Impatiens acaulis	0.55	2.45	4.45	4.24
I. inconspicua	1.00	2.55	2.55	5.19
I. scapiflora	0.45	1.40	3.11	3.05

Justicia simplex	0.40	1.15	2.88	2.71

Leucas marrubioides	1.00	2.45	2.45	5.11
Lepidagathis prostrata	0.40	0.50	1.25	1.93
Murdannia lanuginosa	0.25	0.90	3.60	2.33
M. semiteres	1.00	18.85	18.85	17.03
M. simplex	0.20	0.40	2.00	1.46
Oldenlandia dichotoma	1.00	61.20	61.20	47.79
O. prainiana	1.00	31.40	31.40	26.14
O. stocksii	1.00	7.80	7.80	9.00
Osbeckia cupularis	0.10	0.10	1.00	0.69
Paracaryum coelestinum	0.35	0.60	1.71	1.95
Parnassia mysorensis	1.00	8.45	8.45	9.47
Pedicularis zeylanica	0.50	1.25	2.50	2.96
Pimpinella wallichiana	0.75	1.20	1.60	3.50
Polygonum chinense	1.00	2.00	2.00	4.79
Satyrium nepalense	0.35	0.40	1.14	1.69
Senecio edgoworthi	0.05	0.05	1.00	0.50
S. ludens	0.30	2.30	7.67	4.34
Smithia hirsuta	0.70	1.55	2.21	3.67
S. racemosa	0.15	0.30	2.00	1.25
Sonerila rheedii	0.05	0.15	3.00	1.16
Striga gesneriodes	0.45	1.00	2.22	2.61
Strobilanthes kunthianus	0.40	1.75	4.38	3.42
Strobilanthes sessilis	0.85	4.30	5.06	6.19
Swertia raveendreae	0.95	6.75	7.11	8.18
S. corymbosa	0.85	9.95	11.71	10.61
S. lawii	0.25	1.00	4.00	2.49
S. minor	0.20	0.50	2.50	1.65
Utricularia arcuata	1.00	13.65	13.65	13.25
U. striatula	0.95	17.35	18.26	16.05
Viola patrinii	0.40	1.60	4.00	3.24

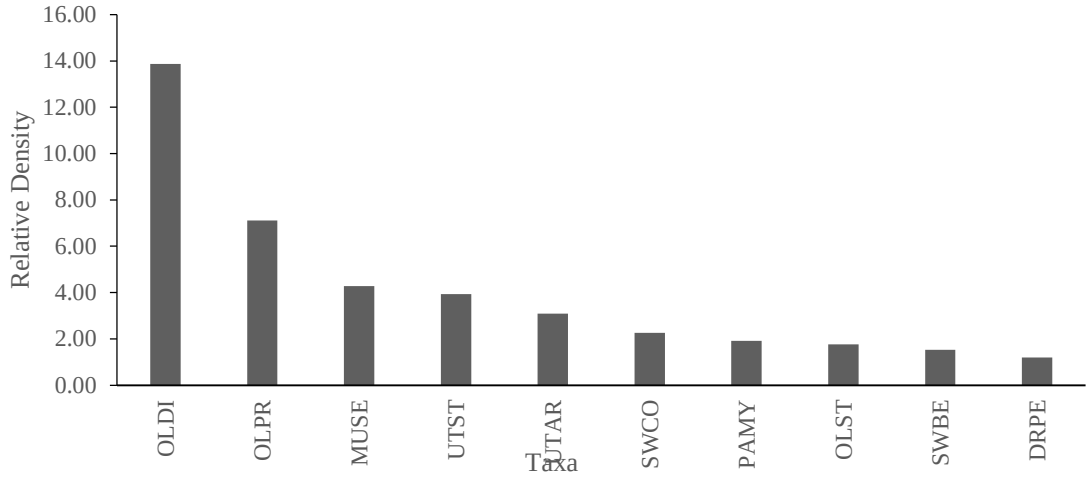

Fig 4.1. Relative density of top ten herbaceous species in Bababudangiri

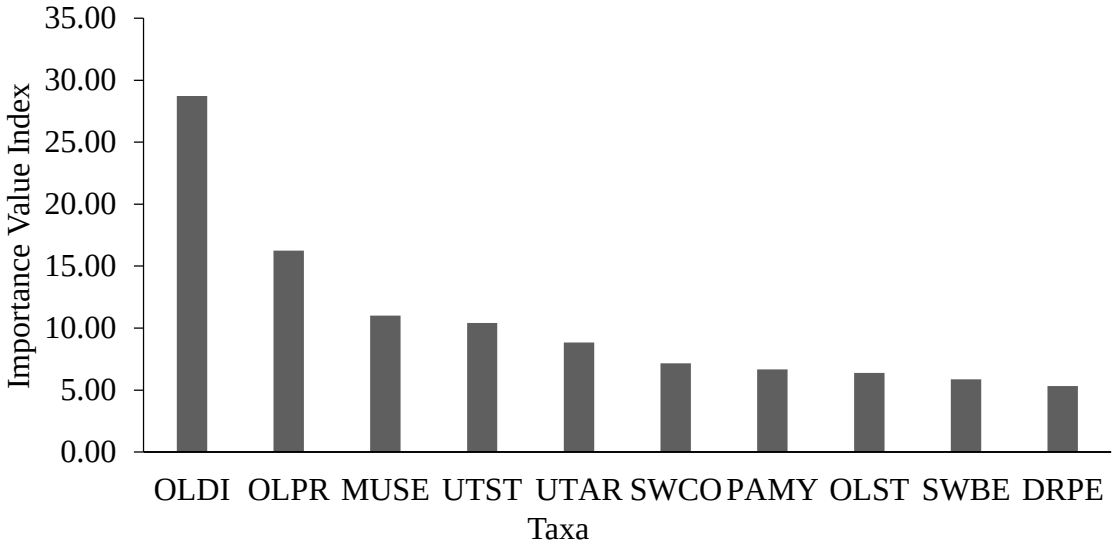

Fig. 4.2. Importance value index of top ten herbaceous species in Bababudangiri grasslands of Chikkamagaluru

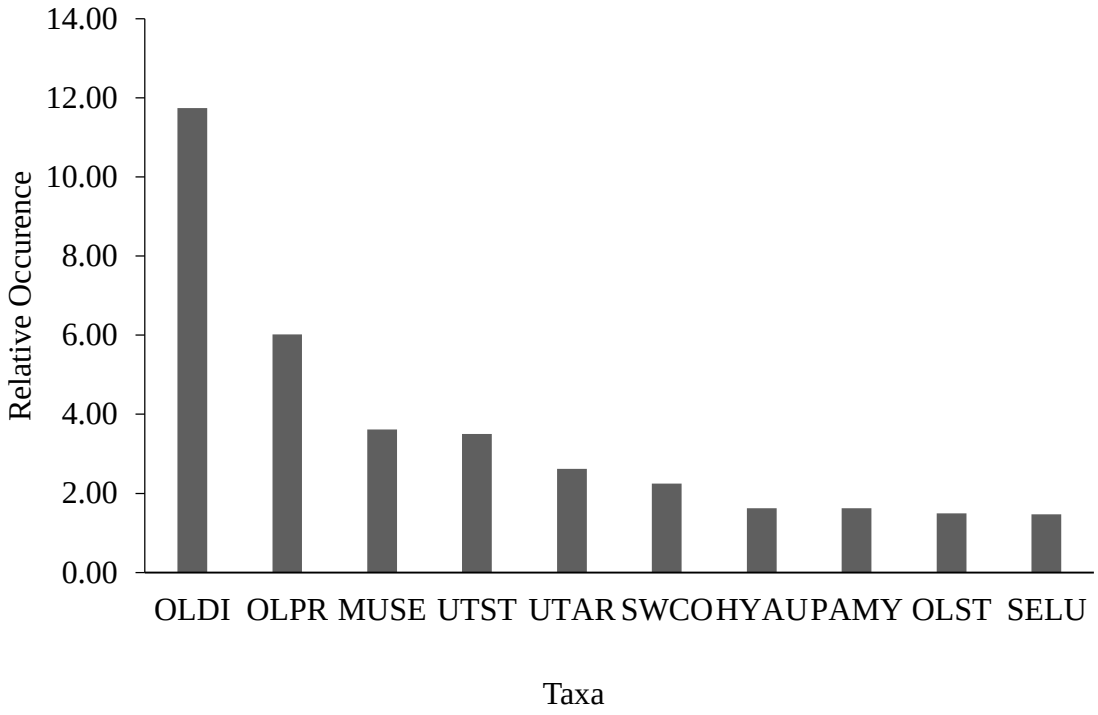

Fig 4.3. Relative occurrence of top ten herbaceous species in Bababudangiri.

Species composition in Kemmannugundi grassland of Chikkamagaluru

The dominant species found in Kemmannugundi region were *Pimpinella wallichiana* (3.85), *Ageratum conizoides* (3.10) and *Hypoxis aurea* (3.10). Top ten species with highest relative density is shown in the Figure 4.6. In these grasslands *Crotalaria heyneana* and *Strobilanthes sessilis* were the more frequent (1.00). *Andrographis paniculata, Curcuma pseudomontana, Habenaria longicorniculata, Senecio ludens, Sonchus oleraceus* and *Vigna vexillata* were less frequent (0.05). Ten species with highest relative frequency value are shown in Figure 4.4. Most abundant species were *Murdannia semiteres, Hypoxis aurea, Neanotis carnosa, Pimpinella wallichiana* and *Ageratum conizoides* (6.25, 6.20, 4.67, 4.53 and 4.43 respectively). The relative occurrence of ten species are given in Figure 4.5.

The most important species with highest IVI was *Pimpinella wallichiana* (19.34), *Hypoxis aurea* (16.67) and *Ageratum conizoides* (16.36). Whereas, the least IVI value was observed in *Sonchus oleraceus* and *Vigna vexillata* (1.32 each). The IVI value of top ten species shown in the Figure 4.7 and Table 4.6.

Table 4.6. Frequency, density, abundance and IVI value of herbaceous species in Kemmannugundi grasslands of Chikkamagaluru

Species name	F	D	Ab	IVI
Ageratum conizoides	0.70	3.10	4.43	16.36
Anaphalis lawii	0.25	0.80	3.20	6.46
Andrographis paniculata	0.05	0.10	2.00	2.33
Asclepias curassavica	0.15	0.65	4.33	6.44
Atylosia dalzelliana	0.15	0.15	1.00	2.21
Biophytum sensitivum	0.40	1.05	2.63	7.55
Cassia mimosoides	0.20	0.35	1.75	3.70
Crotalaria heyneana	1.00	1.35	1.35	10.96
Curculigo orchioides	0.50	1.50	3.00	9.68
Curcuma pseudomontana	0.05	0.10	2.00	2.33
Cyanotis tuberosa	0.20	0.35	1.75	3.70
Disperis zeylanica	0.10	0.20	2.00	2.90
Euphorbia laeta	0.25	0.55	2.20	4.93
E. pycnostegia	0.15	0.20	1.33	2.63
Exacum bicolor	0.25	0.40	1.60	4.01
Habenaria longicorniculata	0.05	0.10	2.00	2.33
Heracleum candolleanum	0.35	0.50	1.43	4.75
Hypoxis aurea	0.50	3.10	6.20	16.67
Impatiens acaulis	0.15	0.55	3.67	5.60
I. chinensis	0.35	0.85	2.43	6.54
Iphigenia pallida	0.25	0.35	1.40	3.71

Justicia procumbens	0.40	0.50	1.25	4.90
J. simplex	0.90	1.35	1.50	10.47
Leucas marrubioides	0.15	0.50	3.33	5.17
Lepidagathis spinosa	0.45	1.35	3.00	8.97
Leucas zeylanica	0.85	1.30	1.53	10.05
Murdannia crocea	0.20	0.25	2.33	3.95
M. gigantea	0.10	0.10	1.00	1.76
M. lanuginosa	0.70	1.15	1.64	8.82
M. semiteres	0.40	2.50	6.25	14.52
Neanotis carnosa	0.15	0.70	4.67	6.87
Ophiorrhiza mungos	0.10	0.20	2.00	2.90
Peristylus densus	0.60	0.55	0.92	5.99
Pimpinella wallichiana	0.85	3.85	4.53	19.34
Plantago major	0.15	0.25	1.67	3.05
Richardia scabra	0.25	0.40	1.60	4.01
Satyrium nepalense	0.20	0.45	2.25	4.40
Senecio ludens	0.05	0.15	3.00	3.34
Smithia hirsuta	0.60	0.85	1.42	7.21
Sonchus oleraceus	0.05	0.05	1.00	1.32
Striga asiatica	0.10	0.25	2.50	3.47
S. gesneriodes	0.30	0.50	1.67	4.64
Strobilanthes kunthianus	0.70	0.90	1.29	7.85
S. sessilis	1.00	2.45	2.45	14.80
Swertia corymbosa	0.25	0.50	2.00	4.63
Tephrosia tinctoria	0.10	0.10	1.00	1.76
Thalictrum dalzellii	0.15	0.35	2.33	3.90
Vigna vexillata	0.05	0.05	1.00	1.32
Wahlenbergia erecta	0.15	0.45	3.00	4.75

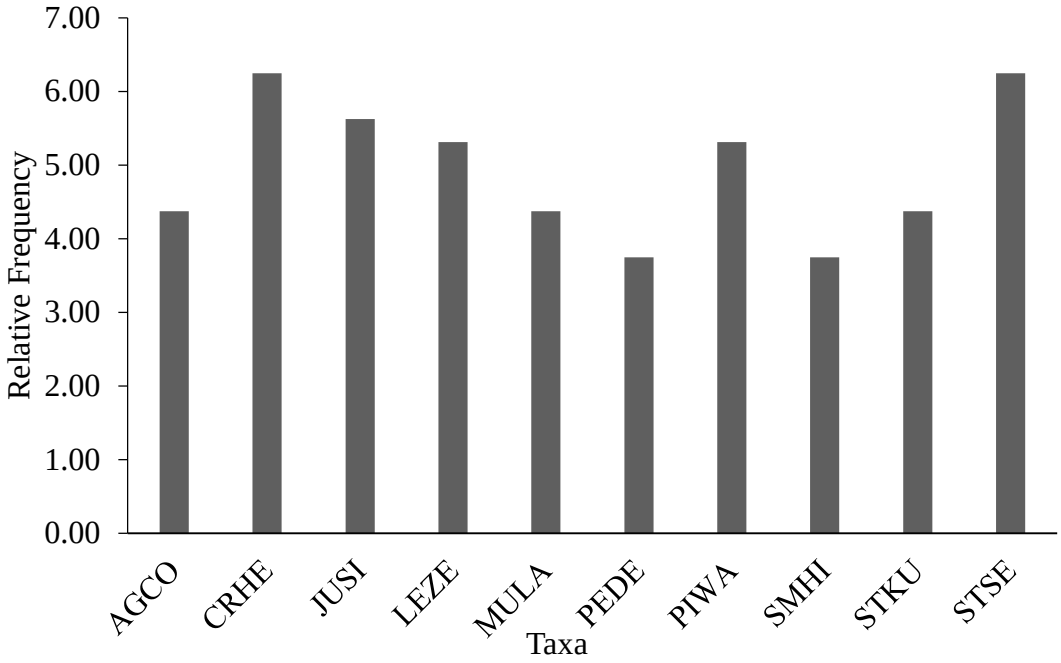

Fig. 4.4. Relative frequency of top ten herbaceous species in Kemmannugundi, Chikkamagaluru district.

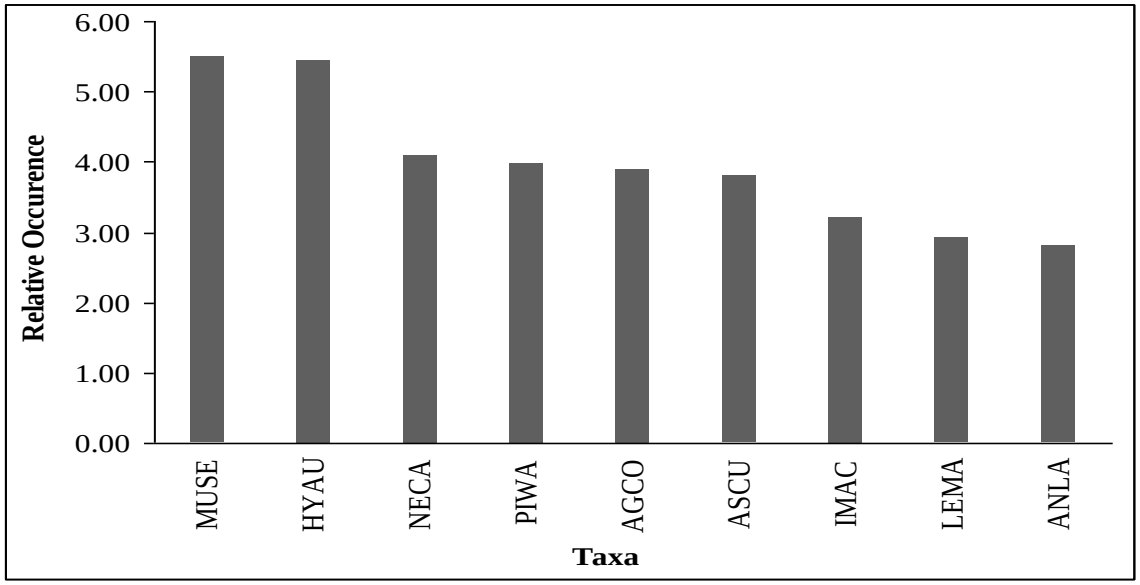

Fig. 4.5. Relative occurrence of top ten herbaceous species in Kemmannugundi, Chikkamagaluru district.

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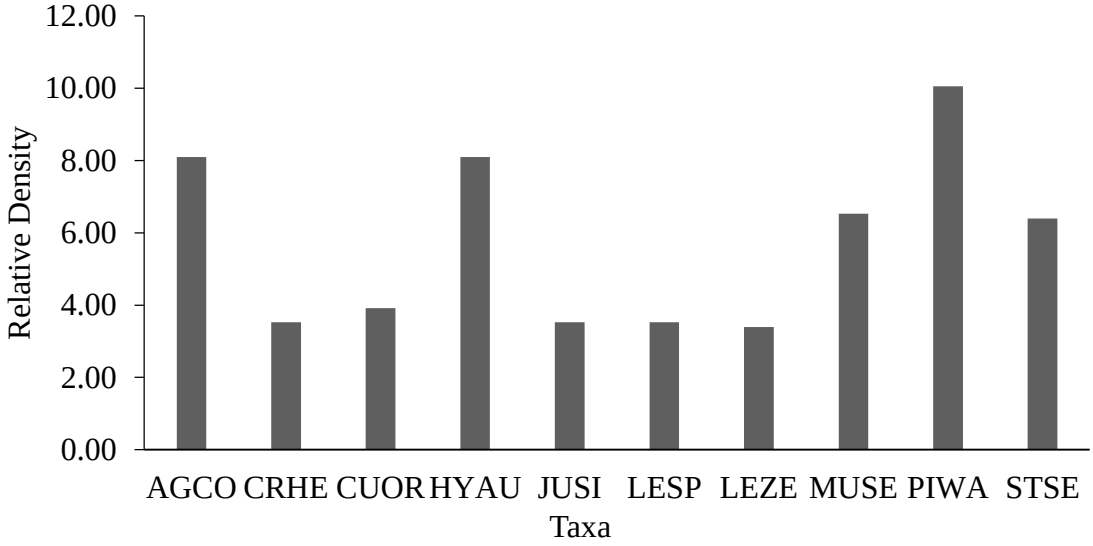

Fig 4.6. Relative density of top ten herbaceous species in Kemmannugundi, Chikkamagaluru district.

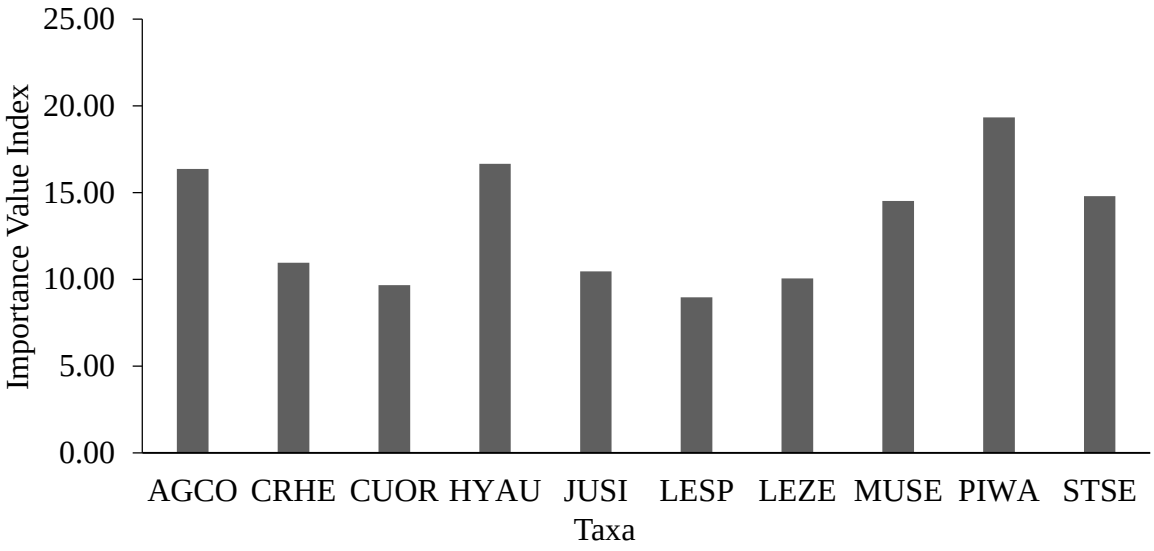

Fig. 4.7. Importance value index of top ten herbaceous species in Kemmannugundi, Chikkamagaluru district.

α-Diversity indices of seven montane grasslands of Karnataka

In the present investigation we have calculated the diversity indices among the two montane grasslands, maximum numbers of species were encountered in these montane grasslands. Highest individuals were found in Bababudangiri range (10124) belonging 73 species. In Kemmannugundi 814 individuals belonging to 50 species were encountered (Table 4.7). The concentration of α- diversity dominance-D from two study sites, probability of encountered dominance of Bababudangiri (0.1) and for Kemmannugundi (0.04)

Table 4.7. α-diversity indices of plant species found in montane grasslands of Karnataka

Diversity Index	**BBG**	**KMG**
Taxa_S	73	50
Individuals	10124	814
Dominance_D	0.1056	0.04479
Simpson_1-D	0.8944	0.9552
Shannon_H	2.883	3.429
Evenness_e^H/S	0.2447	0.6169
Equitability_J	0.6719	0.8765
Fisher_alpha	10.64	11.76

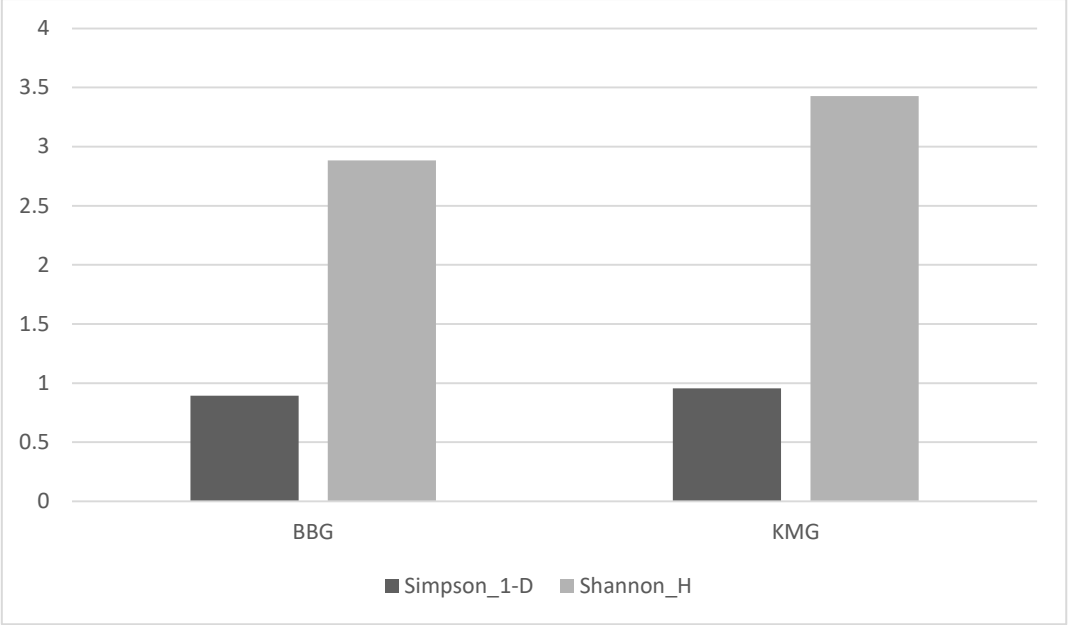

Fig 4.8. Shannon diversity indices of herbaceous plant communities in study sites

When compared with the diversity indices among the study sites, Kemmannugundi is most species rich having Shannon diversity index H' = 3.429 and Simpson value D = 0.9552. and Bababudangiri had the Shannon diversity index H' = 2.883, and the Simpson value D = 0.8944, respectively (Fig.4.8). Highest Fisher alpha index was shown by Kemmannugundi i.e 11.6, and Bababudangiri 10.64 respectively.

Mountain regions throughout the world play an indisputable role in promoting regional and global diversity (Bruke, 2003). The present study shows that highest number of species has occurred in Bababudangiri (73) followed by Kemmannugundi (50). Blasco (1970) has documented 223 plant species known only from the sholas and grasslands of the higher altitude ranges of the Western Ghats. Mohandass and Davidar (2010) collected 69 species from 18 sholas in that they collected four herb species. Brilliant et al. (2012) collected 286 plant species belongs to 85 families in that they collected trees, herbs, shrubs and saplings, they also recorded the RET species from Vagamon hills. In these areas, plant communities are very sensitive to climatic conditions. The landforms of Bababudangiri harbors the iron rich rock surfacess. Here the vegetation growing on irone stone. which are commonly known

as rock outcrops (Jacobi, 2006) or i.e. habitats where portions of freely exposed bed rocks project above the soil level due to natural reason (Watve, 2009), while Porembski and Barthlott (2000) have been used the term rock outcrops for land forms upon the naturally formed or primary outcrops, which are exposed due to geological reasons such as volcanism, weathering etc.This special type of habitat lack proper soil and exhibit extreme climatic conditions allow to grow more ubiquites species in this area, most of these species are edaphically controlled most of the time they characterize island of Xeric communities grown within a matrix of mesophytic vegetation (Porembski et al., 1998). The vegetation diversity of rocky outcropes described here on iron platues is ecologically related to that on the other types of rock outcrops through the world due to these similarities in microclimatic conditions.The iron crust are rich with dicots (Jacobi et al., 2007). Similar result was obtained in Bababudangiri where more number of dicots than monocots were observed. Whereas in Kemmannugundi a total of 50 species were occurred, the habitat in this areas is different from that of Bababudangiri.

Morista β- diversity indices of plant species from the study area.

The floristic composition was studied to assess the richness and diversity of herbaceous species in these montane grasslands and also to analyses the niche sharing of different species between study sites, beta diversity index was calculated using Morista index and is presented in a cluster graph (Fig. 4.9). Morista β-diversity assessment indicated the population structure of the species, since it takes into account. Both the study sites shares similar diversity (r = 0.10). This is also in accordance with the ecological parameters, the nearer study sites comprises similar climatic condition and hence, these places were

somewhat similar in species compositio

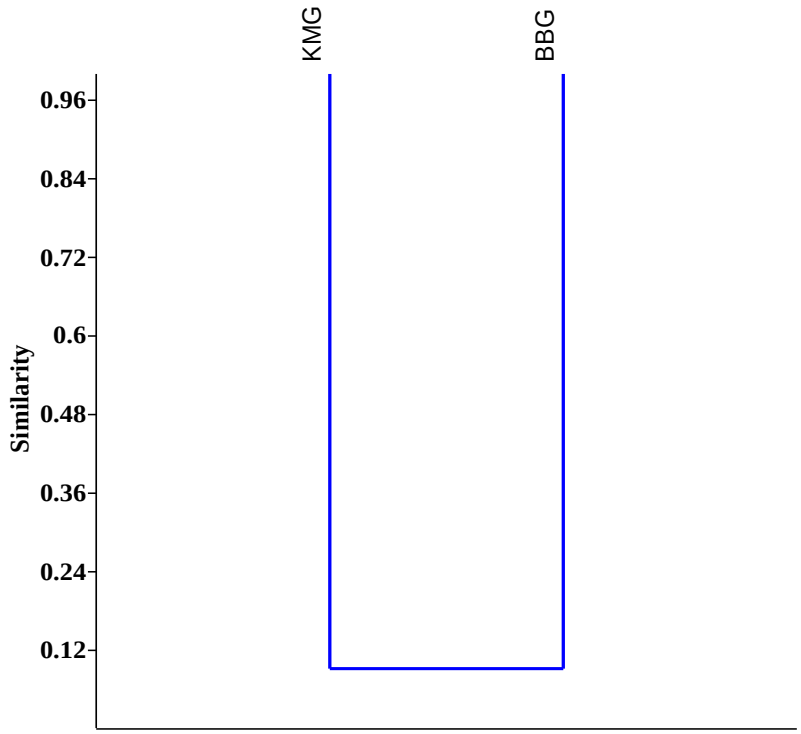

Fig. 4.9. Morista similarity indices for herbaceous species distribution in seveen montane grasslands of Karnataka

Studies on diversity of grasses in Bababudangiri and Kemmannugundi montane grasslands

The result indicated that a total of 73 species of grasses under 43 genera occurred in the study sites. Among 73 species, 60 species belong to Poaceae and 13 species belongs to Cyperaceae (Table 4.8). Montane grasslands are well known for endemic and rare taxa. Among this *Arundinella perpurea*, *A.mesophylla*, *Jansenella grifithiana* and *Paspalum canare* were endemic to Kemmangundi and Bababudangiri (Hooker, 1896). In this montane grasslands of Kemmangundi, comprised tall grasses whereas Bababudangiri harbours the small or stunted grass communities. The common species in Kemmangundi and

Bababudangiri are *Arundinella purpurea*, *Chrysopogan hackelli*, *C.velutinus*, *Heterogan contratus*, *Eulalia trispicata*, *Jansenella griffithiana*, *Themeda triandra* are abundant in Kemmangundi.

Ordination analysis of grass showed 65 species are abundant spread in Kemmangundi and Bababudangiri region. *Isachne* and *Ergrostis* have the highest representation with six and four species each. The genera *Arundinella*, *Bulbostylis*, *Digitaria*, *Ischaemum* and *Themeda* have three species each. *Arthroxan*, *Brachiaria*, *Chrysopogon*, *Cymbopogon*, *Cyperus*, *Dactyloctenium*, *Fimbristylis*, *Kyllinga*, *Panicum*, *Paspalum*, and *Pennisetum* represented by two species. Twenty-five genera represented only one species.

Table 4.8. List of Grass species found in the montane grassland slopes of Karnataka

Plant name	Family	KEMMANGUNDI	BABABUDANGIRI
Alloteropsis cimicina	Poaceae	3	0
Amphilophis insculpta	Poaceae	3	3
Aristida redacta	Poaceae	2	3
Aristida setacea	Poaceae	3	0
Arthraxon villosus	Poaceae	1	3
Arthroxan quartinianus	Poaceae	3	1
Arundinella pumila	Poaceae	3	2
Arundinella purpurea	Poaceae	3	1
Arundinella villosa	Poaceae	1	3
Brachiaria ramose	Poaceae	3	2
Brachiaria reptans	Poaceae	1	3
Bulbostylis capillaris	Cyperaceae	2	3
Bulbostylis densa	Cyperaceae	3	3
Bulbostylis puberula	Cyperaceae	0	0
Capillipedium huegelii	Poaceae	2	3
Carex filicina	Cyperaceae	3	0
Chloris barbata	Poaceae	3	0
Chrysopogon hackelii	Poaceae	3	0
Chrysopogon velutinus	Poaceae	3	0
Cleistachne stocksii	Poaceae	1	3
Cymbopogon caesius	Poaceae	3	0
Cymbopogon flexuosus	Poaceae	3	0
Cyanodon dactylon	Poaceae	2	0
Cyperus digitatus	Cyperaceae	0	0
Cyperus distans	Cyperaceae	3	0

Dactyloctenium aegyptium	Poaceae	3	0
Digitaria stricta	Poaceae	0	3
Digitaria ternata	Poaceae	2	3
Digitaria wallichiana	Poaceae	0	0
Echinochloa colona	Poaceae	2	0
Eleusine indica	Poaceae	3	2
Eragrostis pilosa	Poaceae	3	2
Eragrostis tenella	Poaceae	1	2
Eragrosti stenuifolia	Poaceae	3	0
Eragrostis unioloides	Poaceae	3	0
Eremopogon foveolatus	Poaceae	2	3
Eulalia trispicata	Poaceae	3	0
Fimbristylis miliacea	Cyperaceae	0	0
Fimbristylis sp.	Cyperaceae	3	2
Glyphochloa forticulata	Poaceae	3	0
Heteropogon contortus	Poaceae	3	0
Imperata sp.	Poaceae	3	0
Isachne bourneorum	Poaceae	3	2
Isachne elegans	Poaceae	0	0
Isachne gracillis	Poaceae	3	0
Isachne kunthiana	Poaceae	2	3
Isachne lisboae	Poaceae	0	0
Isachne setosa	Poaceae	3	3
Ischaemum impressum	Poaceae	0	0
Ischaemum indicum	Poaceae	3	1
Ischaemum semisagittatum	Poaceae	3	0
Jansenella griffithiana	Poaceae	3	0
Kyllinga melanosperma	Cyperaceae	3	0
Kyllinga pumila	Cyperaceae	2	0
Manisuris forficulata	Poaceae	3	2
Mariscus cyperinus	Cyperaceae	2	0
Microchloa sp.	Poaceae	3	0
Panicum antidotale	Poaceae	1	0
Panicum psilopodium	Poaceae	3	0
Paspalum canare	Poaceae	3	2
Paspalum compactum	Poaceae	3	1
Pennisetum hohenackeri	Poaceae	3	0
Pennisetum polystachyon	Poaceae	3	0
Polypogon monspeliensis	Poaceae	2	1
Pseudopogonatherum contortum	Poaceae	3	0
Pycreus pumilus	Cyperaceae	3	3
Scleria sumatrensis	Cyperaceae	3	2
Setaria pumila	Poaceae	3	1
Themeda quadrivalvis	Poaceae	3	2

Themeda tremula	Poaceae	3	3
Themeda triandra	Poaceae	3	3
Tripogon bromoides	Poaceae	3	3
Tripogon pauperculus	Poaceae	3	3

In the Western Ghats, Poaceae is the dominant family (Parthasarathy, 1983; Venu, 1998). The family shows the highest generic endemism represented by 13 genera. Seventy two percent of the genera of Poaceae have been reported from grasslands. Higher number of endemic genera in Poaceae can be recognized to earlier stages in evolution and dynamism of the family.

Fyson (1932) reported 87 species of grass from South Indian hill stations. Nine species of grasses were reported from Chikkamagaluru (Yoganarasimhan *et al.,* 1982) and 19 species from Shivamogga district (Ramaswamy *et al.,* 2001). Augustine *et al.* (1998) reported the occurrence of 163 species from Periyar Tiger Reserve. Among those 33 were endemic species to peninsular India. Similarly, Vasanthakumari *et al.* (2010) reported 67 species of grass with 48 genera belonging to nine tribes and six subfamilies from Bhadra Wild Life Sanctuary of Karnataka and some of these species available at specific habitats. Occurrence of 73 species in the present study area showed the moderate richness and diversity of grass species in montane grasslands of Karnataka.

Grasses play a very important role in ecosystem, used as forage for domesticated animal and soil conservation. Due to overgrazing and poor management practices, the grass species are restricted to specific areas (Ahmad *et al.,* 2009). Many of the literature suggest that grasses are useful to human beings as a food and forage. Every year these grasslands are burnt down due to frequent fires. Hence, there is an urgent need for conservation of grasses in the fragile ecosystem of montane grassland complexes.

4.3. Population biology of herbs and grasses

4.3.1. Population dynamics studies in Bababudangiri permanent plot

From the two years study period there was no such differences occurred in the events of phenology of herbs and grass. Only in Kemmannugundi the mass flowering of *Strobilanthes kunthianus* the plant which flowers twelve years once flowered during 2014 September (Plate-2). In Bababudangiri the plant communities are very much sensitive to climatic changes. In 2014 monsoon was delayed to July consequently the growth of plants were also delayed and in September lack of rain for one week made whole plant community of *Murdannia lanuginosa* went to dormant condition. After the reappearance of showers again it started flowering. Except these changes almost all the phenology of herbs were similar in two years. These grassy mountain meadows present a quick succession of herbs that appear short-lived profusion (Plate-2). Both in these grasslands the vegetation cover on the slopes being burnt during the months of March but they recovers with the early showers during June and July.

In Bababudangiri, the ground vegetation was rich and diverse with a different seasonal aspect (Table 4.9 and 4.11). In monsoon, the tuberous or bulbous plants of the family Hypoxidaceae, Zingiberaceae, Liliaceae and Orchidaceae make the first appearance. Just after the first few showers in June seedlings of annuals and perennials start emerging from the ground. The inventors of the species like *Hypoxis arurea*, *Gentiana quadrifaria* and *Hebanaria grandifloriformies* (Plate-12). These herbaceous species complete their life cycle with in few days. They require little warmy conditions and shower. Perennials grasses like *Aristida redacta*, *Arthraxon villosus*, *Arundinella villosa*, *Brachiaria reptans*, *Bulbostylis capillaris* and *B. densa* starts sprouting from the rhizomes, germination of seeds and sprouting followed by dynamic vegetative growth.

In July the habitat becomes lush-green, where plain area and open rock surfaces completely covered by the new plants of annuals and perennials like *Eriocaulon eurypapylon*, *Eriocaulon polycephalum*, *Habenaria heyneana*, *Justicia simplex*, *Pedicularis zeylanica*, *Impatiens acaulis*, *Uticularia striatula*, *Murdannia simplex*, *Murdannia longiulosa* and *Senecio ludens* (Plate-17). These plants underwent vegetative phase in the month of July. They require high amount of moisture content in soil and atmospheric humidity. Most of the annuals start flowering in the middle of August and dispersion in September. These are called ephemerals because of they complete their life cycle within 2-3 months or in a season, a change in climatic condition, the whole mat go disappear.

Next comers are *Analaphis lawii* (Plate-7), *Cyanotis tuberosa*, *Dicrocepale integrefolia*, *Hebanaria hyneana*, *Impatiens inconspicua*, *Justicia procumbens*, *Parnessia mysorensiss* (Plate-13) and *Polygonum chinensis*. These plants undergo vegetative phase in last week of August and comes to reproductive phase in September to October. They require some amount of moisture in soil and small amount of sunlight.

The pointed blue petals of *Gentiana quadrifaria* (Plate-12) open around mid-day during September-October. *Murdannia semiteries*, *Oldenlandia herbaceae*, *O. parniana*, *O. stocksii*, *Satyrium nepalense* and *Swertia raveendreae* entered to vegetative phase in the month of September. They starts flowering at the end of the September and early October. Fruiting also observed in number of species at the same time. Mass blooming of these flowers gives different color to the grasslands.

Leucus morrubidiodies and *Analaphis lawii* showed vegetative phase in the month of June, undergo flowering in the month of September to till January. In winter months they produced seeds and dispersal in summer. *Lepidogathis prostrate* is the perennial plant present in all seasons of the year (Plate-2). It flowers in March and April, and disperses the seeds in the month of May. In summer, the whole plateau dries up due to scarcity of water, and high

intensity of sun light and also by the influence of fire, the whole mass of vegetation get removed due to extreme climatic condition.

These areas are rich with iron plateaus; in rainy season the whole plateau was covered by mat of mosses and grass mat, a small change in the climatic condition causes change in whole mat of vegetation. Variously coloured flowers, in its full bloom, envelops the entire landscape and makes it look like a botanical paradise.

4.3.2. Population dynamics studies in Kemmannugundi permanent plot

The plant community of Kemmannugundi (Table 4.10 and 4.12) totally differs from that of Bababudangiri. The grasslands covers the tall grass viz., *Heteropogan contratus*, *Arundenella perpurea* and *Themeda triandra*, the grass land covered by 5 to 20 cm thick soil. The herbaceous plants also differ from that of Bababudangiri. These grasslands highly diversified in tall grass and also in herbs. Here extreme climatic conditions like desiccation, high intensity of sun light was recorded. In the month of March to May plants were not found in this grassland. *Curculigo orchioides* and *Curcuma psuedomontana* (Plate-9) were the plants, which send up flowers in the middle of May when pre-monsoon rain prevailed.

A tussocks of grass were also produced new shoots in the month of June so that in few weeks the charred mountain slopes become green again. As the monsoon spreads this grassy meadow becomes variable floorings of flowers. *Chrysopogon hackelli*, *Arundinella purpurea* and *A. villosa* are the tall grasses. *Isachen lisboae* is the shorter grass, the whole mass of grass starts flowering in the later months of rainy season and initiation of winter season and fruiting observed till January in the middle of January, whole grass mat get dried up.

In the month of July *Ageratum conizoides*, *Striga asiatica*, *Strobilanthes kuntianus* and *S. sessilis* reappears. *Striga asiatica* (Plate-18) completes its life cycle within a month,

whereas, *S. kuntianus* flowers once in 12 years. *S. sessilis* produces the flowers in the month of October-November and shoots dry up in early winter.

In post monsoon periods (mid of September) the Plateau was covered by *Cassia mimosoides, Exacum bicolor, Justicia simplex, Swertia lawii, Peristylus densuss, Pimpinella wallichiana, Murdannia coracia, M. gigantia, M. semiteries, Neanotis carnosa* and *Thalictrum dalzelli* (Plate-19). These plants require some amount of moisture in the soil, some amount of rain and sun light. Most of the species like *Crotalaria nana, Euphorbia pycnostegia, Leucas eriostoma*, *Smithia hirsuta*, *Vigna vexillata* and *Wahlenbergia erecta* (Plate-20), complete their life cycle in the months of November and December.

Observation on the phenology of herbaceous plant species revealed that maximum number of species in Kemmannugundi and Bababudangiri complete their life cycle from August to December. This shows nearly 80 per cent of plants are annual and hence complete their life-cycle during the favorable edaphoclimatic conditions prior to the onset of dry season. Similar pattern was observed by Lekhak and Yadav (2012) in lateritic plateaus of south western Maharashtra. Watve (2013), also found the similar pattern of growth in early phase of June comprises most of the plants in their vegetative growth, few species starts flowering in the same period. Peak flowering occurs at the end of the August and starting of September. The diversity declined in the month of post monsoon period i.e., in October.

Some areas of Bababudangiri consisting of exposed rock surfaces that leads to distinct microclimatic conditions such as exposure to sun, shallow nutrient soils and water stress. These factors in turn influences the community assemblages and adaptive strategies of flora and fauna of these habitats (Watve, 2013). Rock outcrops are distinct from that of surrounding habitats. Therefore, these rock outcrops were described as terrestrial habitat islands and the microhabitats present in these areas are called islands upon islands

(Porembski *et al*., 2000). The plant communities here are strongly influenced by microclimate (Watve 2007).

4.4. Seasonality and spatial distribution of herbs and grasses in grasslands of Kemmannugundi and Bababudangiri region

4.4.1. Spatial distribution of herbs

Results of the present study showed that a total of 137 species of herbaceous plant communities occurred in Bababudan hill range (Table 4.13). Most of these herbs are annuals and are highly seasonal, which belongs to 37 families with 116 genera.

The common under shrub of this range is *Hypericum mysorense* and *Pleocaclus sessiles,* most common invasive species are *Thithonia* sp., *Eupatorium adenophorum* and *Cestrum aurantiacum*. The common moss found in these exposed rock surface is *Bryum* sp., *Campylopus* sp. and *Grimia* sp., which forms a mat on the rock surfaces, which holds moisture and gives platform to some species.

4.4.1.1. Distribution of herbaceous plants in relation to habitat

Plant species in the montane grasslands were adapted to various habitats. The entire habitats were unique due to different physiographic, edaphic and climatic conditions. All the common habitat types observed in this area are explained below (Plate-5). Categorization for rocky plateau outcrops habitat types according to Porembski and Barthlott (2000), Lekhak (2012) and Watve (2013) (Table 4.13).

Cryptogamic crusts : The exposed rock surfaces contains lichen and mosses mats Mosses such as *Grimia* sp., *Pogonatum* sp., *Polytrichum* sp., cover the rock surface in a thick mat like formations.

Open Exposed rock surfaces : Flat or some uneven surfaces. They are directly exposed to sunlight. They are covered by mosses and grass mat in monsoon, main plant species occur here are *Alysicarpus racemosus, Eriocaulon eurypapylon, E. ritcheanum, Tripogon bromoides, Habenaria heyneana, H. grandifloriformis, Oldenlandia stocksii, O. parniana, Satyrium nepalense, Murdannia lanuginose, Utricularia uliginosa, U. striatula, Striga gesnerioides* and *Parnassia mysorensis*.

Rock rift : Narrow crack or opening in rocks which offers unique slot. Along this some distinctive plant species are found such as *Utricularia striatula, Impatiens inconspicua, I. acaulis, I. scapiflora, Polygonum punetatum, Eriocaulon eurypapylon* and *Pedicularis zeylanica*.

Tall grass covered areas : Areas in which tall grass are covered. The region is occupied by *Ageratum conyzoidess, Wahlenbergia erecta, Smithea hirsuta, Tephrosia tinctoria, Chrysopogon hackelli, Heteropogan controtus, Themeda triandra, Eulalia trispicata, Cassia mimosoides, Vigna vexillata, Tripogon bromoides, Exacum bicolor, Murdannia simplex, Euphorbia pycnostegia* and *Curculigo orchioides.*

Forest edge : The habitats where stunted trees are present, which, forms the characteristic of shola forests. The common species are *Achyranthus bidentata, Oxalis debilis, Zeuxine gracilis, Desmodium repandum, Senecio bombyensis, Blumea hieracifolia, Gymnostachyum latifolium, Curculigo orchioides, Galinsoga parviflora, Eupatorium adenophroum* and *Adenostemma lavenia*.

Soil covered areas : These are areas where 10 to 20 cm thick soil is covered. The surface is occupied by *Curculigo orchioides, Blumea oxyodonta, Peristylis densus, Swertia corymbosa,*

S. beddomei, S. minor, Gentiana quadrifaria, Viola patrinii, Plectranthus stocksii and *Anaphalis lawii*.

Crust edges : They are edges of the hill or highlands colonized by *Sonerila rotundifolia, Impatiens acaulis, I. scapiflora, Neanotis foetida, Chlorophytum malabaricum, Begonia crenata, Calceolaria mexicana, Commelina* sp. and *Cyperus distans*.

Gibber stone : Isolated rocks covered by mosses. Here some specific plants occur, they are *Murdannia semiteres, Oldenlandia stocksii, Eriocaulon eurypapylon, Impatiens acaulis* and *Utricularia striatula*.

Soil rich areas : The places where the soil deposition is indepth, such places are covered by *Alysicarpus vaginalis, Strobilanthes sessilis, Conyza stricta, Cynoglossum zeylanicum, Paracaryum malabaricum, Anaphalis lawii, Oxalis debilis, O. corniculata, Gomphrena serrata, Richardia scabra, Zeuxine gracilis, Abelmoschus angulosus, Leucas zeylanica* and *L. eriostoma*.

Seasonal waterfalls : Small water falls, water flows down in rainy seasons they are rich with herbaceous hydrophytes namely *Pedicularis zeylanica, Sonerilla rotundifolia, Impatiens acaulis, I. scapiflora, Smithea blanda, Pimpinella wallichiana, Carex filicina, Cyperus distans* and *Neanotis foetida.*

Tree trunks : In soil rich areas where small soil debris adhere on the trees due to wind. During monsoon the tree trunk makes the good substrate for seed germination. So the mosses and other species like *Oberonia* sp., *Dendrobium jerdoniana, Utricularia striatula, Impatiens acaulis* and *Begonia crenata* grow on tree trunks.

Diversity and distributions of species are known to be related among other factors to the following geographical parameters latitudinal, altitudinal gradients and environmental

variables (Lomolino, 2004) and at finer scale microhabitats. Plant species in these montane grasslands are adapted to various micro habitats and each of this microhabitats are specific in their properties, namely edaphic factors, water availability and species composition. The monsoon rain favours the appearance of herbaceous taxa in this islands (Porembski and Watve, 2005; Lekhak and Yadav, 2012; Bhattarai, 2012).

4.4.2. Seasonal turnover of herbaceous plant communities

Plant communities in Bababudangiri and Kemmannugundi were continuously changing with respect to change in climatic conditions (Plates-3 and 4). All the species found here are adapted to specific climatic conditions. A change in climate such as rainy season, winter cold and warmer condition that changes the whole mat of flowers with mass flowering of different species.

The growing season starts with ephemerals, the mass blooming of this layer end with in few days, annual plants cover it, they starts from grasses and ends with perennial plants. Based on phenological observation we categorized four phases (Table 4.13).

Pre-monsoon phase (May to June) on the onset of monsoon season the tuberous and bulbous plants such as *Curculigo orchioides*, *Hypoxis arurea*, *Curcuma pseudomontana* are first comers.

During monsoon phase (June to September) main taxa occur here. *e.g*. *Creastrium glomoratum*, *Drymaria cordata*, *Gamphorena serrata*, *Hypoxis aurea*, *Murdannia lanuginosa*, *Parnassia mysorensis*, *Pedicularis zeylanica*, *Tripogan bromides*, *Impatiens inconspicua*, *I. scapiflora*, *I. acaulis* and *Chlorophytum tuberosum*.

In winter season (October to December), mass flowering of grass species takesplace along with some perennials, some are, *Arundinella purpurea, Carex filicina, Heteropogon contortus, Chrysopogon hackelli, Pennisetum polystachyon, Peristylis densus, Pimpinella*

wallichiana, Senecio gramhii, Smithia hirsuta, Tricholepis glaberrima, Swertia lawii, S. raveendrae, S. minor and *Leucus eriostoma*.

During January, plants start drying due to high temperature, winter stress and scarcity of water and loss of moisture in soil. Some of the species present in this season were *Lobelia nicotianefolia, Conyza stricta, Blumea hieracifolia, Rungia pectinata, Lepidagathis spinosa, L. cristata, Ophiorrhiza mungos, Eupatorium adenophorum, Asclepias curassavica, Tephrosia tinctoria, Zeuxine gracilis* and *Pogostemon mollis*. The phenological observation showed that most of the species complete their life cycle between June and December. It revealed that most of the plants were ephemerals that complete their life cycle within six months in favorable edaphoclimatic conditions, before the onset of dry season.

The montane grasslands have unique habitats, where, plant communities changes with respect to climatic conditions. Because of this reason they possess a vegetation that is clearly distinct from their surroundings. MacArthur and Wilson (1967) defined the term turnover as a process of disappearance of some species from local population and their replacement by other species. Species turnover in grassland was first studied by Robinson and Quinn (1988). Rusch and Van der Marrel (1992) studied the species turn over and seedling recruitment in limestone grasslands. Maarel and Sykes (1993) analysed small scale plant species turn over in limestone grasslands, and Rodriguze *et al.* (1997) studied species and life-forms composition of Mediterranean mountain. All these studies were conducted by two to three censuses. According to Tilman (1996) with respect to community or ecosystem level, species richness supports stability but the population level is concerned, increasing diversity leads to greater fluctuations. Plant communities in this plateau are constantly changing with respect to change in the climatic conditions.

Phenological phenomena in montane grasslands studied inadequately in Western Ghats except the studies made by Joshi and Janarthanam (2004); Lekhak and Yadav (2012).

Phenological data were collected by observing phenophases of species (Joshi and Janarthanum, 2004). Isichei and Longe (1984) observed different phenological differences concerning species number and the dominance pattern of species in a rock community in Nigeria. During moisture rich soils and high atmospheric humidity ephemerals were more dominant and this was later replaced by annuals and perennials. The number of species and number of individuals declined after a peak at the beginning of the growing season. Similar pattern was observed by Lekhak and Yadav (2012) on the lateritic plateaus of India. The present study was also in agreement with previous authors. This is because there is a similarity in both habitats. The growing season starts with some ephemerals and annuals, which are mainly Hypoxidaceae, Zingiberacae members along with grasses and ends with perennials like *Lepidagathis cristata.*

Table 4.13. List of the herbs enumerated at different habitats of Bababudangiri and Kemmannugundi and their flowering and fruiting periods

Plant names	Family	Flowering and fruiting	Habitat
Abelmoschus angulosus	Malvaceae	Oct – Nov	SR
Achyranthes bidentata	Amaranthaceae	Nov – Dec	FE
Adenoon indicum	Asteraceae	Nov – Jan	TG
Adenostemma lavenia	Asteraceae	Nov – Jan	FE
Ageratum conizoides	Asteraceae	Oct – Dec	SC, SR,
Alloteropsis cimicina	Poaceae	Sep – Nov	SR,
Alysicarpus racemosus	Fabaceae	Oct – Dec	ERS
A. vaginalis	Fabaceae	Oct – Jan	SR
Anaphalis lawii	Asteraceae	Oct – Jan	ERS, SC
Arundinella purpurea	Poaceae	Sep – Nov	TG, ERS
Asclepias curassavica	Asclepiadaceae	Sep – Apr	FE
Begonia crenata	Begoniaceae	Oct – Nov	GS
Biophytum sensitivum	Oxalidaceae	Oct – Nov	SR
Blumea mollis	Asteraceae	Dec – Feb	SR, SC
Bulbostylis puberula	Cyperaceae	Aug – Oct	SC, ERS
Calceolaria mexicana	Scrophulariaceae	Aug – Nov	RE, GS
Campanula fulgens	Campanulaceae	Sep – Oct	SR

Canscora diffusa	Gentianaceae	Oct – Feb	FE
C. pauciflora	Gentianaceae	Oct – Dec	FE
Cardamine africana	Brassicaceae	Oct – Nov	GS, SC
Carex filicina	Cyperaceae	Oct – Dec	FE, SF
Cassia mimosoides	Fabaceae	Oct – Dec	TG
Cerastium glomeratum	Caryophyllaceae	Aug – Sep	SC, RE, SR
Chlorophytum malabaricum	Liliaceae	Aug – Oct	ERS, GS, RE, SC
Chrysopogon hackelii	Poaceae	Oct – Dec	TG
Commelina sp.	Commelinaceae	Aug – Oct	RE
Conyza stricta	Asteraceae	Dec – Feb	SC
Crotalaria nana	Fabaceae	Oct – Dec	TG, ERS, SC
Curculigo orchioides	Hypoxidaceae	Aug – Nov	TG, FE
Cyanotis cristata	Commelinaceae	Aug – Oct	GS, ERS
C. tuberosa	Commelinaceae	Aug – Nov	ERS, RE
Cynodon dactylon	Poaceae	Jun – Dec	SC,

Cynoglossum zeylanicum	Boraginaceae	Sep – Jan	SR
Cyperus distans	Cyperaceae	Aug – Jan	FE, SF, RE
Dendrobium jerodonianum	Orchidaceae	Mar – Apr	TC
Desmodium repandum	Fabaceae	Nov – Dec	FE
Dichrocephala integrifolia	Asteraceae	Aug – Nov	ERS, SR
Digitaria stricta	Poaceae	Aug – Oct	RE, SF, TG
Digitaria wallichiana	Poaceae	Oct – Dec	RE
Drosera indica	Droseraceae	Aug – Oct	ERS, SC
D. peltata	Droseraceae	Aug – Nov	ERS, SC
Drymaria cordata	Caryophyllaceae	Aug – Sep	ERS, RS, SC
Emilia exserta	Asteraceae	Sep – Dec	ERS, SC, RE
E. sonchifolia	Asteraceae	Sep – Dec	SC
Eragrostis pilosa	Poaceae	Sep – Nov	RE
E. tenuifolia	Poaceae	Sep – Nov	ERS, SC, SF
Eriocaulon eurypapylon	Eriocaulaceae	Aug – Oct	GS, ERS, SC, SF
E. ritcheanum	Eriocaulaceae	Aug – Oct	ERS, SF, GS
Eulalia trispicata	Poaceae	Oct – Dec	TG
Eupatorium adenophorum	Asteraceae	Mar – Apr	FE
Euphorbia pycnostegia	Euphorbiaceae	Oct – Nov	FE, TG
Exacum bicolor	Gentianaceae	Oct – Nov	TG
Galinsoga parviflora	Asteraceae	Nov – Dec	FE
Gentiana quadrifaria	Gentianaceae	Aug – Dec	ERS
Gomphrena serrata	Amaranthaceae	Jan – Dec	SR
Gymnostachyum latifolium	Acanthaceae	Nov – Dec	FE

Gynura nitida	Asteraceae	Oct – Dec	SR
Habenaria grandifloriformis	Orchidaceae	Aug – Oct	ERS
H. heyneana	Orchidaceae	Aug – Oct	ERS
Heracleum candolleanum	Apiaceae	Aug – Oct	ERS, TG
Heteropogon contortus	Poaceae	Oct – Dec	TG, ERS
Hypericum mysorense	Hypericaceae	Mar – May	SC, RE
Hypoxis aurea	Hypoxidaceae	Jun – Sep	ERS
Impatiens acaulis	Balsaminaceae	Aug – Oct	GS, ERS, TC, RE, SF, R
I. chinensis	Balsaminaceae	Jul – Sep	RE, SC
I. inconspicua	Balsaminaceae	Aug – Sep	ERS, GS, RE, SC, SF
I. scapiflora	Balsaminaceae	Aug – Sep	RE, ERS, TC, SF
Impatiens sp.	Balsaminaceae	Oct – Nov	SR, RE

Isachne elegans	Poaceae	Sep – Oct	FE
I. setosa	Poaceae	Sep – Oct	FE, TG
Ischaemum indicum	Poaceae	Oct – Dec	TG
Jansenella griffithiana	Poaceae	Oct – Dec	TG
Justicia procumbens	Acanthaceae	Aug – Dec	ERS, FE, TG
J. simplex	Acanthaceae	Aug – Dec	GS, RE, ERS
Knoxia sumatrensis	Rubiaceae	Aug – Nov	RE, SF
Kyllinga melanosperma	Cyperaceae	Oct – Dec	SF, ERS
Lepidagathis cristata	Acanthaceae	Jan – May	ERS, RE
L. spinosa	Acanthaceae	Mar – May	ERS
Leucus eriostoma	Lamiaceae	Oct – Feb	ERS, SC, TG
L. zeylancia	Lamiaceae	Oct – Dec	ERS, SC
Linum mysorense	Linnaceae	Sep – Nov	TG, ERS, RE
Lobelia nicotianaefolia	Campanulaceae	Nov – Jan	ERS, SC
Murdannia lanuginose	Commelinaceae	Aug – Sep	ERS, SF
M. semiteres	Commelinaceae	Sep – Oct	ERS, GS
M. simplex	Commelinaceae	Oct – Nov	TG, ERS, RE, SF
Neanotis foetida	Rubiaceae	Aug – Oct	FR, GS, RE
Oldenlandia stocksii	Rubiaceae	Oct – Nov	ERS, GS, ERS
Ophiorrhiza mungos	Rubiaceae	Mar – Apr	SF, RE
Osbeckia octandra	Melastomaceae	Dec – Jan	RE
Oxalis corniculata	Oxalidaceae	Sept – Dec	SR
O. debilis	Oxalidaceae	Oct – Dec	SR, RE
Panicum psilopodium	Poaceae	Oct – Nov	FE
Paracaryum malabaricum	Boraginaceae	Sep – Nov	SC,
Parnassia mysorensis	Saxifragaceae	Aug – Sep	ERS, GS, RE
Paspalum canare	Poaceae	Oct – Dec	FE

Pedicularis zeylanica	Scrophulariaceae	Aug – Sep	ERS, SC, RE,
Pennisetum polystachyon	Poaceae	Oct – Dec	TG
Peristylus densus	Orchidaceae	Oct – Nov	TG, ERS
Pimpinella wallichiana	Apiaceae	Oct – Nov	TG, RE
Plantago major	Plantagenaceae	Oct – Jan	FE
Plectranthus incanus	Lamiaceae	Oct – Nov	RE,
P. stocksii	Lamiaceae	Oct – Nov	SC, SR
Pleocaulus sessilis	Acanthaceae	Oct – Nov	ERS, RE, SC
Pogostemon mollis	Lamiaceae	Mar – Apr	RE

Polygonum punctatum	Polygonaceae	Aug – Oct	ERS, RR
Pouzolzia wightii	Urticaceae	Oct – Dec	RE
Pycreus pumilus	Cyperaceae	Oct – Dec	FE
Richardia scabra	Rubiaceae	Aug – Dec	SC, RE, SR
Rubiaceae sp.	Rubiaceae	Oct – May	RE
Rungia pectinata	Acanthaceae	Jan – Mar	TG, FE
Satyrium nepalense	Orchidaceae	Oct – Nov	ERS, RE
Senecio edgeworthii	Asteraceae	Oct – Nov	ERS
S. grahami	Asteraceae	Oct – Nov	ERS, RE
S. ludens	Asteraceae	Aug – Sep	ERS, RE
Setaria pumila	Poaceae	Sep – Oct	RE
Smithea blanda	Fabaceae	Sep – Nov	FE
S. hirsuta	Fabaceae	Sep – Nov	ERS, TG
Sonchus oleraceus	Asteraceae	Dec – Feb	FE
Sonerila rotundifolia	Melastomaceae	Aug – Sep	GS
Spilanthes acmella	Asteraceae	Oct – Dec	FE, SF, RE
Striga gesnerioides	Scrophulariaceae	Nov – Jan	ERS
Swertia lawii	Gentianaceae	Nov – Dec	ERS, SC
S. raveendrae	Gentianaceae	Nov – Dec	ERS, SC
S. minor	Gentianaceae	Oct – Nov	SC, ERS
Tephrosia purpurea	Fabaceae	Mar – Apr	TG
T. tinctoria	Fabaceae	Oct – Nov	TG
Themeda triandra	Poaceae	Oct – Nov	TG
Tricholepis glaberrima	Asteraceae	Oct – Nov	TG
Tripogon bromoides	Poaceae	Aug – Oct	ERS, SC, TG
Triumfetta rhomboidea	Tiliaceae	Oct – Dec	FE
Urena lobata	Malvaceae	Sep – Nov	FE, ERS
Utricularia purpurea	Lentibulariaceae	Aug – Oct	ERS
U. striatula	Lentibulariaceae	Aug – Sep	TC, ERS, GS
U. uliginosa	Lentibulariaceae	Aug – Nov	ERS

Viola patrinii	Violaceae	Sep – Dec	SC, ERS
Wahlenbergia erecta	Campanulaceae	Oct – Nov	TG
Zeuxine gracilis	Orchidaceae	Mar– Apr	FE, SR

SR - Soil rich areas, **FE** - Forest edge, **TG** - Tall grass covered areas, **SC** - Soil covered areas, **ERS** - Open exposed rock surfaces, **GS** - Gibber stone, **RE** - Rock edge, **SF** - Seasonal water falls, **TC** - Tree cover, **RR** - Rock rift

4.4.3. Distribution of herbaceous plant species in relation to altitude

The study on herbaceous plant communities in relation to altitude variation in Bababudangiri and Kemmannugundi resulted in a total of 166 species (Table 4.15). From Bababudangiri 76 species were observed. A total of 13 species were enumerated from the hill base (lower altitude), in the middle elevation 30 species were occurred and at the higher elevation 48 species were found. In Kemmannugundi, 90 species were distributed at lower elevation, most of them are weed plants, in the middle elevation 31 species were observed, at the hill top 50 species has been observed. Most of these are endemic species (Table 4.14). In both the study areas, the number of species gradually increase from lower to higher elevation. In lower elevation because of anthropogenic disturbances the number of species are few and they were weed plants.

Table 4.14. Distribution of number of species in different altitude in Bababudangiri and Kemmannugundi

Sl. No.	Elevation	Altitude (m)	Number of Species occurred	
			Bababudangiri	Kemmannugundi
1	Lower attitude	1000-1200	13	28
2	Middle attitude	1300-1500	30	31
3	Higher attitude	1600-1800	48	50

Table 4.15. Distribution of herbaceous plants based on altitude at study sites

Species Name	Bababudangiri			Kemmannugundi		
	Lower altitude	Middle altitude	Higher altitude	Lower altitude	Middle altitude	Higher altitude
Achyranthes aspera	-	-	-	+	+	-
Adenoon indicum	-	+	+	-	+	-
Ageratum conyzoides	+	-	+	+	+	+
Alternenthera tenella	-	-	-	+	-	-
Alysicarpus racemosus	-	-	+	-	-	-
Amaranthace sp.	-	-	-	-	-	+
Anaphalis lawii	-	+	+	-	-	+
Andrographis paniculata	-	-	-	-	+	-
Aresema sp.	-	+	-	-	-	-
Argyreia sericea	-	-	-	-	+	-
Arundinella pumila	-	-	+	-	-	-
Arundinella purpurea	-	-	+	-	-	+
Asclepias curassavica	-	-	-	-	+	+
Asystasia dalzelliana	-	-	-	-	-	+
Bidens pilosa	-	-	-	+	-	-
Biophytum sensetivum	+	-	-	-	-	-
Borreria stricta	-	-	-	-	+	-
Bulbostylis densa	-	-	+	-	-	-
Calceolaria mexicana	-	+	-	-	-	-
Campanula fulgens	-	-	+	-	-	-
Canscora diffusa	-	+	-	-	-	-
C. pauciflora	-	+	-	-	-	-
Cardamine africana	-	-	+	-	-	-
C. trichocarpa	-	-	-	+	-	-
Carex filicina	-	-	-	-	-	+
Cassia mimosoides	-	-	-	-	-	+
C. tora	-	-	-	+	-	-
Centella asiatica	+	-	-	-	-	-
Cerastium glomeratum	+	-	+	-	-	-
Chloris barbata	-	-	-	-	+	-
Chlorophytum tuberosum	-	-	+	-	-	-
Chrysopogon hackelii	-	-	-	-	-	+
Clerodendron infortunatum	+	-	-	+	+	-
Colocasia antiquorum	-	-	-	+	-	-

Contd…

Conyza stricta	-	-	+	-	-	+
Curculigo orchiodies	-	+	+	-	+	+
Curcuma neilgherrensis	-	-	-	-	+	-
C. pseudomontana	-	-	-	-	-	+

Cyanotis cristata	-	-	-	+	-	-
C. tuberosa	-	-	+	-	-	-
Cynodon dactylon	+	+	-	-	-	-
Cynoglossum zeylanicum	-	-	-	-	+	+
Datura metel	-	-	-	-	+	+
Desmodium triflorum	-	-	-	+	-	-
Dichrocephala integrifolia	-	+	+	-	-	-
Drosera peltata	-	-	+	-	-	-
Drymaria cordata	+	+	+	-	-	-
Elatostemma lineolatum	-	-	-	-	+	+
Emilia sonchifolia	+	+	-	-	-	-
Eragrostis tenufolia	-	-	-	+	-	-
Eriocaulon eurypapylon	-	-	+	-	-	-
E. polycephalum	-	-	+	-	-	-
Eulalia trispicata	-	-	-	-	-	+
Eupatorium adenophorum	+	+	-	+	+	+
Euphorbia laeta	-	+	-	-	-	-
E. pycnostegia	-	-	-	-	-	+
Galinsoga parviflora	-	+	-	-	+	-
Gentiana quadrifaria	-	-	+	-	-	-
Girardinia zeylanica	-	-	-	+	-	+
Gymnostachyum latifolium	-	+	-	-	+	-
Habenaria grandifloriformis	-	-	+	-	-	-
H. heyneana	-	-	+	-	-	+
H. longicorniculata	-	-	-	-	-	+
Heracleum candolleanum	-	-	-	-	-	+
Heteropogon contortus	-	-	+	-	-	-
Hypericum mysorense	-	+	-	-	-	-
Hypoxis aurea	-	-	+	-	-	+
Imaptiens scapiflora	-	+	+	-	-	-
I. acaulis	-	+	+	-	-	-
I. chinensis	-	-	-	-	-	+
I. gardneriana	-	-	-	-	+	-
I. inconspicua	-	-	+	-	-	-

Contd…

I. kleiniformis	-	+	-	-	-	-
I. scapiflora	-	-	-	-	+	+
Ipomea hedrifolia	+	+	-	+	+	-
Jansenella griffithiana	-	-	-	-	-	+
Justicia procumbens	-	-	+	-	-	-
J. simplex	-	+	+	-	-	+
Laggera alata	-	+	-	-	+	-

Leucas marrubioides	-	+	+	-	-	-
L. zeylanica	-	-	-	-	-	+
Lobelia nicotianefolia	-	-	-	-	+	+
Mecardonia procumbens	-	-	-	-	+	+
Michrochloa indica	-	-	+	-	-	-
Mimosa pudica	-	-	-	-	+	-
Murdannia crocea	-	-	-	-	-	+
M. semiteres	-	-	+	-	-	-
M. simplex	-	-	+	-	-	+
Neanotis carnosa	-	-	-	-	-	+
Neanotis foetida	-	+	-	+	-	-
Oldenlandia dichotoma	-	-	+	-	-	-
O. prainiana	-	-	+	-	-	-
O. stocksii	-	-	+	-	-	-
Ophiorrhiza mungos	-	-	-	-	-	+
Osbeckia cupularis	-	+	-	-	-	-
Oxalis corniculata	-	-	-	+	+	+
O. debilies	-	-	-	+	+	+
Paracaryum coelestinum	-	-	+	-	-	-
Parnassia mysorensis	-	-	+	-	-	-
Parthenium hyastrominium	-	-	-	+	-	-
Pavonia zeylanica	-	-	-	+	-	-
Pdicularies zeylanica	-	-	+	-	-	-
Peristylus densus	-	-	+	-	-	+
Pimpinella wallichiana	-	-	-	-	-	+
Plantago major	-	-	-	-	-	+
Plectranthus incanus	-	+	-	-	-	-
Pogostemon mollis	-	-	-	-	-	+
Polygala elongata	-	-	-	-	+	-
Pouzolzia wightii	-	-	-	-	+	+
Satyrium nepalense	-	-	+	-	-	+

Contd…

Senecio ludens	-	-	+	-	-	-
Sida acuta	-	-	-	-	+	-
S. rhomboidea	-	-	-	-	+	-
Smithia hirsute	-	+	-	-	-	-
S. sensitiiva	-	-	+	-	-	-
Solanum nigrum	-	-	-	+	+	-
Sonerila rheedii	-	-	-	-	+	-
Spilanthes acmella	-	-	-	-	+	-
S. calva	-	-	-	+	+	+
S. paniculata	-	-	-	+	+	+

Stachytarpheta indica	-	-	-	+	+	-
S. jamaicensis	-	-	-	+	-	-
Striga asiatica	-	-	-	-	-	+
S. gesnerioides	-	-	+	-	-	-
Strobilanthes kunthianus	-	-	+	-	-	-
S. sessilis	-	-	+	-	-	-
Swertia corymbosa	-	-	+	-	-	-
S. lawii	-	-	+	-	-	+
S. minor	-	-	+	-	-	-
S. raveendrae	-	-	+	-	-	-
Synedrella nudiflora	+	-	-	+	-	-
Tephrosia tinctoria	-	-	-	-	-	+
Themeda tremula	-	-	-	-	-	+
T. triandra	-	-	-	-	-	+
Trichodesma zeylanicum	+	-	-	-	-	-
Tridax procumbens	-	-	-	+	-	-
Tripogon bromides	-	-	-	-	-	+
Triumfetta rhomboidea	+	+	-	+	-	-
Urena lobata	-	-	-	+	-	-
Utricularia arcuata	-	-	+	-	-	-
U. striatula	-	-	+	-	-	-
U. uliginosa	-	-	-	-	-	+
Vigna vexillata	-	-	-	-	-	+
Viola patrinii	-	-	+	-	-	-
Wahlenbergia erecta	-	-	-	-	-	+
Zeuxine gracilis	-	-	-	-	-	+

Note : '+' present and '-' absent

Variation in species diversity is influenced by various ecological gradients (Palmer, 1992). The altitudinal gradient is one of the diverse factors in spatial patterns for floristic diversity (Lomolino, 2001), which can effect the rate of distribution of species in tropical montane forests. Some of the other factors like climatic conditions, temperature, altitude, slope, soil depth, exposure to sun, short period of growing season and other ecological parameters also may influence the distribution of species at different altitudinal gradients (Rawat, 2000). Bray and Gorham (1964) studied influence of slopes in distribution of vegetation due to solar irradiation. The study related to distribution of herbaceous species in relation to altitude

showed a gradual increase in number of species with increase in the altitudinal gradient. On the basis of our observation higher altitude represented more number of species in these two study areas. While at middle elevation moderate number of species and in lower elevation less number of species were distributed. Weed species like *Parthenium hyastrominium*, *Ageratum conyzoides* and *Eupatoruim adenophorum* are more at middle and lower elevations due to much anthropogenic disturbances. Binu *et al.* (2011) studided the floristic diversity of trees along with altitudinal gradient of Mavanna shola forest and they found that, the altitude increases as the distribution of tree species decreases.

In the present study, the lower altitude areas showed few number of species due to high anthropogenic disturbance. In the middle elvations number of coffee estates with closed canopy trees are present, hence, the herbaceous plants are lower in number. Whereas, higher altitude areas number of species were more because of open canopy and species present in this areas are shade intolerent and availability of favourable climatic conditions. At the top of the hills influences the growth of more number of species. This phenomena was supported by Teketay (1997) who specified that regeneration of species is affected by natural phenamenon such as canopy gap and light intensity, which affects the diversity of herbaceous endemic plants. Most of these species are endemic to these hill tops. Both of these two area harbours the cool climate and pleasant summer attracting more number of tourisum related activies. The anthropogenic activities like construction of roads, home stays, invasive weed species in this areas posses a great threat for highly diverse herbaceous plant species. Disturbance of an ecosystem has consequences for the maintanence and restoration of biodiversity at all categories (Pickett and Parker, 1994). Due to human influences many species have been eleminated from these area (Chapin-III *et al*., 2000).

5.0. Summary and Conclusion

5.1. Summary and Conclusion

It has been noted that montane grasslands are completely differ both floristically and characteristically from that of surrounding vegetation. They are facing harsh environmental conditions, nutrient poor soil. These grasslands harbour various micro habitats. Pramod *et al*. (1997) stated that increase in the amount of land utilization resulted in several threats to the biodiversity of the Western Ghats. Various activities like increasing number of home stays inside coffee plantations, exponentially increasing tourism, construction of roads and others are rendering the existence of rich biodiversity. As mentioned earlier the plants present in this grasslands highly seasonal, most of them are ephemerals and most of these herbs are delicate plants. Variation in climatic condition may changes the whole plant communities. In the present study most of the plants were endemic to Karnataka viz., *Campanula fulgens*, *Oldenlandia dichotoma*, *O. praniana*, *O. stocksii. Paracaryum coelestinum*, *Conyza stricta* and *Dendrobium jerodonianum*.

Previous floristic studies in the regional floras gave an idea only about some of the taxa present in these grasslands. Quantitative investigations on the structure, composition, diversity and dynamics of herbs were practically not studied. With this background the present work "A study on the ecology of herbaceous plant communities in montane grasslands Kemmannugundi and Bababudangiri areas of Karnataka." of has generated a baseline data on the above mentioned aspects along with distributional pattren of the plant species. As the study is very descriptive and informative, the data will be helpful in effective conservation strategies. Even the study can be said to be the preliminary to the montane grasslands and subsequent investigations will provide additional data on composition and diversity. Long term studies are necessary to understand the sucession.

Therefore, the present study strongly supports the further research program in better understanding of the ecosystem, which will useful in better forest management and conservation efforts.

5.2. Recommendations

Montane grasslands are the unique habitats and valuable forest tract of the Western Ghats. These grasslands are restricted found only in the Western Ghat areas, 1500m above. They are generally called as Sky island, these islands harbours many rare, endemic and distinct taxa. The results indicated that these areas are rich in herbaceous diversity and should be given a preference for conservation priority area and declare some areas as protected areas, because most of these plant communities are ephemerals and annuals and complete their life cycle within a short periods. These grasslands are neglected in the concern of conservation priority due to most of the taxa present in this area are highly seasonal. Therefore, in depth understanding of the pattern of distribution of the different parameters that can be used to increase abundance and diversity at different taxonomic hierarchies and at different spatial scales are needed. Following are the generalized threats to these grasslands.

5.3. Threats to the herbs in montane grasslands

Causes of threat to herbs have been broadly classified into two factors *viz*., i) Biotic factors and ii) Natural factors (Plate-6).

i. Biotic factors

Advance of modernization has changed the human socio-economic structure which need to rapid urbanization, habit loss, fragmentation and global climatic change, demand on forest products, exotic invasion, grazing etc are creating serious threats to diversity of herbs in high altitude grasslands.

a. Habitat destruction

These montane grasslands are the popular hill stations. As these places have cooler climate, tourists visiting these areas because of climate and pilgrimage places. Herbs are facing considerable stress due to biotic interferences caused by visitors. Easy road access enhances the likely hood of landscape level impacts from habitat conversion, trampling, trajectories and tourist services such as tea shops, home stays, resorts, that could have direct or indirect impact on floristic diversity. Like many coffee estates become commercial home stays, which destroys the local inhibiting taxa. Tourists destroy these ecosystem by throwing plastic and glass waste materials, wastes, clothes all over grassland and also in the middle of the forest area.

b. Over exploitation

Some of these places are famous religious stations. More number of visitors are visiting to these places and also more number of Hakims or traditional healers are marketing some forest products like roots, tubers, leaves, barks, some of orchides, herbs like *Swertia lawii*, *S. raveendrae* and *Heraculum candolleanum* for economic reason.

c. Lack of proper knowledge

Montane grasslands herbs are the neglecting groups of plants these are less studied from the botanists because of they are highly seasonal, complete their life cycle with in few days. Very few people are aware of this group of plants. Before investigation of grassland herbs many habitats are being destroyed by unknowingly which is leading to extinction of many rare taxa. So, lack of proper knowledge about this group may lead to loss of genetic diversity of these groups.

d. Lack of intensive and extensive exploration

In India, very few people are working on these floristic diversity of herbs in comparison to higher groups of plants, many herbaceous plants are yet to be explored.

e. Global warming

Gobal warming is one of the most harmful reasons responsible for loss of mass blooming land glimpse. Most of the herbs are growing on cool, moist climatic zone in these hilly areas. The growth is mainly dependent on water availability, some of the herbs are ephiphytic grow on bark or rock edge or rock cervices. Due to global warming microclimatic condition required for their growth is changing temerature and precipitation amount in hilly areas are changing day by day thus resulting loss of microhabitats for herbs.

f. Exotic invasion

The posibility of invasion by exotic species like *Ageratum conizoides*, *Cestrum aromanticum*, *Thithonia* sp., *Eupatorium adenophorum* that inadvertently get transported from horticulture department and also from the sand brought for construction and building construction.

g. Grazing

Cattle grazing is another serious threat to this shola grasslands, domestic and wild animals (cattles, deer, bisons and wild goat) graze grasses in the grassland. Some important grass species grow in the same habitat. Although the animals feed grasses many of the midicinal grasses come under their feet and destroyed.

h. Fire

In these grasslands, from the months of February to March, forest fire is common. This phenomena leads destrction of flora and fauna.

ii. Natural factors

Apart from the biotic factors natural factors like catastrophic activites biological imparities between taxa are also responsible for loss of herbaceous plant diversity.

a. Catastrophic activites

Natural factors like land sliding, rains etc., are responsible for destruction of habitats of herbs. In montane grasslands during the monsoon heavy rain causes land slide destroying the flora.

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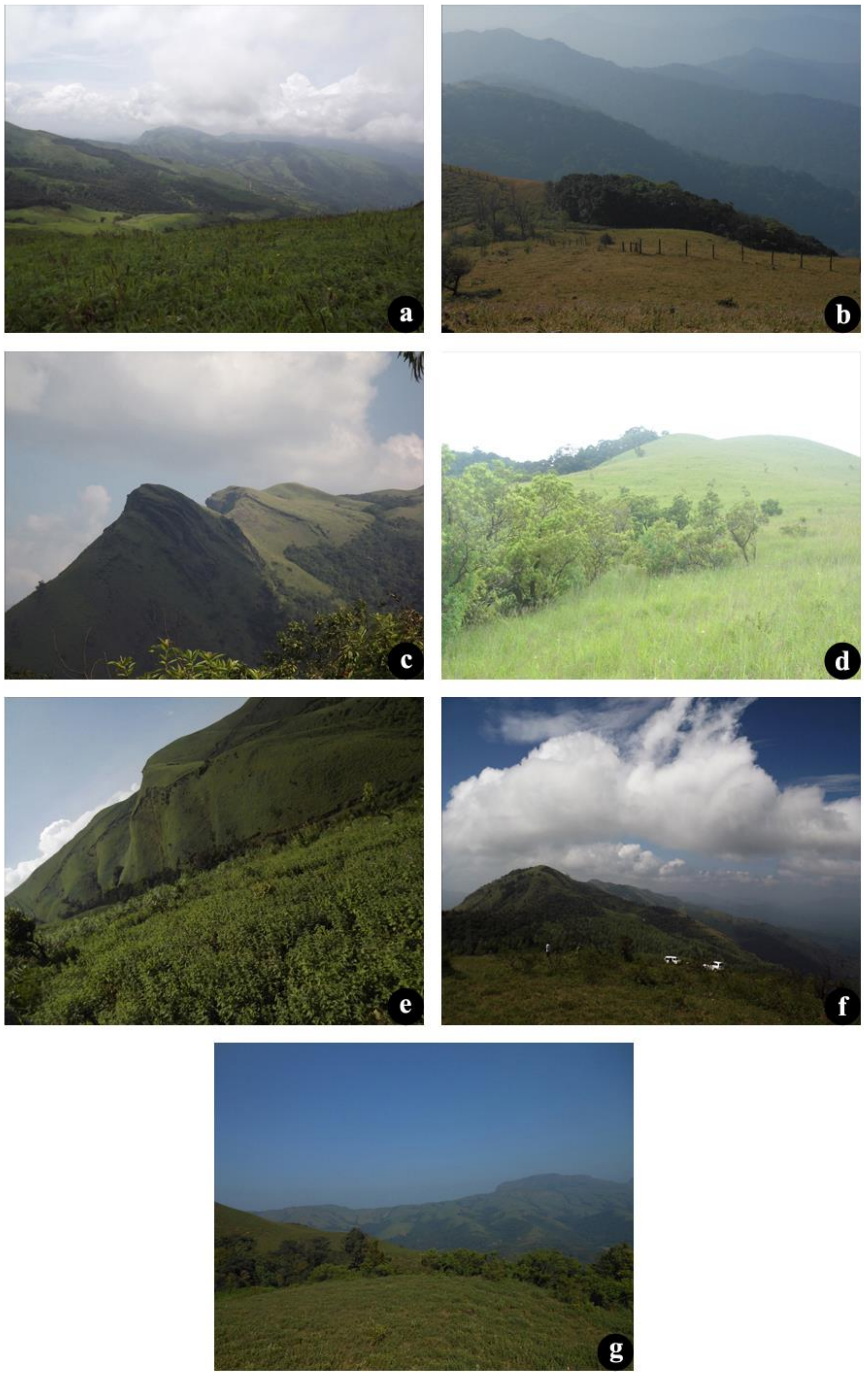
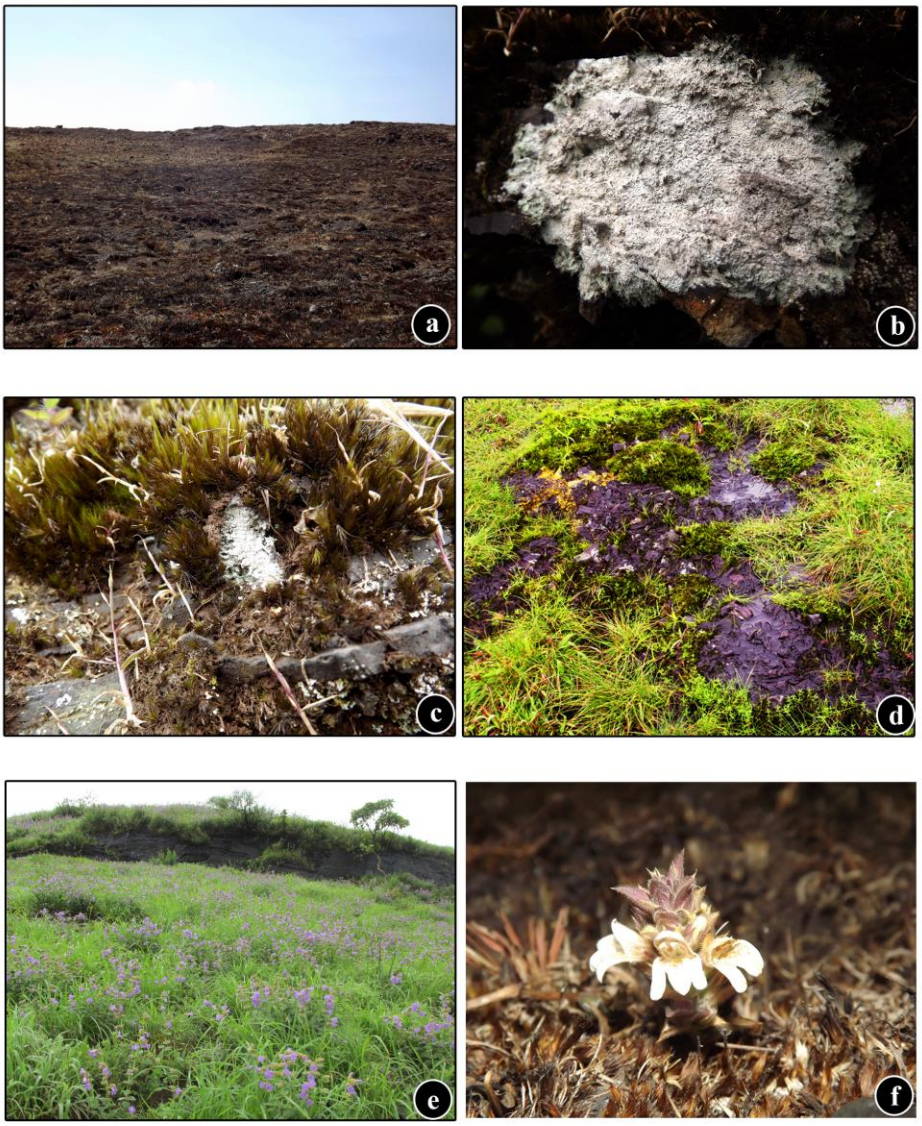
Plate - 1



Different views of montane grasslands of study sites: Fig. a. Bababudangiri, b. Brahmagiri, c. Kemmannugundi, d. Kodachadri, e. Kudremukh, f. Mullayyanagiri, g. Pusphagiri.

Plate - 2

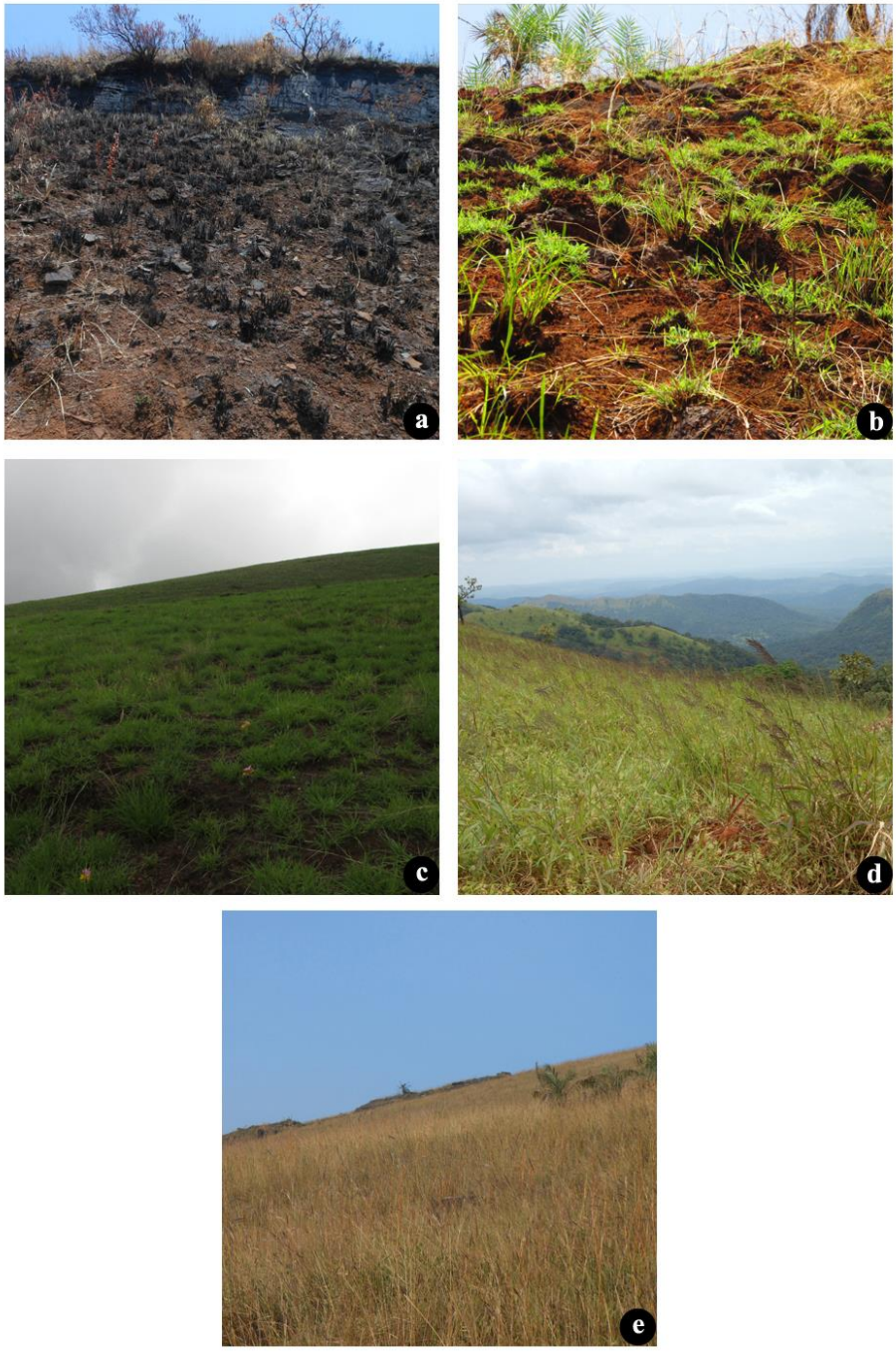


Quick succession of herbs in short profussion: Fig. a. Exposed rock surface, b. Colonization of lichens, c. Colonization of mosses, d. Growth of grass mat, e. Succession of dicots and monocots (mass flowering of *Strobilanthes kunthianus*), f. Appearance of perennial plant.

Plate - 3

Views of study site at Bababudangiri in different climatic seasons: Fig. a. Summer season, b. Monsoon season, c. Winter season.

Plate - 4



Views of study site at Kemmannugundi in different climatic seasons: Fig. a. Summer season, b. Pre monsoon season, c. Monsoon season, d. Post monsoon, e. Winter season.

Plate - 5

Different type of habitats studied for exploring herbaceous plant comminuties in Bababudan hill range: Fig. a. Forest edge, b. Seasonal waterfall, c. Forest area, d. Exposed rock surface, e. Gibber stone, f. Soil covered area, g. Rock cervices, h. Soil rich area, i. Tall grass covered area, j. Tree trunk

Plate - 6

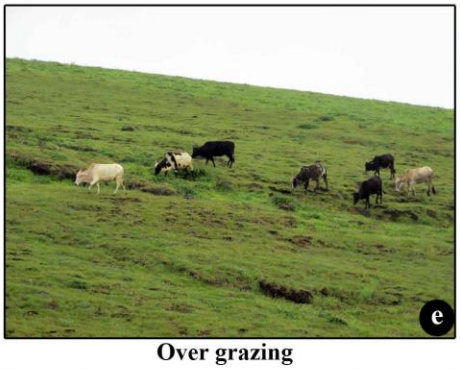
Major threats to herbaceous plants cover in the study area

Movement of Vehicles

Construction activities

Land slide

Plastics and Exotic invasion



Over grazing

Tower construction

Raw materials for medicine

Fire

Plate - 7

Herbaceous flora of the montane grasslands of Karantaka

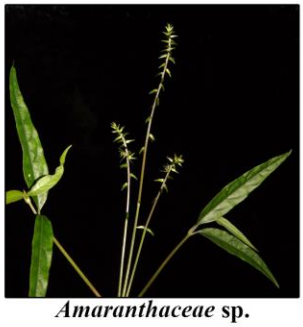
Abelmoschus angulosus

Adenostemma lavenia

Alysicarpus vaginalis

Abelmoschus manihot

Aerides crispum



Amaranthaceae sp.

Anaphalis lawii

Adenoon indicum

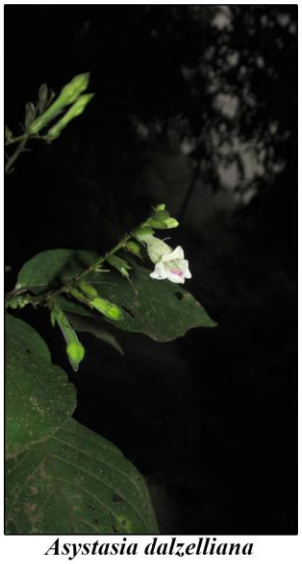
Aeschynanthes perrottetii

Alysciarpus racemosus

Anaphalis subdecurrens

Plate - 8

Anisochilus carnosus



Asystasia dalzelliana

Blepharis asperrima

Blepharis maderaspatensis

Argeria sp.

Begonia crenata

Bosenbergia pulcherrima

Arisaema tortuosum

Begonia malabarica

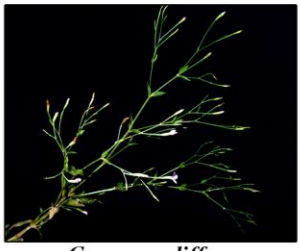
Calceolaria mexicana

Asclepias curassavica

Belosynapsis vivipara

Campanula flugens

Plate - 9



Canscora diffusa

Ceropegia gardneri

Crotalaria nana

Cardamine africana

Chlorophytum tuberosum

Crotalaria sp.

Cassia mimosoides

Commelina diffusa

Curcuma karnatakensis

Cerastium glomeratum

Conyza stricta

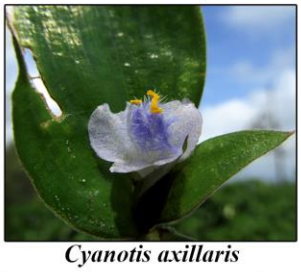
Curcuma pseudomontana

Plate - 10

Curcuma sp

Dendrobium barbatulum

Drosera indica



Cyanotis axillaris

Dendrobium nutantiflorum

Drosera peltata

Cyanotis tuberosa

Desmodium repandum

Cyanotis tuberosa

Dichrocephala integrifolia

Drymaria cordata

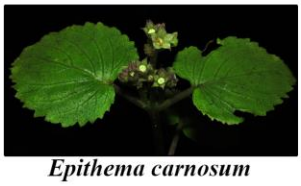
Cynoglossum zeylanicum

Disperis zeylanica

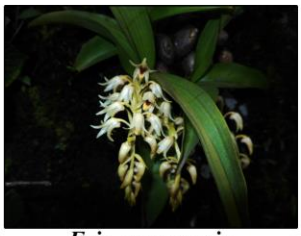
Plate - 11

Elatostema lineolatum

Emilia sonchifolia



Epithema carnosum



Eria mysorensis

Elephantopus scaber

Eria reticosa

Emilia exserta

Emilia flammea

Eriocaulon eurypeplon

Eriocaulon polycephalum

Eriocaulon sp.

Eriocaulon stellulatum

Euphorbia laeta

Euphorbia pycnostegia

Plate - 12

Exacum bicolor

Exacum petiolare

Exacum sessile

Galinsoga parviflora

Gentiana quadrifaria

Girardinia zeylanica

Gloriosa superba

Gymnostachyum latifolium

Gynura sp.

Habenaria grandifloriformis

Habenaria heyneana

Habenaria longicorniculata

Plate - 13

Habeneria crinefera

Hypoxis aurea

Impatiens acaulis

Heracleum candolleanum

Impateins aadhishankarii

Impatiens balsamina

Hoppea fastigiata

Impateins chinensis

Impatiens inconspicua

Hydrocotyle javanica

Impatiens kleiniformis

Hypericum mysorense

Impateins gardneriana

Impatiens oppositifolia

Plate - 14

Impatiens pulcherrima

Lagasca mollis

Leucas eriostoma

Impatiens scapiflora

Launaea acaulis

Leucas zeylanica

Lepidagathis prostrata

Iphigenia pallida

Lepidagathis spinosa

Linum mysurense

Justicia procumbens

Leucas ciliata

Lobelia nicotianaefolia

Knoxia mollis

Plate - 15

Malaxis rheedei

Murdannia pauciflora

Neanotis quadrilocularis

Murdannia semiteres

Neanotis sp.

Murdannia coreca

Murdannia simplex

Neurocalyx calycinus

Murdannia gigantia

Neanotis carnosa

Oldenlandia stocksii

Ophiorrhiza hirsutula

Murdannia langinosa

Neanotis foetida

Ophiorrhiza mungos

Plate - 16

Osbeckia parviflora

Pdicularies zexlanica

Plectranthus incanus

Oxalis corniculata

Peristylus densus

Plectranthus mollis

Oxalis debilies

Phyllanthus virgatus

Plectranthus paniculatus

Paracarium coelestinum

Pimpinella wallichiana

Plectranthus stocksii

Parnassia mysorensis

Plantago major

Plate - 17

Pogostemon mollis

Strobilanthes kunthianus

Satyrium nepalense

Pogostemon paniculatus

Strobilanthes sesiles

Bosenbergia pulcherrima

Pouzolzia wightii

Rhynchoglossum notonianum

Senecio intermedius

Richardia scabra

Senecio ludens

Plate - 18

Sigesbcekia orientalis

Sonerila rheedii

Striga angustifolia

Smithia hirsuta

Sopubia delphinifolia

Striga asiatica

Striga gesnerioides

Smithia racemosa

Spermacoce verticillata

Swertia corymbosa

Sonchus oleraceus

Spilanthes calva

Swertia lawii

Plate - 19

Swertia minor

Thalictrum dalzellii

Torenia bicolor

Trichodesma zeylanicum

Swertia raveendrae

Thunbergia fragrans

Unidentified sp.

Tephrosia tinctoria

Thunbergia mysorensis

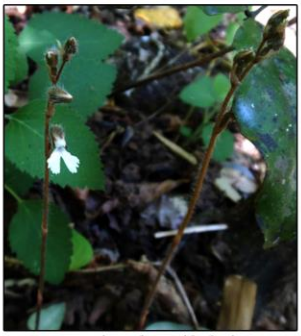
Unidentified sp.

Urena lobata

Plate - 20

Utricularia arcuata

Vigna vexillata



Zeuxine longilabries

Viola patrinii

Zingiber cernuum

Utricularia uliginosa

Wahlenbergia erecta

Zingiber neesanum

Vernonia conyzoides

Zeuxine gracilis

Plate - 21

Grass flora of the montane grasslands of Karnatka

Arundinella purpurea

Carex falicina

Chrysopogon hackelii

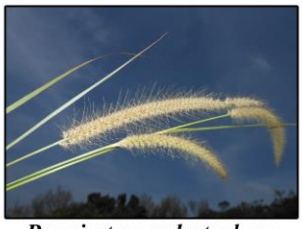
Cymbopogon ceasius

Ergrostis uniloides

Ischaemum indicum

Cyperus distans

Jansenella griffithiana



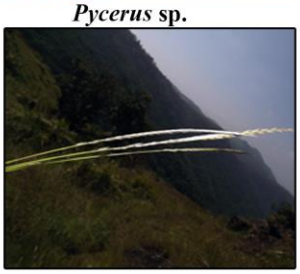
Pennisetum polystachyon

Eulalia trispicata

Pycerus sp.

Themeda tremula

Themeda triandra



Tripogan bromides