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Floristic composition and biological spectrum of a sacred grove in West Midnapore district, West Bengal, India

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ABSTRACT

Traditional cultural and religious beliefs and practices in the form of sacred groves play a crucial role in environmental conservation and biodiversity. The present study was conducted to explore plant resources, their biological spectrum, leaf size spectrum, sacred grove conservation status, locally known as *Kankabati Sitabala Than* (KST) in the district of West Midnapore, West Bengal in India. The study's floristic list revealed that the KST vegetation was diverse and composed of 277 species of 238 genera distributed over 77 families under 36 orders according to APG IV classification, of which 87 species were aliens. Poales (23.40%) and Poaceae (15.38%) were the dominant order and family in terms of species wealth. Biological spectrum shows the study area was classified as "thero-crypto-chamaephytic" type of phytoclimate. Leptophyll (26.60%) and ovate (18.91%) were found to be high in the leaf size spectrum and lamina. The vulnerable climber and tree species are *Cayratia pedata* and *Pterocarpus indicus*. The vegetation phenology, observed during different seasons revealed that most of the species were dominant in rainy seasons (99.68%), followed by winter (69.87%) and summer (29.81%). The study area being a sacred grove remains fairly undisturbed. For the long-term conservation of germplasm of the grove some recommendations have been suggested.

1. Introduction

Sacred groves have a variety of history, cultures and ancient connections with their adjacent people within environments [1]. Due to certain restrictions associated with them, sacred groves have been shown to have a major impact on conservation and the environment in many countries of the world [2]. Traditional environmental reverence and restrictions on access to sacred groves have often resulted in well-preserved areas with high biodiversity in otherwise degraded environments [3]. Sacred groves are distributed across the glove, and diverse culture recognizes in different ways encoding various roles in their protection. Especially where indigenous communities live, there are many parts of India [4]. These are known to the ethnic people in different names. As a unique example of traditional conservation practices, their diversity has been documented. Many workers have discussed their potential for conservation worldwide [5]. They are believed to be more effective than government-protected areas because they are managed by the community and cover a wide range of habitats. Sacred groves are surviving patches of pristine tropical forests, rarely degraded by human activities, but protected and modeled by local people, and acting as historical indicators, ecological and archeological [3]. There was a general understanding among the ancient people that in places of natural sacred sites the godly element was actively at work. For the adjacent people, therefore, the vegetation was sacred. Such sites continue to exist today and play an important role at different ecological levels [6].

The adaptation of a plant to certain ecological conditions determines a life form; therefore, it is an important physiognomic characteristic that has been widely used in the analysis of vegetation. It indicates a certain area's macro and microclimate and human disturbances [7]. Raunkiaer [8] proposed the term "Biological Spectrum" to express the distribution of life-form in a flora as well as the phytoclimate under which the prevailing life-forms evolved. The plant species may be grouped as five main classes under this system, i.e. phanerophytes, chamaephytes, hemicryptophytes, cryptophytes and therophytes. The percentage of various life form classes put together is called as the biological spectrum. Raunkiaer [8] has built a normal spectrum that can act as a model, against which spectra may be compared to different life-forms. The normal spectrum of Raunkiaer indicates a phanerophytic community and the deviation (from it) determines a habitat's phytoclimate. The occurrence in different regions of similar biological spectra indicates similar climatic conditions. Thus, the differences between the biological spectrum's normal spectrum and life forms may indicate that life is characterized by the phytoclimate or vegetation.

Under a specific climate regime, climatic types can be characterized by the prevailing plant life forms in plant communities [9–11]. The biological spectrum from Indian region is related to specific edaphic,

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altitudinal and climatic factors [12–16]. Life-form study is therefore an important vegetation description tool that ranks next to the floristic composition. Therefore, the biological spectrum is useful as an index of forest landscape health status. Biological spectrum may set guidelines for a community's optimization and eco-restoration when performed at periodic intervals. Life form may also be categorized using leaf size i.e. leptophylls, nanophyll, microphyll, notophyll, mesophyll, macrophyll and megaphyll. It has some justification for using a leaf size to characterize different types of vegetation based on percentages of the different leaf sizes present. However, light intensity and soil conditions, especially nitrogen and phosphorus available; also have a significant influence on the size of the leaf even within the same genotype [17]. Therefore, the present study of a sacred grove may be used in India as an example for other sacred groves in general and in particular for phytoclimatic study.

2. Materials and methods

2.1. Study site

The present sacred grove, known popularly as “KST” (Fig. 1) [latitude 22°25′15.12″- 22°25′15.55” N and longitude 87°15′11.90″- 87°15′ 12.16″, average altitude 36.26 m named after its presiding folk deity *Sitabala* or *Sitala* (Table 1)], is located 7 km away from the West Midnapore district headquarter Midnapore town along the east-west running Midnapore-Jhargram via Dherua roadways under Midnapore Sadar block. The grove is spread over an area of 4 acres on a public land at the common outskirts of Lodhasai, Kankabati and Badhi villages. This 800-year old semi-evergreen, part-marshy, part-terrestrial grove stands as an island of forest amidst the crop fields. In addition to the daily worship offered to the deity of the grove, local people, both tribal (*Bhumij*, *Kora*, *Santal*) and non-tribal of the surrounding villages visit the sacred forest *en masse* during annual ‘*Makar Sankranti*’(Middle of the month January) when village fair is held for two days. Since the grove is the abode of goddess, people neither cut any plant of the grove nor foul the serenity of the area, thus strictly adhering to the taboos and ethics. The folk belief goes that worshipping the deity gives people immunity against pox, and heralds' well-being and prosperity of the villages.

2.2. Field survey and data collection

During the period from September 2013 to October 2018, the study area was thoroughly surveyed in different seasons to study botanical and social perspectives. Floristic surveys were conducted on the basis of “spot identification.” Samples of plants with flowers or fruits were collected for unknown plants. The specimens were processed, preserved, poisoned and mounted on herbarium sheets using standard and modern herbarium techniques after collection [18]. In the sacred grove, photographs were taken of some common, locally rare, endemic and valuable plant species. Herbarium sheets were identified by matching properly annotated materials available at

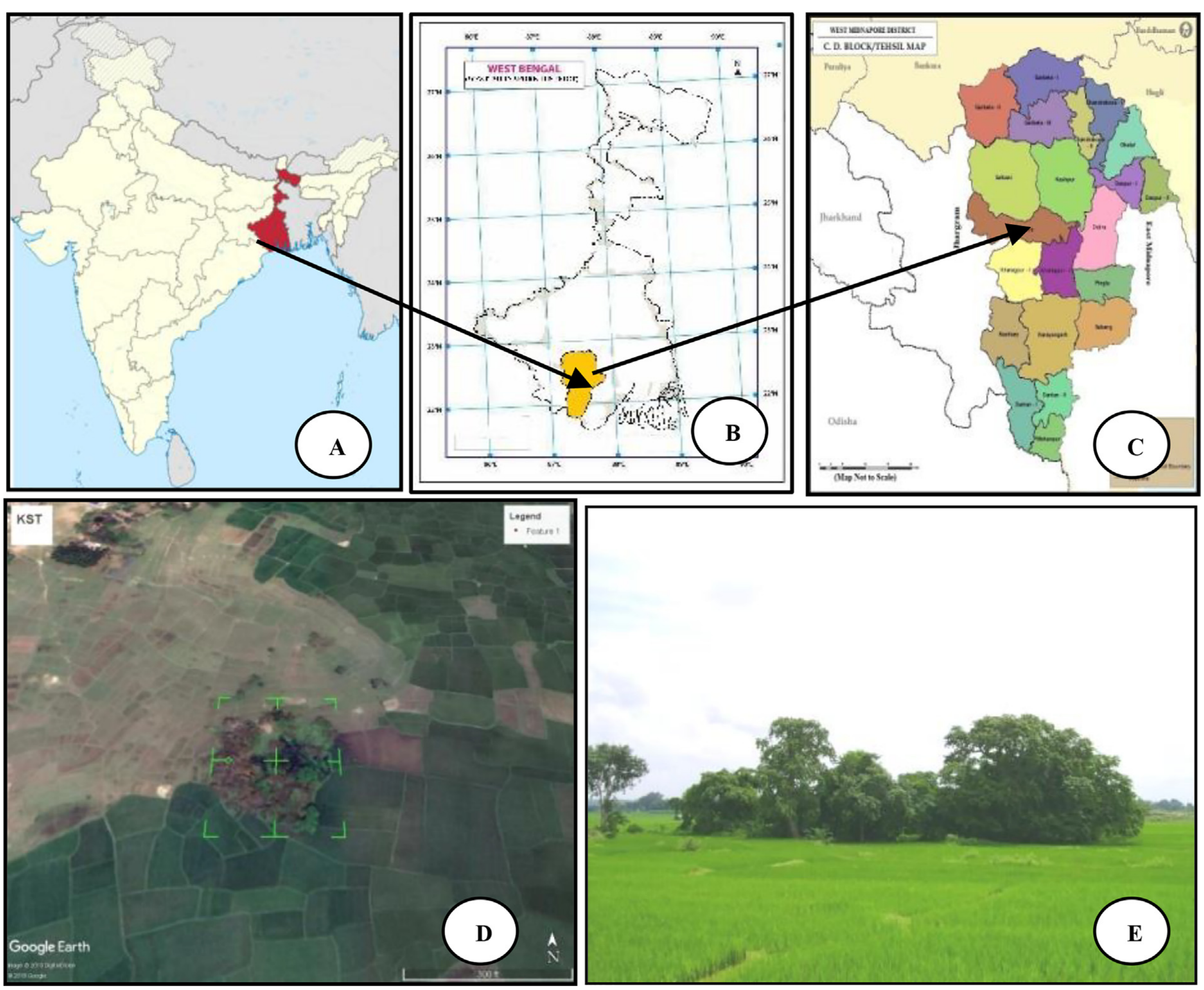

Fig. 1. Location of the study area (A: India, B: West Bengal with West Midnapore district, C: West Midnapore district with Midnapore Sadar block, D: Google Earth image showing KST sacred grove, E: KST sacred grove).

Table 1
Database of floristic and functional trait diversity of KST sacred grove.

Name of the species	Voucher no.	Habit	Life-span	Nativity	Fl. & Fr. time	Raunkiaer's life-form	Sub-type	Leaf spectra	Shape of the leaf lamina	IUCN Red List Status	Seasons		
											Summer	Rainy	Winter
Nymphaeales Salisb. ex Bercht. & J.Presl													
Nympheaceae Salisb.													
Nymphaea nouchali Burm. f.	USNY1	H	P	N	Aug.–Dec.	Cr		Mg	Or	LC	A	P	P
MESANGIOSPERMS													
MAGNOLIIDS													
Piperales Bercht. & J.Presl													
Aristolochiaceae Juss.													
Aristolochia indica L.	USAS1	C	A	N	Jul.–Jan.	Cr		No	La	NE	A	P	P
Magnoliales Juss. ex Bercht. & J.Presl													
Annonaceae Juss.													
Annona reticulata L.	USAN1	T	P	E	Jul.–Dec.	Ph	*N*	Me	La	NE	P	P	P
Annona squamosa L.	USAN2	T	P	E	Mar.–Sep.	Ph	*N*	Me	La	NE	P	P	P
INDEPENDENT LINEAGE: UNPLACED TO MORE INCLUSIVE CLADE													
MONOCOTS													
Alismatales R.Br. ex Bercht. & J.Presl													
Araceae Juss.													
Alocasia macrorrhizos (L.) G. Don	USAR1	H	P	E	Apr. –May	Cr		Mg	Sg	NE	P	P	P
Amorphophallus bulbifer (Roxb.) Blume	USAR2	H	P	N	May–Nov.	Cr		Mg	Ha	NE	A	P	P
Lemna perpusilla Torr.	USAR3	H	A	N	Jun.–Jan.	Cr		Le	Cu	LC	A	P	P
Pistia stratiotes L.	USAR4	H	A	E	Apr.–Oct.	Cr		Na	Cu	LC	A	P	P
Scindapsus officinalis (Roxb.) Schott	USAR5	C	P	N	–	Cr		Ma	Ov	NE	P	P	P
Typhonium trilobatum (L.) Schott	USAR6	H	A	N	Sep.–Oct.	Cr		Mi	Co	NE	P	P	P
Wolffia arrhiza (L.) Horkel ex Wimm.	USAR7	H	A	N	Jun.–Oct.	Cr		Le	Lu	LC	A	P	P
Alismataceae Vent.													
Butomopsis latifolia (D.Don) Kunth	USAL1	H	P	N	Sep.–Feb.	He		Mi	La	LC	A	P	P
Caldesia parnassifolia (L.) Parl.	USAL2	H	P	N	Apr.–Sep.	He		Mi	Re	LC	P	P	P
Sagittaria guayanensis Kunth	USAL3	H	P	N	Aug.–Nov.	He		Ma	Lu	LC	P	P	P
Hydrocharitaceae Juss.													
Blyxa octandra (Roxb.) Planch. ex Thwaites	USHD1	H	A	N	Nov.–Jan.	Cr		Le	La	LC	A	P	P
Hydrilla verticillata (L.f.) Royle	USHD2	H	A	N	Nov.–Mar.	Cr		Le	Li	LC	A	P	P
Najas graminea Delile	USHD3	H	A	N	Nov.–Jan.	Cr		Na	Ac	LC	A	P	P
Nechamandra alternifolia (Roxb. ex Wight) Thwaites	USHD4	H	A	N	Nov.–Feb.	Cr		Na	Li	LC	A	P	P
Ottelia alismoides (L.) Pers.	USHD5	H	A	N	All	Cr		Le	Sp	LC	A	P	P
Aponogetonaceae Planch.													
Aponogeton natans (L.) Engl. & K.Krause	USAN1	H	P	N	Aug.–Nov.	Cr		Ma	Li	LC	A	P	P
Potamogetonaceae Bercht. & J. Presl													
Potamogeton crispus L.	USPM1	H	A	N	Feb.–Apr.	He		Me	La	LC	A	P	P
Potamogeton nodosus Poir.	USPM2	H	A	E	Oct.–Dec.	He		Me	Oo	LC	A	P	P
Dioscoreales Mart.													
Burmanniaceae Blume													
Burmannia coelestis D.Don	USBU1	H	A	N	May.–Aug.	Th		Le	Li	LC	A	P	A
Dioscoreaceae R. Br.													
Dioscorea belophylla (Prain) Voigt ex Haines	USDI1	C	P	N	Sep.–Mar	Cr		Me	Re	NE	A	P	P
Dioscorea glabra Roxb.	USDI2	C	P	N	Sep.–Mar.	Cr		Me	Sg	NE	A	P	P
Dioscorea pentaphylla L.	USDI3	C	P	N	Sep.–Feb.	Cr		Me	Co	NE	A	P	P
Dioscorea pubera Blume	USDI4	C	P	N	Oct.–Jan.	Cr		Me	Co	NE	A	P	P
Tacca leontopetaloides (L.) Kuntze	USDI5	H	P	N	Aug.–Nov.	Cr		Na	Sp	LC	A	P	P
Pandanales R. Br. ex Bercht. & J. Presl													
Pandanaceae R. Br.													
Pandanus odorifer (Forssk.) Kuntze	USPN1	S	P	N	Jul.–May	Ph	*N*	Mg	Ob	LC	P	P	P
Liliales Perleb													
Colchicaceae DC.													
Gloriosa superba L.	USCO1	C	P	N	Jul.–Sep.	Ph	*N*	Me	Su	LC	A	P	A
Smilacaceae Vent.													
Smilax ovalifolia Roxb.	USSM1	C	P	N	Jun.–Dec.	Ph	*N*	Ma	Sg	NE	P	P	P
Asparagales Link													
Orchidaceae Juss.													
Geodorum recurvum (Roxb.) Alston	USOR1	H	P	N	Jul.–Aug.	Cr		Mi	La	LC	A	P	P
Vanda tessellata (Roxb.) Hook. ex G. Don	USOR2	H	P	N	Apr.–Jul.	Ph	*N*	No	Su	LC	P	P	P
Hypoxidaceae R. Br.													
Curculigo orchioides Gaertn.	USHP1	H	P	N	Aug.–Oct.	Cr		Mi	La	NE	A	P	A
Xanthorrhoeaceae Dumort.													
Aloe vera (L.) Burm.f.	USXA1	H	P	E	Dec.–Feb.	Ch		No	Su	NE	P	P	P
Asphodelus tenuifolius Cav.	USXA2	H	A	E	Jan.–Mar.	Th		No	La	NE	A	P	P
Amaryllidaceae J. St.-Hil.													
Crinum viviparum (Lam.) R.Ansari & V.J. Nair	USAY1	H	P	N	Aug.–Oct.	Cr		Mg	Li	LC	P	P	P

(continued on next page)

Table 1 (*continued*)

Name of the species	Voucher no.	Habit	Life-span	Nativity	Fl. & Fr. time	Raunkiaer's life-form	Sub-type	Leaf spectra	Shape of the leaf lamina	IUCN Red List Status	Seasons		
											Summer	Rainy	Winter
Asparagaceae Juss.													
Agave sisalana Perrine	USAP1	S	P	E	Mar.–Oct.	Ch		Mg	Su	NE	P	P	P
Agave vivipara L.	USAP2	S	P	E	Mar.–Oct.	Ch		Mg	Su	NE	P	P	P
Asparagus racemosus Willd.	USAP3	C	P	E	Aug.–Dec.	Cr		Le	Ac	NE	P	P	A
Arecales Bromhead													
Arecaceae Bercht. & J.Presl													
Borassus flabellifer L.	USAE1	T	P	E	Mar.–Oct.	Ph	*MM*	Mg	Pa	NE	P	P	P
Calamus viminalis Willd.	USAE2	C	P	N	Sep.–May.	Ph	*N*	Mi	Pa	NE	P	P	P
Phoenix sylvestris (L.) Roxb.	USAE3	T	P	N	Feb.–Jun.	Ph	*M*	Mi	Pa	NE	P	P	P
Commelinales Mirb. ex Bercht. & J.Presl													
Commelinaceae Mirb.													
Commelina benghalensis L.	USCM1	H	A	N	Aug.–Nov.	Th		Mi	Ov	LC	A	P	A
Commelina diffusa Burm.f.	USCM2	H	A	N	Aug.–Nov.	Th		Mi	Ov	LC	A	P	A
Cyanotis axillaris (L.) D.Don ex Sweet	USCM3	H	A	N	Sep.–Dec.	Th		Na	Su	LC	A	P	A
Cyanotis tuberosa (Roxb.) Schult. & Schult.f.	USCM4	H	A	N	Jul.–Sep.	Th		Na	Su	NE	A	P	A
Murdannia nudiflora (L.) Brenan	USCM5	H	A	N	Jul.–Nov.	Th		Na	Su	NE	A	P	A
Murdannia spirata (L.) G.Brückn.	USCM6	H	A	N	Sep.–Jan.	Th		Na	Su	LC	A	P	A
Zingiberales Grisebach													
Costaceae Nakai													
Cheilocostus speciosus (J.König) C. Specht	USCS1	H	P	E	Jul.–Sep.	Cr		Ma	Oo	NE	P	P	P
Zingiberaceae Martinov													
Alpinia calcarata (Haw.) Roscoe	USZI1	H	P	E	Apr.–Jun.	Cr		Ma	Li	NE	A	P	P
Curcuma aromatica Salisb.	USZI2	H	P	N	May–Jun.	Cr		Mg	Oo	NE	A	P	P
Globba marantina L.	USZI3	H	P	N	Aug.–Sep.	Cr		Ma	La	NE	A	P	P
Zingiber capitatum Roxb.	USZI4	H	P	N	Jul.–Aug.	Cr		Ma	La	NE	A	P	P
Poales Small													
Eriocaulaceae Martinov													
Eriocaulon cinereum R.Br.	USER1	H	A	N	Oct.–Jan.	Th		Le	Ac	NE	A	P	P
Eriocaulon quinquangulare L.	USER2	H	A	N	Oct.–Feb.	Th		Le	Li	NE	A	P	P
Cyperaceae Juss.													
Bulbostylis barbata (Rottb.) C.B.Clarke	USCY1	H	P	E	Jul.–Oct.	He		Na	La	NE	A	P	A
Carex filicina Nees	USCY2	H	P	N	Sep.–Dec.	He		Na	Ac	LC	A	P	P
Cyperus difformis L.	USCY3	H	P	E	Jul.–Nov.	He		Le	Li	LC	A	P	P
Cyperus compactus Retz.	USCY 4	H	P	N	Sep.–Nov.	He		Le	Ac	LC	A	P	P
Cyperus compressus L.	USCY5	H	P	N	Jul.–Nov.	He		Le	Ac	LC	A	P	P
Cyperus cyperoides (L.) Kuntze	USCY6	H	P	N	Aug.–Sep.	He		Le	Ac	LC	A	P	A
Cyperus distans L.f.	USCY7	H	P	E	Jul.–Sep.	He		Le	Ac	LC	A	P	A
Cyperus haspan L.	USCY8	H	P	E	May–Jun.	He		Le	Ac	NE	A	P	P
Cyperus iria L.	USCY9	H	P	E	Aug.–Dec.	He		Le	Ac	LC	A	P	P
Cyperus laevigatus L.	USCY 10	H	P	N	Aug.–Oct.	He		Le	Ac	LC	A	P	A
Cyperus pangorei Rottb.	USCY11	H	P	N	Oct.–Feb.	He		Le	Ac	LC	A	P	P
Cyperus paniceus (Rottb.) Boeckeler	USCY12	H	P	N	Jul.–Sep.	He		Na	Li	LC	A	P	A
Cyperus rotundus L.	USCY13	H	P	E	Sep.–Dec.	He		Na	Ac	LC	A	P	P
Cyperus tenuispica Steud.	USCY14	H	P	E	May–Dec.	He		Le	Ac	LC	A	P	P
Fimbristylis aestivalis Vahl	USCY15	H	P	E	Feb.–May	He		Le	Ac	NE	A	P	P
Fimbristylis dichotoma (L.) Vahl	USCY16	H	P	E	Aug.–Oct.	He		Le	Ac	LC	A	P	A
Fimbristylis quinquangularis (Vahl) Kunth	USCY17	H	P	E	Aug.–Nov.	He		Le	Li	LC	A	P	P
Fimbristylis schoenoides (Retz.) Vahl	USCY18	H	P	N	Jul.–Oct.	He		Le	La	LC	A	P	A
Fuirena ciliaris (L.) Roxb.	USCY19	H	P	E	Sep.–Jan.	He		Le	Ac	LC	A	P	P
Kyllinga brevifolia Rottb.	USCY20	H	P	E	May–Oct.	He		Le	Ac	LC	A	P	A
Rhynchospora colorata (L.) H. Pfeiff.	USCY21	H	P	E	May–Oct.	He		Le	Li	NE	A	P	A
Rhynchospora wightiana (Nees) Steud.	USCY22	H	P	N	Aug.–Oct.	He		Le	Li	NE	A	P	A
Schoenoplectiella articulata (L.) Lye	USCY23	H	P	N	Oct.–Feb.	He		Le	Li	NE	A	P	P
Poaceae Barnhart													
Alloteropsis cimicina (L.) Stapf	USPA1	H	A	E	Jul.–Oct.	He		Le	Co	NE	A	P	A
Apluda mutica L.	USPA2	H	P	N	Sep.–Nov.	He		Le	La	NE	A	P	P
Aristida setacea Retz.	USPA3	H	P	N	Aug.–Dec.	He		Le	Ac	NE	A	P	P
Arthraxon lancifolius (Trin.) Hochst.	USPA4	H	P	N	Sep.–Dec.	He		Le	Ac	NE	A	P	P
Brachiaria ramosa (L.) Stapf	USPA5	H	P	N	Jul.–Nov.	He		Le	Co	LC	A	P	P
Brachiaria reptans (L.) C.A. Gardner & C.E. Hubb.	USPA6	H	A	N	Aug.–Oct.	He		Le	La	LC	A	P	A
Chloris barbata Sw.	USPA7	H	P	E	Aug.–Nov.	He		Le	Li	NE	A	P	P
Chrysopogon aciculatus (Retz.) Trin.	USPA8	H	P	N	Sep.–Dec.	He		Le	Li	NE	A	P	P
Chrysopogon lancearius (Hook.f.) Haines	USPA9	H	P	N	Sep.–Dec.	He		Le	Ac	NE	A	P	P
Chrysopogon zizanioides (L.) Roberty	USPA10	H	P	N	Aug.–Dec.	He		Le	Li	NE	A	P	P
Coix lacryma-jobi L.	USPA11	H	A	N	Aug.–Jan.	He		No	Sg	NE	A	P	P
Cymbopogon martini (Roxb.) W. Watson	USPA12	H	A	N	Oct.–Dec.	He		No	Li	NE	A	P	P

Table 1 (*continued*)

Name of the species	Voucher no.	Habit	Life-span	Nativity	Fl. & Fr. time	Raunkiaer's life-form	Sub-type	Leaf spectra	Shape of the leaf lamina	IUCN Red List Status	Seasons		
											Summer	Rainy	Winter
Cynodon dactylon (L.)Pers.	USPA13	H	P	E	All	He		Le	Li	NE	P	P	P
Dactyloctenium aegyptium (L.) Willd.	USPA14	H	P	E	Jul.–Nov.	He		Le	La	NE	A	P	P
Desmostachya bipinnata (L.) Stapf	USPA15	H	P	E	Jun.–Oct.	He		Le	Ac	LC	A	P	A
Digitaria bicornis (Lam.) Roem. & Schult.	USPA16	H	P	N	Jul.–Oct.	He		Le	Ac	NE	A	P	A
Eleusine indica (L.) Gaertn.	USPA17	H	P	N	Aug.–Nov.	He		Le	Li	LC	A	P	P
Elytrophorus spicatus (Willd.) A.Camus	USPA18	H	P	N	Nov.–Jan	He		Le	Ac	LC	A	P	P
Eragrostiella brachyphylla (Stapf) Bor	USPA19	H	P	N	Aug.–Oct.	He		Le	Li	NE	A	P	A
Eragrostis amabilis (L.) Wight & Arn.	USPA20	H	P	E	Aug.–Feb.	He		Le	Li	NE	A	P	P
Eragrostis coarctata Stapf	USPA21	H	P	N	Aug.–Feb.	He		Le	Ac	LC	A	P	P
Hackelochloa granularis (L.) Kuntze	USPA22	H	P	N	Aug.–Nov.	He		No	Ac	NE	A	P	P
Hemarthria compressa (L.f.) R.Br.	USPA23	H	P	N	Jul.–Oct.	He		Le	Ac	LC	A	P	A
Heteropogon contortus (L.) P.Beauv. ex Roem. & Schult.	USPA24	H	P	N	Sep.–Jan.	He		Le	Ac	NE	A	P	P
Hygroryza aristata (Retz.) Nees ex Wight & Arn.	USPA25	H	A	N	Oct.–Mar.	He		No	La	NE	A	P	P
Hymenachne amplexicaulis (Rudge) Nees	USPA26	H	P	E	Oct.–Dec.	He		Le	Su	NE	A	P	P
Imperata cylindrica (L.) Raeusch.	USPA27	H	P	E	Oct.–Dec.	He		Le	Li	NE	A	P	P
Isachne globosa (Thunb.) Kuntze	USPA28	H	P	N	Sep.–Feb.	He		Le	Li	LC	A	P	P
Leersia hexandra Sw.	USPA29	H	A	E	Sep.–Dec.	He		Le	Li	NE	A	P	P
Microchloa indica (L.f.) P.Beauv.	USPA30	H	P	N	Aug.–Oct.	He		Le	Li	NE	A	P	A
Miscanthus fuscus (Roxb.) Benth.	USPA31	H	P	N	Aug.–Oct.	He		Le	Ac	NE	A	P	A
Oplismenus burmannii (Retz.) P.Beauv.	USPA32	H	P	N	Sep.–Nov.	He		Le	Ov	NE	A	P	P
Oryza sativa L.	USPA33	H	P	N	Sep.–Dec.	He		No	Li	NE	P	P	P
Panicum cuviflorum Hornem.	USPA34	H	P	N	Sep.–Dec.	He		Le	Ac	NE	A	P	P
Panicum notatum Retz.	USPA35	H	P	N	Sep.–Nov.	He		No	Li	NE	A	P	A
Panicum sumatrense Roth	USPA36	H	P	N	Aug.–Nov.	He		No	La	LC	A	P	A
Paspalidium flavidum (Retz.) A.Camus	USPA37	H	P	N	Aug.–Nov.	He		Le	Li	LC	A	P	A
Paspalum distichum L.	USPA38	H	P	N	Sep.–Nov.	He		Le	Li	NE	A	P	P
Pennisetum pedicellatum Trin.	USPA39	H	P	N	Oct.–Dec.	He		Le	Ac	NE	A	P	A
Pennisetum polystachion (L.) Schult.	USPA40	H	P	N	Aug.–Nov.	He		Le	Li	NE	A	P	A
Perotis indica (L.) Kuntze	USPA41	H	P	N	Jul.–Nov.	He		Le	Ac	NE	A	P	A
Pogonatherum paniceum (Lam.) Hack.	USPA42	H	P	N	All	He		Le	La	LC	A	P	P
Sacciolepis interrupta (Willd.) Stapf	USPA43	H	P	N	Sep.–Nov.	He		Le	Li	NE	A	P	P
Sacciolepis myosuroides (R.Br.) A.Camus	USPA44	H	P	N	Sep.–Dec.	He		Le	Ac	LC	A	P	P
Setaria verticillata (L.) P.Beauv.	USPA45	H	P	N	Aug.–Nov.	He		Le	Li	NE	A	P	P
Setaria viridis (L.) P.Beauv.	USPA46	H	P	N	Jul.–Oct.	He		Le	Ob	NE	A	P	A
Sporobolus coromandelianus (Retz.) Kunth	USPA47	H	P	N	Aug.–Nov.	He		Na	Ac	NE	A	P	A
Tragus mongolorum Ohwi	USPA48	H	P	N	Aug.–Oct.	He		Le	Ac	NE	A	P	A
EUDICOTS													
Ranunculales Juss. ex Bercht. & J.Presl													
Papaveraceae Juss.													
Argemone mexicana L.	USPP1	H	A	E	Dec.–Apr.	Th		Ma	Sp	NE	P	A	P
Fumaria indica (Hausskn.) Pugsley	USPP2	H	A	E	Jan.–Mar.	Th		Ma	Sp	NE	A	P	P
Menispermaceae Juss.													
Cissampelos pareira L.	USMN1	C	P	N	Jul.–Jan.	Ph	*N*	Me	Co	NE	P	P	P
Cocculus hirsutus (L.) W.Theob.	USMN2	C	P	N	Aug.–Nov.	Ph	*N*	Me	Co	NE	P	P	P
Stephania japonica (Thunb.) Miers	USMN3	C	P	N	Jul.–Dec.	Ph	*N*	Me	Or	NE	P	P	P
Tiliacora racemosa Colebr.	USMN4	C	P	N	Nov.–May	Ph	*N*	Me	Ov	NE	P	P	P
Tinospora sinensis (Lour.) Merr.	USMN5	C	P	N	Feb.–Jun.	Ph	*N*	Me	Co	NE	P	P	P
ROSIDS													
Vitales Juss. Ex Berht. & Presl.													
Vitaeae Juss.													
Ampelocissus tomentosa (B.Heyne & Roth) Planch.	USVT1	C	P	N	Aug.–Dec.	Ph	*N*	Me	Sg	NE	P	P	P
Cayratia pedata (Lam.) Gagnep.	USVT2	C	P	N	Aug.–Feb.	Ph	*N*	No	Ov	VU	P	P	P
Cayratia trifolia (L.) Domin	USVT3	C	P	N	Aug.–Dec.	Ph	*N*	No	Co	NE	A	P	P
Cissus quinquangularis Chiov.	USVT4	C	P	N	Jul.–Jan.	Ph	*N*	No	Co	NE	P	P	P
Leea macrophylla Roxb. ex Hornem.	USVT5	S	P	N	Jul.–Sep.	Ch		Me	Sg	NE	P	P	P
Fabales Bromhead													
Fabaceae Lindl.													
Abrus precatorius L.	USFA1	C	P	N	Aug.–Mar.	Ph	*N*	Na	Ob	NE	A	P	P
Acacia torta (Roxb.) Craib	USFA2	C	P	N	Feb.–Dec.	Ph	*N*	Na	Sb	NE	P	P	P
Adenanthera pavonina L.	USFA3	T	P	N	Mar.–Jan.	Ph	*M*	No	Co	NE	P	P	P
Albizia lebbeck (L.) Benth.	USFA4	T	P	N	Mar.–Feb.	Ph	*MM*	Mi	Sb	NE	P	P	P
Albizia saman (Jacq.) Merr.	USFA5	T	P	E	Mar.–Feb.	Ph	*MM*	Me	Co	NE	P	P	P
Alysicarpus monilifer (L.) DC.	USFA6	H	A	N	Aug.–Nov.	Th		Mi	Ob	NE	A	P	A
Caesalpinia bonduc (L.) Roxb.	USFA7	C	P	N	Aug.–Apr.	Ph	*N*	Me	Co	NE	P	P	P
Cajanus cajan (L.) Millsp.	USFA8	S	P	E	Aug.–Feb.	Ch		Me	La	NE	A	P	P
Cajanus scarabaeoides (L.) Thouars	USFA9	C	A	N	Sep.–Feb.	Ph	*N*	Mi	Ov	LC	A	P	P

(continued on next page)

Table 1 (*continued*)

Name of the species	Voucher no.	Habit	Life-span	Nativity	Fl. & Fr. time	Raunkiaer's life-form	Sub-type	Leaf spectra	Shape of the leaf lamina	IUCN Red List Status	Seasons		
											Summer	Rainy	Winter
Cassia fistula L.	USFA10	T	P	N	Feb.–Dec.	Ph	*N*	No	Sb	NE	P	P	P
Chamaecrista absus (L.) H.S.Irwin & Barneby	USFA11	H	A	E	Aug.–Dec.	Th		Na	Ov	LC	A	P	A
Chamaecrista mimosoides (L.) Greene	USFA12	H	A	N	Mar.–Dec.	Th		Na	La	LC	A	P	A
Codariocalyx gyroides (Link) Hassk.	USFA13	S	A	N	Aug.–Dec.	Ch		Na	La	NE	A	P	A
Crotalaria calycina Schrank	USFA14	S	A	N	Jul.–Nov.	Ch		Na	Li	NE	A	P	P
Crotalaria pallida Aiton	USFA15	S	A	E	Aug.–Jan.	Ch		Na	Ov	NE	A	P	P
Crotalaria retusa L.	USFA16	S	A	E	Jul.–Jan.	Ch		Mi	Ov	NE	P	P	P
Dalbergia sissoo DC.	USFA17	T	P	E	Feb.–Aug.	Ph	*MM*	Mi	Ov	NE	P	P	P
Derris scandens (Roxb.) Benth.	USFA18	C	P	N	Jul.–Jan.	Ph	*N*	Na	Ob	LC	P	P	P
Desmodium gangeticum (L.) DC.	USFA19	H	A	N	Oct.–Dec.	Th		Na	Ov	NE	A	P	A
Flemingia strobilifera (L.) W.T.Aiton	USFA20	H	A	N	Feb.–Sep.	Ch		Na	Ov	NE	A	P	P
Indigofera linifolia (L.f.) Retz.	USFA21	H	B	E	Aug.–Nov.	Th		Na	Oo	LC	P	P	P
Lablab purpureus (L.) Sweet	USFA22	C	A	E	Nov.–Mar.	Ph	*N*	Mi	Co	NE	A	P	P
Mimosa pudica L.	USFA23	H	P	E	Jul.–Nov.	Th		Na	La	LC	A	P	P
Mucuna pruriens (L.) DC.	USFA24	C	A	N	Sep.–May	Ph	*N*	No	Co	NE	A	P	P
Neptunia natans W. Theob.	USFA25	H	A	N	Sep.–Nov.	Th		Na	La	NE	A	P	P
Pongamia pinnata (L.) Pierre	USFA26	T	P	N	Apr.–Feb.	Ph	*M*	Me	Co	LC	P	P	P
Pseudarthria viscida (L.) Wight & Arn.	USFA27	H	P	N	Oct.–Jan.	Th		Mi	Ov	NE	A	P	A
Pterocarpus indicus Willd.	USFA28	T	P	N	Jul.–Dec.	Ph	*M*	No	Ov	VU	P	P	P
Pueraria phaseoloides (Roxb.) Benth.	USFA29	C	P	N	Aug.–Jan.	Ph	*N*	Mi	Co	NE	P	P	P
Senna alata (L.) Roxb.	USFA30	S	A	E	Aug.–Nov.	Ch		Ma	Ob	NE	A	P	P
Senna occidentalis (L.) Link	USFA31	S	P	E	Aug.–Dec.	Ch		No	Co	NE	A	P	P
Sesbania grandiflora (L.) Pers.	USFA32	T	P	N	Dec.–Mar.	Ch		Na	Ob	NE	P	P	P
Tephrosia candida (Roxb.) DC.	USFA33	H	P	N	Sep.–Dec.	Th		Na	Ob	NE	A	P	P
Tephrosia pumila (Lam.) Pers.	USFA34	H	P	N	Jul.–Oct.	Th		Na	Oo	NE	A	P	P
Uraria rufescens (DC.) Schindl.	USFA35	H	P	N	Aug.–Dec.	Th		Na	Oo	NE	A	P	A
Vigna vexillata (L.) A.Rich.	USFA36	C	A	N	Jul.–Oct.	Ph	*N*	Mi	Co	NE	A	P	A
Zornia gibbosa Span.	USFA37	H	A	N	Aug.–Nov.	Th		Na	La	NE	A	P	A
Polygalaceae Hoffmanns. & Link													
Polygala crotalarioides Buch.-Ham. ex DC.	USPO1	H	A	N	Aug.–Nov.	Th		Me	Ov	NE	A	P	A
Salomonia ciliata (L.) DC.	USPO2	H	A	N	Aug.–Nov.	Th		Me	Li	NE	A	P	A
Rosales Bercht. & J.Presl													
Rhamnaceae Juss.													
Ventilago denticulata Willd.	USRH1	C	P	N	Nov.–Mar.	Ph	*N*	Me	La	NE	P	P	P
Ziziphus oenopolia (L.) Mill.	USRH2	C	P	N	Nov.–Mar.	Ph	*N*	No	Co	NE	P	P	P
Ulmaceae Mirb.													
Holoptelea integrifolia Planch	USUL1	T	P	N	Jan.–Jun.	Ph	*MM*	Me	Ov	NE	P	P	P
Moraceae Gaudich.													
Ficus benghalensis L.	USMO1	T	P	N	Mar.–Sep.	Ph	*MM*	Ma	Co	NE	P	P	P
Ficus lacor Buch.-Ham.	USMO2	T	P	N	Mar.–Sep.	Ph	*MM*	Me	Co	NE	P	P	P
Ficus racemosa L.	USMO3	T	P	N	Mar.–Aug.	Ph	*M*	Ma	Co	NE	P	P	P
Streblus asper Lour.	USMO4	T	P	N	Feb.–Jun.	Ph	*N*	Mi	Oo	NE	P	P	P
Urticaceae Juss.													
Pouzolzia zeylanica (L.) Benn.	USUR1	H	A	N	Sep.–Jan.	Th		Le	Ov	NE	A	P	A
Cucurbitales Juss. ex Bercht. & J. Presl													
Cucurbitaceae Juss.													
Cayaponia laciniosa (L.) C.Jeffrey	USCU1	C	A	N	Jun.–Jan.	Ph	*N*	Mi	Sg	NE	A	P	A
Diplocyclos palmatus (L.) C.Jeffrey	USCU2	C	P	N	Aug.–Oct.	Ph	*N*	Me	Sg	NE	A	P	P
Luffa cylindrica (L.) M.Roem.	USCU3	C	A	N	Jul.–Feb.	Ph	*N*	Me	Sg	NE	A	P	P
Melothria trilobata Cogn.	USCU4	C	A	N	Jul.–Feb.	Ph	*N*	Me	Ov	NE	A	P	P
Solena amplexicaulis (Lam.) Gandhi	USCU5	C	A	N	Apr.–Dec.	Ph	*N*	Me	Sg	NE	A	P	P
Trichosanthes cucumerina L	USCU6	C	P	N	Aug.–Dec.	Ph	*N*	Me	Sg	NE	P	P	P
Trichosanthes tricuspidata Lour.	USCU7	C	A	N	Apr.–Sep.	Ph	*N*	Me	Ha	NE	P	P	P
Celastrales Link													
Celastraceae R.Br.													
Celastrus paniculatus Willd.	USCL1	C	P	N	Apr.–Dec.	Ph	*N*	Mi	Ov	NE	A	P	P
Oxalidales Bercht. & J. Presl													
Oxalidaceae R. Br.													
Oxalis corniculata L.	USOX1	H	A	E	All	Th		Na	Cu	NE	P	P	P
Malpighiales Juss. ex Bercht. & J.Presl													
Hypericaceae Juss.													
Hypericum japonicum Thunb.	USHY1	H	A	N	Feb.–Apr.	Th		Le	Co	NE	A	P	P
Elatinaceae Dumort.													
Bergia ammannioides Roxb. ex Roth	USEL1	H	A	N	Nov.–Mar.	Th		Na	Ov	NE	A	P	P
Violaceae Batsch													
Hybanthus enneaspermus (L.) F.Muell.	USVI1	H	P	N	Jul.–Nov.	Th		Na	La	NE	A	P	A
Passifloraceae Juss. ex Roussel													
Passiflora foetida L.	USPS1	C	A	E	Aug.–Nov.	Ph	*N*	No	Sg	NE	P	P	P
Salicaceae Mirb.													
Flacourtia indica (Burm. f.) Merr.	USSA1	S	P	N	Sep.–May.	Ch		Mi	Ov	NE	P	P	P

Table 1 (*continued*)

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											Summer	Rainy	Winter
Euphorbiaceae Juss.													
Acalypha lanceolata Willd.	USEU1	H	A	N	Aug.–Nov.	Th		No	Ov	NE	A	P	P
Chrozophora rottleri (Geiseler) A.Juss. ex Spreng.	USEU2	H	A	E	Jul.–Feb.	Th		Na	Co	NE	A	P	P
Croton bonplandianus Baill.	USEU3	H	P	E	All	Th		No	Co	NE	P	P	P
Euphorbia antiquorum L.	USEU4	T	P	N	Jan.–Apr.	Ph	*N*	Le	Oo	NE	P	P	P
Euphorbia hirta L.	USEU5	H	A	E	Feb.–Dec.	Th		Na	Co	NE	A	P	P
Euphorbia tithymaloides L.	USEU6	H	P	N	Mar.–Apr.	Th		No	Co	NE	P	P	P
Jatropha curcas L.	USEU7	S	P	E	Mar.–Aug.	Ch		Ma	Sg	NE	P	P	P
Jatropha gossypiifolia L.	USEU8	S	P	E	Mar.–Aug.	Ch		Ma	Oo	NE	P	P	P
Mallotus repandus (Willd.) Müll.Arg.	USEU9	T	P	N	Nov.–Apr.	Ph	*M*	Me	Co	NE	P	P	P
Suregada multiflora (A.Juss.) Baill.	USEU10	T	P	N	Mar.–Jul.	Ph	*N*	Mi	Ov	NE	P	P	P
Tragia involucrata L.	USEU11	C	P	N	Mar.–Jan.	Ph	*N*	Me	Ov	NE	A	P	P
Phyllanthaceae Martinov													
Breynia vitis-idaea (Burm.f.) C.E.C.Fisch.	USPY1	S	P	N	Apr.–Dec.	Ch		Mi	Ov	NE	P	P	P
Phyllanthus debilis Klein ex Willd.	USPY2	H	A	N	Apr.–Sep.	Th		Le	Ov	NE	A	P	P
Phyllanthus fraternus G.L.Webster	USPY3	H	A	N	Apr.–Sep.	Th		Na	Ov	NE	A	P	P
Phyllanthus virgatus G.Forst.	USPY4	H	A	N	Apr.–Sep.	Th		Na	La	NE	A	P	P
Myrtales Juss. ex Bercht. & J.Presl													
Combretaceae R.Br.													
Combretum album Pers.	USCB1	C	P	N	Nov.–May	Ph	*N*	Me	Ov	NE	P	P	P
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	USCB2	T	P	N	Apr.–Mar.	Ph	*MM*	Ma	Oo	NE	P	P	P
Terminalia catappa L.	USCB3	T	P	N	Apr.–Feb.	Ph	*MM*	Ma	Oo	NE	P	P	P
Lythraceae J. St.-Hil.													
Ammannia multiflora Roxb.	USLY1	H	A	N	Nov.–Mar.	Th		Le	Li	LC	A	P	A
Nesaea brevipes Koehne	USLY2	H	A	N	Jun.–Feb.	Th		Le	Li	LC	A	P	A
Rotala rotundifolia (Buch.-Ham. ex Roxb.) Koehne	USLY3	H	A	N	Jan.–May	Th		Le	Li	LC	A	P	A
Trapa natans var. *bispinosa* (Roxb.) Makino	USLY4	H	A	N	Jun.–Nov.	Cr		No	Ha	NE	A	P	A
Onagraceae Juss.													
Ludwigia octovalvis (Jacq.) P.H.Raven	USON1	H	A	E	Sep.–Jan.	Th		Mi	Ov	LC	A	P	A
Myrtaceae Juss.													
Syzygium cumini (L.) Skeels	USMY1	T	P	N	Mar.–Jul.	Ph	*MM*	Me	La	NE	P	P	P
Melastomataceae Juss.													
Sonerila erecta Jack	USME1	H	A	N	Jun.–Dec.	Th		Mi	Ov	NE	A	P	A
Sapindales Juss. ex Bercht. & J.Presl													
Sapindaceae Juss.													
Allophylus cobbe (L.) Raeusch.	USSP1	C	P	N	Jul.–Oct.	Ph	*M*	No	Ov	NE	A	P	A
Cardiospermum halicacabum L.	USSP2	C	A	N	Jul.–Dec.	Ph	*N*	No	Sp	NE	A	P	P
Dodonaea viscosa (L.) Jacq.	USSP3	S	P	N	Nov.–Apr.	Ph	*N*	No	Ob	NE	A	P	P
Meliaceae Juss.													
Azadirachta indica A. Juss.	USML1	T	P	N	Mar.–Jul.	Ph	*M*	No	La	NE	P	P	P
Melia azedarach L.	USML2	T	P	E	Feb.–Nov.	Ph	*M*	No	La	NE	P	P	P
Malvales Juss. ex Bercht. & J.Presl													
Malvaceae Juss.													
Abelmoschus crinitus Wall.	USMA1	S	A	N	Mar.–Sep.	Ch		No	Ov	NE	A	P	P
Azanza lampas (Cav.) Alef.	USMA2	S	A	N	Sep.–Dec.	Ch		No	Sg	NE	P	P	P
Byttneria herbacea Roxb.	USMA3	H	A	N	Sep.–Nov.	Th		No	Co	NE	A	P	P
Corchorus aestuans L.	USMA4	H	A	E	Jul.–Nov.	Th		Me	Ov	NE	A	P	A
Hibiscus mutabilis L.	USMA5	S	P	N	Aug.–Feb.	Ch		Me	Or	NE	P	P	P
Malachra capitata (L.) L.	USMA6	H	A	E	Sep.–Nov.	Th		Mi	Ha	NE	A	P	A
Malvastrum coromandelianum (L.) Garcke	USMA7	H	A	E	Jul.–Nov.	Th		Mi	Co	NE	A	P	A
Melochia corchorifolia L.	USMA8	H	A	E	May.–Jun.	Th		Na	Co	NE	A	P	A
Sida cordata (Burm.f.) Borss.Waalk.	USMA9	H	A	N	Aug.–Feb.	Th		Mi	Co	NE	A	P	A
Sida cordifolia L.	USMA10	S	A	N	Aug.–Dec.	Th		Mi	Co	NE	A	P	A
Sida mysorensis Wight & Arn.	USMA11	H	A	N	Sep.–Dec.	Th		Mi	Co	NE	A	P	A
Triumfetta rhomboidea Jacq.	USMA12	H	A	E	Sep.–Jan.	Th		Mi	Ha	NE	A	P	A
Urena lobata L.	USMA13	S	A	E	Sep.–Dec.	Ch		No	Ha	NE	A	P	P
Waltheria indica L.	USMA14	H	P	E	Aug.–Nov.	Th		Mi	Co	NE	A	P	A
Brassicales Bromhead													
Capparaceae Juss.													
Capparis zeylanica L.	USCP1	C	P	N	Mar.–Oct.	Ph	*M*	No	La	NE	P	P	P
Crateva nurvala Buch.-Ham.	USCP2	T	P	N	Mar.–Jul.	Ph	*M*	Me	Ov	NE	P	P	P
Cleomaceae Bercht. & J.Presl													
Cleome monophylla L.	USCE1	H	A	E	Aug.–Oct.	Th		Mi	Co	NE	A	P	P
SUPERASTERIDS													
Santalales R.Br. ex Bercht. & J.Presl													
Santalaceae R. Br.													
Viscum multinerve (Hayata) Hayata	USSN1	S	P	N	Mar.–Jul.	Th		Le	La	NE	P	P	P
Loranthaceae Juss.													

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Table 1 (*continued*)

Name of the species	Voucher no.	Habit	Life-span	Nativity	Fl. & Fr. time	Raunkiaer's life-form	Sub-type	Leaf spectra	Shape of the leaf lamina	IUCN Red List Status	Seasons		
											Summer	Rainy	Winter
Dendrophthoe falcata (L.f.) Ettingsh.	USLO1	S	A	N	Nov.–Mar.	Ph	*N*	No	Ov	NE	A	P	P
Macrosolen capitellatus (Wight & Arn.) Danser	USLO2	S	A	N	Mar.–Sep.	Ph	*N*	No	Li	NE	A	P	P
Caryophyllales Juss. ex Bercht. & J.Presl													
Polygonaceae Juss.													
Antigonon leptopus Hook. & Arn.	USPL1	C	A	E	Aug.–Jan.	Ph	*N*	Na	Co	NE	P	P	P
Persicaria hydropiper (L.) Delarbre	USPL2	H	A	N	May–Jan.	Th		Na	La	LC	A	P	P
Droseraceae Salisb.													
Drosera burmanni Vahl	USDR1	H	A	N	Nov.–Apr.	Th		Le	Or	LC	A	P	A
Caryophyllaceae Juss.													
Polycarpon prostratum (Forssk.) Asch. & Schweinf.	USCR1	H	A	N	Dec.–Apr.	Ch		Na	Co	NE	A	P	A
Spergula arvensis L.	USCR2	H	A	N	Jan.–Mar.	Ch		Le	Ac	NE	A	P	A
Vaccaria hispanica (Mill.) Rauschert	USCR3	H	A	N	Jan.–Mar.	Th		Le	Su	NE	A	P	A
Amaranthaceae Juss													
Achyranthes aspera L.	USAM1	H	A	N	Sep.–Feb.	Th		Mi	Ov	NE	A	P	A
Alternanthera sessilis (L.) R. Br. ex DC.	USAM2	H	A	E	Jul.–Feb.	Th		Mi	Ov	LC	P	P	P
Amaranthus spinosus L.	USAM3	H	A	E	All	Th		Na	Ov	NE	P	P	P
Aizoaceae Martinov													
Trianthema portulacastrum L.	USAI1	H	A	E	Apr.–Oct.	Th		Mi	Oo	NE	P	P	P
Nyctaginaceae Juss.													
Boerhavia diffusa L.	USNC1	H	A	N	Jun.–Dec.	Th		Mi	Re	NE	A	P	A
Portulacaceae Juss.													
Portulaca oleracea L.	USPR1	H	A	E	Jun.–Dec.	Th		Mi	Oo	NE	P	P	P
Cactaceae Juss.													
Cereus pterogonus Lam.	USCC1	S	P	N	Jun.–Jul.	Ch		Le	Ac	LC	P	P	P
Opuntia stricta (Haw.) Haw.	USCC2	S	P	E	Apr.–Aug.	Ch		Le	Ac	LC	P	P	P
ASTERIDS													
Cornales Link													
Cornaceae Bercht. & J.Presl													
Alangium salviifolium (L.f.) Wangerin	USCN1	T	P	N	Mar.–Jul.	Ph	*N*	Me	Ov	NE	P	P	P
Ericales Dumortier													
Primulaceae Batsch ex Borkh.													
Anagallis arvensis L.	USPI1	H	A	E	Jan.–Mar.	Th		Mi	Ov	NE	A	P	P
Gentianales Juss. ex Bercht. & J.Presl													
Rubiaceae Juss.													
Benkara malabarica (Lam.) Tirveng.	USRU1	S	P	N	Apr.–Nov.	Ch		No	La	NE	P	P	P
Gardenia resinifera Roth	USRU2	S	P	N	Feb.–Jun.	Ph	*N*	No	Ov	NE	P	P	P
Neolamarckia cadamba (Roxb.) Bosser	USRU3	T	P	N	Jul.–Nov.	Ph	*MM*	Ma	Ov	NE	P	P	P
Oldenlandia pinifolia (Wall. ex G.Don) Kuntze	USRU4	H	A	N	Sep.–Nov.	Th		Na	Li	NE	A	P	A
Spermacoce brachystema R.Br. ex Benth.	USRU5	H	A	E	Jul.–Dec.	Th		Na	Ov	NE	A	P	A
Loganiaceae R. Br. ex Mart.													
Mitrasacme indica Wight	USLO1	H	A	N	Aug.–Dec.	Th		Na	Li	NE	A	P	A
Strychnos nux-vomica L.	USLO2	T	P	N	Mar.–Jan.	Ph	*MM*	Me	Ov	NE	P	P	P
Apocynaceae Juss.													
Gymnema sylvestre (Retz.) R.Br. ex Sm.	USAO1	C	P	N	Apr.–Mar.	Ph	*N*	Mi	La	NE	A	P	P
Pergularia daemia (Forssk.) Chiov.	USAO2	C	P	N	Sep.–Jan.	Ph	*N*	Me	Co	NE	A	P	P
Rauvolfia tetraphylla L.	USAO3	S	P	N	Feb.–Dec.	Ch		No	La	NE	P	P	P
Boraginales Juss. ex Bercht. & J.Presl													
Boraginaceae Juss.													
Heliotropium indicum L.	USBO1	H	A	N	Oct.–Jan.	Th		No	Co	NE	A	P	P
Solanales Juss. ex Bercht. & J.Presl													
Convolvulaceae Juss.													
Evolvulus alsinoides (L.) L.	USCV1	H	A	N	Jul.–Feb.	Th		Na	La	NE	A	P	P
Ipomoea aquatica Forssk.	USCV2	H	P	N	All	Th		No	Co	LC	P	P	P
Solanaceae Juss.													
Solanum americanum Mill.	USSO1	H	A	E	Dec.–Jun.	Th		Ma	Ov	NE	A	P	A
Solanum sisymbriifolium Lam.	USSO2	S	A	E	Jul.–Mar.	Ch		Ma	Ov	NE	A	P	P
Lamiales Bromhead													
Plantaginaceae Juss.													
Bacopa monnieri (L.) Wettst.	USPT1	H	A	N	Sep.–Jan.	Th		Na	Re	LC	A	P	A
Limnophila indica (L.) Druce	USPT2	H	A	N	Sep.–Jan.	Th		Na	Ac	LC	A	P	A
Acanthaceae Juss.													
Andrographis paniculata (Burm.f.) Nees	USAC1	H	A	N	Sep.–Apr.	Th		No	Ov	NE	A	P	A
Barleria prionitis L.	USAC2	S	P	N	Dec.–Apr.	Ch		Mi	La	NE	A	P	A
Ecbolium viride (Forsk.) Alston	USAC3	H	P	N	Dec.–Apr.	Ch		Mi	Ov	NE	A	P	A
Hygrophila auriculata (Schumach.) Heine	USAC4	H	A	N	Sep.–Jan.	Th		Mi	La	LC	A	P	A
Hygrophila polysperma (Roxb.) T. Anderson	USAC5	H	A	N	Sep.–Jan.	Th		Mi	La	LC	A	P	A
Verbenaceae J.St.Hil.													
Lantana camara L.	USVE1	S	P	E	Nov.–Feb.	Ch		No	Ov	NE	P	P	P

Table 1 (*continued*)

Name of the species	Voucher no.	Habit	Life-span	Nativity	Fl. & Fr. time	Raunkiaer's life-form	Sub-type	Leaf spectra	Shape of the leaf lamina	IUCN Red List Status	Seasons		
											Summer	Rainy	Winter
Lippia javanica (Burm.f.) Spreng.	USVE2	S	P	N	Sep.–Apr.	Ch		Mi	Ov	NE	P	P	P
Lamiaceae Martinov													
Anisomeles indica (L.) Kuntze	USLA1	H	A	N	Sep.–Jan.	Ch		Mi	Ov	NE	A	P	A
Clerodendrum infortunatum L.	USLA2	S	P	N	Feb.–Jul.	Ch		Ma	Co	NE	A	P	P
Leonotis nepetifolia (L.) R.Br.	USLA3	S	A	E	Apr.–Jul.	Th		Me	Co	NE	A	P	A
Leonurus sibiricus L.	USLA4	S	A	N	Sep.–Feb.	Ch		Mi	La	NE	A	P	A
Hyptis suaveolens (L.) Poit.	USLA5	S	A	E	Sep.–Jan.	Ch		Me	Ov	NE	A	P	A
Ocimum basilicum L.	USLA6	H	P	N	May–Jul.	Ch		Na	Ov	NE	A	P	A
Vitex negundo L.	USLA7	T	P	N	Mar.–Jun.	Ph	*N*	Mi	Ov	NE	P	P	P
Asterales Link													
Asteraceae Bercht. & J.Presl													
Ageratum conyzoides (L.) L.	USAT1	H	A	E	Nov.–Mar.	Th		Mi	Ov	NE	A	P	P
Ayapana triplinervis (Vahl) R.M.King & H.Rob.	USAT2	H	A	N	Sep.–Feb.	Th		No	La	NE	A	P	A
Blumea lacera (Burm.f.) DC.	USAT3	H	A	E	Aug.–Feb.	Th		Mi	La	NE	A	P	P
Chromolaena odorata (L.) R.M.King & H. Rob.	USAT4	S	A	E	Mar.–Sep.	Ch		Mi	Ov	NE	A	P	P
Cyanthillium albicans (DC.) H.Rob.	USAT5	H	A	N	Aug.–Mar.	Th		Mi	Li	NE	A	P	P
Eclipta prostrata (L.) L.	USAT6	H	A	E	All	Th		Mi	La	LC	A	P	P
Elephantopus scaber L.	USAT7	H	A	N	Sep.-Jan.	Th		No	Oo	NE	A	P	A
Enydra fluctuans DC.	USAT8	H	A	N	Dec.–Mar.	Th		Mi	La	LC	A	P	P
Grangea maderaspatana (L.) Poir.	USAT9	H	A	E	Dec.–May	Th		Le	Sp	LC	A	P	P
Sonchus oleraceus (L.) L.	USAT10	H	A	N	Sep.–Jan.	Th		Na	Ha	NE	A	P	P
Sphaeranthus senegalensis DC.	USAT11	H	A	E	Nov.–Apr.	Th		Le	Ov	NE	A	P	P
Synedrella nodiflora (L.) Gaertn.	USAT12	H	A	E	Sep.–Jan.	Th		No	Ov	NE	A	P	P
Tridax procumbens (L.) L.	USAT13	H	A	E	All	Th		Na	Sg	NE	A	P	A
Xanthium strumarium L.	USAT14	H	A	E	Sep.–Apr.	Th		Me	Sg	NE	A	P	A
Apiales Nakai													
Apiaceae Lindl.													
Centella asiatica (L.) Urb.	USAP1	H	A	N	Jul.–Jan.	Th		No	Re	LC	A	P	A

Abbreviation:
Habit: C-Climber, H-Herb, S-Shrub, T-Tree.
Life-Span: A- Annual, B- Biennial, P-Perennial.
Nativity: E-Exotic, N-Native.
Flowering and Fruiting time: Jan.-January, Feb.-February, Mar.-March, Apr.-April, Jun.-June, Jul.-July, Aug.-August, Sep.-September, Oct.-October, Nov.-November, Dec.-December, All- All season.
Raunkiaer's Life-form and Sub-type: Ch- Chamaephytes, Cr- Cryptophytes, H-Hemicryptophytes, M- Mesophanerophyte, MM- Megaphanerophytes, N- Nanophanerophytes, Ph- Phanerophytes, T-Therophytes.
Leaf spectra: Le- Leptophyll, Na-Nanophyll, Mi-Microphyll, No-notophyll, Me-Mesophyll, Ma-Macrophyll, Mg-Megaphyll.
IUCN Red List status: DD-Data Deficient, LC- Least Concern, LR/LC-Lower Risk/ Least Concerned, NE -Not Evaluated, VU-Vulnerable.
Leaf Lamina: Ac- Acicular, Co- Cordate, Cu- Cuneate, Ha- Hastate, La- Lanceolate, Li- Linear, Lu- Lunate, Ob- Oblong, Oo- Obovate, Or- Orbicular, Ov- Ovate, Pa- Palm like, Re- Reniform, Sb- Sabulate, Sg- Sagitate, Sp- Spathulate, Su- Subulate.
Seasons: A-Absent, P-Present.

Vidyasagar University's Herbarium. Several relevant catalogs [19], regional floras [20–24], monographs [25], revision works [26] and other literature had been consulted for identification purposes. The socio-cultural functions surrounding the grove were recorded through information gathered during the *Paus Sankranti* festival through interviews and cross-interviews with devotees and local people.

2.3. Analysis of vegetation

In the systematic enumeration of the taxa; clades, order, family, species along with voucher number, habit, life-span, nativity, flowering and fruiting time, life-form of Raunkiaer with subtype, leaf spectra, shape of the leaf lamina, red list status of IUCN [27] and distribution of plants in the grove in summer, rainy and winter seasons were arranged according to the classification of Angiosperm Phylogeny Group IV. [28] (Table 1). An additional summary table showing the total number of orders, families, genera and species in dicots and monocots was prepared (Table 2). All the species were classified into different categories of Raunkiaer's life form depending on the position of regenerating parts or propagules in all the species collected and a biological spectrum was prepared for the grove, which was subsequently compared to the normal spectrum of the Raunkiaer to determine the phytoclimate of the grove [8–10] (Tables 1, 3). Leaf size knowledge became very helpful to understand plant physiological development and plant communities played useful role in classifying plant associations. Various plant leaf sizes were arranged with the life forms of their respective Raunkiaer [8] (Table 4). Plants were divided into (a) leptophyll (<25 mm^2), (b) nanophyll (25–225 mm^2), (c) microphyll (225–2025 mm^2), (d) notophyll (2025–4500 mm^2), (e) mesophyll (4500–18,225 mm^2), (f) microphyll (18225–164,025 mm^2) and (g) megaphyll (>164,025 mm^2) [8].

3. Results

3.1. Different plant taxa

In this study, according to the APG IV (2016) classification, a total of 312 species belonging to 257 genera distributed among 78 families of 34 orders were recorded from the sacred grove. Monocots and Rosids were the top two clades. Approximately 60% of the flora was represented by orders from Eudicot and Core Eudicot. The major contributions (≥10 species) were from Poales 73 (23.40%), Fabales 39 (12.50%), Malpighiales 20 (6.41%), Alismatales 18 (5.77%), Lamiales 16 (5.13%), Asterales 14 (4.49%), Caryophyllales 14 (4.49%), Malvales 14 (4.49%) and Myrtales 10 (3.21%) (Tables 1 and 2; Fig. 2).

Table 2
Total angiosperm taxa.

Angiosperm type	Orders	Families	Genera	Species				
				Herbs	Shrubs	Trees	Climber	Total
Dicots	25	56	167	88	35	28	38	189
Monocots	9	22	90	109	3	2	9	123
Total	34	78	257	197	38	30	47	312

The sixteen well-represented families (≥5 species) were Poaceae 48 (15.38%), Fabaceae 37 (11.86%), Cyperaceae 23 (7.37%), Malvaceae 14 (4.49%), Asteraceae 14 (4.49%), Euphorbiaceae 11 (3.53%), Araceae 7 (2.24%), Cucurbitaceae 7 (2.24%), Lamiaceae 7 (2.24%), Commelinaceae 6 (1.92%), Acanthaceae 5 (1.60%), Dioscoreaceae 5 (1.60%), Hydrocharitaceae 5 (1.60%), Menispermaceae 5 (1.60%), Rubiaceae 5 (1.60%) and Vitaceae 5 (1.60%) in descending array (Table 1; Fig. 3). Another 4 families had 4 (1.28%), 8 families had 3 (0.96%), and 18 families each had 2 (0.64%) species each, each with 32 families carrying only one species.

The ten dominant plant families encompassed more than 51% genera with descending numbers (≥6 species) were Fabaceae 14 (8.33%), Apocynaceae 11 (6.55%), Asteraceae 11 (6.55%), Lamiaceae 9 (5.36%), Malvaceae 9 (5.36%), Poaceae 9 (5.36%), Acanthaceae 6 (3.57%), Cyperaceae 6 (3.57%), Euphorbiaceae 6 (3.57%) and Rubiaceae 6 (3.57%) (Table 1).

The ten well represented genera were *Cyperus* (12 spp.), *Dioscorea* (4 spp.), *Fimbristylis* (4 spp.), *Chrysopogon* (3 spp.), *Crotalaria* (3 spp.), *Euphorbia* (3 spp.), *Ficus* (3 spp.), *Panicum* (3 spp.), *Phyllanthus* (3 spp.) and *Sida* (3 spp.). *Agave*, *Albizia*, *Annona*, *Brachiaria*, *Cajanus*, *Cayratia*, *Chamaecrista*, *Commelina*, *Cyanotis*, *Eragrostis, Eriocaulon*, *Hygrophila*, *Jatropha*, *Murdannia*, *Pennisetum*, *Potamogeton*, *Rhynchospora*, *Sacciolepis*, *Senna*, *Setaria*, *Solanum*, *Tephrosia*, *Terminalia* and *Trichosanthes* were the 24 well represented genera with 2 species. There was only one species in another 223 genus (Table 1).

In all, 225 species were native, while 87 species were exotic (Table 1).

3.2. Species diversity in different growth form

The current sacred grove floristic study showed that it harbored a total of 312 plant species [dicots 189 (60.58%) and monocots 123 (39.42%)] of the genera 257 [dicots 167 (64.98%) and monocots 90 (35.02%)] of 78 families [dicots 56 (71.80%) and monocots 22 (28.20%)] under 34 orders [dicots 25 (73.53%) and monocots 9 (26.47%)]. Of the reported species, 197 (63.14%) were herbs. Other species reported were 38 shrubs (12.18%), 30 trees (9.62%) and 47 climbers (15.06%). Among the total dicots 189 (60.58%) and monocots 123 (39.42%), herbs, shrubs, trees and climbers represented 88, 35, 28, 38 and 109, 3, 2, 9 species respectively, representing 28.21%, 11.22%, 8.97%, 12.18% and 34.94%, 0.96%, 0.64%, 2.88% of the total species (Table 2, Fig. 4).

Major seven herbaceous families (≥5 species) were Poaceae 48 (24.37%), Cyperaceae 23 (11.68%), Asteraceae 13 (6.60%), Fabaceae 13 (6.60%), Malvaceae 9 (4.57%), Araceae 6 (3.05%) and Commelinaceae 6 (3.05%) held above 59% of the total herb population. The three major less-woody shrub families were Fabaceae 7 (18.42%), Malvaceae 5 (13.16%) and Lamiaceae 4 (10.53%) held above 42% of the total shrubs population. Fabaceae 8 (26.67%), Moraceae 4 (13.34%) and Euphorbiaceae 3 (10%) were three highly diversified families with over 50% of the total tree population. Another four families included 2 species and seven families of single tree species. The five most speciose families in descending manner included Fabaceae 9 (19.15%), Cucurbitaceae 7 (14.89%), Menispermaceae 5 (10.64%), Dioscoreaceae 4 (8.51%) and Vitaceae 4 (8.51%) clasp above 61% of the total liana population (Table 1).

3.3. Life span

In the sacred grove, in one growing season, 130 (41.67%) annual plants would go through their life cycle. There were 1 (0.32%) biennial plants with a two-years life cycle and 181 (58.01%) perennial plants that could survive the most unfavorable conditions and stay alive for more than two years. (Table 1).

3.4. Raunkiaer's life form and its distribution

Phanerophyte, one of the life-form categories of Raunkiaer, is a plant whose perennial buds or shoots apices bore on aerial shoots and the three most speciose families (≥5 species) in descending form included Fabaceae 16 (21.34%), Cucurbitaceae 7 (9.34%) and Menispermaceae 5 (6.67%) containing more than 37% of the total phanerophytes. Three major descending chamaephytic families (≥4 species) were Fabaceae 9 (23.68%), Lamiaceae 5 (13.16%) and Malvaceae 4 (10.53%), with a total population of 47.37%. Two leading hemicryptophytic families explicitly contained Poaceae 48 (63.16%), Cyperaceae 23 (30.26%) and 93.42% of the total population. Araceae 7 (23.34%), Dioscoreaceae 5 (16.67%), Hydrocharitaceae 5 (16.67%), Zingiberaceae 4 (13.34%) and the total contained above 70% of the population were four dominant descending cryptophytic families. The five main therophytic families (≥5 species) were Asteraceae 13 (13.98%), Fabaceae 12 (12.90%), Malvaceae 10 (10.75%), Commelinaceae 6 (6.45%), Euphorbiaceae 5 (5.38%) and the total population of 49.46%. (Table 1).

Table 3
Biological spectrum (% of all life forms) of sacred grove and its comparison with Raunkiaer's normal spectrum.

Life forms	Total no. of species	Biological spectrum (%) of the sacred grove	Raunkiaer's normal spectrum (%)	Deviation = (Raunkiaer's normal spectrum- Biological spectrum)
Phanerophytes (Ph)	75	24.04	46.00	−21.96
Megaphanerophytes (MM)	*12*	*3.85*	*3.00*	*0.85*
Mesophanerophyte (M)	*11*	*3.53*	*28.00*	*−24.47*
Nanophanerophytes (N)	*52*	*16.67*	*15.00*	*1.67*
Chamaephytes (Ch)	38	12.18	9.00	3.18
Hemicryptophytes (He)	76	24.36	26.00	−1.64
Cryptophytes (Cr)	30	9.62	6.00	3.62
Therophytes (Th)	93	29.81	13.00	16.81
Total	312	100	100	

Table 4
Life-form analysis with different leaf size.

Raunkiaer's life form	Leaf spectra							Total
	Le	Na	Mi	No	Me	Ma	Mg	
Ph	1	4	14	19	29	6	2	75
MM	0	0	2	0	5	4	1	12
M	0	0	1	6	3	1	0	11
N	1	4	11	13	21	1	1	52
Ch	3	7	9	8	4	5	2	38
He	59	5	2	7	2	1	0	76
Cr	6	4	3	2	4	6	5	30
Th	14	32	27	12	5	3	0	93
Total	83	52	55	48	44	21	9	312

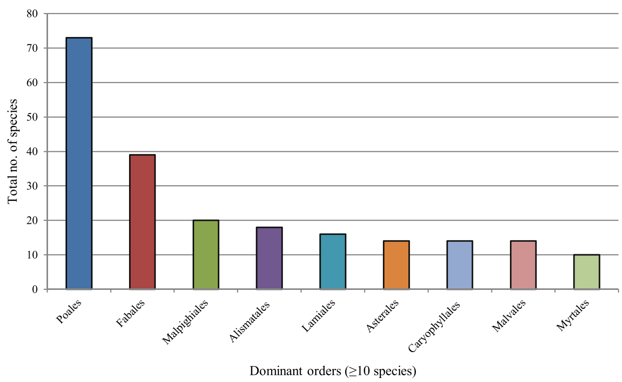

Fig. 2. Major contribution of orders (≥10 species) in the KST.

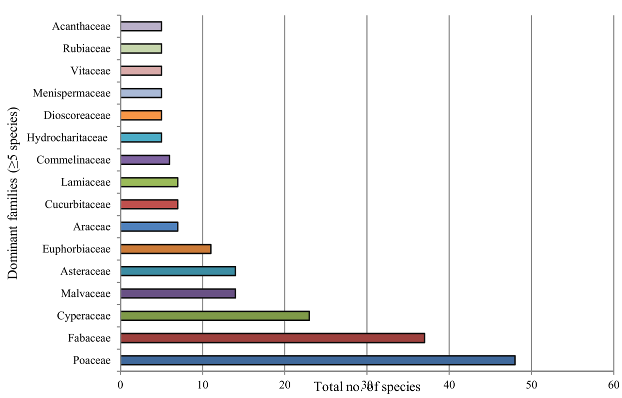

Fig. 3. Major contribution of Families (≥5 species) in the KST.

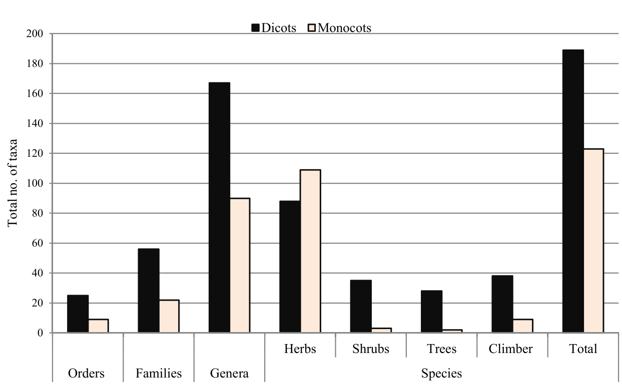

Fig. 4. Total angiosperm taxa.

3.5. Life form and biological spectrum

The biological spectrum showed that therophytes 93 (29.81%) was the dominant, followed by hemicryptophytes 76 (24.36%), phanerophytes 75 (24.04%), chamaephytes 38 (12.18%) and cryptophytes 30 (9.62%). The phanerophytes, nanophanerophytes 52 (16.67%) was the dominant than megaphanerophytes 12 (3.85%) and mesophanerophytes 11 (3.53%) (Tables 1 and 2).

This study revealed that therophytes, cryptophytes and chamaephytes constituted the higher percentage 16.81%, 3.62% and 3.18% respectively than the normal spectrum exhibiting "thero-crypto-chamaephytic" phytoclimate. Further, the number of phanerophytes (21.96%) and hemicryptophytes (1.64%) were comparatively smaller in percentage than the Raunkiaer's normal spectrum. Out of the total phanerophytes, nanophanerophytes (1.67%) and megaphanerophytes (0.85%) were somewhat larger and mesophanerophyte (24.47%) was a comparatively smaller value than the Raunkiaer's normal spectrum (Table 3, Fig. 5).

3.6. Leaf size spectra

The overall spectrum of leaf sizes showed that leptophyll 83 (26.60%), nanophyll 52 (16.67%), microphyll 55 (17.63%), notophyll 48 (15.38%), mesophyll 44 (14.10%), macrophyll 21 (6.73%) and megaphyll 9 (2.88%) existed. As regards the spectrum of the leaf size, leptophyll had been found to be the high followed by microphyll, nanophyll, notophyll, mesophyll, macrophyll and megaphyll. Poaceae 40 (12.82%), Fabaceae 18 (5.77%), Fabaceae 9 (2.88%), Poaceae 7 (2.24%), Cucurbitaceae 6 (1.92%), Zingiberaceae 3 (0.96%) and Araceae 2 (0.64%) were dominant leptophyll, nanophyll, microphyll, notophyll, mesophyll, macrophyll and megaphyll families (Table 1, Fig. 6).

In case of leaf spectra, the presence of leptophyll 59 (18.91%), nanophyll 32 (10.26%), microphyll 27 (8.65%), notophyll 19 (6.09%), mesophyll 29 (9.29%), macrophyll 6 (1.92%) and megaphyll 5 (1.60%) have the maximum in comparison to hemicryptophytes, therophytes, therophytes, phanerophytes, phanerophytes, both phanerophytes and cryptophytes, and cryptophytes respectively (Table 4).

3.7. Shape of the leaf lamina

Leaf was generally a flat, green photosynthetic organ on the stem. As regards the shape of leaf lamina, ovate 59 (18.91%) was found to be the maximum followed by lanceolate 46 (14.74%), cordate 44 (14.10%), acicular 39 (12.50%), linear 31 (9.94%), sagitate 16 (5.13%), obovate 14 (4.49%), subulate 11 (3.53%), oblong 9 (2.88%), hastate 7 (2.24%), spathulate 6 (1.92%), reniform 5 (1.60%), orbicular 4 (1.28%), cuneate 3 (0.96%), palm like 3 (0.96%), sabulate 3 (0.96%), and lunate 2 (0.64%) (Table 1).

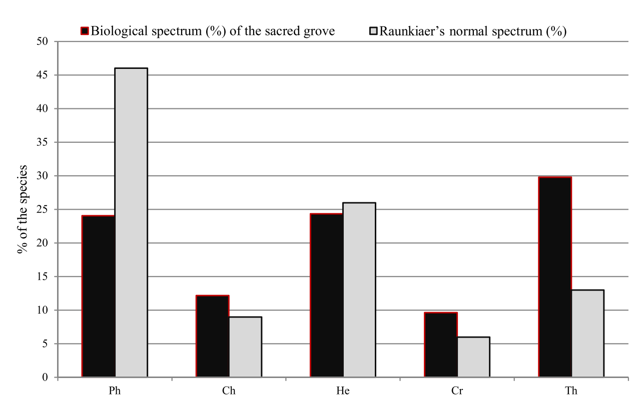

Fig. 5. Comparison of Biological spectrum with Raunkiaer's normal spectra.

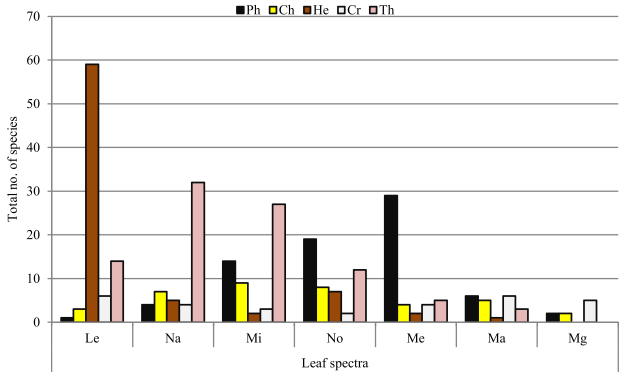

Fig. 6. Analysis of life form with different leaf size.

The vegetation phenology observed during different seasons revealed that most of the species were dominant in rainy seasons 311 (99.68%), followed by winter 218 (69.87%) and summer 93 (29.81%). Seasonally habit-wise species content varied; in the summer season, tree>climber>herb>shrub; rainy season, herb>climber>shrub>tree; winter season, herb>climber>shrub>tree, respectively (Table 1, Fig. 7).

3.8. IUCN categories

230 plants have not yet been evaluated till now. There might be 80 species of Least Concerned (LC). *Cayratia pedata* was the vulnerable liana, whereas *Pterocarpus indicus* was the IUCN-species of vulnerable tree (Table 1).

4. Discussion

4.1. Patterns of floristic diversity

In the KST sacred grove studied, the presence of 312 plant species belonging to 257 genera, 78 families and 34 orders indicates a significant level of plant diversity. These species formed various communities tailored to their ecological needs and the management that human beings had imposed over the past few years. It appeared that the topographic, edaphic and physiographic conditions caused high plant diversity in the area. Of course, the micro-climatic factor was also effective in this respect, but there were fewer variations in the area's climate conditions than the other factors [29]. From the study, Monocots and Rosids could be identified as the dominant clades; Poales, Fabales, Malpighiales, Alismatales, Lamiales, Asterales, Caryophyllales, Malvales and Myrtales were the dominant orders. Magallon and Sandarson [30] and Wang et al. [31] highlighted similar dominance and distribution in angiosperm-dominated forests. Poaceae, Fabaceae, Cyperaceae, Malvaceae, Asteraceae, Euphorbiaceae, Araceae, Cucurbitaceae, Lamiaceae, Commelinaceae, Acanthaceae, Dioscoreaceae, Hydrocharitaceae, Menispermaceae, Rubiaceae and Vitaceae were the well-represented families. The result was consistent support from the study as the families emerged as the common taxa in the area under investigation because their wide ecological amplitude showed diversity in the occurrence of their habitat [13,32,33].

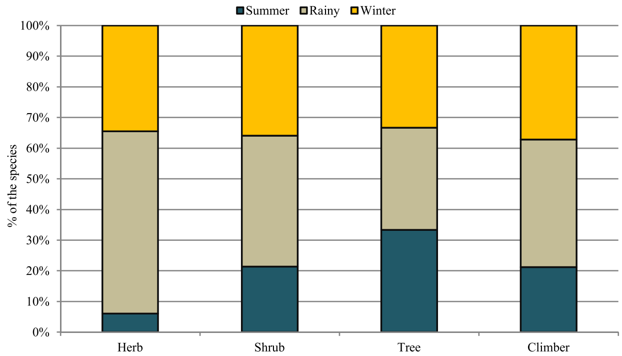

Fig. 7. Vegetation phenology of KST.

Of the total recorded 312 species, 225 species were native, while 87 species were alien, most of which thrive in the grove's disturbed habitats. Because alien plant species tended to be more plasticity than native plants and in several fitness components superior to natives, they were usually able to colonize disturbed areas more efficiently than native species, regardless of their life history strategy [34]. Common invasive species growing in the grove were therefore herbs (*Alternanthera sessilis*), shrubs (*Chromolaena odorata*, *Hyptis suaveolens*, *Lantana camara*) and climbers (*Antigonon leptopus*). The unsustainable anthropogenic activities in this grove had been considered a major threat to the native flora in recent times [35]. The introduction of alien species posed a serious threat to the endemic flora because of its increased competitiveness [36]. Once naturalized in their non-native ranges, these alien plant species had the potential to compete with a region's native flora, paving the way for the biological invasion phenomenon. This process of invasion could change the floristic composition and modify the functioning of the region's ecosystem [34]. These species had already begun to naturalize in the study area in the recently opened gaps in the forest and degraded areas. It was observed during the present study that alien plants (*Chromolaena odorata*, *Hyptis suaveolens*) spreaded very rapidly in the gaps in the forest [37]. Other alien species as recorded from the region during the current study were likely to become serious plant invaders in the immediate future and therefore need immediate attention and appropriate management action.

4.2. Patterns in biological spectrum

Therophytes, cryptophytes and chamaephytes were generally well represented in the biological spectra of the KST sacred grove, than the normal spectrum exhibiting “thero-crypto-chamaephytic” phytoclimate. Therophytes showed the maximum divergence of the normal spectrum; the similar phytoclimatic association had also been reported by other workers for different tracks of vegetation [11,38,39]. Therophytes were expected to become dominant where growing conditions were so adverse that the probability of survival until the second year became very poor [40]. However, unfavorable growing conditions for part of the year did not hinder the occurrence of perennials, as they favored selection by other strategies, such as dormant structures that enabled species to survive in harsh conditions. Therophytes usually dominated in some of the driest environments of the world [41]. The highest percentage of therophytes taking place in the area was the trait of the subtropics and often related to soil and climatic conditions [42]. The prevalence of therophytes was accredited to diverse factors like widespread microclimate of the region united with anthropogenic activities like grazing, looping, felling, deforestation, introduction of exotics etc., was also reported by other workers [43,44]. Thus, the present study reveals that the vegetation was predominantly sub-tropical type having a higher percentage of therophytes and chamaephytes as compared to normal biological spectra. Prevalence of therophytes was also an indicator of biotic pressure [45]. The growth of therophytes was much favored in disturbed areas [46]. According to Meher-Homji [12], the life forms were reflected by bioclimate of the area.

Generally, in all the seasons and in rainy season in particular therophytes and nanophanerophytes remained dominant due to favorable growing season. During the start of rainy season, there was always flush of annual plants. The dominance of therophytes occured due to unfavorable habitat conditions as suggested by others [47–49], and the finding agree with them. Nazir and Malik [50] reported that the biological spectrum of Sarsawa hill Kotli consisted of nanophanerophyte and therophytes. The predominance of therophytes was also reflected similar to the present study.

Hemicryptophytes were mainly represented by grasses, because the upper layer of the soil contains more organic matter, it had a higher capacity for holding water during the dry season, while it had a higher level of oxygen than the lower ones during the rainy season. It might explain the fact that hemicryptophytes were more dominant in the sacred groves with poor drainage. In addition, there were other anatomical adjustments that favored monocots in partly marshy areas [51].

Batalha and Martins [52] also considered therophytes, cryptophytes and chamaephytes as the major life forms in unfavorable conditions in the desert and open physiognomies. In the investigated area hot and dry and waterlogged condition coupled with overgrazing led to harsh conditions. The results also agree with those of Sher and Khan [43], who also stated that therophytes and nanophanerophyes were characteristics of subtropical habitats. The findings also report the dominance of therophytes and nanophanerophytes in Odisha, India. However, in the Indian tropics, cryptophytes died back to underground storage organs to survive the unfavorable dry period, fire, etc. In the tropical ecosystem, cryptophytes were conceived as relics of the paleoclimate, which prevailed prior to the present exterminating of the Indian subcontinent. According to Zohary [53], a fraction of the flora of a place might be in discordance with the present-day climate and could be the remnant of past climate. Singh and Arora [54] described the phytoclimate of the Gangasagar district of Rajasthan as of therocryptophytic; also, nearly similar to the study. In this regard, the KST is floristically rich and potential for further research in the future.

Therophytes were adapted in vacant niches indicates that the investigated area was under heavy biotic pressure due to deforestation, overgrazing and agricultural land encroachment. Many plant species were decreasing in the area. It would be the moral and ethical duty of the local people to protect the plant resources. Most of the medicinal plants were uprooted for burning purposes and grazed by the livestock. It, therefore, seemed appropriate to manage the grazing system. Most of the fuel wood and timber wood were extracted from these forests. Even fruiting trees were also grazed by animals and used for burning. The forests were refuge for valuable and endangered animals and plants. Further study is needed to quantify the data and suggests plans for the conservation of the sacred grove.

4.3. Patterns in leaf size spectra, leaf lamina and phenology

Although the leaf spectra were distributed in seven different types, it was mostly dominated by (≥15%) leptophyll, microphyll, nanophyll and notophyll (76.28%), while as the remaining three leaf size types were least represented (23.72%) in the total species pool. Leaf spectra tell us about the community's plant adaptation and association. Small leaves were present at the base whereas the large leaves were present at high altitude and correlated with climate warming and the availability of water in the soil [7,32,55,56]. The medium type of leaf size showed the subtropical type of climate. In the sacred grove, the elements of *meso* and microphyllous were dominant, showing moisture and perennial availability of water or wet condition [57].

In the present study it was observed that due to the presence of therophytes and cryptophytes, the proportion of different leaf size classes changed seasonally. However, in all seasons, the phanerophytes and some chamaephytes nearly retained the same status. Other plant characteristics like habit and root system could also play a major role [58]. For the ecological study of a sacred grove in a region, the leaf spectra and biological spectrum alone were not sufficient, but quantitative studies such as vegetation structure and conservation were consequential equipment.

The type of leaf lamina exists in a variety of forms, ranging from ovate to lunate. The shape of the leaf helps plants optimize light capture and water loss and minimizes the avoidable energy consumption in leaf production [59]. The distribution of leaf sizes in different resource poor environments strongly supports this theory [8,60]. Not only do leaf laminas vary in size, but some leaves have distinct serrations, and the blades are almost completely dissected even in some leaves. Leaf dissection helps plants reduce self-shading and in turn plays a role in ensuring that the adjacent leaves get sufficient light [61].

The change in species composition within the community is accompanied by significant seasonal changes [62]. As the climate of the study region had well-defined seasons, the vegetation phenology observed during different seasons revealed a significant difference in vegetation among the seasons. Most species dominated during the rainy season (99.68%), followed by winter (69.87%) and summer (29.81%). Expectedly, it may be attributed to the fact that a high proportion of therophytes, cryptophytes and chamaephytes in the region appeared during rainy and winter seasons.

4.4. IUCN categories

Based on the above-mentioned phytosociological analysis with ecological information on IUCN Red Listed plants, it is revealed that plants are still present and regenerate in the sacred groves but locally disappear in nearby forests. This study would highlight the status and distribution of the species in the study area, the ecological characteristics necessary for their survival, and the threats to some of the species identified by following the IUCN [27] criteria.

The increase in the number of vulnerable species in the area was caused by various factors. Overgrazing was a major cause leading to seedlings being destroyed. By contrast, the most effective factors on the vulnerability of *Cayratia pedata* and *Pterocarpus indicus* were determined to be limited population and low natural reproduction. Human activity, such as plant overexploitation and land use change, was the most important factor that caused the deterioration of these species.

5. Conclusion and recommendation

The present study denotes the possibility of using Raunkiaer's approach to ascertain the remarkable distinctions between the communities of angiosperm plants in a forested landscape or biome and their associations, the proportion of species in floristic life forms that led by existing ecological parameters and environmental gradients. Life forms analysis gives a clear picture of the sacred grove's biological spectrum. Therophytes, cryptophytes and chamaephytes each share the significance of the “thero-crypto-chamaephytic” phytoclimate in the present study. This study may therefore be useful in comparing and contrasting the adjacent natural vegetation along the gradients of the environment, revealing more information about the ecosystem than the mere cover of the forest. It also suggests that by directing succession, the biotic factors play an important role in shaping a landscape's vegetation. This indicates the influence in the sacred grove of anthropogenic disturbance that favors the growth of more therophytes.

Although well protected, the sacred grove faces some mild threats due to the influx of a large number of devotees, littering the place with plastic bags and thermocouple plate, human trampling on seedlings, loss of climax vegetation, erosion of plant-religious ethics and exotic weed invasion. Therefore, the following aspects should require instant attention for effective long-term conservation and better management of the grove: 1. In the allocated part of the grove, the annual festival should be restricted so that natural plant regeneration will not be disturbed. 2. To enrich the grove flora, artificial seeding of the area should be practiced with indigenous species. 3. In order to ensure proper conservation, the grove should be brought under the ‘Protected Area.’ 4. Increase of public awareness related to the value of such groves and plants is badly needed. 5. It is necessary to highlight the ecological services rendered by the sacred grove and to make people realize that the conservation of the grove is crucial to the subsistence.

Declaration of Competing Interest

None.

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