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DIVERSITY AND SPECIES COMPOSITION OF SUBAERIAL ALGAE IN KUVEMPU UNIVERSITY CAMPUS, SHIMOGA, KARNATAKA, INDIA

H.D. AMBIKA AND S.R. KRISHNAMURTHY

Department of Applied Botany, Kuvempu University, Jnana Sahyadri, Shankaraghatta – 577 451, Karnataka, India

E-mail: srk_sampa2005@rediffmail.com; ambika.hd@gmail.com

The sub aerial algae on barks of the trees of dry deciduous forests of the Kuvempu University has been studied for their systematics, species composition and diversity. A total of six trees, flame of the forest *(Butea monosperma);* rose wood *(Dalbergia latifolia,);* mountain persimmon *(Diaspyros montana);* nandhi *(Legestroemia lanceolata);* Indian ash tree *(Lannae coromandelica) and* flowering murdals (*Terminalia paniculata)* are selected to collect algal samples. The trees of flowering murdals *(Terminalia paniculata)* are also selected from different locations namely open undisturbed, shaded undisturbed and open disturbed areas to compare the subaerial algal flora. A total of 56 taxa are recorded. Of the 56 taxa, 53 belong to Cyanophyceae, 2 belongs to Chlorophyceae and the remaining one taxa belongs to Bacillariophyceae. The members of the blue green algae are dominant in all the bark samples. Among the blue green algae, chroococcales are dominant except in the bark samples of mountain persimmon *(Diaspyros montana)* in which members of nostocales are dominant. The members of green algae *Trentepohlia* sp. and *Printzina effusa* are recorded only in the bark samples of rose wood *(Dalbergia latifolia)* and flowering murdals (*Terininalia paniculata)* respectively. Only the bark samples of nandhi *(Legestroemia lanceolata)* harboured the diatoms. Further, the comparative study of algal samples of flowering murdals (*Terminalia paniculata)* reveal that the members of chroococcales are dominant at all the sites namely open undisturbed, shaded undisturbed and open disturbed areas respectively. Of the 10 taxa of algae, *Chroococcus minutus, Chroococcus minor, Chroococcus tenax* and *Calothrix marchica* are observed at all the sampling sites. The green algal taxon, *Printzina effusa* is present only in the samples of shaded undisturbed area. The average abundance data reveal that the diversity of taxa is highest at shaded undisturbed area which is followed by either open undisturbed or open disturbed area respectively. The systematics along with dominance of algal taxa is given. The study is in the agreement with the majority of the earlier investigators who reported dominance of cyanophyceae or blue green algae in the sub aerial algal flora of the tropical regions.

The sub aerial algal studies initiated in the South East Asia during the later period of the 18^{th} and early period of the 19^{th} century (Fritsch 1907, Jeeji Bai 1962, Kamat and Harankhedkar 1976, Schmidle 1897, 1898, Van Oye 1921). The studies of sub aerial algae till 1990 lack detail classical systematics and documentation. During the early part of the 20^{th} century the studies on biodiversity and conservations attracted the botanists to study various aspects of sub aerial algae. The recent studies of sub aerial algae of bark samples of tropical regions deal with occurrence, systematics, diversity and related topics (Lakshmi Kumari and Adhikary 2008). The recent published papers deal with the vague information on sub aerial algae of India (Karagupta and Keshri 2006, Mitker and Shukla 2006, Mukesh *et al*. 2011, Kharkongor and Ramanujam 2014 and Bhakta *et al.* 2014). However, there are no published reports on sub aerial algal flora of Western Ghats which is known as one of the hot spots of biodiversity. Present study is proposed with the following objectives :

- To study the occurrence, distribution and species composition of sub aerial algae on different bark of trees of tropical forests of Kuvempu University.
- To study the diversity of sub aerial algae of different areas.
- The role of factors where influence the diversity of sub aerial algae.

MATERIALS AND METHODS

Study area : The samples were collected in the forests of the Kuvempu University which is located on the eastern side of the Western Ghats. The Kuvempu University has an area

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of 230 acres in Shimoga district of Karnataka state of India. The geographical coordinates 75.567E longitude and I 3.92N latitude. The area receives an average rainfall of 140 cm/year. The average temperature ranges between 20 and 30°C, relative humidity varies between 60 and 100% and the campus is covered by dry deciduous to semi evergreen forest. The year is separated into three distinct seasons namely, the rainy between June and November, the winter between December and February and the summer between March and May. Six trees are randomly selected for the collection of algal samples (Table 1) : Rose wood (*Dalbergia latfolia*), flowering murdals (*Terminalia paniculata*) flame of the forest (*Butea monosperma*), mountain persimmon (*Diaspyros montana*), Indian ash (*Lamnae coromandelica*) and nandhi (*Legerstromia lanceolata*). The trees of flowering murdals (*Terminalia paniculata*) are also selected from the following areas :

- The **open disturbed area :** The area is open disturbed, the forest is cleared for the construction of foot path and the construction of nursery of the University. The percentage of open sky is 70.
- The **shaded undisturbed area :** The area is undisturbed and fully shaded area. There are trees which are luxuriously growing, the ground vegetation is totally absent or partially present. The percentage of open sky is 30.
- The **open undisturbed area :** The forest is undisturbed, however the area receives maximum sunshine due to cutting of forests for the construction of buildings. The 20-25% of the ground vegetation is 2.2.
- **Field sampling :** Samples were collected on monthly basis from the bark of trees. The collections were made between May and August 2014. The samples are collected from the sampling trees with a trunk diameter of more than 30 cm at the height of 20-40 cm above the soil level. Care is taken to ensure no contamination between samples by sterilizing the knife and the fresh polythene bags. The

Table l. Botanical name, English name and habitat of trees on which sampling are made

Sample No.	Tree species			
	Botanical Name	**English Name**	**Bark**	**Habitat**
1	*Butea monosperma* (Lam.) Taub. (Fabaceae / Papilionaceae)	Flame of the forest	Rough	Forest
2	*Dalbergia latifolia* (Roxb.) (Fabaceae/Papilionaceae)	Rose wood	Rough	Forest
3	*Diaspyros montana* (Roxb.) (Ebinaceae)	Mountain persimmon	Wrinkled	Forest
4	*Lagestroemia lanceolata* (Wall.ex.cl.) (Lythraceae)	Nandhi tree	Smooth	Forest
5	*Lannae coromandelica* (Houtt.) Merr. (Anacardaceae)	Indian ash tree	Smooth	Forest
6	*Terminalia paniculata* Roth. (Combritaceae)	Flowering murdals	Smooth	Forest

collected bark samples are sealed with polythene bags and brought to the laboratory for further detailed studies.

Data analysis : The collected samples are kept in small volume (5 ml) of water in petridish. Three slides are prepared from each sample and observed under microscope and micro photographed with the help of Mayo Binocular Compound Microscope with Sony cyber shot DSC-WS10 camera attached. The individual count from three slides of each samples of each taxa are counted and documented. Identification is done by using following the standard taxonomic literatures (Desikachary 1959, John and Robert, 2003, Neustupa and Skaloud, 2010, Kharkongor and Ramanujum, 2014, Lakshmi Kumari and Adhikary, 2008). Species diversity is calculated using Shannon-Wiener diversity index (Shannon and Weaver 1963), following the formula

$$H' = -\sum pi \ln pi$$

Where $pi = ni/N$, ni = no. of individuals in the ith species; N= Total number of individuals of all species.

The average abundance, density and frequency are calculated by the following formulas

$$\text{Frequency} = \frac{\text{Total no. of quadrates in which the species present}}{\text{Total no of quadrates studied}}$$

$$\text{Abundance} = \frac{\text{Total no. of individuals of the species in all quadrates}}{\text{Total sum of quadrates in which species occurred}}$$

$$\text{Density} = \frac{\text{Total no. of individuals of the species in all sample quadrates}}{\text{Total no. quadrates studied}}$$

RESULTS

The different plants on which algal samples are made are detailed (Table 1), the algae enumerated along with systematics are listed (Table 2) and the photograph are given (Plate l, Fig. 1-13). The algal taxa on the barks of flowering murdals at different areas occurred between May and August 2014 are tabulated (Table 3). The abundance of the members of algal taxa on the bark samples of flowering murdals (*Terminalia paniculata*) are detailed (Tab1e 4). The quantitative algal taxa counts on the bark samples of flowering murdals are also tabulated (Table 5).

DISCUSSION

Systematics : The study records a total of 56 algal taxa from the Kuvempu University campus. Of the 56 taxa 53 belongs to cyanophyceae and remaining 2 belongs to chlorophyceae and 1 taxa belongs to bacillariophyceae (Table 2). Though, the number of taxa recorded are less, it agrees with the concept of Lopez-Bautista *et al*. (2007) who reported that subaerial algal communities consists of 4 groups of algae namely cyanophyta, chlorophyta (chlorophyceae, trebauxiophyceae, ulvophyceae). In addition, few members of heterokontophyta which includes bacillariophyceae and xanthophyceae. Another lineage charophytic includes a wide spread genera *Klebsormidium marium* which is not recorded in our present investigation. Neustupa and Skaloud (2010) said that the subaerial algae of tree barks, leaves or bare wood surfaces contain characteristics and diverse assemblages consisting usually mainly of coccoid green and different cyanobacterial morphotypes.

Lopez-Bautista *et al*. (2007) summarized the current state of knowledge of the diversity and systematic of the sub aerial algae with attention to tropical rain forests for which the sub aerial algal flora is poorly known and is urgently needed for further investigation. They (op.cit) said that the sub aerial algae flora constitute cyanophyta, chlorophyta and heteokontophyta. The cyanobacterial diversity of subaerial algae still under reported due to difficulties in employing morphological character to identify species and a lack of specialists exploring nobel habitats. In addition the systematics of cyanophyta is in a phase of rearrangements (Lopez-Bautista *et al.* 2007). The rearrangement accompanied several interesting factors (example; description of new species, recognition of monophytic origin, ITS regions and endemic species of distinctive habitats). Along with cyanobacteria, the systematics of chlorophyta is also in phase of major rearrangements. Lopez-Bautista *et al.* (2007) based on their

Table 2. A list of taxa observed on different sampling trees

Sl. No.	Taxa observed	Trees					
		BM	DL	DM	LL	LC	TP
Cyanophyta : Order : Chroococcales							
Family : Chroococcaceae							
1	*Chroococcus limneticus* Lemmermann		+				
2	*Chroococcus macrococcus* (Kutzing) Rabenhorst		+				
3	*Chroococcus minor* (Kutzing) Nageli	+			+	+	+
4	*Chroococcus minimus* (Keissler.) Lemmermann			+			
5	*Chroococcus turgidus* (Kutzing) Nageli				+		
6	*Chroococcus minutus* (Kutzing) Nageli		+		+		+
7	*Chroococcus tenax* (Kirchner) Hieronymus	+	+		+		+
8	*Chroococcus pallidus* Nageli				+		
9	*Aphanocapsa virescens* (Hassall) Rohenhorst		+				
10	*Aphanocapsa microscopica* Nageli	+				+	
11	*Aphanothece stagnina* (Sprengel) A.Braun						+
12	*Aphanothece clathrata* West and G. S. West					+	
13	*Aphanothece pallida* (Kutzing) Rabenhorst				+		
14	*Glococapsa atrata* Kutzing				+		
15	*Gloeocapsa polydermatica* Kutzing					+	
16	*Gloeothece rupestris* (Lyngbye) Bornet				+		
Order : Chaemosiphonales							
Family : Cyanidiaceae							
17	*Chroococcidiopsis indica* Desikachary	+			+		
Order : Pleurocapsales							
Family : Pleurocapsaceae							
18	*Myxosarcina spectabilis* Geitler						+
Order : Nostocales							
Family : Oscillatoriaceae							
19	*Hydrocoleum heterotrichum* Kutztng ex Gornont		+				
20	*Lyngbya lagerheimii* Gornont ex Gomont		+				
21	*Lyngbya mesotricha* Skuja	+		+			
22	*Lyngbya kuetzingii* Schmidle			+			
23	*Lyngbya rubida* Fremy			+			
24	*Lyngbya nordgardii* Wille				+		
25	*Lyngbya perelegans* Lemmerman					+	
26	*Lyngbya ceylanica* Wille		+				
27	*Lyngbya contorta* Lemmerman		+				
28	*Phormidium ambiguum* Gomont	+	+				
29	*Phormidium purpurascens* Gomont. ex. Gomont	+					

30	*Phormidium microtomum* Skuja					+	
31	*Oscillatoria perornata* Skuja		+				
32	*Schizothrix friesii* Gornont		+				
33	*Symploca cartilaginea* Gomont				+		
Family : Scytonemataceae							
34	*Scytonema hofmannii* Agardh ex Bernet andFlahault	+					
35	*Scytonema bohneri* Schmidle		+				
36	*Scytonema burmanicum* Skuja			+		+	
37	*Scytonema zellerianum* Bruhl and Biswas				+		
38	*Scytonema pseudopunctatum* Skuja				+	+	
39	*Scytonema dialatatum* Bharadwaja						+
40	*Scytonema ocellatum* Lemmermann			+			
41	*Scytonema myochrous* Agardh ex. Bornet and Falhault			+			
42	*Scytonema mirabile* (Dillw) Brown	+					
43	*Tolypothrix bout eillei* (Bornet and Flahault) Lemmermann				+		
44	*Tolypothrix foreaui* Fremy			+		+	
45	*Tolypothrix distorta* Kutzing ex. Bornet and Flahault		+				
Family : Nostocaceae							
46	*Nostoc parmeliodes* Kutzing ex. Bornet and Flahault		+				
47	*Pseudanabaena* Lauterborn	+					
Family : Rivularaceae							
48	*Calothrix marchica* Lemmermann.	+	+		+		+
49	*Calothrix parietina* Thuret ex. Bornet and Flahault						+
50	*Calothrix braunii* Bornet and Flahault		+				
51	*Calothrix dolichomeres* Skuja		+				
52	*Calothrix fusca* Bornet and Flahault						+
53	*Homeothrix hansgirgi* (Schmidle) Lemmermann					+	
Chlorophyta							
Order : Trentepohliales							
Family : Trentepohliaceae							
54	*Trentepohlia* Martius		+				
55	*Printzinia effusa* (Krempelhuber) R.H. Thompson & D.E.Wujek						+
Heterokontophyta							
Family : Bacillariophyceae							
56	*Flagellaria* Lyngbye				+	+	

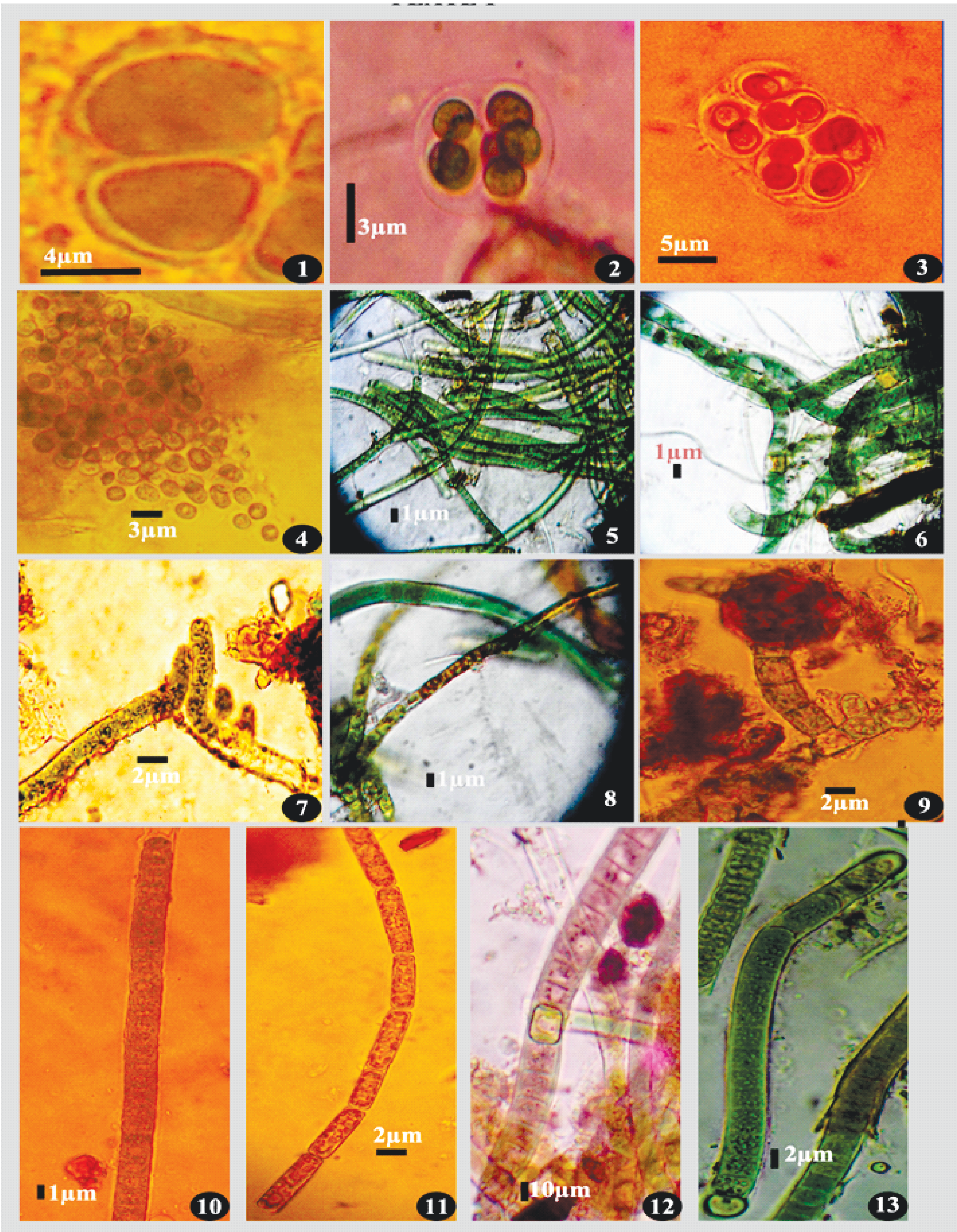

Plate 1 : ***1.*** *Chroococcus limneticus* ***2.*** *Chroococcus minutes* ***3.*** *Gloeocapsa atrata* ***4.*** *Aphanothece clathrata* ***5.*** *Lyngbya perelegens* ***6.*** *Tolypothrix distorta* ***7.*** *Scytonema dialatatum* ***8.*** *Printzina effuse* ***9.*** *Trentepohlia sp.* ***10.*** *Oscillatoria perornata* ***11.*** *Pseudanabaena sp.* ***12.*** *Scytonema zellarianum* ***13.*** *Calothrix marchica.*

Scale bar : 1-3 Colony size. **4, 11, 8, 9** Size of the cell and **5-7, 10, 12, 13** Size of the trichome

Table 3. Monthly variation of algal taxa of flowering murdal (*Terminalia paniculata*) between May and August 2014

Sl. No.	Taxa observed	Sampling sites											
		Open undisturbed area				Shaded undisturbed area				Open disturbed area			
		May	June	July	August	May	June	July	August	May	June	July	August
1	*Chroococcus minor*	+	+	+	-	-	+	-	-	+	+	-	-
2	*Chroococcus minutus*	+	+	-	-	+	-	-	-	-	+	-	-
3	*Chroococcus tenax*	+	+	+	-	-	+	-	-	+	-	-	-
4	*Aphanothece stagnina*	-	-	-	-	+	+	+	-	-	-	-	-
5	*Myxosarcina spectabilis*	-	-	-	-	+	+	-	+	-	-	-	-
6	*Scytonema dialatatum*	-	-	-	-	+	+	-	-	-	-	-	-
7	*Calothrix marchica*	+	+	-	+	-	+	-	-	+	+	-	-
8	*Calothrix parietina*	-	-	-	-	+	+	-	-	-	-	-	-
9	*Calothrix fusca*	-	-	-	-	+	+	+	-	-	-	-	-
10	*Printzina effusa*	-	-	-	-	+	+	-	+	-	-	-	-

Table 4. Average abundance, frequency and density of host sample *Terminalia paniculata* from all three sampling sites.

Taxa observed	Sampling sites								
	Open undisturbed area			Shaded undisturbed area			Open disturbed area		
	Density	Abundance	Frequency	Density	Abundance	Frequency	Density	Abundance	Frequency
Chroococcus minor	2.0	2.0	1.0	0.5	1.0	0.5	1.5	1.5	1.0
Chroococcus minutus	1.0	2.0	0.5	0.5	1.0	0.5	0.5	1.0	0.5
Chroococcus tenax	2.0	2.0	1.0	0.5	1.0	0.5	0.5	1.0	0.5

Aphanothece stagnina	0.0	0.0	0.0	3.0	2.0	1.5	0.0	0.0	0.0
Myxosarcina spectabilis	0.0	0.0	0.0	2.0	2.0	1.0	0.0	0.0	0.0
Scytonema dialatatum	0.0	0.0	0.0	1.0	2.0	0.5	0.0	0.0	0.0
Calothrix marchica	3.0	2.0	1.5	1.0	2.0	0.5	1.0	2.0	0.5
Calothrix parietina	0.0	0.0	0.0	1.0	2.0	0.5	0.0	0.0	0.0
Calothrix fusca	0.0	0.0	0.0	2.0	2.0	1.0	0.0	0.0	1.0
Printzina effusa	0.0	0.0	0.0	2.0	2.0	1.0	0.0	0.0	0.0

Table 5. Quantitative variations of algal taxa on the bark samples of flowering murdals (*Terminalia paniculata)* at different areas.

Sl. No.	**Taxa**	**Open undisturbed area**				**Shaded undisturbed area**				**Open disturbed area**			
		May	**June**	**July**	**August**	**May**	**June**	**July**	**August**	**May**	**June**	**July**	**August**
1	*Chroococcus minor*	2	1	1	0	0	1	0	0	2	1	0	0
2	*Chroococcus minutus*	1	1	0	0	1	0	0	0	0	1	0	0
3	*Chroococcus tenax*	2	1	1	0	3	2	1	0	1	0	0	0
4	*Aphanothece stagnina*	0	0	0	0	2	1	0	1	0	0	0	0
5	*Myxosarcina spectabilis*	0	0	0	0	1	1	0	0	0	0	0	0
6	*Scytonema dialatatum*	0	0	0	0	0	2	0	0	0	0	0	0
7	*Calothrix marchica*	3	2	0	1	1	1	0	0	1	1	0	0
8	*Calothrix parietina*	0	0	0	0	2	1	1	0	0	0	0	0
9	*Calothrix fusca*	0	0	0	0	2	1	1	0	0	0	0	0
10	*Printzina effusa*	0	0	0	0	2	1	0	1	0	0	0	0

laboratory studies along with their direct microscopic observations, discussed systematics of several groups of green algae. They are of the opinion that the morphological convergence caused three (unicellular, sarcinoid and uniserrate) thallus types in green algae (Lopez-Bautista *et al.* 2007). The morphological and reproductive feature do not reflect phylogeny patterns in most groups of green algae. As a result, the systematics and diversity studies in chlorophyceae is difficult. In addition, the members of chlorophyceaen sub aerial algal communities acquired following adaptations; the capacity to utilize water in the form of vapour, the production of mucilaginous envelope retaining moisture, the production of resistance stages such as akinetes, the production of pigments acting as a protection from solarization, the production of antifreezing compound, the production of mycosporine like amino acids as a protection from UV radiation, which influence their identification further difficult.

Algal associations : The algal taxa observed on the different barks of the trees formed

Serial No.	Tree samples	Genera/ Individuals	Dominance sequence
1	*Dalbergia latifolia* (Roxb.)	11/62	*Aphanocapsa virescens≥Phormidium ambiguum> Chroococcus limneticus ≥ Hydrocoleum heterotrichum≥ Lyngbya lagerheimii ≥ Lyngbya ceylanica≥Oscillatoria perornata ≥Schizothrix friesii≥ Scytonema bohneri≥ Nostoc parmeliodes≥ Lyngbya contorta≥Calothrix braunii≥Trentepohlia* sp. *≥Chroococcus macrococcus≥ Calothrix dolichomeres.* **Occurrence:** thick green mat
2	*Legerstroemia lanceolata* (Linnaeus)	11/42	*Chroococcus turgidus≥Aphanothece pallida≥ Scytonema zellerianum≥Tolypothrix bouteillei≥ Chroococcus pallidus ≥ Gloeocapsa atrata≥ Gloeothece.rupestris≥Scytonema pseudoputatum≥ Chroococcidiopsis indica≥Lyngbya norgardhii≥ Symploca cartiloginea≥Fragilaria* sp. **Occurrence:**dark green algal mat
3	*Lannea coromandelica* (Houtt.) Merr.	9/34	*Aphanothece clathrata≥Phormidiurn microtomum≥ Gloeocapsa polydermalica≥ Lyngbya perelegens≥ Scytonema burmanicum≥Homeothrix hangsgirgi≥ Chroococcus minor≥Chroococcus tenax≥ Aphanothece microscopica≥ Scytonema pseudoputatum≥ Fragilaria* sp≥ *Tolypothrix fore aui* **Occurrence :** Light greenish mat with brophytes
4	*Butea monosperma* (Lam.) Taub.	8/40	*Aphanothece microscopica ≥ Scytonema hofmanni≥ Chroococcus minor≥ Chroococcidiopsis indica≥ Lyngbya mesotricha≥Phormidium anbiguum≥ Phormidium purpurascens≥Calothrix marchica> Scytonema mirabile≥Pseudanabaena* sp. **Occurrence:** cushion like blue Green mat.

5	*Terminalia paniculata* (Roth)	6/27	*Aphanothece stagnina≥ Chroococcus minutus≥ Chroococcus tenax≥Myxosarcina spectabilis≥ Calothrix marchica> Calothrix fusca≥ Printzina effusa≥ Chroococcus minor≥Scytonema dialatatum≥ Calothrix parietina* **Occurrence :**light greenish mat
6	*Diaspyros montana* (Roxb.)	4/21	*Lyngbya kuetzingii≥Chroococcus minimus≥Lvngbya rubida ≥Scytonema burmanicum≥Scytonema ocellatum≥ Lyngbya mesotricha≥ Scytonema myochrous≥Tolypothrix foreaui* **Occurrence:**Cushion like algal mat along with ferns

specific associations. The observed associations are not only in the composition of specific genera but also of specific species. On the basis of quantitative variations the associations are arranged as detailed below.

The investigations on sub aerial algal communities are less in general and particular in tropical countries (Fritsch 1907, 1922, Fremy 1930, Nakano and Takeshita, 1991). A few investigators who studied and reported the excellent concept of distribution, occurrence and factors impacted on them. In addition, the forests are treasure of biodiversity of sub aerial algae. The investigations on subaerial algae of Indian region are meager (Kharkongor and Ramanujum 2014. Lakshmi and Adhikary 2008, Mitker and Shukla 2006, Bhakta *et al.* 2014, Mukesh *et al.* 2011). It is also true that there is a remarkable difference between the sub aerial algal flora of the forests of high attitudes and low altitudes of tropical rain forests (Neustupa and Skaloud, 2010). Of the six above samples, associations of sub aerial algae varies remarkably between 4/21 and 11/62 genera/individuals respectively. As it is already stated that, the surface of the bark samples (smooth, rough, wrinkled), availability of nutrients and climatic components and also microclimatic nature of the bark surface may influence on the distribution of sub aerial algal flora.

Among the six bark samples the bark samples of rose wood (*Dalbergia latifolia*) harbored maximum of 11 genera and 62 individuals and the bark samples of mountain persimmon (*Diaspyros montana*) harbored 4 genera and 21 individuals. The rough surface of the rose wood and wrinkled surface of the mountain persimmonmay be the reason for having highest and lowest number of algae respectively. The bark surface may be arranged on the basis of algal associations.

Rose wood > Nandhi > Indian ash tree > Flame of the forest > Flowering murdals > Mountain persimmon.

Few taxa of green algae, *Trentepohlia* sp and *Printzina effusa* are recorded in the bark samples of *Dalbergia latifolia* and *Terminalia paniculata* respectively. The diatom *Fragilaria* sp are found on the bark samples of *Lagestroemia lanceolata* and *Lannae coromandelica.* Among the members of cyanophyceae, unicellular members are recorded highest on all bark samples except *Diaspyros montana* in which filamentous blue green algaeare recorded highest. The genus *Chroococcus* and *Scytonema* are recorded on all the bark samples. The variation of number of taxa on the bark samples may be influenced by the nature of the bark, percentage of sun shine and availability of nutrients. Similar types of associations are reported by Barkman (1958) from Europe, who observed three specific associations of algae.

1. The *Pleurococcetum vulgaris* forms a dull green, powdery, water repellent cover that loosely adheres to the bark on the shady side of trees. *Pleurococcus vulgaris* Nag., *Protococcus viridis* Ag., and *Chlorella vulgaris* Beyer are the major components. It occurs wherever the habitat is too harsh for the other associations and is generally

the only association that can survive on city trees. It has a wide ecological amplitude and occurs on a great variety of trees.

2. The *Prasioletum crispae,* association. It forms a velvety felt on tree barks, especially in alternatively wet and dry rain-tracks. The main species are *Prasiola crispa* (Lightf.) Menegh and *Hormidium flaccidum* A.Br. This association develops at certain age of the tree, where the crown is able to produce sufficient water supply for the rainy tracks. The association succeeds the *Pleurococcetum* and may in turn be replaced by bryophytes.

3. *Trentepohlietum abietinae,* forms orange cushions or crusts on trees. It prefers shady sites, particularly N and E side of isolated wayside trees in montane regions. *Trentepohlia abietina* (Pers.) Hansg and *Tr. umbrina* (Kutz.) Born. are its representative species.

Fristch (1907) observed blue green algal forms a major part of the epiphytic vegetation, besides *Trentepohlia* species. The species of *Trentepohlia* requires minimum percentage of moisture. Fremy (1930) found the following blue green algae on tree barks in tropical Africa; *Aphanocapsa naegelii* Richt., *Gloeocapsa aurata* Stiz.,*Gl. ambigua* Kirchn., *Gl. lignicola* (Kutz.) Rabenh., *Microcoleus tisserantii* Fremy, *Schizothrix natans* W. & G. S. West, *Porphyrosiphon notarisli* (Menegh.) Kutz., *Symploca muscorum* (Ag.) Gom., *S. muralis* Kutz., *S. elegans* Kutz., *S. parietina* (A. Br.) Gom., *Tolypothrix arboricola* Fremy, *T. byssoidea* (Berk.) Kirchn., *Scytonema milleii* Born., *S. javanicum* (Kutz.) Born., *S.guyanense* (Mont.) Born. & Flah., *S. hofmannii* Ag., *S. myochrous* (Dillw.) Ag., *S. crustaceu* Ag., *Nostoc sphaericum* Vauch., *N. macrosporum* Menegh., and *Fischerella tisserantii* Fremy.

Diversity : The algal diversity studies have been made on the algal samples of bark of flowering murdals *(Terminelia paniculata)* at three different localities (open undisturbed, shaded undisturbed and open disturbed). The percentage of open sky is 50, 30, and 70% at the open undisturbed, shaded undisturbed and open disturbed respectively. The average species at the open undisturbed, shaded undisturbed and open disturbed is 4, 10 and 4 respectively. The algal taxa *Chroococcus minor, Chroococcus minutus, Chroococcus tenax* and *Calothrix marchica* are recorded at all the bark samples of *Terminalia paniculata.* However, the remaining five taxa of blue

Table 6 : Algal diversity of different sample sites of host tree *Terminelia paniculata.*

Serial No.	Area	Genera / Individuals	Dominance pattern
1	Open undisturbed area, the area has 50% of open sky for radiation.	4/16	*Calothrix marchica>Chroococcus minor> Chroococcus tenax> Chroococcus minutus* Occurrence : light blue green mat
2	Shaded undisturbed area, the area has 30% of open sky for radiation.	10/26	*Aphanothece stagnina> Calotrhrix fusca> Printzina effusa>Myxosarcina spectabilis> Calothrix marchia> Scytonema dialatatum> Calothrix parietina > Chroococcus minor> Chroococcus tenax> Chroococcus minutus* Occurrence : cushion like thick mat
3	Open disturbed area, the area has 70% open sky for radiation.	4/6	*Chroococcus minor> Calothrix marchia> Chroococcus tenax> Chroococcus minutus* Occurrence: light blue green mat

green algae, *Aphanothece stagnina, Myxosarcina spectabilis, Scytonema dialatatum, Calothrix parietina* and *Calothrix fusca* and the one green alga, *Printzina effusa* are found only in the bark samples of shaded undisturbed area (Table 4). The observations are detailed below on the basis of quantitative estimation (Table 6).

The Shannon index varied between 0.013 and 0.033; 0.013 and 0.033; and 0.007 and 0.019 at open undisturbed, shaded undisturbed and open disturbed area respectively (Table 7). The average abundance are high at the samples of shaded undisturbed area when compare to open undisturbed and open disturbed area. The shaded undisturbed area with high average abundance has more number of algal taxa which include the green algae, *Printzina effusa* which is recorded only at undisturbed area and present throughout the sampling period except in the month of July 2014 (Table 4). The shaded undisturbed area has 30% of open sky which is one of the factors to influence abundant growth of algal taxa (Neustupa and Skaloud, 2010).

Table 7 : Shannon wiener index of different sampling sites of host tree *Terminalia paniculata*

Taxa observed	Sampling sites		
	Open undisturbed area	**Shaded undisturbed area**	**Open disturbed area**
Chroococcus minor	0.024	0.007	0.019
Chroococcus minutus	0.013	0.007	0.007
Chroococcus tenax	0.024	0.007	0.007
Aphanothece stagnina	0	0.033	0
Myxosarcina spectabilis	0	0.024	0
Scytonema dialatatum	0	0.013	0
Calothrix marchica	0.033	0.013	0.013
Calothrix parietina	0	0.013	0
Calothrix fusca	0	0.024	0
Printzina effusa	0	0.0241	0

Sub aerial habitats of tropical rain forests represent one of the least known algal habitats worldwide (Thompson and Wujeck 1997, Neustupa 2005, Rindi *et al.* 2006, Neustupa and Skaloud 2008). Further, Neustupa and Skaloud (2008) estimated the proportion of possibly undescribed and new taxa of green micro algae undistinguishable according to the traditional criteria was about 60%. However, given the overall high proportion of pseudo cryptic and cryptic species among these groups (Henley *et al.* 2004, Krienitz *et al.* 2004 and Neustupa 2005), the real proportion of new species might be even higher. Likewise in Trentepohliales cryptic diversity seems too led to the considerable underestimate of the presumed total species member in tropical habitats (Lopez-Bautista *et al.* 2007, Neustupa and Skaloud, 2008). Therefore, Neustupa & Skaloud (2008) suggested combination of molecular and phylogenic approaches. The application of comparing several epixylic microlocalities, he said that microscopic and cultivation methods for enumeration and individual morphotypes could not be followed for the identification of morphotypes, because the microscopic and cultivation methods do not capture non-cultivated cyanobacteria and algae. The environmental sequencing approaches also have limitations (Neustupa & Skaloud (2010).

The distribution pattern of bark algae of flowering murdals (*Terminalia paniculata*) is in the agreement of the previous investigators (Hoffmann 1989, Fristch 1907, Fremy 1930) who reported specific genera and species from the Europe and tropical regions. During the present investigation also association is dominated by the members of blue green algae. Shaded undisturbed area facilitated growth of maximum taxa whereas open disturbed and open undisturbed recorded the same number of species. However, there is a remarkable difference between the species of open undisturbed and open disturbed area qualitatively (Table 5). The open undisturbed area is dominated by the species of *Calothrix* whereas the open disturbed area is dominated by the species of *Chroococcus.* The density, abundance and frequency of the open undisturbed, shaded undisturbed and open disturbed area ranges between 0.00 and 3.0; 0.0 and 2.00; 0.0 and 1.5; 0.5 and 3.0; 1.0 and 2.0; 0.5 and 1.0; 0.0 and 1.5; 0.0 and 1.5; 0.0 and 1.0 respectively (Table 4). Among the tree bark samples, samples of shaded undisturbed area has high percentage of diversity, abundance and frequency. In addition, the maximum of 10 taxa of algae are recorded including green algae *Printzina effusa.*

There are number of investigators who studied diversity of species and reported different results for various habitats. Neustupa and Skaloud (2010) reported species number of 8.9 and 7.1 for bark and wood samples. Further Neustupa and Skaloud (2010) that there is no difference in alpha diversity between the groups of samples, on the other hand the bark diversity based on the Bay-Curtis difference of species composition between samples was constantly higher between the two samples. Mikhaiyuk (1999) and Mikhailyuk *et al.* (2001) reported species number of 4.0 and 1.9 from temperate (Ukraine) and subtropical ecosystem (Israel) respectively. Nakano *et al.* (1991) reported average species number of 1.9 and 5.9 from different habitats of Japan. Therefore, the values recorded in the present investigation are in agreement with the earlier investigators. The systematics of sub aerial algae are limited and scanty. It is true that diversity of many groups or terrestrial algae is still poorly understood and the availability of new collection inventories of their biodiversity and molecular characterization is particularly urgently needed as stated by Lopez- Bautista *et al.* (2007).

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