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DISTRIBUTION OF CYANOBACTERIA IN BIOLOGICAL SOIL CRUSTS IN SACRED GROVES FOREST OF ARIYALUR AND PUDUKOTTAI DISTRICTS, TAMILNADU, INDIA

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ABSTRACT: Distribution of cyanobacterial species in biological soil crust (BSC) from two different sacred groves namely Ariyalur and Pudukottai during summer and monsoon seasons showed that species richness was high in summer season in both sacred groves while species evenness was high in monsoon season especially in Pudukottai sacred grove. Frequency of filamentous non heterocystous cyanobacterial species was high in the studied grove forest which implies on increased nitrogen fixation, ends with great diversification of plants in the Ariyalur and Pudukottai district. These results proved that increased cyanobacterial species increased the floral content in the study sites.

KEYWORDS:BSC, Cyanobacteria, Shannon index, Species richness

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1.INTRODUCTION

Biological organisms associated with the upper millimeter of soil surface is called biological soil crusts (BSCs), which are flourished by numerous living things in monsoon and its surface become wrinkled by withering in summer. BSCs consist of soil granules and various biological organisms including cyanobacteria, algae, mosses, lichens and fungi (West, 1990). These organisms interact variously with flora (Boeken et al., 2004; Serpe et al., 2006) and fauna (Bamforth, 2008). BSCs prevent wind and water erosion, provide soil stability (Bowker, 2007) involve in carbon and nitrogen

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fixation (Burgheimer et al., 2006; Wu et al., 2009) and in hydrological processes as well (Belnap, 2006). BSCs are distributed in hot, cool, cold arid, semi-arid and forest ecosystems (Ullmann and Büdel, 2001) including sacred groves forest. Sacred groves are forest ecosystem that are rich in vegetation and distributed around India in general and Tamilnadu in particular. Sacred groves play an important role in plant preservation practices and the forest floor is often noticed with biological soil crust in the form of mats, crusts or patches. These soil crusts act as reservoir of plant nutrients and influence soil structure and activity of other microorganisms. Soil crust acts as agents for the incorporation of organic carbon and nitrogen through photosynthesis and nitrogen fixation (Smith et al., 1990; Johansen, 1993) especially by cyanobacteria. Cyanobacteria, among other group of organisms are the main component part of biological soil crusts of sacred groves. They promote the nitrogen economy of soil by converting atmospheric nitrogen (Ernst et al., 1992). The morphology of soil-crust cyanobacteria largely determines the ecological function of cyanobacteria, relative to water infiltration, erosion, water retention. (Belnap et al., 2001) and excrete several organic acids which increases and maintains the soil fertility, nutrient availability and water holding capacity (Roger and Reynaud, 1982; Saadantia and Riahi, 2009; Wilson, 2006) of the sacred groves soil. Studies on sacred groves forest has although increased considerably (Ganesan et al., 2009) information on BSC communities is not available. This investigation, therefore aimed to survey the cyanobacterial population its diversity and seasonal variation in the biological soil crusts of sacred groves forest of Ariyalur and Pudukottai districts, Tamil Nadu, India.

2. MATERIALSAND METHODS

2.1. Study Area and Sample collection

Sacred groves forest situated at N11°11, E79°10 and N10°29, E78°44 in Ariyalur and Pudukottai districts Tamil Nadu, India were selected for this study (Table 1). The vegetation in these areas was dry and deciduous. Biological soil crusts were collected from these regions in properly labeled polythene bags. Their colour, type, thickness and appearance in the field (Figure 1) were noted down. Samples were collected during summer (March-May, 2016) and monsoon (September-November, 2016) seasons from different sacred groves sites and processed at Department of Botany, Jamal Mohamed College (Autonomous), Tiruchirappalli, India.

2.2. Morphological analyses

Soil crust samples were briefly wetted with sterile water and examined under light microscope in the laboratory. Another portion of dry biological soil crusts were wetted by the addition of BG-11 medium under optimal growth conditions. The samples were analyzed as and when the green colour appeared in polythene bags. Cyanobacterial compositions of the samples were identified based on shape and size of vegetative cells, presence and absence of sheath, heterocysts, akinetes (if present), their position-, and branching pattern following the standard monograph of Desikachary (1959).

2.3. Physicochemical properties of soil samples

Soil samples were analyzed for their physicochemical properties such as pH, electrical conductivity (EC), salinity, macro and micro nutrients namely organic carbon (OC), nitrogen (N), phosphorous (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) following the standard protocols of Tamil Nadu Government Department of Agriculture, Perambalur, India.

2. 4. Data analysis

Diversity indices, richness and evenness were calculated using the biodiversity software PRIMER (Ver 6.1.11, Primer-E Ltd., Plymouth, United Kingdom). For species diversity, Shannon's diversity index (H) was used (Begon et al., 1996):

$$H = \sum(pi) \ln pi$$

Where i is the proportion of species, pi is the total number of species.

Species richness (D) was calculated using the formula given by (Roth et al., 1994):

$$D = \frac{s}{\sqrt{N}}$$

Where s is the number of different species represented in collected samples; N is the total number of individual organisms

Species evenness or equitability was calculated using pielou's (J) formula (McCune and Grace, 2002):

$$J = H/\ln(S)$$

Where *S* is the sample size

3. RESULTS AND DISCUSSION

Of the 10 sacred groves distributed in Ariyalur and Pudukottai districts, the sacred groves of Pudukottai districts were densely populated with vegetation and they survived for many years without any hardship, but the sacred grove forests of Ariyalur had a sparse population of vegetation.

The BSCs observed in the field were dry during summer and wet in the rainy season. Three types of BSCs namely mat form, crust and patches were observed in the field (Table 2). The mat form of biological crusts appeared thick; light coloured and tightly bound with soil surfaces was associated with/without mass plants in the field. Totally nine cyanobacterial species were found in this mat crust namely Aphanocapsa roseana, Microcoleus paludosus, Phormidium sp., Lyngbya sp., Plectonema sp., Nostoc sp., Anabaena sp., Scytonema sp. The patches types of BSCs were brown/green coloured and sited mostly in shady places. The patches were composed of Oscillatoria perorate, Phormidium sp, Plectonema sp.and Scytonema javanicum (Figure 2). The second type namely the crust was dark in colour, very thinly adhered with soil granules and exposed to direct sunlight. The crusts were composed of Microcoleus paludosus, Lyngbya sp., Plectonema sp. and Scytonema javanicum.

Table 1: GPS locations of sacred groves forest in Ariyalur and Pudukottai districts, Tamil Nadu, India.

Name of sacred groves	Lat. and Long. Geographical locations
Ariyalur district	
Paapathi amman (Otakovil)	N11°10.967', E076°06.749'
Karuppu samy (Nakkampadi)	N11°15.460', E079°09.069'
Vellachi amman kovil (Vellur)	N11°14.887', E079°08.490'
Karumpaeram samy kovil (Odayan kudikkadu)	N11°11.343', E079°10.442'
Karuppusamy (Odayan kudikkadu)	N11°16.311', E079°10.849'
Pudukottai district	
Iyanar kovil (Keeranur)	N10°30.977', E078°46.850'
Karuppusamy kovil (Keeranur)	N10°29.619', E078° 44.596'
Iyanar kovil (Kulathur)	N10°32.538', E078° 46.811'
Sankili karupu kovil (Kothamalapatti)	N10°35.068', E078°46.422'
Adikkalam katha iyanar (Oorapatti)	N10°33.785', E078°46.396'

Table 2: Cyanobacterial morphotypes distinguished in the biological soil crusts of sacred groves forest of Ariyalur and Pudukottai.

Nature of biological crusts		Names of species involved
1. Mat form	with/without moss Dark /light green colour, 1-3mm thickness, Direct sunlight.	1. *Aphanocapsa roseana* 2. *Phormidium sp.* 3. *Lyngbya sp.* 4. *Microcoleus paludosus.* 5. *Microcoleus sp.* 6. *Anabaena sp.* 7. *Nostoc sp.* 8. *Plectonema sp.* 9. *Scytonema sp.*
	Bottom of the plants, Dark/light green colour, 1-2mm thickness,	1. *Oscillatoria annae* 2. *Phormidium sp.* 3. *Schizothrix sp.*

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	Shade places.	4. *Microcoleus sociatus.* 5. *Scytonema javanicum* 6. *Hapalosiphon sp.* 7. *Stigonema minutum*
2.Crust	Brownish/blackish, 0.5-1mm thickness, Direct sun light.	1. *Microcoleus paludosus.* 2. *Lyngbya sp.* 3. *Plectonema sp.* 4. *Scytonema javanicum.*
3. Patches	Brown / green colour, 0.5-1mm thickness, Shade places.	1. *Oscillatoria perorate.* 2. *Phormidium sp.* 3. *Plectonema sp.* 4. *Scytonema javanicum.*

Figure 1: Appearance of mat, crust and patch forms of biological soil crusts in field condition

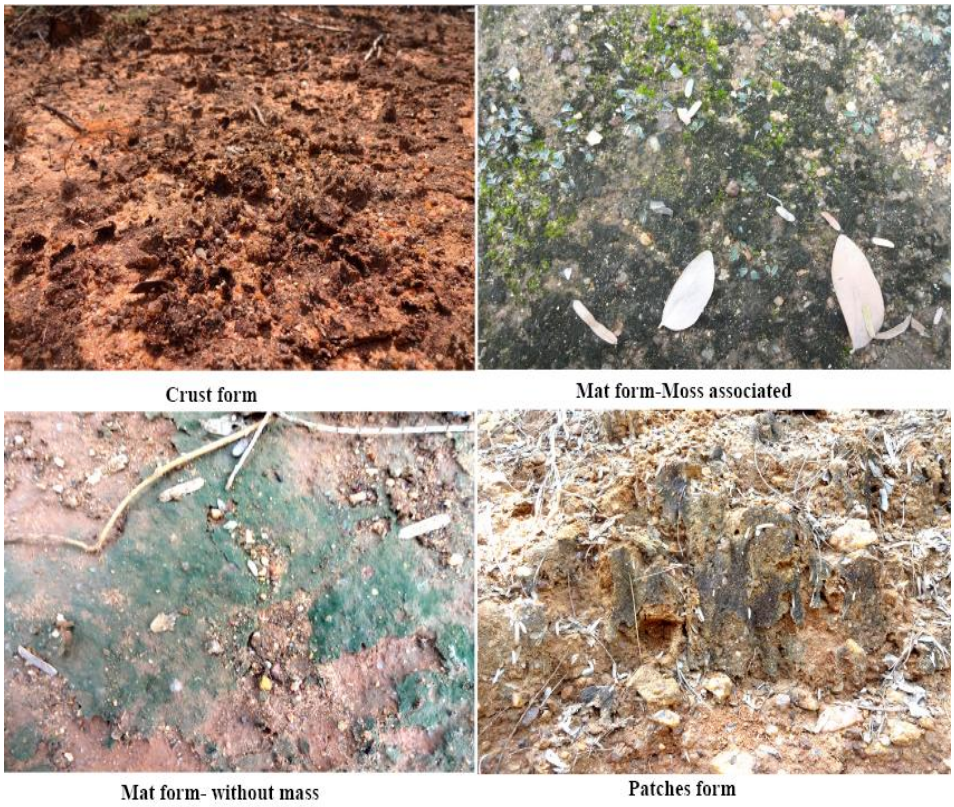
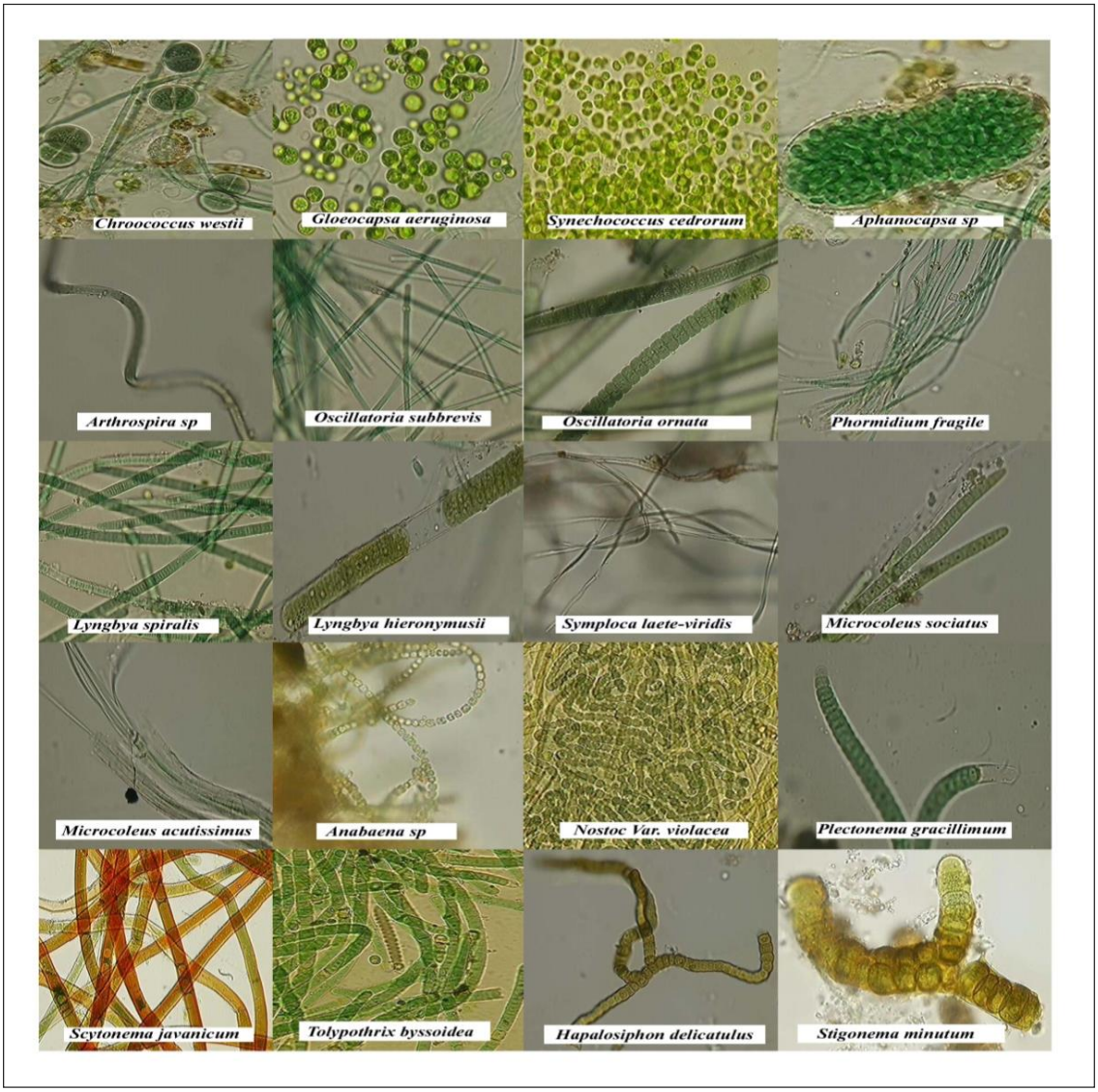


Figure 2: Photomicrographs of cyanobacteria from different sacred groves.



The physiochemical properties of the soil crust from Ariyalur and Pudukottai revealed that organic carbon, nitrogen, manganese, pH, electrical conductivty were high during the monsoon season compared to summer season (Table 3). Table 4a showed various cyanobacterial species forming in BSC collected from sacred groves forest of Ariyalur and Pudukottai districts. In Ariyalur district, 156 and 93 species found in summer and monsoon seasons respectively whereas 141 and 67 species found in summer and monsoon seasons respectively in Pudukottai district. Totally six different cyanobacterial families (Table 4b) were found: 139 species of Oscillatoriaceae (60%), 47 species of Scytonemataceae (21%), 21 species of Chroococcaceae (9%), 16 species of Nostocaceae (7%), 5 species of Stigonemataceae (2%) and 3 species of Microchaetaceae (1%) (Figure 3).

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2017 Sept-Oct RJLBPCS 3(3) Page No.220

Table 3: Physiochemical properties of soil samples of sacred groves of Ariyalur and Pudukottai districts

Physiochemical properties	Ariyalur		Pudukottai	
	Summer	Monsoon	Summer	Monsoon
Organic carbon (kg/acre)	0.43	0.86	0.29	0.96
Nitrogen (kg/acre)	59.6	88.4	50.0	94.8
Phosphorous (kg/acre)	7.5	1.4	11.65	2.8
Potassium (kg/acre)	70.0	122.5	180.0	177.5
Iron (ppm)	3.06	8.09	2.16	1.03
Manganese (ppm)	1.77	3.94	2.06	2.64
Zinc (ppm)	0.94	0.12	1.08	0.08
Copper (ppm)	0.42	0	0.51	0
Electrical conductivity (dsm^{-1})	0.09	0.06	0.36	0.09
pH	5.14	6.6	7.49	7.3

Table 4a: Checklist of BSC forming cyanobacteria of sacred groves forest of Ariyalur and Pudukottai districts

Cyanobacteria species	Ariyalur		Pudukottai	
	Summer	Monsoon	Summer	Monsoon
Chroococcaceae				
Microcystis sp.	-	-	+	-
Micricystis pulvera	-	-	+	-
Chroococcus westii	-	+	-	-
Chroococcus dispasus	-	-	+	-
Chroococcus minor	+	-	-	-
Chroococcus minute	-	-	+	-
Chroococcus sp.	+	+	-	-
Chroococcus varius	-	-	+	-
Gloeocapsa aeruginosa	+	+	-	-
Gloeocapsa calcara	-	+	-	-
Gloeocapsa livida	-	-	-	+
Synechococcus cedrorum	-	+	-	-
Synechococcus sp.	+	-	-	-
Aphanocapsa bioformis	-	+	+	-
Aphanocapsa pulchra	-	-	+	-

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Aphanocapsa roeseanade	-	+	-	+
Aphanocapsa virescens	-	-	+	-
Total	**4**	**7**	**8**	**2**
Oscillatoriaceae				
Arthrospira massartii	+	-	-	-
Arthrospira sp.	-	-	-	+
Oscillatoria simplissima	+	-	-	-
Oscillatoria subuliformis	+	-	-	-
Oscillatoria agarrdhii	-	+	-	-
Oscillatoria ambhibia	-	-	+	-
Oscillatoria amoena	-	-	-	+
Oscillatoria animalis	-	+	-	-
Oscillatoria annae	+	-	+	+
Oscillatoria calcuttensis	-	+	-	-
Oscillatoria chalybea	-	-	+	-
Oscillatoria chlorine	-	+	+	-
Oscillatoria decolorata	+	-	-	-
Oscillatoria foreaui	-	-	-	+
Oscillatoria formosa	+	-	-	-
Oscillatoria irrigua	+	-	+	-
Oscillatoria jasorvensis	+	-	-	+
Oscillatoria laete-virens	-	+	+	-
Oscillatoria limosa	+	-	-	-
Oscillatoria mougeotii	+	-	-	-
Oscillatoria nigra	+	-	-	-
Oscillatoria obscura	+	+	+	+
Oscillatoria okeni	+	+	-	-
Oscillatoria ornate	-	-	-	+
Oscillatoria perornata	-	-	+	+
Oscillatoria proteus	+	-	-	-
Oscillatoria sabuliformis	-	-	+	-
Oscillatoria sp.	+	-	-	-
Oscillatoria subbrevis	+	+	+	-
Oscillatoria sutilissima	-	-	+	-
Oscillatoria terebriformis	+	+	-	-

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Oscillatoriya geitleriana	+	-	-	-
Phormidium abronema	+	-	+	+
Phormidium africanum	-	-	+	-
Phormidium ambiguum	-	-	+	-
Phormidium angastissimum	+	+	+	+
Phormidium cebennense	+	+	-	-
Phormidium ceylanicum	-	-	+	-
Phormidium foveolarum	+	+	+	+
Phormidium fragile	+	+	-	-
Phormidium hansgirgi	-	-	+	-
Phormidium jadinianum	-	-	+	+
Phormidium jenkedianum	-	-	+	-
Phormidium molle	+	-	+	-
Phormidium tenue	-	+	-	+
Phormidium subincrustatum	-	-	+	-
Phormidium trunicicda	-	-	+	-
Phormidium sp.	+	+	-	+
Phormidium tunicoll	-	-	+	-
Phormidium usterii	-	-	+	+
Phromidium rotheanum	-	-	+	-
Lynbya birgei	-	-	+	-
Lynbya hieronmusii	-	-	+	-
Lyngbya achracea	-	-	+	-
Lyngbya allorgei	+	-	+	-
Lyngbya birgei	-	-	+	-
Lyngbya borgerti	+	+	+	-
Lyngbya calcifera	-	-	-	+
Lyngbya ceylanica	+	+	+	-
Lyngbya cryptovaginata	-	-	+	+
Lyngbya gracilis	+	-	+	-
Lyngbya hieronymusii	-	+	+	+
Lyngbya kashyapii	+	-	-	+
Lyngbya kuetzingiana	+	-	-	-
Lyngbya limnetica	+	-	-	-
Lyngbya lutea	+	-	-	-

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Lyngbya martensiana	+	-	+	-
Lyngbya mucicola	+	-	-	-
Lyngbya palmarum	+	-	-	-
Lyngbya scotti	+	-	-	-
Lyngbya shackletoni	-	-	+	-
lyngbya spiralis	-	+	-	-
Lyngbya sp.	+	-	-	-
Schizothrix lardaceae	-	-	+	-
Schizothrix sp.	-	+	-	+
Schozothrix tenuis	-	-	-	+
Symloca muscorum	-	-	+	-
Symploca laete-viridis	-	-	-	+
Symploca muralisV.minor	-	-	+	-
Microcoleus acutissimus	-	+	+	+
Microcoleus lacustris	+	-	-	-
Microcoleus paludosus	+	+	+	+
Microcoleus sociatus	+	-	+	+
Microcoleus sp.	+	+	+	+
Microcoleus subtorulosus	-	-	+	+
Microcoleus vaginatus	-	-	+	-
Hydrocoleum lyngbyaceum	-	-	+	-
Total	**42**	**23**	**47**	**27**
Microchaetaceae				
Microchaete calothricoides	-	-	+	-
Microchaete tenera	-	-	+	-
Microchaete uberrima	-	-	+	-
Total	**0**	**0**	**3**	**0**
Nostocaceae				
Anabaena khannae	+	-	-	-
Anabaena orientalis	+	-	-	-
Anabaena sp.	+	+	-	+
Anabaena variabilis	+	-	-	-
Anabena anomala	+	-	+	-
Nostoc calcicola	+	-	-	-
Nostoc commune	-	-	+	-

Nostoc endophytum	+	-	-	+
Nostoc sp.	+	+	-	-
Nostoc Var. violacea	-	+	-	-
Aulosira aenigmatica	-	-	+	-
Aulosira fritschii	-	-	+	-
Total	**7**	**3**	**4**	**2**
Scytonemataceae				
Plectonema gracillimum	+	-	-	-
Plectonema hansgirgi	+	-	-	-
Plectonema nostocorum.	+	-	-	-
Plectonema radiosum	-	-	+	-
Plectonema terebranes	-	-	+	-
Plectonema tomasinianum	+	-	+	-
Plectonema Var.gracile	+	-	-	-
Scytonema iyengari	+	-	-	-
Scytonema bohneri	+	+	-	-
Scytonema burmanicum	+	-	-	-
Scytonema coactile	+	-	+	-
Scytonema dilatatum	+	-	-	-
Scytonema fremyii	+	-	-	-
Scytonema geitleri	+	-	-	-
Scytonema hofmanni	+	+	-	-
Scytonema javanicum	+	+	+	+
Scytonema malaviyaensis	+	-	-	-
Scytonema ocellatum	+	-	-	-
Scytonema pascheri	-	+	-	-
Scytonema pseudohofmanni	+	-	-	-
Scytonema pseudopunctatum	+	-	+	-
Scytonema schmidtii	+	+	+	-
Scytonema sp.	+	+	-	-
Scytonema stuposum	+	-	-	-
Scytonema Var.minus	+	-	-	-
Scytonema varium	+	+	-	-
Tolyporthrix campylonemoides	+	+	-	-
Tolypothrix bouteillei	-	+	-	-

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Tolypothrix byssoidea	+	+	+	-
Tolypothrix distorta	-	+	-	-
Tolypothrix fragilis	-	+	-	-
Tolypothrix rechingeri	-	+	-	-
Total	**25**	**13**	**8**	**1**
Stigonemataceae				
Hapalosiphon delicatulus	-	-	-	+
Hapalosiphon welwitschii	-	+	-	+
Haplosiphon fjagelliformis	-	-	+	-
Stigonema minutum	-	-	-	+
Total	**0**	**1**	**1**	**3**
Overall Total	**156**	**93**	**141**	**67**

+ presence; - absence;

Table 4b: Overall frequency of cyanobacterial species based on their family

S.No	Family Name	Frequency	Percentage (%)
1	Chroococcaceae	21	9
2	Oscillatoriaceae	139	60
3	Microchaetaceae	3	1
4	Nostocaceae	16	7
5	Scytonemataceae	47	21
6	Stigonemataceae	5	2

The dominant vegetation types identified in the present study at Ariyalur and Pudukottai sacred groves regions, were Albizia, Atalandia, Benkara, Bleppharia, Carmona, Chloris, Cissus, Clausena, Euphorbia, Evolvulus, Gyrocarpus, Jatropha, Pavonia, Perotis, Prosopis, Sida and Wrightia (Table 5). A total of 237 plant species belonging to 63 families were recorded together from the sacred groves of Ariyalur and Pudukottai. Members of Legumiosae were the dominant group comprising 27 sp. belonging to 17 genera followed by Poaceae with 20 sp. and 15 genera. A maximum of 163 plant sp. were recorded in Pudukottai district which included 53 sp.in Iyanarkovil sacred groves forest. 49 sp. in Karuppusamy kovil, 38 sp. in Kulathur Iyanar kovil, 59 sp. in Sankili karupukovil and 57 sp. in Adikkalam katha iyanar.

Table 5: Checklist of vegetation in sacred groves forest of Ariyalur and Pudukottai district

S.No	Names of plant species	Ariyalur	Pudukottai
	Leguminosae		
1.	*Acacia ferruginea* DC.		+
2.	*Acacia leucophloea* (Roxb.) Willd.		+
3.	*Acacia nilotica* (L.) Delile	+	
4.	*Albizia amara* (Roxb.) B.Boivin	+	+
5.	*Albizialebbeck* (L.) Benth.	+	
6.	*Aloe vera*	+	
7.	*Alysicarpusmonilifer* (L.) DC.	+	
8.	*Cassia auriculata* L.	+	+
9.	*Cassia fistula* L.	+	
10.	*Cassia sp.*	+	
11.	*Derris scandens* (Roxb.)Benth.		+
12.	*Desmodiumtriflorum* (L.) DC	+	
13.	*Galactiatenuiflora* (Willd.) Wight & Arn.	+	
14.	*Indigofera aspalathoides* DC.		+
15.	*Indigofera linnaei* Ali.	+	
16.	*Indigofera sp.*	+	
17.	*Leucaena leucocephala* (Lam.) de Wit.	+	
18.	*Leucas aspera* (Willd.) Link	+	+
19.	*Leucasbiflora* (Vahl) Sm.	+	
20.	*Pongamiapinnata* (L.)	+	
21.	*Prosopis juliflora* (Sw) dc.	+	+
22.	*Prosopiscineraria* (L.) Druce.	+	
23.	*Pterolobium hexapetalum* (Roth)Santapau & Wagh.	+	+
24.	*Sennaauriculata* (L.) Roxb.		+
25.	*Tamarindus indica* L.	+	+
26.	*Tephrosiapurpurea* (L.) Pers.	+	+
27.	*Vachellianilotica* (L.) P.J.H. Hurter & Mabb.	+	
	Rhamnaceae		

28.	*Scutiamyrtina* (Burm.f.) Kurz.	+	
29.	*Ziziphus oenoplia* (L.) Miller.	+	+
30.	Ziziphus sp.		+
31.	*Ziziphuscotinifolia* Reissek.	+	+
	Apocynaceae		
32.	*Caralluma sp.*	+	
33.	*Caralluma umbellata* Haw.		+
34.	*Carissa carandas* Lour.	+	
35.	*Carissa sp*.	+	+
36.	*Catharanthus roseus* (L.) G. Don.	+	+
37.	*Gymnemasylvestre* (Retz.) R.Br. ex Sm.	+	
38.	*Hemidesmus indicus* (L.) R. Br.	+	+
39.	*Sarcostemma intermedium* Decne.		+
40.	*Wrightiatinctoria* R.Br.		+
	Malvaceae		
41.	*Abutilon indicum* L.	+	
42.	*Corchorus sp.*	+	
43.	*Grewia rhamnifolia* Heyne ex Roth.		+
44.	*Grewia sp.*		+
45.	*Hibiscus micranthus* L. f.	+	
46.	*Pterospermumacerifolium* (L.) Willd.		+
47.	*Sida acuta Burm* f.	+	+
48.	*Sida carpinifolia* L.f.		+
49.	*Sida rhombifolia* L.	+	
50.	*Sida schimperiana* Hochst. ex A. Rich.		+
51.	*Sidacordata* (Burm.f.) Borss.Waalk.	+	+
52.	*Waltheria indica* L.		+
	Euphorbiaceae		
53.	*Acalypha indica* L.	+	+
54.	*Croton bonplandianum* Baill.	+	+
55.	*Euphorbia antiquorum* L.	+	+
56.	*Euphorbia hirta*	+	

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2017 Sept-Oct RJLBPCS 3(3) Page No.228

57.	*Euphorbia sp.*	+	
58.	*Euphorbia tortilis* Rottler ex Ainslie.		+
59.	*Jatropha glandulifera* Roxb.	+	
60.	*Jatropha gossypifolia*. L.	+	+
	Amaranthaceae		
61.	*Achyranthes aspera* L.	+	+
62.	*Aerva lanata* (L.) Juss.	+	+
63.	*Allmania nodiflora* (L.) R. Br. ex Wight.		+
64.	*Alternantherasessilis* (L.) R.Br. ex DC.		+
65.	*Celosia sp.*		+
66.	*Celosiapolygonoides* Retz.	+	
67.	*Gomphrena globosa* L.		+
68.	*Gomphrenadecumbens* Jacq.	+	
	Passifloraceae		
69.	*Adenia wightiana* (Wall. ex Wight&Arn.) Engl.		+
70.	*Passiflora foetida* L.	+	
	Acanthaceae		
71.	*Adhatoda vasica* L.	+	
72.	*Andrographispaniculata* (Burm.f.) Nees	+	
73.	*Asystasiagangetica* (L.) T.Anderson	+	
74.	*Barleria cristata* L.		+
75.	*Barleria prionitis* L.	+	
76.	*Barleria sp.*	+	
77.	*Barlerianoctiflora* L.f.	+	
78.	*Barleria obtuse* Nees.		+
79.	*Blepharis maderaspatensis* (L.) B.Heyne ex Roth.	+	+
80.	*Blepharismolluginifolia* Pers.	+	
81.	*Dipteracanthus prostratus* (Poir.) Nees	+	+
82.	*Ecbolium viride* (Forssk.) Alston.	+	
83.	*Elytraria acaulis* (L.f) Lindau.	+	
84.	*Justicia glauca* Rottl.		+
85.	*Justicia prostrata* (Roxb. ex C. B. Cl.) Gamble.	+	+

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2017 Sept-Oct RJLBPCS 3(3) Page No.229

86.	*Justicia tranquebariensis* L.f.	+	
87.	*Peristrophebicalyculata* (Retz.) Nees	+	
	Asparagaceae		
88.	*Agave americana* L.	+	
89.	*Asparagus racemosus* Willd.	+	+
90.	*Sansevieriaroxburghiana* Schult & Schult.f.	+	+
91.	*Scilla hyacinthine* (Roth) J.F.Macbr.		+
	Cornaceae		
92.	*Alangium salviifolium* (L. f.) Wangerin	+	+
93.	*Alangium sp.*	+	
	Xanthorrhoeaceae		
94.	*Aloevera* (L.) Burm.f.	+	
	Lythraceae		
95.	*Ammanniabaccifera* L.	+	
	Poaceae		
96.	*Aristidafuniculate* Trin. & Rupr.	+	+
97.	*Aristidasetacea* Retz.	+	+
98.	*Brachiaria sp.*	+	
99.	*Chloris barbata* Sw.	+	+
100.	*Chrysopogon fulvus* (Spreng.) Chiov.	+	+
101.	*Cymbopogon flexuosus* (Nees ex Steud.) W.Watson.		+
102.	*Cynodon dactylon* (L.) Pers.	+	
103.	*Dactyloctenium sp*.	+	
104.	*Dactyloctenium aegyptium* (L.) Willd.	+	
105.	*Dactyloctenium scindicum* Boiss.	+	
106.	*Dichanthium sp.*	+	
107.	*Dichanthium annulatum* (Forssk.) Stapf.	+	+
108.	*Digitaria longiflora* (Retz.) Pers.	+	
109.	*Eragrostiella brachyphylla* (Stapf) Bor.		+
110.	*Eragrostis viscosa* (Retz.) Trin.	+	+
111.	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.		+

112.	*Iseilema sp.*	+	
113.	*Perotis indica* (L.) Kuntze.	+	+
114.	*Setaria verticillata* (L.) P.Beauv.	+	
115.	*Tragus roxburghii* Panigrahi.	+	
	Rutaceae		
116.	*Atalantia monophylla* DC.	+	+
117.	*Chloroxylon swietenia* DC.		+
118.	*Chloroxylon sp.*	+	
119.	*Clausena dentata* (Willd.) M. Roem.	+	+
120.	*Clausena sp.*	+	
121.	*Limonia acidissima* Groff.	+	
122.	*Pleiospermium alatum* (Wight &Arn.) Swingle.	+	+
	Meliaceae		
123.	*Azadirachta indica* A. Juss.	+	+
	Salvadoraceae		
124.	*Azima tetracantha* Lam.	+	
125.	*Salvadora persica* L.	+	
	Zygophyllaceae		
126.	*Balanites roxburghii* Planch.	+	
127.	*Balanites sp.*	+	
128.	*Tribulus terrestris* L.	+	+
	Rubiaceae		
129.	*Benkara malabarica* (Lam.)Tirveng.		+
130.	*Canthium parviflorum* Lam.		+
131.	*Coffea wightiana* Wall. ex Wight & Arn.	+	
132.	*Ixora pavetta* Andr.		+
133.	*Mitracarpus hirtus* (L.) DC.		+
134.	*Morinda coreia* Buch, Ham.	+	
135.	*Oldenlandia herbacea* (L.) Roxb.		+
136.	*Oldenlandia umbellata* L.		+
137.	*Oldenlandia corymbosa* Aiton.	+	
138.	*Tarenna asiatica* (L.) Kuntze ex K.Schum.	+	+

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Oxalidaceae			
139.	*Biophytum sensitivum* (L.) DC.	+	
Compositae			
140.	*Blumea sp.*	+	
141.	*Blumea obliqua* (L.) Druce.	+	
142.	*Chromolaena odorata* (L.) R.M.King & H.Rob.		+
143.	*Parthenium hysterophorus* L.	+	
144.	*Parthenium sp.*		+
145.	*Tridax procumbens* (L.) L.	+	
146.	*Vernonia cinerea* (L.) Less.	+	+
147.	*Vicoa indica* (L.) DC.	+	+
Nyctaginaceae			
148.	*Boerhavia diffusa* L.	+	
Arecaceae			
149.	*Borassus flabellifer* L.		+
150.	*Phoenix sp.*	+	
151.	*Phoenix pusilla* Lour.		+
152.	*Phoenix sylvestris* (L.) Roxb.	+	
Capparaceae			
153.	*Cadaba fruticosa* (L.) Druce.	+	+
154.	*Capparis divaricata* Lam.	+	+
155.	*Capparis sp.*	+	+
156.	*Maerua oblongifolia* (Forssk.) A.Rich.		+
Cannabaceae			
157.	*Cannabis indica* Lam.		+
Sapindaceae			
158.	*Cardiospermum halicacabum L.*	+	
159.	*Dodonaea viscosa* (L.) Jacq.		+
Boraginaceae			
160.	*Carmona retusa* (Vahl) Masam.	+	+
161.	*Cordia monoica* Roxb.		+
162.	*Ehretia sp.*	+	

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163.	*Heliotropium zeylanicum* (Burm. f.) Lam.		+
	Violaceae		
164.	*Holoptelea integrifolia* Planch.		+
165.	*Hybanthus enneaspermus* (L.) F.Muell.	+	+
	Celastraceae		
166.	*Cassine glauca* (Rottb.) Kuntze.	+	+
	Lauraceae		
167.	*Cassytha filiformis* Mill.	+	+
	Vitaceae		
168.	*Cayratia trifolia* (L.) Domin.		+
169.	*Cissus quadrangularis* L.	+	+
	Cactaceae		
170.	*Cereus pterogonus* Lem.		+
171.	*Opuntia dillenii* (Ker Gawl.) Haw.	+	+
172.	*Opuntia sp*.		+
173.	*Opuntia robusta* J.C. Wendl.		+
	Rutaceae		
174.	*Atalantia monophylla* DC.	+	+
175.	*Chloroxylon swietenia* DC.		+
176.	*Chloroxylon sp*.	+	
177.	*Clausena dentata* (Willd.) M. Roem.	+	+
178.	*Clausena sp*.	+	
179.	*Limonia acidissima* Groff.	+	
180.	*Pleiospermium alatum* (Wight &Arn.) Swingle.	+	+
	Phyllanthaceae		
181.	*Cleistanthus collinus* (Roxb.) Benth. ex Hook.f.	+	+
	Cleomaceae		
182.	*Cleome viscosa* L.		+
	Cucurbitaceae		
183.	*Coccinia grandis* (L.) Voigt.	+	+
	Menispermaceae		
184.	*Cocculus hirsutus* (L.) W.Theob.	+	+

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185.	*Menispermum sp.*	+	
	Commelinaceae		
186.	*Commelina erecta* L.		+
187.	*Commelina benghalensis* L.	+	+
	Burseraceae		
188.	*Commiphora berryi* (Arn.) Engl.		+
189.	*Commiphora caudata* (Wight &Arn.) Engl.		+
	Hypoxidaceae		
190.	*Curculigo orchioides* Gaertn.		+
	Convolvulaceae		
191.	*Cuscuta europaea* L.	+	
192.	*Cuscuta sp.*	+	
193.	*Evolvulus alsinoides* (L.) L.	+	+
194.	*Merremia tridentata* (L.) Hallier f.	+	
	Cyperaceae		
195.	*Cyperus sp.*	+	
196.	*Fimbristylis miliacea* (L.) Vahl	+	
	Solanaceae		
197.	*Datura inoxia* Mill.	+	
198.	*Solanum melongena* L.	+	
199.	*Solanum trilobatum* L.	+	
200.	*Solanum xanthocarpum* Schrad. & H. Wendl.	+	
	Loranthaceae		
201.	*Dendrophthoe falcata* (L.f.) Ettingsh.	+	+
	Dioscoreaceae		
202.	*Dioscorea oppositifolia* L.		+
	Ebenaceae		
203.	*Diospyros ebenum*.J.Koenig ex Retz.	+	+
204.	*Diospyros sp.*	+	
205.	*Diospyros ovalifolia* Wight.		+
	Putranjivaceae		
206.	*Drypetes sepiaria* (Wight &Arn.) Pax&K.Hoffm.		+

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Orchidaceae			
207.	*Eulophia epidendraea* (J.Koenig ex Retz.) C.E.C.Fisch.		+
Moraceae			
208.	*Ficus sp.*		+
209.	*Ficus benghalensis* L.		+
210.	*Ficus macrophylla* Desf. ex Pers.		+
211.	*Streblus asper* Lour.	+	
Colchicaceae			
212.	*Gloriosa superba* L.		+
Lamiaceae			
213.	*Gmelina asiatica* L.	+	
214.	*Ocimum Sanctum* L.	+	
215.	*Ocimum canum* Sims.	+	+
216.	*Orthosiphon thymiflorus* (Roth) Sleesen.	+	
Hernandiaceae			
217.	*Gyrocarpus americanus* Jacq.		+
Oleaceae			
218.	*Jasminum angustifolium* (L.) Willd.	+	
219.	*Jasminum sambac* (L.) Aiton.	+	
220.	*Jasminum sp.*	+	+
Anacardiaceae			
221.	*Lannea coromandelica* (Houtt.) Merr.	+	+
Verbenaceae			
222.	*Lantana camara* L.	+	
223.	*Lantana wightiana* Wall. ex Gamble.	+	
Sapotaceae			
224.	*Manilkara hexandra* (Roxb.) Dubard.	+	+
Melastomataceae			
225.	*Memecylon umbellatum* Burm. f.		+
Molluginaceae			
226.	*Mollugo oppositifolia* L.	+	

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227.	*Mollugo nudicaulis* Lam.		+
228.	*Mollugo pentaphylla* L.		+
Amaryllidaceae			
229.	*Pancratium sp.*		+
230.	*Pancratium triflorum* Roxb.		+
Plumbaginaceae			
231.	*Plumbago zeylanica* L.	+	
Caryophyllaceae			
232.	*Polycarpaea corymbosa* (L.) Lam.		+
Portulacaceae			
233.	*Portulaca quadrifida* L.	+	
Spermacoceae			
234.	*Spermacoce hispida* L.		+
Loganiaceae			
235.	*Strychnine sp.*		+
236.	*Strychnos nux-vomica* L.		+
237.	*Strychnos potatorum* L. fil.		+

The vegetations diversity in Ariyalur and Pudukottai districts was calculated through Shannon indices and Pielou's evenness values (Table 6). Ariyalur district showed high number of vegetation species (156 and 93 sp. in summer and monsoon seasons) than pudukottai district (141 and 67 sp.) (Figure 4). The sacred groves of Pudukottai showed increased species diversity (0.975) and Pielou's evenness values (0.894) (Figures 5 and 6). Cyanobacterial species support the soil fertility and the growth of plants. They constitute the most important member of the BSCs. Their diversity varies depending on the season, chemical and physical properties of the soil. In the case of sacred groves, the ecological change in the area is accompanied by monsoon. In the present work, both heterocystous and non heterocystous

Table 6. Calculated diversity indices of vegetation in the sacred groves forest of Ariyalur and Pudukottai districts.

Parameters	Ariyalur		Pudukottai	
	Summer	Monsoon	Summer	Monsoon
No. of species	156	93	141	67
Shannon index	0.968	0.971	0.975	0.961
Pielou's evenness	0.870	0.869	0.871	0.894

Figure 3. Overall frequency of cyanobacterial species based on their family

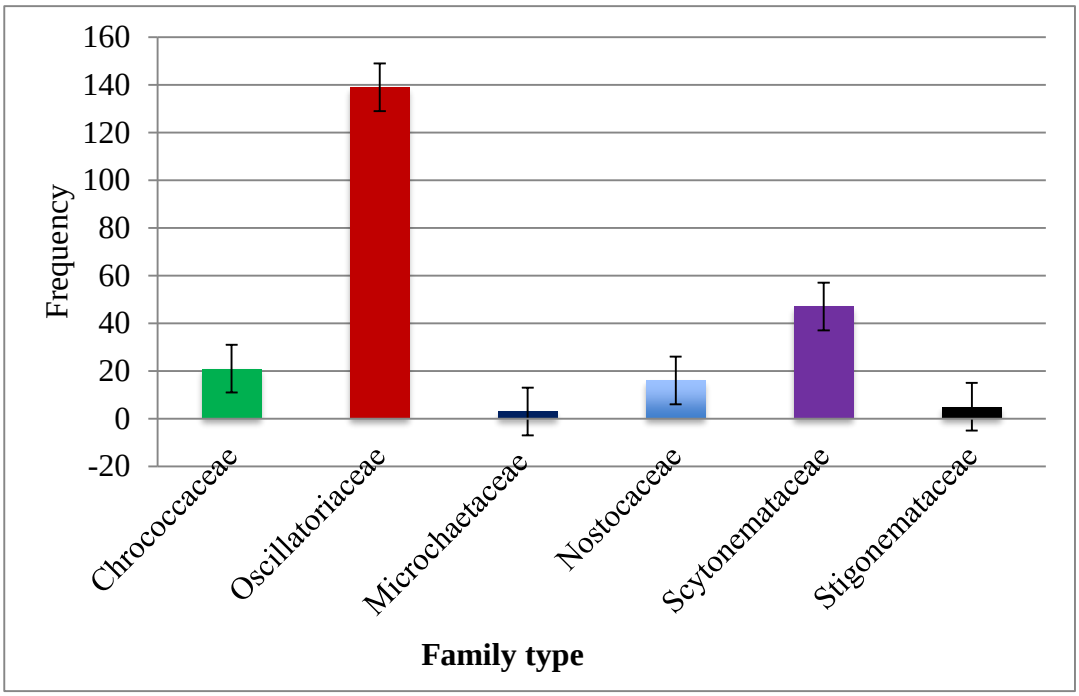


Figure 4. Number of vegetations found in the sacred groves forest of Ariyalur and Pudukottai districts.

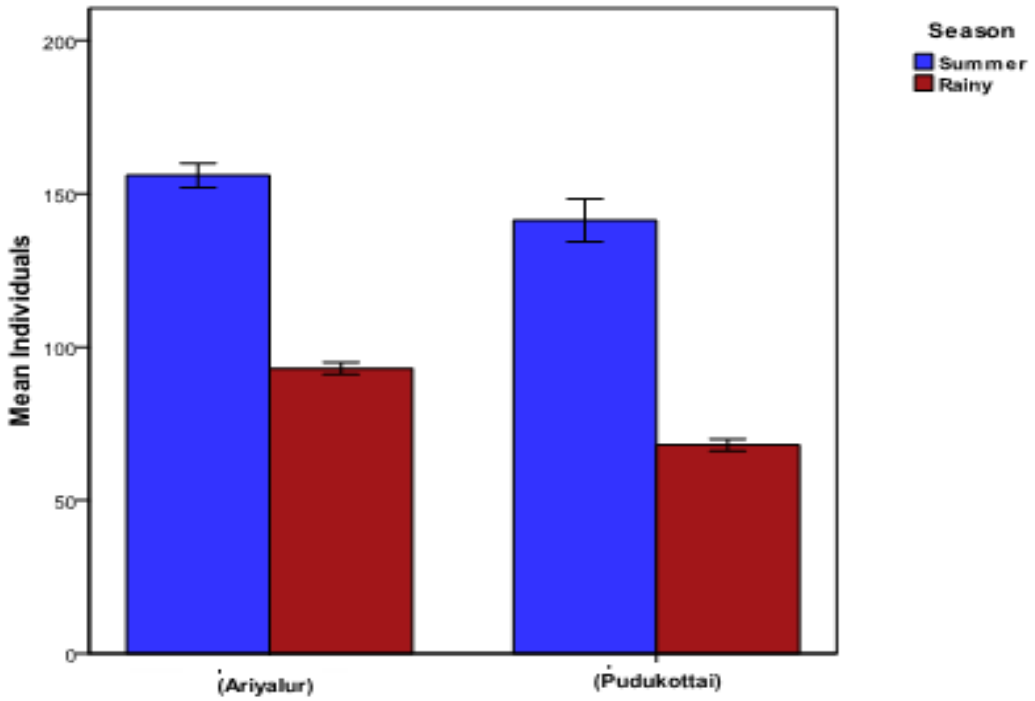


Figure 5: Shannon-indices of cyanobacterial species of BSCs of sacred groves forest of Ariyalur and Pudukottai districts during summer and monsoon seasons

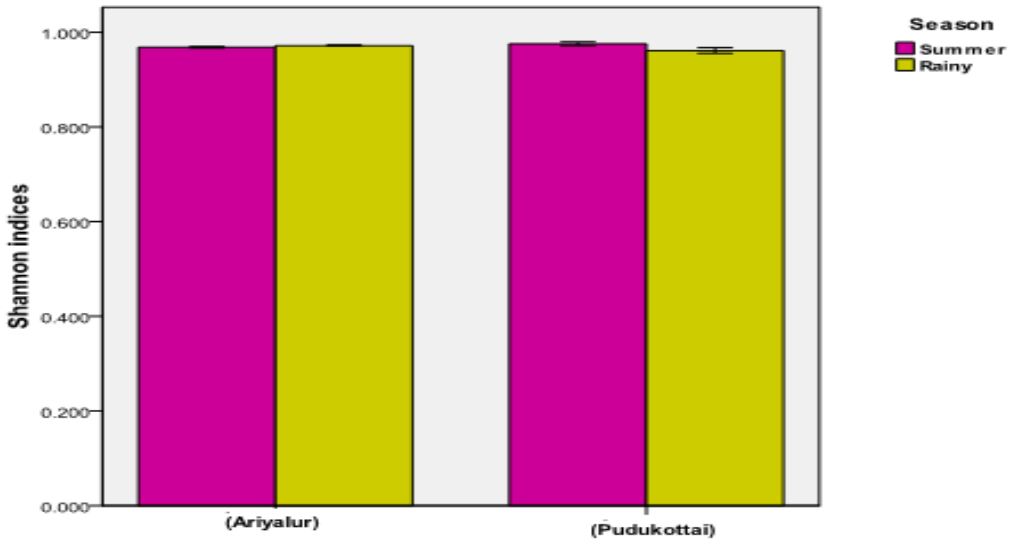
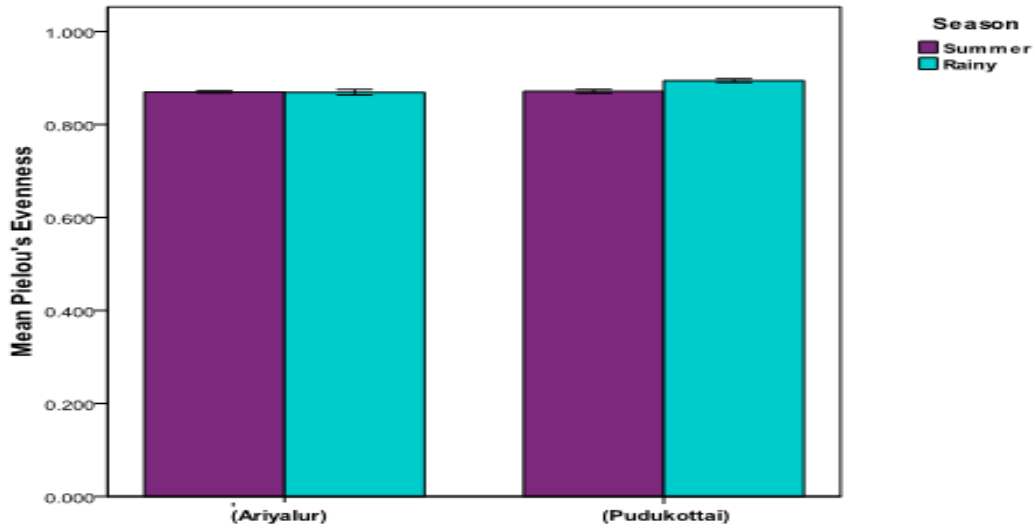


Figure 6: Pielou's evenness of cyanobacterial species of BSCs of sacred grove forest of Ariyalur and Pudukottai districts during summer and monsoon seasons



Cyanobacterial species were found high number that accounted for the improvement of nitrogen content in the soil of sacred groves forest of Ariyalur and Pudukottai districts. The soil nitrogen content favoured the growth of the plants by positive correlation between the cyanobacterial species and the plant species. In our results, diversified plant species (146) were observed in the Ariyalur and Pudukottai sacred groves. In India, *Chroococcus*, *Oscillatoria, Phormidium, Nostoc*, *Anabaena*, *Calothrix*, *Scytonema* occur as soil-crust cyanobacteria at Thar Desert (Bhatanagar and Bhatanagar, 2005). *Oscillatoria*, *Phormidium*, *Lyngbya*, *Microcoleus*, *Plectonema*, *Cylindrospermum*, *Nostoc*, *Tolypothrix*, *Calothrix*, *Aulosira*, *Hapalosiphon*, *Frischerella*, *Stigonema*, *Westiellopsis* are isolated from Bhubaneswar, Salboni, Ranigaunj, Tiruchirapally and Goa (Tirkey and Adhikary, 2006).

Gloeocapsa, *Aphanocapsa*, *Oscillatoria*, *Phormidium*, *Calothrix*, *Anabaena*, *Nostoc*, *Cylindrospermum*, *Scytonema*, *Frischerella*, *Westiellopsis* occur as soil-crust cyanobacteria at cemented building facades, tree trunks, soil surface of barren land (Sethi *et al.*, 2012).

Cyanobacterial population taxa are studied at ten different study sites, and they are belongs to Chroococcaceae, Pluerocapsaceae, Oscillatoriaceae, Notocaceae, Rivulariaceae, and Scytonemataceae and Stigonemataceae families. The observation shows the maximum dominance of *Oscillatoriaceace* and *Nostocaceae* family over the other families of Blue green algae at all study sites, where as the family Stigonemataceae shows least occurrence (Ghadai *et al.*, 2010). *Microcoleus* and *Chroococcidiosis*species found dominated in the BSC community (Potts, 1994). *Scytonema* often found to be a dominant genus in BSC's (Billi *et al.*, 2000). Microchaete taxa are known from summer season in pudukottai sacred groves. Heterocyst forming cyanobacteria found in summer season in both sacred groves. The findings here also proved that most cyanobacteria members especially (filamentous form) Oscillatoriaceae and some taxa of Nostocaceae could grow well in both site of BSC. They could adapt to harsh environmental conditions by developing different strategies to survive, mainly by producing high carotenoids in Trentepohliales and forming a sheath composed of extracellular polymeric substances (EPS) outside in cyanobacterial cells as a protection against desiccation (Urzi and Realini, 1998; Tomaselli, 2003). N, K, P compositions in soil were the main factors which determine the diversity and dominance of cynobacteria and also responsible for the plant diversity. So the finding proved each of the sacred groves maintained physical and chemical parameter which facilitates the growth of both cyanobacterial and floral species. The species cyanobacteria from different sacred groves formed a very different group from the crust forming species reported from India. The biological soil crusts within the sacred groves are unique species assemblages of different group of cynobacteria (154) with strong base of species found in other part of places.

4. CONCLUSION

The results of the present study showed that mat form of biological soil crust had more number of cyanobaceria such as unicellular, heterocystous and non heterocystous forms. Their population varied between two seasons due to the soil physico-chemical properties. The species diversity was high in summer season in both Ariyalur and Pudukottai while species richness was high in monsoon season. These results proved that ecosystem rich with biological soil crusts showed enhanced population of cyanobacterial species which in return increased the growth of floral species in their places.

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