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Survey, distribution pattern and elemental composition of lichens in Yercaud hills of Eastern Ghats in southern India

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Abstract

Due to climate change, occurrence of both higher and lower plants in forest areas is deteriorated considerably. Keeping this in view, a survey was undertaken to study the distribution of lichen communities in Yercaud hills belonging to Eastern Ghats, Tamil Nadu, India. The results indicated that distribution of lichens was registered from 700 m above msl in silver oak trees and the same was noted from 900 m above msl in rock surface. Distribution of lichen colonies was abundant, while temperature was low along with sunshine and RH was high along with rainfall pattern. Sunshine was negatively correlated with lichen distribution, but rainfall was positively correlated. These biologically important hills exhibited a total of 61 different lichen species covering 13 families with 33 genera in the survey. In addition, about 22 new species of lichens were recorded in the lichen database of Yercaud hills. The results revealed that lichens grew well in the pH range of 4.3 - 5.5 in silver oak tree barks and 4.5 - 6.0 in rocks, which coincided with the buffering action of bark and rock. There was a direct relationship between the moisture content of tree barks and rocks and lichen adherence. Estimation of various micro and macro elements including ash contents were found to be more in fruticose than in foliose lichen and lest in crustose lichens. The study revealed that there was a drastic reduction in lichen density due to low tree bark moisture content and pH values owing to change in environmental parameters at Yercaud hills.

Key words

Eastern Ghats, Environment, Lichen, Survey of lichens, Yercaud hills

Introduction

Lichens are biological indicators of air pollution in which various lichen species have different degree of sensitivity to air pollution. The population of lichens has declined now-a-days due to the environmental disturbances like industrial and automobile smokes and exhausts and environmental factors like high sunshine with least temperature and low rainfall with least relative humidity (Stevens *et al*., 2012) . Lichens are highly sensitive in nature among the plant kingdom, and only found abundantly in pollution free atmosphere (Kekuda *et al*., 2011). They are widely used in biomonitoring and bioaccumulators studies to assess air quality and the rate of atmospheric deposition in terms of heavy metals and trace elements (Sczepaniak and Biziuk, 2003). Lichen population is severely affected due to global warming effects even at high altitude areas (Ponmurugan *et al*. 1999).

It has been reported by several authors that lichens have been deteriorated significantly in town and industrial complexes including forest areas all over the world due to environmental degradation (Nayaka *et al*., 2013a). Some of the lichen groups are being endangered every year even in greenish deciduous forests due to complex mixture of air pollutants and high sunshine with least rainfall pattern (Ponmurugan *et al*. 2002).

Lichens grow under diverse ecological conditions; they occur from arctic habitats to tropical rainforests where they colonize broad variety of substrates such as rock, bark, soil and even leaf / bark surfaces (Negi and Upreti, 2000). Lichen metabolites exert a wide variety of biological actions including antibiotic, antimycobacterial, antiviral, anti-inflammatory, antioxidant, analgesic, antipyretic, antiproliferative and cytotoxic effects, besides lichens are also having anti-snake venom activity (Tanas *et al*., 2010; Shrestha *et al*., 2015). Even though these manifold activities of lichen metabolites have now been recognized, their therapeutic potential has not yet been fully explored due to many reasons including lack of sufficient quantity of lichen materials available (Muller, 2001). Moreover, it is not possible to collect more quantity of lichen samples from the forests due to biodiversity conservation. It has been reported that photosynthetic pigments are degraded in thallus due to impact of toxic airframe pollutants (Ayyappadasan and Ponmurugan, 2012). Lichens in urban and industrial areas have shown many injury patterns like loss of chlorophyll and carotenoid pigments due to pollutants such as heavy metals, sulphur dioxide and other particulate matter (Yildiz *et al*. 2011).

Yercaud hills are biologically important hills situated at 1,500 m a msl in Tamil Nadu, India. These hills have many faunal and floral similarities to the Western Ghats of southern India (Pandey, 2004). The diversity of higher plant flora and fauna in Yercaud has been studied in great detail by Kadavul and Parthasarathy (1999). Lichen flora is dominated by crustose lichens followed by foliose and fruticose lichens represented by 22 *taxa*. Most of the lichens in the region are bark inhabiting, but many also occur on rock and soil (Nayaka *et al*., 2013b). In addition, attempts have been made to define the current baseline concentrations in detecting local environmental changes and assessing increased human impact in Yercaud hills of southern India by studying the delivery of lichens (Jeyaprakash *et al*., 2015). Considering the seriousness and economic importance, a survey was taken up to find out the present status of lichen distribution in Yercaud hills of Eastern Ghats in southern India, despite the serious issues of global warming and climate change. The study also aimed at estimating the air quality of Yercaud hills with respect to distribution of lichens.

Materials and Methods

Study area : Survey of lichen distribution at different altitudes covering various agroclimatic zones of Yercaud (Shevroy hills) located in Eastern Ghats of Tamil Nadu, India was conducted. The study was conducted for a period of four years from 2010 to 2013. Different living and non-living substrata were collected along with lichen thalli to study the nature of attachment and to check the moisture content, pH and buffering action. During survey, attachment of lichens upon silver oak trees and rocks were counted uniformly. Fruticose and foliose lichens were peeled-off along with tree barks, but in case of crustose lichens small pieces of rock substrate were collected carefully. The voucher specimen of identified lichen samples were deposited at National Botanical Research Institute Herbarium Centre, Lucknow, India and K.S.R. College of Technology Herbarium Collection Centre, Tiruchengode, India for future authentication and research purposes.

Measurement of pH, buffering action and bark moisture content : Lichens growing on the barks of silver oak trees and rocks collected were air-dried and subsequently powdered. Bark and rock samples were dissolved in distilled water in ratio 1:2 to measure pH using a pH meter equipped with a combined pH electrode (Elico - LI120). Same solutions were mixed with 0.1M Tris buffer and measured the buffering action following the method of Kim and Uchida (1991) with slight modifications. The samples were titrated against 0.01N NaOH until pH increased to 7.0. Bark moisture content of silver oak tree was estimated following the method of Bier (1959). Five mm disc of barks were removed from the plants with the help of a sharp cork borer and recorded the fresh weight. The discs were soaked in distilled water till tissues attained constant weights. Bark tissue saturated with water was weighted and subsequently bark moisture content was calculated by taking the final fresh and dry weight, which was multiplied by 100.

Identification of lichen specimens : Lichen identification was carried out by following the standard procedures from genus to species level according to the method of Awasthi (2000). Lichen morphology, anatomy, lichen acid existence, growth forms, powdery appearance on the thallus and nature of fruiting bodies were critically analyzed to identify the lichen communities. Moreover, colour spot tests were performed using 10% aqueous solution of potassium hydroxide and a mixture of potassium hydroxide and calcium hypochlorite (1:2 w/v) by applying on the thallus change in the colour of thallus medulla was recorded.

Estimation of various elements in lichen thalli : For various micro and macroelemental analysis, 1.0 gm of powdered lichen materials was taken in a beaker to which 10 ml of concentrated nitric acid and perchloric acid mixture (1:1) was added. These samples were digested for 24 hr using a hot plate. After digestion, 10 ml of 10% nitric acid was added and left for two hours without any disturbance. The liquid was filtered though Whatman No. 1 filter paper from which clear supernatant was saved after discarding the debris. The filtrate was subjected to estimate various elements using atomic absorption spectrophotometeric (Sarangi *et al*., 2002) and flame photometric (Jackson, 1973) methods. Total chlorophyll and carotenoid (Harborne, 1973), sugars (Dubois *et al*., 1956), nitrogen (AOAC 2012), proteins (Lowry *et al*., 1951), amino acids (Moore and Stein, 1948) and polyphenols (Bray and Thorpe, 1954). The meteorological parameters such as temperature, relative humidity, rainfall and sunshine were recorded periodically with standard equipments. Data obtained were subjected to analysis of variance and linear regression (Gomez and Gomez, 1984).

Results and Discussion

Survey of lichens in Yercaud hills, lichens were found in silver oak trees and rocks at 500 and 700 m a msl distance; respectively. Existence of lichens in silver oak trees and rocks showed the average number of lichens recorded was 4.3 and 2.3; respectively (Table 1). A positive correlation between altitude distance and number of lichens in silver oak trees and rocks was noted. Among the lichen groups, foliose group of lichens were found abundantly followed by crustose and fructicose in both silver oak trees and rocks. The results further indicated that lichens could survive well between 4.3 - 5.5 pH in silver oak trees and 4.5 - 6.0 in rocks. Moreover, a close relationship between pH and buffering reaction of bark and rock samples was observed. Data indicated that buffering action was recorded between 5.0 and 5.5 (Table 1). There was a gradual increase in moisture content of silver oak trees when bark samples were collected from various high altitude areas. However, it remains constant after 1300 m above MSL altitude.

Different lichen groups covering foliose, fruticose and crustose were collected from silver oak trees and rocks and their nature of adherence upon various living (silver oak trees) and non-living substrata (rock) were studied. The influence of abiotic factors like temperature, relative humidity, wind speed, sunshine and rainfall and biotic factors such as pH and moisture content of silver oak tree barks were studied. pH is also one of the essential factors responsible for existence of lichens on substrata. Attachment of lichen thalli upon substrates is purely based on buffering action and pH (Marmor and Randlane, 2007). It is worth mentioning that the buffering action takes place between plant barks and rocks and lichen thalli to balance the equilibrium which in turn is useful for attachment.

A direct correlation between plant tree moisture content and lichen attachment was observed. Least population of lichens on rocks might be due to poor adherence and uneven surface with least moisture content. According to Rahman *et al*. (2011), the population density of living organisms were generally found to be positively correlated with moisture content, organic matter, phosphorus, potassium, nitrogen and pH. Besides, variation in lichen populations was also due to anthropogenic activity of human beings in the forest areas. It affected the photosynthetic pigments such as chlorophyll and carotenoids in the lichen thalli containing cyanobacterial photobionts. A total of four foliose lichens (*Parmotrema*, *Xanthoparmelia*, *Pyxine* and *Rocella* spp.) existing in Eastern Ghats are considered as indicators of healthy forests (Marmor *et al*. 2011). In addition, *Pyrenocarpous, Parmelioid* and *Physcioid* lichens are most common in the area (Nayaka *et al*., 2013). The result of the present study in terms of healthy nature of Eastern Ghats including significant environmental consequences is in confirmation with the previous reports (Balaji *et al*. 2007).

Pearson's correlation coefficient between environmental parameters and lichen population showed that there was significant correlation between environmental parameters such as rainfall, sunshine, wind speed, temperature and relative humidity and number of lichens. There was a profound influence in temperature and relative humidity upon lichen growth which reflects sunshine and rainfall pattern. Among the environmental parameters, rainfall (r=0.85), temperature minimum (r=0.87) and relative humidity maximum (r=0.97) were positively correlated. However, a negative correlation was drawn in the values of maximum temperature (r = -0.73), minimum relative humidity (r = -0.80) regimes and sunshine hrs (r = -0.75), but no correlation was analyzed in wind speed with lichen population.

Table 1 : Existence of lichens in silver oak trees and rocks with respect to distance in Yercaud hills of Eastern Ghats in Tamil Nadu, India*

Altitude of the hills (mamsl)	300	500	700	900	1100	1300	1500	CD at P=0.05
pH of silver oak tree barks	4.3(5.0)	4.5(5.3)	4.7(5.5)	4.7(5.3)	5.0(5.5)	5.5(5.3)	5.5(5.3)	0.03
pH of rocks	4.7(5.3)	4.5(5.3)	4.5(5.5)	4.7(5.3)	6.0(5.5)	5.7(5.3)	5.7(5.0)	0.05
Bark moisture of silver oak trees (%)	55.7	68.0	77.0	82.3	90.5	98.3	98.3	14.5
No. of lichens in silver oak trees	0.0	0.0	4.3	12.3	26.7	45.5	44.7	8.67
No. of lichens in rocks	0.0	0.0	0.0	2.3	11.7	22.7	25.5	4.23

* Mean of four years; Values in the parentheses indicate the buffering reaction of samples

Table 2 : Estimation of micro and macroelements in thallus of different lichen groups

Elements	Lichen groups			CD at P=0.05
	Fruticose	Foliose	Crustose	
Chlorophyll*	2.75	1.53	0.85	0.54
Carotenoids*	1.04	0.85	0.35	0.25
Carbohydrates**	65.03	63.93	64.77	1.07
Proteins**	33.07	30.07	26.67	2.07
Nitrogen**	36.65	35.03	33.33	2.04
Amino acids**	25.55	23.17	20.15	1.74
Lipids**	80.25	69.60	63.41	5.07
Polyphenols#	75.55	68.00	60.00	4.98
Phosphorus#	22.67	16.50	11.33	5.55
Potassium#	1527.55	1423.50	1324.00	98.87
Sodium#	1235.17	1189.30	1087.77	97.78
Magnesium#	1523.35	1498.07	1047.23	414.15
Calcium#	5236.85	5041.15	4768.00	388.63
Iron#	890.77	808.57	750.55	52.23
Zinc#	60.07	55.55	47.23	5.09
Manganese#	57.00	53.55	50.17	4.10
Copper#	5.50	4.00	3.15	1.12

* (μg^{-1} fresh weight); ** (μg^{-1} dry weight); # PPM

Table 3 : Ash composition of lichen groups

Ash components	Lichen groups			CD at P=0.05
	Fruticose	Foliose	Crustose	
SiO_2	46.37	41.23	36.89	3.38
$Fe_2O_3 + Al_2O_3$	22.23	19.45	17.45	3.07
CaO	2.80	2.00	1.87	0.84
MgO	5.83	4.56	4.00	0.84
K_2O	12.83	10.89	6.58	4.12
P_2O_5	8.00	6.24	5.17	1.23
Cl	2.25	1.88	1.13	0.67

Lichen species were identified based on the morphology, anatomy and colouring tests including thin layer chromatography methods. The results indicated that there were about 61 different species covering 13 families with 33 genera of lichens. Nearly, about 22 new species of lichens were recorded in the lichen database of Yercaud hills as per the report of Nayaka *et al*. (2013). Totally (Including previous results) Yercaud hills have around 230 species of lichens covering 70 genera and 35 families. According to Hariharan *et al*. (2003), a total of 40 new lichen species were added in the list of Yercaud hills of Tamil Nadu, India in 2003.

Number of lichens were found to be least at low altitude areas, due to high temperature with low relative humidity and heavy sunshine. It also coincided with presence of toxic chemicals present in air which might get accumulated on the thallus resulting in decreased tolerance capacity (Hill and Ahmadjian, 2003). The algal component of lichens were damaged by trace amount of toxic compounds like suphur, lead and copper which were present in polluted air, ultimately leading to poor attachment of fungus on the substratum and finally senescence takes place (Karakoti, 2013). Ponmurugan *et al*. (1999) at higher altitude areas in Munnar located in western Ghats, Kerala, India which revealed there was a slight reduction in the populations of lichens at roadsides which might be due to automobile smoke and car exhaust.

An appreciable amount of both macro and microelements were detected in all three groups of lichens. Polyphenol content was found to be more in fruticose (75.55 ppm) followed by foliose (68 ppm) and crustose (60 ppm) lichens. Phenolic compounds are known to have antioxidant activity and are important constituents due to their scavenging ability (Tepe *et al*., 2006). According to the report of Khoddami *et al*. (2013), a highly positive relationship between total polyphenols and antioxidant activity was found in many plant species, which play an important role in inhibitory effects on mutagenesis and carcinogenesis in humans.

All the micro and macro elements estimated were found to be higher in fruticose than in foliose followed by crustose lichens (Table 2) , which indicated that former had better profuse growth and development as compared to other two lichen groups. Total chlorophyll and carotenoid contents were higher in fruticose (2.75 and 1.04 μg^{-1} f.wt.) than foliose (1.53 and 0.85 μg^{-1} f.wt.) however no significant difference were found drawn between fruticose, foliose and crustose lichens in carbohydrate content. Macroelements like proteins, nitrogen, amino acids lipids and microelements such as N, P, K, Mg. Mn, Ca, Zn and Fe^{+} showed significant difference (P=0.05) between lichen groups. Polyphenol content was found to be 75.55 ppm in fruticose followed by 68 ppm in foliose and 60 ppm in crustose lichens. Similarly, ash content such as SiO_2, Fe_2O_3 + Al_2O_3, CaO, MgO, K_2O, P_2O_5 and Cl was more pronounced in fruticose followed by foliose and least in crustose lichens (Table 3).

A study was undertaken by Kekuda *et al*. (2011) to estimate various mineral composition of foliose lichen *Everniastrum cirrhatum* which revealed that among principal elements, calcium was found in high concentration followed by magnesium, potassium and phosphorus; and among trace elements, iron content was found to be higher followed by zinc, manganese and copper contents. Since lichens are bioindicators, they are more sensitive to threats like climate change, air pollution, ecological continuity and anthropogenic disturbances. The present study would of more useful to study the ecological preferences of lichens in Yercaud hills due to global warming, anthropogenic impact and in prioritizing areas for conservation purpose (Michaeli *et al*., 2015; Matchavariani *et al*., 2015). The data generated from this study would be the baseline data for lichens in Yercaud hills with respect to the present climatic conditions. The present study might be useful to take steps to conserve lichen species which in turn would be useful for biomedical applications, especially in anti-cancerous, anti-arthritis and anti-inflammatory. The study indicated there was a significant deterioration in lichen density due to air pollution in Yercaud hills which reflected in the estimation of tree bark pH and various metal elements including ash composition in lichen thallus.

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