INTRODUCTION
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About lichens

The word lichen has a Greek origin, which denotes the superficial growth on the bark of olive trees. Theophrastus (370-285), the father of Botany introduced the term lichen and this group of plant to the world. Lichen is not a single plant but it is a result of symbiotic association of two different plants, algae and fungi. The foremost taxonomic account under the genus lichen comprising 80 species was published under the 24th class of cryptogamic algae in Species Plantarum by Linnaeus (1753).
Lichens are one of the most important group of epiphytic organisms. Lichens are among the simplest form of plants, consisting of green algal cells protected by strands of mould or fungi. They have no specialized organs such as root, shoot and leaves, but like plants it makes its own food using energy from sunlight and this permits them to live economically even in the harshest of environmental conditions. They have an ability to quickly absorb minute concentrations of water from air or dew and become metabolically active within a few minutes. Inversely, under scorching sunny conditions they lose water and become dry. Lichens are generally an association of a fungus with algae or cyanobacteria in which the organisms are intertwined to form a single thallus. The lichen thallus is a vegetative plant body of remarkable complexity of two organisms an alga and fungus living together in symbiotic association. The dual nature of lichens was first propounded by Simon Schwendener in 1867 a Swiss Botanists, till then lichens are thought to be simple organisms between algae and fungi. The relationship between the alga and the fungus in lichen depends primarily upon the evolutionary status of the fungus. Lichens are usually hard and dry to touch, with rough surfaces that are often covered with scaly outgrowths. It is one of the most successful of symbiotic organisms on earth constitute the dominant life form over as much as 8% of the earth surface. In lichen thallus mycobiont predominates 90% of the thallus volume and provide shape, structure and colour to the lichen with partial contribution from the algae. The fungal part in the lichen thallus is visible from outside, which holds algal cells inside. Hence the lichens are placed within class mycota (fungi). The fungi which present in the lichen are called as
lichenized fungi. Among the 20,000 lichen species known in the world 95% belongs to the Ascomycetes group of fungi while Basidiomycetes and Deuteromycetes groups are present by only 3% and 2% of species respectively. Lichens are fungi that live in symbiotic association with one or more green algae or cyanobacteria. They constitute 47% of ascomycetes and one fifth of all known fungi (Crittenden et al, 1995) and with nearly 18,500 species (Stocker-Worgottez, 2008). The lichens are composed of algal component with photosynthetic structure called photobiont and the heterotrophic fungus the mycobiont. The lichen thallus is a vegetative plant body of remarkable complexity of two organisms an alga and fungus living together in symbiotic association. The mycobiont is an Ascomycetes, Basidiomycetes or Deuteromycetes that has succeeded in establishing symbiotic association with green alga or blue green alga. The photobiont and the mycobiont loose their original identity during the association and the resulting entity behave as a single organism, both morphologically and physiologically. Hence the lichen is called a composite organism. After recognition to blue green algae as cyanobacteria, the term phycobiont was used for an algal symbionts and cyanobiont for cyanobacterial symbionts. The cyanobacterial photobionts cells lack a nucleus, the central part and the thylakoids are present in the outer part. The algal cells are eukaryotic, have a distinct nucleus the chloroplast of variable shape contain a chlorophyll a, b, c and the cytoplasm contains mitochondria. The multiplication of the photobiont cell within the lichen thallus takes place by mitotic or simple cell division. There is usually no spore formation of the algal photobionts by sexual
or asexual method in the lichenized condition. The ground tissue of lichen thallus is constitute by the fungal hyphae. There is no fundamental difference between lichenized and nonlichenized fungi in the cell wall structure and composition. The hyphae of mycobiont are septate branched, thin or thick walled and the walls are colorless or variously coloured. The protection however is provided by the mycobiont with the development of specialized hyphal tissue in the form of cover or cortex over the stratum of photobiont. In the majority of lichen taxa, over 95%, the mycobiont is ascomycetes, while in few taxa it is basidiomycetes. Lichens can grow in diverse climatic conditions. Some lichens especially those growing on rocks or tree bark is attached by a disc-like holdfast. Most lichens are grey or brown when dry but in wet thallli condition the color of the algae can be seen more distinctly through the cortex and these lichens become more or less green. Lichens occur in a wide variety of habitats from the arctic to the Antarctic and all regions in between. One finds them on exposed rock and soil surfaces in deserts, on solidified lava flows, within or on frozen substrata in the Polar regions. Lichens of different types are similar in their basic construction, that is the presence of an algal and a fungal partner based on their distribution in a thallus, they are divided into two forms:

**Homogenous**

When two symbionts are uniformly distributed throughout the thallus known as homoiomerous, e.g. *Collema*. The homoiomerous gelatinous lichen absorb much more water in relation to their dry weight then non gelatinous, heteromerous
lichens do. Thus CO₂ gas diffusion to the photobiont is strongly limited or may even be blocked in supersaturated thalli and CO₂ can become the limiting factor.

**Heteromorous**

The photobiont cell filaments are stratified in a layer, usually below the upper cortex, and the thallus is known as heteromorous. The main subdivisions are into upper cortex, photobiont layer, medulla and lower cortex. Despite that, the lichen thalli occur in different forms. These structures of the lichen thallus are known as growth forms.

Lichens can be primarily categorized into three main groups depending on their growth form, morphology and size, these are:

- (A) Crustose
- (B) Foliose
- (C) Fruticose

**Crustose lichens**

Crustose lichen forms a crust over the substratum. The thallus of the crustose lichens is closely attached to the soil, rock or tree bark by the hyphae of the medulla and the contact is so intimate that they are practically inseparable from the substrate. They may not be removed from the substratum without destruction of the thallus. The vast majority of lichens grows on the surface of rocks and trees and has a distinct thallus. The thallus of crustose lichen is of insignificant size, flat thin and usually without any distinct lobes. A patch of crustaceous
lichen may belong to one species and yet be composed of many individual, which have fused together. There is an upper cortex and an algal layer but never possess a lower cortex and rhizines and are therefore granular in structure. Water loss is restricted primary to the upper exposed surface, and these organisms can tolerate extreme habitat, such as bare or rock surface. In the majority of crustose lichens the protective layers is usually formed by horizontally or periclinal oriented compact hyphae to form a corticiform layer, or there is a true paraplectenchymatous cortex.

**Foliose lichens**

The thallus of foliose lichens are formed by flattened lobes, which are either homoiomerous (no distinction of different layers) or heteromerous (thallus is stratified into layer) and dorsiventral in structure. The thallus of the foliose lichens are loosely attached to the substratum at least at the margin. It is free of the substrate but usually attached to it by rhizines and are also called as leafy lichens. Thalli are generally orbicular, suborbicular or irregular in outline with rotund subrotund, narrowly elongate or laciniate lobes. Lobes remain discrete from each other become imbricate or crowded. This highly developed form has given rise to a great range of thallus size and diversity.

**Fruticose lichens**

The thallus of the fruticose lichens are strap-shaped or thread like structure attached to the substratum at one part and the remaining major portion become
completely free or hanging. The lobes may be flat or cylindrical and always stand 
out from the surface of the substratum. Fruticose lichens that grow on soil from 
little cushions which consists of separated upright lobes. Some species degenerate 
at the base and become completely free. In fruticose lichens, size varies 
tremendously from few mm to several meters (Usnea). The stiffness of the 
fruticose lobes is achieved by two different types of basic construction, 
depending on the position of the supporting tissues. This type of lichens usually 
appears as small shrub on bark.

In some lichens, the hyphae of the cortex as supporting tissue. They form 
cylindrical tube at the lateral edge of the thallus, while the center of the thallus is 
hollow or filled with cottony medulla. This type of construction serves to keep 
the plant upright and withstand the lateral pressure. The supporting tissue is a 
prosoplectenchyma or pseudoparenchyma with hyphae being closely cemented. 
Another type of fruticose lichens, the supporting tissue is situated in the center of 
the medulla. A central chord or axial strand is constructed from thick walled, 
perpendicular, agglutinated hyphae. This central axial strand gives the requisite 
tensile and skeletal strength to pendulous lichen.

Besides the three major growth forms there are some intermediate forms such as 
leprose (granular, powdery or powder like), placodioid (closely attached to the 
substratum at centre and lobate or free at margin), squamulose (minute lobes 
having dorsiventral differentiation, intermediate between crustose and foliose) 
and dimorphic (single thallus having characteristics of both foliose/squamulose 
and fruticose lichens, squamules are primary thallus which bears erect body of
fruticose lichen, the secondary thallus). The crustose, leprose, placodioid and squamulose forms are called microlichens because of their smaller size and require microscopic studies to identify and the foliose, dimorphic and fruticose are called as macrolichens (Awasthi, 1988; 1991). They have comparatively larger thallus than microlichens and can be identified by using a hand lens or stereozoom microscope. Lichens can grow on any substratum which provides a convenient foothold to them or any structure that has been standing for a reasonable amount of time is likely to be adorned with lichen. They colonize great variety of substrates both natural as well as manmade. The tree trunks, branches, leaves, rocks, soil, decaying woods, animal shells, bones and insects back are the natural substrate for lichen growth while synthetic materials such as plastic taps and substrates derived from mineral sources such as bricks, cements, concrete roofs and walls glass and iron amongst are others (Brightman et al, 1977; Simpson, 1994; Schroeter and Sancho, 1996). It was long believed that lichens were incapable of growing on animals for with their exceptionally slow growth they need a relatively stable substrate. The lichens can colonize almost any substrate that does not flake off too quickly, so long as there is enough light for the contained algae to photosynthesize.

On the basis of substrata, the lichens can be differentiated into the following categories:

Lichens growing on tree trunk and bark are called as corticolous, growing on wood as lignicolous and the twig inhabiting lichens are known as ramiicolous lichens. Lichens growing on soil are called as terricolous, on humus as
humicolous; on bricks, rocks and boulders are called as saxicolous; on mosses as musicolous; on lime plaster or cemented walls as calcicolous and those present on evergreen leaves are called as foliicolous, and omnicolous on different kinds of substrates (Upreti, 1998).

Attachment organs and appendages

Various modes of attachment organs by which a lichen thallus is attached to its substrate are describe below:

Rhizines

They grow from the underside of the thallus consist of strongly conglutinated prosoplectenchymatous hyphae. These structures are found mainly in foliose lichens. Rhizines are simple to richly branched, are also found in squamulose, fruticose lichen growing on rock fissures, over loose sand and soil. Rhizines are generally brown or black, simple to branched and the length is much variable. Rhizines are generally formed on lower surface when it is corticated thallus. The tip of rhizines often possesses adhesive discs which help to attached them to the substratum.

Holdfast

This is a disc like structure found in some lichens, especially those growing on or tree bark. Umbilicate lichen as well as Usnea and similarly structured fruticose
Lichens are also attached to the substrate with a holdfast, from which hyphae may penetrate slightly into the substrate.

**Cilia**

Vegetative structures emerging from the margin of the thallus and closely resembling the rhizines are called cilia. They appear as fibrillar outgrowth and can also arise from the upper surface of the thallus.

**Tomentum**

They consist of densely arranged short, hair-like hyphae. They may be formed on the upper and lower cortex. These hair-like may form a felted, hirsute or cottony mat. The tomentum may become a thick spongy layer of netlike, branched hair.

**Reproduction in lichen**

Lichens like all other plants have simple organization and are capable of reproducing asexually and sexually. Genetic makeup of taxa determines the occurrence of one or both methods. If the sexual and asexual methods are present, the dominance of one over other is generally aided by ecological and environmental conditions.

**Vegetative (Asexual) reproduction**

The simplest method of asexual reproduction takes place by isidia, soredia, fragmentation, etc.
Isidia: An isidium is an outgrowth on the surface of the thallus of many lichens. Morphologically the isidium is of various shape and size, it may be cylindrical, simple or coralloid branched and some are globular to cylindrical. The density and size of isidia are governed by ecological and environmental conditions.

Soredia: Soredia, a minute vegetatively produced propagule consisting of a few cells of the photobiont that are interspersed and enveloped by the hyphae of the mycobiont. They occur on the surface of the thallus in diffused manner in several species.

Fragmentation: This is the commonest means of reproduction. Dry lichens are brittle, small fragments break away and separate from the main thallus. These species are blown away by wind and give rise to new thalli.

Sexual reproduction
This may be noted that the sexuality involves the development of asci and ascospores within the apothecium or perithecium. In case of lichens, sexual reproduction involving the two symbionts together is not possible but experimentally it has been proved that mycobiont is the only partner that reproduces sexually and photobiont has got no role in that.
Apothecia: A cup shaped or disc shape fruiting body, which is situated on the thallus surface in immersed or partially sessile position, they can also be present in a slightly raised position with the help of a stalk present at the base of the apothecia. The fertile region of the apothecia is known as hymenium, which range from light brown to dark brown in colour.

Perithecia: A flask shaped structure 0.5-2mm in diameter immersed in the thallus. A pore for releasing spores from the hymenium forms at the upper surface of the thallus. The perithecial wall is derived from thalline tissue and may be carbonized or made up of several layers.

The lichens crustose, foliose, placodioid, squamulose and sometimes dimorphic forms of lichens usually grows in a circular or centripetal manner. The rough and uneven shapes of the substratum may change the shapes of the lichen colonization. The leprose lichens form irregular patches of thallus on the substratum. The fruticose lichens of smaller size usually grow erect while the larger ones hang from the substrate with their growing point located at the tips. The lichens are never as green as algae, liverworts or mosses. Foliose lichens in the moist places or in wet condition may look greener, and have thick, leathery thallus while liverworts have nonleathery and shiny thallus. The dimorphic form of lichen such as Cladonia may easily be confused with the leafy liverworths and mosses. However, leafy liverworts and mosses have dense small leaf like structures throughout the central axis of the plant while in case of dimorphic lichens the squamules of semicircular shape usually present at the base of the
central axis sparse throughout. Algal mat are usually found in flooded water habitat and shiny. The beginners may confuse the dried mat on rocks and bark for lichens. The non-lichenized fungi are the most confusing one with crustose lichens in the field. Such fungus usually form patches with loosely woven hyphae, which will be evident under hand lens. The lichens on the other hand form smooth and circular patches. The fungi are usually whitish in colour and lichens are greyish, off white, yellowish, yellowish green or bright yellow orange in colour. The lichen thallus usually bears button or cup like structures called as apothecia, or bulged, globular or immersed pitcher like structures called perithecia as sexual reproductive organs. The finger like projections called isidia or granular, powder like structure called soredia is common vegetative organs. Some crustose lichens belonging to family Graphidaceae bear worm like structures, the modified apothecia, called as lirellate apothecia. While collecting lichens it is necessary to look for such structures with the help of hand lens. When a lichen thallus does not have any such structures makes it difficult to differentiate from fungus.

Lichens growing on trees are not parasites on them and do not feed on them but are simply using the tree as a home. The climate i.e. condition of a particular area plays vital role for habitat diversity of lichens. Tree bark usually contains resins, and tannins which inhibit the plant growth, but water relations, pH, light and nutrient status appear more important to determine the lichen species colonization. Among the soil factors which favour lichen rich vegetation are drought, high calcium content and low nutrient status. Many environmental
factors including precipitation, light, and darkness, humidity and dryness, unpolluted atmosphere, wind currents and absence of biotic interference together with nature shows varying effects on the growth of different species of lichens. Lichen produce a wide range of unique secondary metabolites. Out of about 1000 secondary metabolites observed in plant around 50 are common to all plant groups and the rest 950 are unique to lichens, not available in any other plants. Lichen metabolites exert a wide variety of biological action including antibiotic, antibacterial, antiviral anti-inflammatory, analgesic, antipyretic and cytotoxic effects. Lichens were used in preparation of different medicine in remote ages in different regions of the world (Llano, 1948). More than 50% of the lichen species are known to possess antibiotic value. The most promising lichen substance is usnic acid, a broad spectrum antibiotic. The main sources of usnic acid are the yellow species of Cladonia (Reindeer Moss Lichens). Hence lichen secondary metabolites act as antibiotics as well as allelopathic compounds to combat biotic stresses.

Lichen secondary compounds also protect lichen thalli against viruses, bacteria, algae, bryophytes, plants and animals. The lichens growing on rocks release some organic acids which disintegrate rocks and form soil and substratum for subsequent establishment of other vegetation types. Thus, lichens are of considerable ecological importance as pioneer plants to grow on barren, rocky surfaces, where neither the fungal partner nor the algal partner could survive alone and also no other plant grows, further they colonize the habitat where other plants can grow. They play a vital role in primary ecological succession, mineral
cycling and part of food chain. Lichens are well known as pioneers in plant succession. Lichen succession is largely directional and changes in the environment to determine the climate fate of the communities. Stages in the succession can be arrested only if the environment remains unchanged or is not subject to change. These conditions can easily get in the polar regions, deserts, rock surfaces in temperate areas where tree growth is prevented, rocks along the rivers, lakes or the oceans. The role of lichens in succession illustrates many of the principles of ecosystem development. Lichens are usually considered as poor competitors as they establish themselves where other organisms cannot. Changes in environment which change the succession will alter the competitive ability of the species present. For instance pollution resistant species such as *Lecanora*, *Pamelia*, *Cetraria* and *Buellia* may exist in areas of pure air as minor constituents of the flora.

Different bioindication methods based on epiphytic flora composition have been used in different countries. Methods varied from simply observing epiphytic lichen thallus type to recording lichen species diversity and/or investigating phytosociological relationship between different lichen species and environmental conditions (Richardson, 1991). Lichens are extremely sensitive to atmospheric pollutant and have disappeared in many metropolitan and industrial areas over the past century. Lichens have been shown to be outstanding bioindicators in a wide range of air pollution studies. This is due to the physiological properties of the lichen thallus, namely slow growth rate and its effectiveness in absorbing soluble and insoluble mineral nutrients from ambient
air and rain with little subsequent loss (Ahmadjian and Hale, 1973; Ferry et al, 1973 and Nash, 1996). Various sources emit trace metals in to the atmospheric air through anthropogenic activities mainly from the volatility of most elements at the high temperature reached during fossil fuel combustion, waste incineration and many other high temperature industrial processes. Natural sources also contribute such as aerosol formation from sea spray, windblown soil and rock dust, and volcanic activity. Since atmospheric concentrations of trace elements vary greatly from day to day and from location to location, large-scale monitoring can be done by using suitable biomonitors.

Air pollution does not necessarily kill off all the lichens. They can be used to biomonitor the levels of SO$_2$, NO$_2$ and a number of toxic metals. This is one of the most popular fields in lichenology. The lichen thallus is a perennial, stable and long lived structure. Air-borne elements are absorbed very efficiently over the entire surface since there are no protective structures such as a waxy cuticle and stomates. The absence of cuticular membrane and root system together with spongy nature of thallus, slow growth rate, dependence on atmospheric depositions for mineral nutrient, long life and non shedding organ parts are the characteristic features of the lichens for their extreme sensitivity to environmental stress. Photochemical toxins are generally associated with automobile exhaust pollution in urban area but also arise from burning of fossil fuels. They are most visible in the landscape as smog and haze. An important element in photochemically induced smog is ozone, while ozone is toxic to many higher plants, it seems to have little immediate effect on roadside lichens in large cities.
The air pollution and dry atmospheric condition are responsible for the disappearance of lichens in urban areas. Many environmental factors including precipitation, light, and darkness, humidity and dryness, unpolluted atmosphere, wind currents and absence of biotic interference together with nature shows varying effects on the growth of different species of lichens. Semi moist tropical area has seasonal rains and provides favorable condition for member of Lichinaceae which retain moisture for longer while temperate regions, where the rain are intermittent; the foliose and fruticose lichens grow luxuriantly. The cold deserts and hot deserts have scarce or no rains, exhibits poor growth of few crustose and squamulose lichens on rocks and soil.

The different climatic factors which influence the lichen growth are:

**Sunlight:** Bright sunlight and high temperature has an inhibiting effect on lichen growth. Such lichens develop cortical pigments. The thallus of such lichens contains anthraquinones to protect the algal layers. e.g. *Acarospora* and *Rhizocarpon* growing in exposed places in alpine cold deserts.

**Temperature:** The most suitable temperature for the growth of lichen is 20-25°C, therefore the lichen growth and their variety, particularly of macrolichens is more in temperate regions of the world. Many lichens are able to withstand high temperatures of the tropics with high rainfall. These lichens mostly grow on trees. Many lichens can tolerate very low temperature in high altitudes in the
Arctic and the Antarctic regions as their thallus structure is well adapted for such climate.

**Wind:** In areas of high wind currents the crustose lichens exhibits their dominance. The *Usnea* and *Ramalina* lichens have cushion like or brush like growth which help them to withstand the strong wind currents.

The chemical composition of soil is also plays an important role for the type of lichens that grow on it. The saxicolous lichens exhibit diversity of the habitat due to influence of the chemical composition and physical texture of rocks and boulders. The quartzite rocks have few lichens on them due to their hardness and smoothness. *Caloplaca* only grows on such types of rocks. Lichen genera *Endocarpon, Lecanora, Peltula* and *Staurothele* prefers lime containing rocks while majority of saxicolous lichens grow on granite and allied rocks.

The bark with rich nutrient is known as eutrophiated and the bark with less nutrients and low pH is known as non eutrophiated. Usually some species of *Arthonia, Bacidia, Graphis,* and *Lecanora* requires a non eutrophiated bark while *Caloplaca, Phyllopsora, Phaeophyscia* and *Physcia* requires a eutrophiated bark.

The folicolous lichen needs a perennial leaf for their growth. The ferns, broad leaved trees and shrubs growing in shady or subshady situations in tropical, subtropical regions with frequent and from SO2 pollution (acidic gas) hence such habitat exhibit a dominance of pollution tolerant species of *Arthopyrenia, Bacidia, Endocarpon, Phylliscum* and *Peltula* on the lime or cement plaster building. The lichens growing on rocks release some organic acids which
disintegrate rocks and form soil and substratum for subsequent establishment of other vegetation types. The vast topography and climatic diversity of India is endowed with a rich lichen flora, both in luxuriance and species diversity. Inspite of constant endeavour exploration and survey during the last five decades the knowledge about lichens remains incomplete. Vast areas of the country are still unexplored lichenologically (Awasthi, 1983). Even many floristically rich areas like the North-Eastern India, considered to be the “Botanical Eden” (Balakrishnan, 1981, 1983; Haridsan and Rao, 1985-1987; Jamir and Rao, 1988; Joseph, 1982, Kanjilal et al, 1934-40; Kataki, 1986; Rao, A.S. 1974; Rao and Hazra, 1986) remain terra incognito from the lichenological point of view. Consolidated information of all these contributions indicates that in the present state of knowledge a total of approximately 2303 species under 305 genera and 74 families occurred on various substrates in tropical, subtropical, temperate and alpine regions of India. Out of this 520 species are endemic (Singh and Sinha, 2010). An analysis of species diversity at family level indicates that foliose lichen family Parmeliaceae shows maximum diversity with 345 species and widely distributed in subtropical, temperate and alpine regions of India, followed by Graphidaceae 279 species mostly distributed in tropical and subtropical regions. Similarly at generic level, the genus Graphis shows maximum diversity and represented by 111 species in tropical and sub tropical regions of India. Pyrenula is the next genus with 90 species distributed in tropical regions of the country. The Eastern Himalayan region is endowed with rich lichen flora both in luxuriance and diversity. The region with special horse shoe shaped arrangement
of the fold of mountains coupled with moisture laden monsoon winds, blowing across the Bay of Bengal, ensure plenty of rain in most of the areas is the factors for rich lichen flora. The topography and varied altitude of the area are the other factors which have greatly contributed to the rich lichen diversity. North east India being a hotspot region which is characterized by major concentrations of endemic plants and high species diversity, the lichens from this part of country are not explored extensively. One of the earliest publication of Nylander (1860 and 1863) reported 80 species from North East India based on the collection of G. Watt and A. Watt. Some of the contributions made from this region by several workers by Awasthi (1961), Singh (1980, 1981), Rout et al (2005, 2010). On the basis of data from available literature, herbaria and field surveys, an attempt is made to analyse the flora of this hotspot region. The lichen flora of Arunachal Pradesh, Meghalaya and Sikkim is very poorly known, while the reports of lichens from Tripura and Mizoram are yet to be recorded.

The state Assam, particularly Barak valley region is awefully neglected in this front. The lichens from Cachar district both floristic and as pollution biomonitor has been addressed by Rout et al and her group (2005, 2010 a, b). An occurrence of 176 species of lichens from Cachar district of Assam has been described by Das (2008). Rout et al (2010) also reported the 55 species detected from Lohar bund reserve forest of Barak Valley. So far no records of lichens growing on Areca catechu are available in the country as the tree serves as many as lichen colonization to their substratum and it is a most common tree growing in the area both in rural and urban areas of the district.
Physiography and climate

India is one of the twelve mega biodiversity centers of the world with two peculiar hotspots viz. Eastern Himalaya and Western Ghats and fourteen Biosphere Reserve. The Himalayan region situated on the North eastern tip of India bounded by Myanmar on its east, Bhutan on the west, China on the north. Each Biosphere Reserve has its unique flora, fauna and ecosystem. Areas rich in biodiversity and encompassing Biosphere Reserve, facilitate the conservation of biological diversity and unique landscapes. The North Eastern region of India covers an area of 2,62,379sq.km. has been divided into two biogeographic zones, Eastern Himalaya and North East India, based on floristic composition, the nature of the flora and the climatic conditions (Rodgers and Panwar, 1988). The Eastern Himalaya comprises of Arunachal Pradesh and Sikkim is more mesic due to high degree of precipitation resulting from direct confrontation of monsoon laid wind blowing from Bay of Bengal by abruptly raising hills. The biogeographic zone of North East India comprises of Assam, Nagaland, Manipur, Meghalaya, Mizoram and Tripura is most significant one and represents the transition zone between the India, Indo-Malayan, Indo-Chinese bio-geographic regions as well as meeting points of Himalayan Mountains with that of Peninsular India. The North Eastern region of India lies between 22° N and 29°5′ N latitude and 88°00′ E and 97°30′ E longitudes, and shares international border with Bhutan, China, Myanmar and Bangladesh. The North-Eastern region of India contains more than one third of the countries biodiversity. The region, comprising of the states of Arunachal Pradesh, Assam, Meghalaya, Manipur, Tripura, Mizoram, Nagaland and Sikkim
can be physiographically categorized into the Eastern Himalayas, North East hills and the Brahmaputra and the Barak Valley plains. The region is also the abode of approximately 225 tribes out of 450 in the country, the culture and customs of which has an important role in understanding biodiversity conservation and management issues. The North Eastern region has been focused for its rich biodiversity and this region has a priority for leading conservation agencies of the world. While WWF has identified the entire Eastern Himalayas as a priority Global 200 eco region while Conservation International has up-scaled the Eastern Himalaya Hotspot which initially covered the states of Arunachal Pradesh, Sikkim, Darjeeling Hills, Bhutan and Southern China to Indo Burma Hotspot (Myers, 2000) which now includes all the eight states of North East India along with the neighboring countries of Bhutan, Southern China and Myanmar. North-East India supports some of the highest bird diversity in the orient with about 850 bird species. The region has been identified by the Indian Council Agricultural Research (ICAR) as a centre of rice germplasm while the National Bureau of Plant Genetic Resources (NBPGR), India, has highlighted the region as being rich in wild relatives of crop plants. It is the centre of origin for Citrus fruits. Although Jhum cultivation, a traditional system of agriculture has been practiced by local tribes reflects the usages of 35 varieties of crops. It is often cited as a reason for the loss of forest cover of the region. The region is rich in medicinal plants and other rare and endangered taxa. Its high endemism in higher plants, vertebrates and avian diversity has qualified it to be a “Biodiversity hotspot”. Out of 9 important vegetation types of India, 6 are found in the North Eastern region,
these forests harbor 8000 out of 15000 species of flowering plants which includes 40 out of 54 species of gymnosperms, 500 out of 1012 species of pteridophytes, 825 out of 1145 species of orchids, 80 out of 90 species of rhododendrons, 60 out of 110 species of bamboo, 25 out of 56 species of canes. According to the Indian Red Data Book published by the Botanical Survey of India, 10% of the total flowering plants in the country are endangered. Of the 1500 endangered floral species, 800 are reported from North East India. North East India has 64% of the total geographical area under forest cover and it is often quoted that it continues to be a forest surplus region. However the forest cover is rapidly disappearing from the entire region. There has been a decrease of about 1800 sq.km.in the forest cover between 1991 to 1999 (F.S.I. 2000). The quality of forest is deteriorating day by day with dense forest (canopy closure to 40% or more becoming degraded into open forests. Assam, the state famous for its Bihu dances and the rhinos of Kaziranga National Park also has a substantial contribution to the Indian economy through the production of oil and a variety of other minerals. The mineral rich geology of Assam is a topic of much interest and research for their probable commercial potential. Assam is located in the North eastern region of India, has a diversified geological spectrum. It is located near the hairpin bend of the Himalayas. Hence the extreme geostatic pressure exerted on the landmass during the creation of the Himalayas have resulted in Assam having large areas of sedimentary deposits. This explains the huge amount of oil found in places like Digboi, Bongaigaon, etc.
Blessed with natural wealth, Assam is a land of vibrant traditions, exotic wildlife sanctuaries and perennial river beds that collectively make the place unique one. Assam is one the most enriched states of India. Bearing the imprints of the past civilization, Assam stands tall the vocational contours of the country. The dense forest of Assam make for a flourishing industry of wood in the place. Also, the tea estates of Assam the biggest revenue generator and engage a major portion of the Assamese population.

**Location:** Assam is located on the North Eastern forest of India, surrounded by Brahmaputra River, the state boasts of a fertile agricultural land. There are quaint hills too in Assam that adorn the state with their majesty. The population of Assam represents a unique combination of various ethnic sects that inhabit the rich land from a very long time..

The topography and other mountain slopes in combination with perennial streams and dark shady valleys have created micro-climatic conditions in the area to provide diverse environmental conditions encouraging luxuriant growth of several moisture loving species of ferns, orchids, bryophytes, algae and several herbs, shrubs and climbers which have immense ecological as well as economical values.

Barak valley zone comprises the district of Cachar, Hailakandi and Karimganj with an area of 6922sq. km. This zone is separated from the Brahmaputra valley by the two hill districts viz., Karbi Anglong and N.C. Hills recently named as Dima Hasao district. This zone has a total area of 6962 sq.km. and is bounded in
the north by N.C. hills in the east by Manipur hills, in the north by the hills of Mizoram and in the west by Bangladesh and Tripura. The zone is characterized by undulating topography. The hills and hillocks locally known as tillas predominate the land surface. The plains have a great deal of marshy lands. There are two important rivers namely Barak and Kushiyara in this zone. The climate is characterized by high rainfall more than 200mm, high temperature and high humidity. The Barak plains have a great deal of low marshy lands, alluvial soils in the flood plains are fertile and red loamy soils in the submontane tracts are relatively more deficient in plant nutrients. Organic soils are found in the swampy bheels and most of the soils are acidic in nature.

**Cachar district**: The Cachar district is located on the bank of the river Barak of southern Assam. The district occupies a total land area of 3786sq. km. accommodating 14,42,141 (acc.to 2001 census) people within its premises. Geographically, Cachar district is not situated in an advantageous position but strategically, this district is considered as important. Cachar district is the gateway to the neighbouring states of Mizoram and also to the western parts of Manipur and is principally surrounded by hills in all the three sides. Climate of Cachar district is significant for excessive humidity and being surrounded by ranges of hills on the North, East and South of the district. Heat during summer time is unbearable because of high humidity. The air is surcharged with moisture and rainfall is extremely heavy. Summer is hot, humid and interspersed with rains and thunderstorms. The actual rainy season starts
from May and remains upto October. The district receives an average annual rainfall of more than 3,000mm. The winter season is not so cold like other states of India. Winter generally starts towards the end of November and lasts till February. The vegetation is mostly tropical evergreen and there are large tracts of rainforests in the northern and southern parts of the district.

About host tree

*Areca catechu* commonly known as Betel nut or Betel palm or Pinang is a species of palm. Palms, defined by Linnaeus “Principles planterum” on account of their imporing habit and thick leaf crown are one of the largest monocotyledonous angiosperm families in that they include about 2500 species, grouped in 215 genera. They can also be Aracaceae according to a convention of Scientific nomenclature whereby family names are not to be taken from the most representative genera (*Areca*).

Palms are to be found mostly throughout tropical and subtropical regions both in Old and New World; just a few species grow over temperate northern regions. The regions richest in palms are Tropical Amercia, notably Amazonia and East Indies, the poorest are boast several endemic genera. Europe, rich in palms during tertiary era, currently lost two spontaneous species only,viz *Phoenix theophrasti*, endemic to Crete and *Chamacrops humilis* spread through the Western Mediterranean basin, present in Italy too as a kind of relict. Current distribution of palms whose most ancient fossil remains date as far back as the Cretaceous period (ca. 100 million years ago), results from a variety of factors, first of all, it should be taken into consideration the detachment of the ancient continent Laurasia from Gondwana, with the attendant appearance of new species and
genera over the various quarters of the world; secondly, manners of seed dispersal, these usually being quite heavy and therefore not easy to travel, finally poor tolerance of palms to cold temperatures so that they are bound to grow in tropical and sub tropical areas at altitudes not exceeding 300 m.a.s.l. The commonest and best known habit of palms is that of woody tree plants featuring a single, unbranched trunk apically ending in crown of leaves. Actually there are acaulescent palms exhibiting a much reduced stem, or shrub palms with multiple stems or even climbing palms. Pinnate or bipinnate leaves exhibit pinnae attached on both sides of the rachis. Palms are found to be grow in the most varied habitats, from tropical forests to mangrove marshes, from highland woods to deserts. Moreover, a number of climatic factors affect their growth, the most significant factors to be taken in to account are temperature, air, humidity, water supply, sunlight, kind of substratum. In the tropical and subtropical climate regions where temperature and atmospheric humidity are rather high, palm features as an important and conspicuous element of vegetation.

Scientific classification of *Areca catechu*

Kingdom: Plantae  
Division: Magnoliophyta  
Class: Liliopsida  
Order: Arecales  
Family: Areaceae  
Sub family: Arecoideae  
Genus: *Areca*  
Species: *catechu*.

Botanical name: *Areca catechu* L.
Betel nut is a name given to the seed of the *Areca catechu* tree. *Areca catechu* is the botanical name of a species of palm tree that grows in parts of the tropical Pacific, Asia and Africa. More commonly known as betel palm or betel nut tree, it can grow to a height of 65-90 feet. *Areca catechu* is part of the Areceae family. There are over 200 genera and about 2600 species contained in the family. Most members of the Areceae family only grow in tropical and subtropical climates. *Areca catechu* is a very attractive monoecious palm exhibiting a slender single trunk with a prominent crown shaft. The palm reaches a mature height of up to 15-30 m tall with a trunk 15-20 cm in diameter. The leaves are 1.5-2 m long, pinnate with numerous crowded leaflets. Mostly cultivated in all the warmer parts of Asia. An easily grown palm for both the tropics and warm sub tropical areas. It prefers shade as a seedling, but it take full sun at quite a young age. It likes a moist, well drained soil and does not like to dry out. The tree is limited to growing in warm tropical or subtropical areas but it is not known where *Areca catechu* originated. It may have come from the Philippines or an area near there but that is not certain. Many other areas have been suggested as the original homeland, including South or Southeast Asia. From Southeast Asia, betel nut was distributed by indigenous peoples throughout the tropical Asia as far as East Africa and the Pacific well before the arrival of Europeans in the region. The palm was distributed Pacific islands aboard sailing canoes by pre historic ancestors of the Micronesians who explored and settled the islands of the Western Pacific. Today it is grown in East Africa, Madagascar, Arabian Peninsula, India, Bangladesh, Myanmar, Thailand, Cambodia, Laos,
Vietnam, southern China, Malaysia, Indonesia, Taiwan and the Philippines. It can also be found on some atolls such as Mwoakilloa in Pohnpei state. It has also been recorded as being present on Jaluit Atoll in the Marshall Islands. In Hawaii it is grown mainly as an ornamental. The Areca palm is also used as an interior landscaping species. It is often used in large indoor areas such as malls, and hotels. In many parts of the world betel nut palm is planted around homesteads for home consumption of nuts. It is also interplanted with fruit trees at the margins of fields and along paths and irrigation channels. In Sri Lanka betel nut palms are often grown as boundary markers. Wild Areca catechu trees can be found growing in Malabar, a region in India between the Western Ghats and Arabian Sea. Betel nut palm was introduced to the Pacific before the advent of Europeans. It is grown around homesteads and farms or in plantations where it is associated with other cultivated plants or those typically found in disturbed sites. The name betel nut is misleading, Piper betle, commonly known as betel, is a plant that originated in Asia. A very important associated species is betel pepper (Piper betle), which is grown for its leaves. The leaves of the betel vine are used as the wrapper when preparing a quid of betel nut with lime, tobacco, or other ingredients. By association, the Areca nut has become known as the betel nut. Betel nut palm is ideally suited for tropical climates, humid tropical lowland, maritime tropical, subtropical wet, tropical wet forest with high rainfall that is evenly distributed throughout the year. In areas with a seasonal dry period, irrigation must be provided to assure evenly distributed moisture year-round. These palms are unable to withstand extreme temperatures or a wide variance of
daily temperatures. They thrive best at low altitudes, (above 900m) flowering and fruiting are adversely affected. It prefers uniform distribution of rainfall throughout the year. They are very cold sensitive. Betel nut palm grows in many types of soil varying in texture from laterite to loamy, provided the soil has thorough drainage, yet has the ability to retain optimum moisture. Light and sandy soils are unsuitable unless copiously irrigated and manured. In the Pacific islands, the palm does best in volcanic clays but can also be grown in coralline soils. More important is soils capacity for thorough drainage during the wet season. The most desirable soils are rich in organic matter. Betel nut has poor drought tolerance but thorough drainage with high moisture retention is essential. Despite a strong ecological preference for moist to wet environments, betel nut palm does not tolerate waterlogged soils. In urban area the majority of betel nut palm grown for nut production is in home gardens, so the species is eminently suitable for this purpose. In fact, like all the cultigens, betel nut palm depends on human care for its survival. Where nut consumption is not the primary reason for growing this palm, it is esteemed for its ornamental qualities. There are no special varieties or types favored for use in urban environments. The betel nut palm, although an attractive tree, is not recommended for landscaping of parks or other public facilities in the Pacific islands where the nut is used. *Areca catechu* is grown for its economically important seed crop the betel nut. Being a shade loving species, Areca nut is always does well when grown as a mixed crop with fruit trees. Areca nut is sensitive to drought, and therefore irrigation is essential in
areas with prolonged dry spells. Betelnut is growing both in urban and rural areas. It is such an excellent host for the lichen species.

Cachar district is bordered by three Reserve Forests, Barail Reserve Forest to the North, Barak Reserve Forest to the East and Innerline Reserve Forest to the South. The border region in and around these reserve forests has high forest cover and no pollution. But the central part of the district is highly populated and pollution is also maximum. Forest cover is quite thin and in many areas barren if not used as agricultural land. Even, with this thin forest cover, *Areca catechu* is found to be available in plenty and is the most common tree growing luxuriantly in all the areas of the district. This trees serves as an ideal host for lichen colonization in this area. It is therefore much suitable to study lichens growing on this betel nut tree to monitor the pollution level in urban areas using lichens.

The present thesis describes on the lichen diversity growing on *Areca catechu* host tree covering the entire district which is segmented to 5 zones with different habitat conditions. The floristic diversity of the lichen with well illustrated photographs of different life forms, their taxonomic treatment, ecological attributes, substrates quality and lichen transplant experiment for pollution biomonitoring of air quality were dealt in different chapters with following objectives.

**Objectives:**

1. To collect and identify the lichen samples from different strategically selected area of the Cachar district.
(2) To assess the diversity and distribution of lichen flora in the betelnut host tree.

(3) To estimate the frequency, density and dominance of lichens in the 5 x 5 inch quadrate and also record the absence and presence of single species *Dirinaria aegialita*.

(4) To correlate the results of various sites and monitor the pollution level utilizing a single foliose lichen *Dirinaria aegialita*.

(5) To transplant the healthy lichens into a polluted area and measure the metal accumulation after 30-days.

(6) To analyze the heavy metal accumulation in single dominant, foliose lichen *Dirinaria aegialita*.

(7) To analyze the the tree bark for the colonization of lichen.