Studies on Lichen Diversity in relation with Air Pollution Monitoring around some selected Thermal Power Plants of Uttar Pradesh, India

THESIS

SUBMITTED TO
BABASAHEB BHIMRAO AMBEDKAR UNIVERSITY
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Namita Gupta

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2017

Dedicated to my respected Grandparents, Parents & Family members

CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in the thesis entitled **"Studies on Lichen Diversity in relation with Air Pollution Monitoring around some selected Thermal Power Plants of Uttar Pradesh, India"** submitted for the award of Degree of Doctor of Philosophy in Environmental Science in the School of Environmental Sciences of Babasaheb Bhimrao Ambedkar (Central) University, Lucknow, is an authentic record of my own work carried out during 2013-2017 under the supervision of **Prof. S. K. Dwivedi**, Head, Department of Environmental Science, School for Environmental Sciences, Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow (Supervisor) and **Dr. D. K. Upreti**, Chief Scientist & Head, Lichenology Laboratory, Plant Diversity, Systematics & Herbarium Division, CSIR-National Botanical Research Institute, Rana Pratap Marg, Lucknow (Co-supervisor).

The matter presented in the thesis has not been submitted for the award of degree or diploma to this or any other University. I also declare that the thesis embodies my own research work, observations and analysis and also contributes towards advancement of knowledge in the subject. The experimental part of my research work was carried out by me.

Place: Lucknow

Date: 10.08.2017

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CERTIFICATE

This is to certify that the thesis titled **"Studies on Lichen Diversity in relation with Air Pollution Monitoring around Thermal Power Plants of Uttar Pradesh, India"** submitted by **Namita Gupta** is an original research work and has not been previously submitted in part or full for the award of any other degree or diploma to this or any other University.

The thesis submitted to Babasaheb Bhimrao Ambedkar University, Lucknow satisfies all the requirements as stipulated in the *Doctor of Philosophy (Ph. D.) regulations-1999 as amended in 2008/2010/2013* and it is fit for submission and evaluation for the award of the Degree of **Doctor of Philosophy** in **Environmental Science** of the University. The candidate has completed the research work for the full period prescribed and that the thesis embodies the results of her investigation conducted during the period.

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Among the different group of organisms, lichen in particularly considered as one of the best bioindicator of environmental changes either due to natural or anthropogenic factors. Lichens show differences in pollutants sensitivity towards the wide range of the area. Some species of lichens are more sensitive towards air pollution, while some species shows their tolerance to high level of air pollutants. On the basis of their sensitivity and tolerance, lichens are best and suitable species utilized as an indicator species for various pollutants including metal, metalloids, radionuclides and organic pollutants. Lichens are the most widely distributed group of organism in the World represented by 20000 species of which about 2450 species are known from India and 135 species from the state of Uttar Pradesh.

Lichen biomonitoring studies was introduced in India in the eighties of the last century, and it was after 1995 that more systematic studies were carried out in different regions and cities of the country. The biomonitoring studies with help of lichens in some cities of Uttar Pradesh, Uttarakhand, Maharashtra and Karnataka are available from India. However, a single information on pollution monitoring around Thermal Power Plants of Uttar Pradesh utilizing lichens is available. Thermal power plants are the major source of electricity generation in the country but also contributes pollution upto a greater extend to the environment.

Though, pollution monitoring in an area may be measured with help of equipments but the effect of pollution on biological organisms can only be studied utilizing the living organisms and lichens are considered one of the best organisms for such studies.

The list of publications (Appendix- I & II), ecological studies (Appendix- III) and statistical analysis of the data have been also appended at the end of the thesis (Appendix- IV).

The present thesis is an attempt to inventorize the lichens growing around Thermal Power Plants of Uttar Pradesh not only generate an awareness about lichens among common people but also will be of immense help to scientist, teachers, students and environmentalist in their studies. The thesis will also play an important role not only in preparation of database of lichens around thermal power plants of Uttar Pradesh but also to know the status of lichen diversity in the region. The thesis will also provide a baseline data for future biomonitoring studies.

+	Present; positive reaction
-	Negative; negative reaction
±	More or less; Plus or minus; present or absent; with or without
%	Percentage
µm	Micrometer
mg	Miligram
gm	Gram
ml	Mililitre
°C	Degree celcius
Alt	Altitude
AWAS	Awasthi Personnel herbarium
pH	Potentia Hydrogenii
cm	Centimeter
NTPC	National Thermal Power Plant Corporation
C	Calcium hypochlorite
DMSO	Dimethyl sulfoxide
I	Potassium iodide
K	Potassium hydroxide
OD	Optical Density
IAP	Index of Atmospheric Purity
Cfr.	Confer, compare (with)
Diam.	Diameter
LWG	Acroynm of NBRI Herbarium (earlier Lucknow Botanic Garden, LWG)
et al.	*et alii/et aliorum;* and others
eg.	*Exempli gratia*;for example
>	More than or greater than
<	Less than or lesser than
ppm	Parts per million
km	Kilometres
μgg^{-1}	Microgram per gram
D.W.	Dry weight
F. W.	Fresh weight
Chl.	Chlorophyll
PAHs	Polyaromatic Hydrocarbons
LSD	Least Significant Difference
mg/l	Miligram per litre
ANOVA	Analysis of Variance
&	And
GIS	Geographic Information System
GPS	Global Positioning System
MW	Megawatt
UV	Ultraviolet
TLC	Thin Layer Chromatography
KOH	Potassium Hydroxide
PD	*para*- phenylenediamine
Rf Class	Reference Class or relative front class or retention factor
HPLC	High Performance Liquid Chromatography
SD	Standard Deviation

nm	Nanometer
SEM	Scanning Electron Microscopy
EDX	Energy Dispersive Microanalysis
FTIR	Fourier Transform Infrared Spectroscopy
rpm	Round per minute
Min.	Minute/minutes
Fig.	Figure
edn	Edition
ed./ eds	Editor/ editors
sp. nov.	Species nova; a new species
Sp. (pl. Spp.)	Species
Sq	Square
var.	*varietas*; variety
viz.	*videlicet;* namely
i.e.	*id est;* that is
Hyphen (-)	Used to link together two words
Pp.	Prescribed page
N. D.	Not detected

Chapter- 1
Introduction

"Get good counsel before you begin and when you have decided act promptly".

1. Introduction

The word lichen is derived from a Greek word which denotes the superficial growth on the bark of olive tree. Theophrastus (370-285), the Father of Botany introduced the term lichen. Tournfort (1700 AD) proposed lichen as one of the genera of plant entities. The foremost taxonomic account under the genus lichen comprising 80 species was published comprised of 24th class of cryptogamic algae in **"Species Plantarum"** by Linnaeus (1753).

Lichens species collectively called "stone flower" in English, 'Patthar ka phool' in Hindi, 'Dagad phool' in Marathi; 'Kalachu' in Karnataka; 'Kalpasi' in Tamil; 'Richamkamari' in Urdu and 'Shilapushpa' in Sanskrit.

Lichens are being used as an effective biomonitors of air pollution. Several lichen species have been employed worldwide for monitoring of air quality (Conti and Cecchetti, 2001; Garty et al., 2003; Shukla and Upreti, 2007a, b; 2009). A large number of studies with reference to the pollution monitoring with higher plants are available in India; however, kind of studies with the help of lichens have been started recently. Contribution of lichen biomonitoring to the understanding of environmental changes, especially caused by pollution including the aggregation of pollutants are carried out worldwide in the recent few decades. The lichens can be used as "Yardstick" and can be used to calculate the biological effect of pollutants by measuring alteration at population, community or even the species level.

Lichens, which are epiphytic 'read' the environment different than do the vascular plants because lichens located above the ground and devoid of roots. Epiphytic lichens are best organism to study the effect of air pollution on lichen communities, lichen physiology and/ or growth and for the study of pollutant distribution on dispersion.

Lichens are one of the most worth able biomonitors of atmospheric pollution. For the estimation of biological effects of contaminants by measuring alterations at community or population level and as collective monitors of persistent contaminants, lichens can be utilized as sensitive indicators (Loppi et al., 2000). Lichens are peculiar plants in having strange impulsivity for acidic gases, but collect several organic and inorganic even radionuclides contaminants in huge amount beyond their physiological level and thus can be used as biological indicators of air quality.

Lichens can be used as an important tool to assess the level of air borne pollutants arising from anthropogenic activities, mining, construction, agriculture, automobiles, smelters (Sawidis et al., 1995; Garty, 2001). The sensitivity of lichens to pollution is related to the degree of reliance of the mycobiont (fungus) on the photobiont (algae) for energy required for metabolic activity. It is well evident that as stronger the reliance, more sensitive would be the lichen. The demotion of chlorophyll in the symbiotic photobiont is one of the most obvious mark of the harm that occur in sensitive lichens (Zaharopoulou et al., 1993). The sensitivity of photosynthetic parameter proves as the most suitable sign for advance biomonitoring.

Lichen growth rate, trapping of air borne soil particles and presence of element are affected by the accumulation of element within thalli and there are also some environmental factors which also contribute to the accumulation of elements (Garty, 2001).

Lichens are very sensitive to air pollution and alteration in air quality directly affects the lichen diversity, therefore, they are generally considered as good indicators of air quality (Seaward, 1993; Cislaghi and Nimis, 1997; van Dobben and ter Braak, 1999; Crespo et al., 2004). Lichens have certain characteristics viz., the perennial nature, absence of root and lack of cuticles which meet several requirements of the ideal biological monitors. The high capability of lichens to accumulate air pollutants resistance to environmental stress and longevity are the other features that make them most suitable for biomonitoring studies (Garty, 2001).

The first observation on sensitivity of lichens to air pollution dates back to 19th century when Nylander (1866), first suggested that lichens could be used as a very sensitive hygrometer to measure the health of the air. Disappearance of lichens from urban areas was recognized as early in the year 1800 and the "city effect" popularly called as ***lichen desert*** was first systematically mapped by Sernander (1926) in Stockholm. Subsequent studies involving more cities showed a clear correlation of zonation with the degree of pollution. The use of lichens in biomonitoring of particulate pollutants has gained increasing acceptance in recent years. A number of parameters are used to estimate the effect of air pollution on lichens (Ronrn and Galun, 1984).

In the last two-three decades, a large number of studies exist on response of lichen diversity and lichen community changes to air pollution. Lichens have been utilized as worldwide as valuable biomonitors for assessing changes in air quality by Conti and Cecchetti (2001); Jeran et al. (2002); Garty et al. (2003); Loppi and Frati (2006); while In India, lichens have been utilized as biomonitors of atmospheric pollution in different climatic zones by several researchers.

Lichens are generally regarded as nutritionally specialized fungi deriving carbon from algal or cyanobacterial phytobiont (Hallingbäck, 1991). Moreover, lichens are often dependent on the deposition of nutrients including nitrogen directly on the thallus (Nash III, 1996), the exception being nitrogen fixing cyanobacterial lichens (Rai, 1990). Tretiach et al. (2007) assessed influence of environmental conditions on sample vitality before and after exposure by transmission electron microscopy observation, measurements of C, N, S and photosynthetic pigment, CO_2 gas exchange and chlorophyll fluorescence. It is universally accepted that SO_2 has been the single most important pollutant causing elimination of lichens from urban and industrialized regions (Hallingbäck, 1991; Hawksworth and Rose, 1970).

Lichens are the organisms formed from a combination of fungi (mycobiont) and algae (phycobiont). Usually the second species is an alga, but sometimes it can be a photosynthesizing bacterium known as a cyanobacterium. However, in some of the cases more than one fungi can be found in the lichenized association.

When the moisture is completely absent, lichen tissues may undergo dryness and this is not a simple dehydration as it occurs in plants and animals, but the lichen becomes quite brittle when the body water is completely lost. Even the lichen can quickly absorb the water when the moisture is once again available and become soft and fleshy. Not only can lichens undergo this drying, but while they are dry and brittle, pieces may flake off and later grow into new lichens.

Lichens can grow anywhere i.e. on surfaces like soil, rock or even the sides of trees. Lichens may absorb certain mineral nutrients from any of these substrates on which it grows, but is generally self-reliant in feeding itself through photosynthesis in the algal cells. Lichens growing on the tree barks simply using the tree as their home. Lichens growing on rocks, though, may release chemicals which speed the degradation of the rock resulting in weathering process, and thus promote production of new soil.

Most lichens are temperate or arctic, though there are many tropical and desert species. Lichens seem to do better in drier environments where they are not often left in standing water. In bayous and in cool rainforests, large lichens, species of *Usnea* known as "old man's beard" may often be seen hanging from the branches of trees. Though there is considerable water in these habitats, the air is not saturated, and drying breezes may serve to desiccate arboreal organisms.

1.1 Lichen Symbionts

Lichens are an outstanding successful group of symbiotic organisms (algae and fungi) available in a wide range of habitats throughout the world. The lichens are composed of the photosynthetic structure called **photobiont** and the heterotrophic fungus, the **mycobiont**. Lichen- the mutual association of an alga (green and/ or blue-green) and fungus. The symbiotic association of two different components resulted in a vegetative structure (thallus) that appears to be distinct plant (they are not plant) and have ability to grow on a variety of substratum including natural as well as man-made artifacts. The mycobiont belongs to Ascomycetes (app. 80%), Basidiomycetes (app. 1.5%) or Deuteromycetes (app. 0.5%) that have established symbiotic association with green alga. The algae and the fungi lose their original identity when they have in the association and ultimately behave as a single organism (i.e. lichen), both physiologically and morphologically. The fungal partner in a lichen thallus is visible from outside and holds algal cell inside. The mycobiont predominates with 90% of the thallus volume and provide shape, size, structure and color to the lichen, with partial contribution from algae.

Hence, the lichens are placed in the Kingdom **Mycota** (fungi). The fungi which are present in lichen thallus are called as Lichenized fungi. Likewise, in order to algal partner in lichen, it has chlorophyll pigment which is used for the process of photosynthesis. They provide nutrition to the fungal partner. Only cyanobacteria have ability to use the nitrogen gas from the atmosphere for the formation of amino acid but it is neither done by algae nor fungi.

The unique anatomical (absence of cuticle and root) and physiological (poikilohydric and absorbance of nutrient from thallus) characteristics allow lichens to grow in all types of domains. The unique association probably evolved as an adaptation to the varied microhabitats with standing extreme microclimate condition unfavorable for the fungi and algae in isolation (Negi and Upreti, 2000). Lichen can also absorb moisture from the atmosphere in the presence of high humidity and low temperature. This quality of lichens is very much common in desert and Polar Regions and also on rocks, monuments, trees etc.

The presence or absence of certain plant or other vegetative life can provide important clues about the health of the environment in an ecosystem. Due to absence of root, water and gases are exchanged in the entire lichen thalli as the plant have access to soil nutrient pools and must depend on deposition, water seeping over substrate surface and atomic and other dilute sources of nutrients.

1.2 Morphology of lichen thallus

The morphology of lichens does not vary with seasons; thus accumulation can occur not only throughout the year but it has cumulative accumulation of organic and inorganic metals of many years. Lichens usually have longevity which led to their use as long-term integrators of atmospheric deposition (Sloof, 1993). The vast geographical range of lichens helps to provide information for monitoring of pollutants from a wide range.

Lichens of different types are similar in their basic structure i.e. the presence of an algal and a fungal partner but based on their distribution in a thallus, they are divided in to two forms:-

1.2.1 Homoiomerous/ Homogenous- When two symbionts are uniformly distributed throughout the thallus, it is known as homoiomerous; example *Collema.* The photobiont and mycobiont hyphae are uniformly distributed. The homoiomerous gelatinous lichen absorbs much more water in diffusion to the photobiont is strongly limited or may even blocked in supersaturated thalli; and CO_2 can become the limiting factor (Fig-1.1A).

1.2.2 Heteromerous- The photobiont cell filaments are stratified in a layer, usually below the upper cortex and the thallus is known as heteromerous. The main subdivision is into upper cortex, photobiont layer, medulla and lower cortex. Despite that, the lichen thalli occur in different growth forms recognized in lichens (Fig-1.1B).

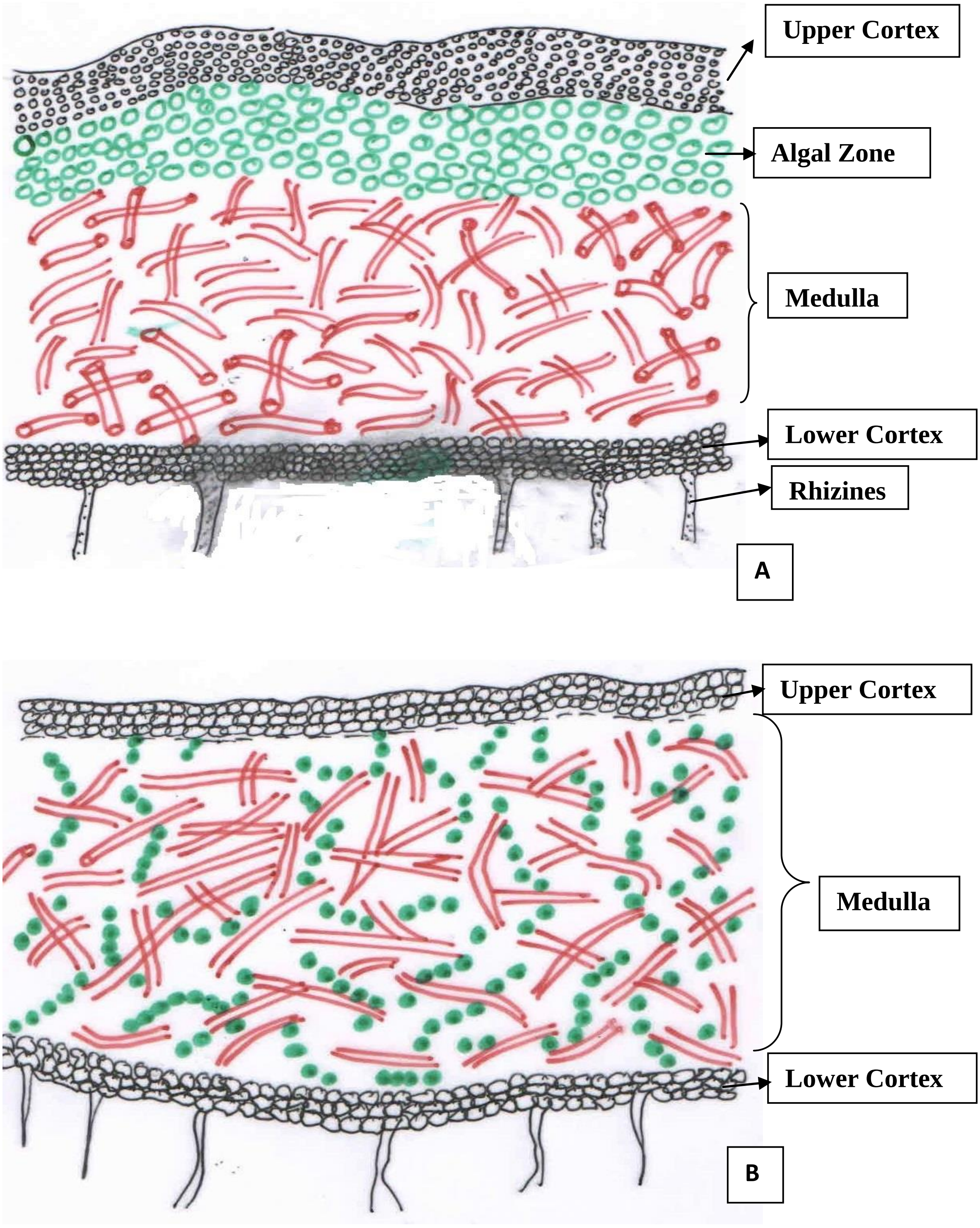


Fig-1.1: Structure of Lichen Thallus: (A) Structure of heteromerous lichen thallus; (B) Structure of homiomerous lichen thallus

1.3 Growth and Growth forms of lichens

Lichens are perennial, slow growing organisms in nature that maintain a fairly uniform morphology in time (Nyangababo, 1987; Puckett, 1988; Garty, 1993) are highly dependent on the atmosphere for nutrients, and do not shed parts. The lack of waxy cuticle and stomata allows many contaminants to be absorbed easily over the whole lichen surface (Hale, 1983) without exhibiting damage by permitting monitoring over wide areas. Rapid uptake, collection of cations and their longevity are the other features of lichen (James, 1973). Lichen possess noteworthy properties of ion- exchanges to resins (Knight et al., 1961) and are therefore suitable for restraint and accumulation of air borne metals (Robert, 1972).

On the basis of their general habitat of growth form and manner of attachment to the substratum, these are:-

1.3.1 Crustose lichens- They forms a crust over the substratum. They are attached to soil, rock, or tree bark by the hyphae of 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. A patch of crustaceous lichen may belong to one species and yet be composed of many individual, which are fused together. For example: *Ochrolechia foregoneness*.

The thallus of crustose lichen is of insignificant size. It is flat, thin and usually without any distinct lobes. Simple crustose lichen thallus is homoiomerous (no distinction of different layers). They lack cortex therefore, granular in structure. Water loss is restricted primary to the upper exposed surface and these organisms can tolerate extreme habitat, such as bare rock surface. In the majority of crustose lichens the protective layers is usually formed by horizontally or periclinally compact hyphae to form a cortex.

1.3.2 Foliose lichens- They are leaf like, flat and only partially attached to the substratum by the rhizines arising from the lower surface. The foliose thallus may consist of a single lobe which is usually rounded. It is attached to rocks and twig by Rhizoids like out growth which arise from its lower surface eg. *Flavoparmelia* and *Lobaria.* Foliose thalli are either Homoiomerous (no distinction of different layers) or Heteromerous (thallus is stratified into layer). Thalli are generally orbicular, suborbicular or irregular in outline with rotund-sub rotund, narrowly elongate or lacinate lobes. Lobes remain discrete from each other become imbricate or crowded.

1.3.3 Fruticose lichens- The lobes of fruticose lichens are hair like, strap shaped or shrubby. The lobes may be flat or cylindrical. They always stand out from the surface of the substrate. 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*) (Fig-1.2).

Depending on the position of the supporting tissues, the stiffness of the fruticose lobes is achieved by two different types-

(1) In some lichens, the hypahe 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 prosoplectenchymatous or pseudoparenchymatous with hyphae being closely cemented.

(2) In second type of fruticose lichen, the supporting tissues are situated in the center of the medulla. A central chord or axial stand is constructed from thick walled, perpendicular and agglutinated hyphae. This central axial stand gives the requisite tensile and skeletal strength to pendulous lichen.

On the basis of sensitivity of lichens to the pollution, they exhibit different level. The following series of lichen growth form shows elevation in air pollution sensitivity. **Crustose lichens (crust like, flat and tightly adhered)** are considered to

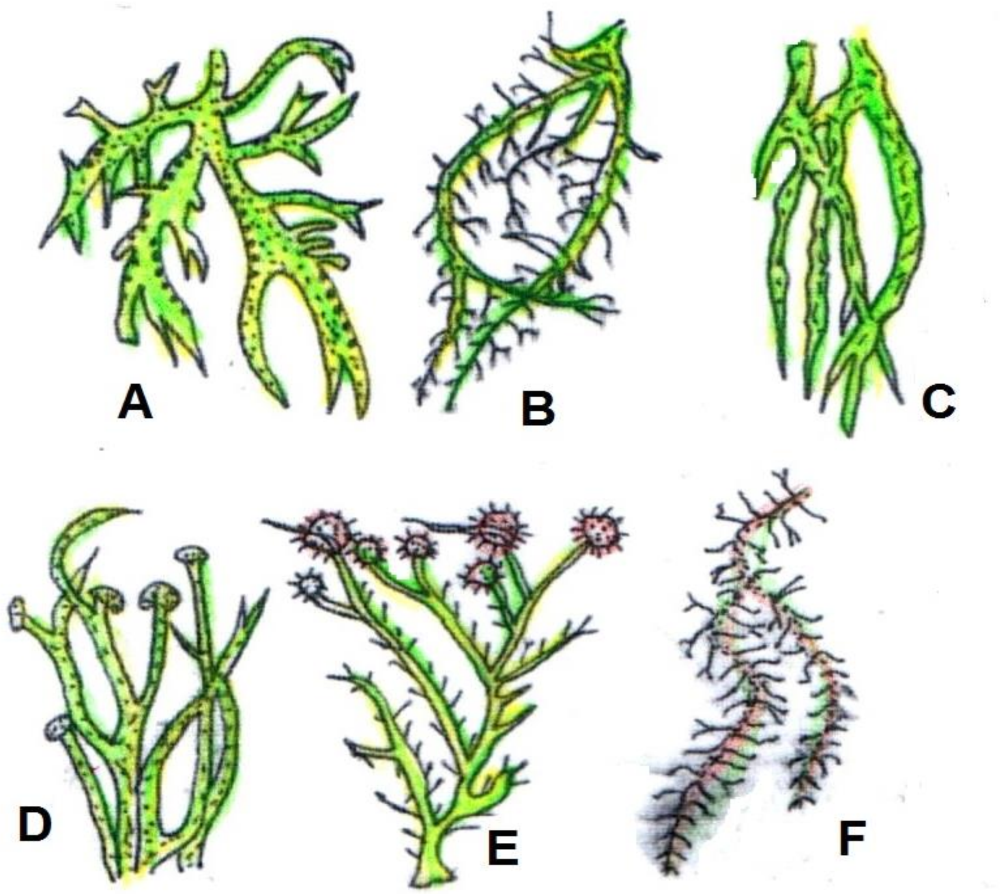


Fig-1.2: Different types of fruticose thalli; (A) *Rocella montagenii* with marginal soralia, (B) *Bryoria himalayana*, (C) *Evernia mesomorpha*, (D) *Ramalina* sp., (E) *Usnea* sp., (F) *Usnea longissima*

be tolerant to pollution; **foliose lichens (leafy like, loose margin)** and **fruticose lichens (shrubby lichen)** are more or less sensitive to the pollution. *Ramalina, Pseudocyphellaria, Lobaria, Usnea* are some of the most sensitive lichens which are available in forest, park and refugees (McCune and Geiser, 1997). Harmful level of sulphur and nitrogen containing accumulation or exposure to fluorine gases and SO_2 shows decline in the biomass of these genera.

Lichen Types on Habitat Based

Based on the type of substratum, lichens are classified into following categories: **Ramicolous** (growing on the twigs), **Folicolous** (growing on leaves), **Saxicolous** (growing on stones of rocks), **Corticolous** (growing on bark, tree trunk or wood),

Muscicolous (growing over mosses), **Terricolous** (growing over soil), **Ligncolous** (growing on dead wood).

Lichen changes at the community and population level are used as sensitive indicator of the biological effect of pollutants (Richardson, 1991). Lichens have different levels of sensitivity to the pollution which increases among growth forms in the following manner: Crustose (flat, tightly adhered, crust-like lichens) < Foliose (leafy lichens) < Fruticose (shrubby lichens).

1.4 Appendages and Attachment Organs

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

1.4.1 Rhizines: They grow from underside of thallus and consists of strongly coglutinated prosplectenchymatous hyphae. Rhizines are commonly found in foliose lichens. Rhizines are simple, richly branched, are also found in squamulose, crustose, fruticose lichen growing on rock tissues, over loose sand and soil. Rhizines are generally brown or black, simple to branched, eg: *Phaeophyscia* and *Parmelia.* The length is much variable. Rhizines are generally formed on lower surface when it is corticated thallus. The nature and branching of rhizines are often characteristic of different taxa. The tip of rhizines often poses adhesive discs. These help to attached them to the substratum. Anatomically they are composed of thick walled, confluent hyphae.

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

1.4.3 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.

1.4.4 Tomentum: They consist of densely arranged short hair like hyphae. They may be formed on the upper and lower cortex. These hair-like structures may form a felted hissute or cottony mat. The tomentum may become thick spongy layer of net like branched hair.

1.5 Reproduction in lichens

Lichens like all lower plants have simple organization and are capable of reproducing asexually and sexually. Genetic make-up 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.

1.5.1 Vegetative (Asexual) Reproduction

- **Isidium (pl. Isidia):** An isidium is an outgrowth on the surface of the thallus in many lichens. Morphologically the isidium is of various shape and size. It may be cylindrical, simple or coralloid branched. It is globular to cylindrical in many species of *Collema* and *Leptogium,* Squamuliform to microphylline in *Parmelia reducta, Peltigera praptextata* and *Punctellia rudecta.* The density and size of isidia are governed by ecological and environmental conditions (Fig-1.3) (Awasthi, 2000).
- **Soredium (pl. Soredia):** Soredia is a minute vegetatively produced propagule (lichenized diaspores) consisting of a few cells of the photobiont that are interspersed and enveloped (but not corticated) by the hyphae of the mycobiont. Dimensions of soredia are usually 50-100 µm across only occur on the surface of the thallus in diffused manner in several species (Fig-1.4) (Awasthi, 2000).
- **Fragmentation:** It is a common reproduction method. Dry lichens are brittle and small fragments break away and separate from the main thallus. Species are blown away and give rise to new thalli.

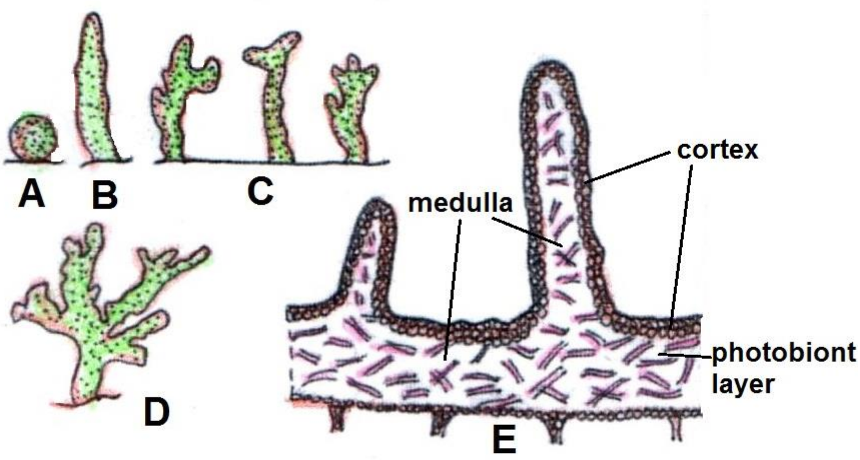


Fig-1.3: Types of isidia and nature of isidium; (A) globose isidium (*Collema* sp.), (B) filiform isidium (*Parmotrema tinctorum*), (C) Coralloid isidia (*P. tinctorum*), (D) Squamulose or microphylline isidium (*Punctelia rudecta*), (E) Section of *Parmelinella wallichiana* thallus through isidia showing the continuity of the layers of cortex, photobiont layer and medulla of the thallus and isidium

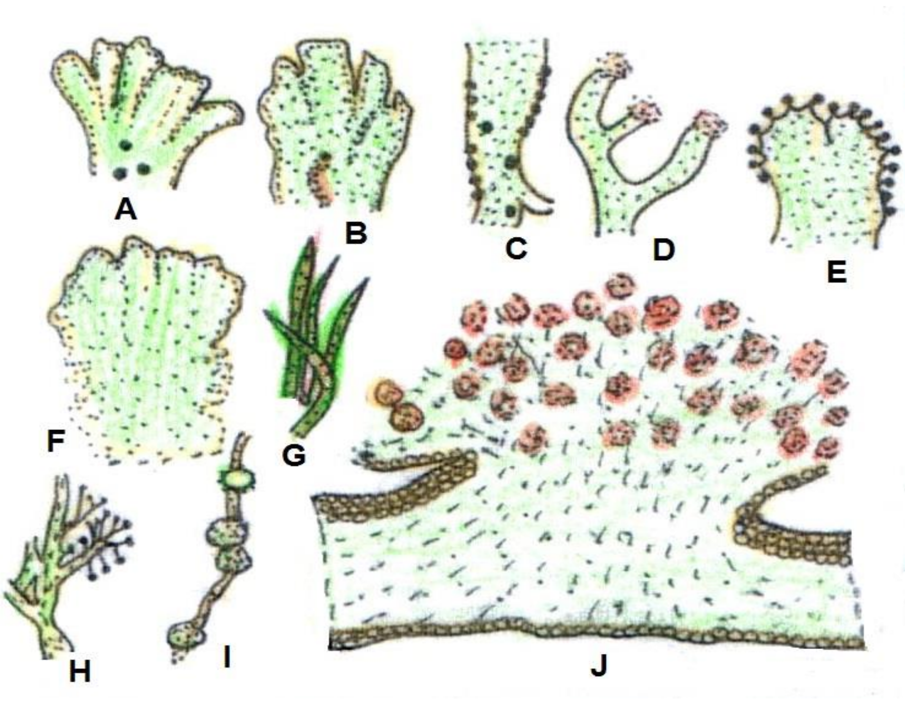


Fig-1.4: Types of soralia and section through soralium; (A) laminal capitate soralium (*Dirinaria appalanta*), (B) laminal soralia (*Flavoparmelia caperata*), (C) laminal to marginal soralia (*Rocella montagenii*), (D) labriform (lip-like) soralia (*Hypogymnia vittata*), (E) marginal capitate soralia (*Rimelia reticulate*), (F) marginal soralia (*Parmotrema austrosinense*), (G) superficial diffused soredia on podetia (*Cladonia ramulosa*), (H) capitate soralia on ultimate fine branches (*Ramalina roseleri*), (I) laminal soralia on fronds (*Bryoria poeltii*), (J) V. S. of thallus of *Dirinaria appalanta* through soralium denoting soredia(s)

1.5.2 Sexual Reproduction

In lichens, sexual reproduction has been implies by the mycobiont and two symbionts together is not possible. The mycobiont basically produces similar reproductive structures in lichenized and non-lichenized conditions (when grow in culture medium) (Awasthi, 2000). The mycobiont of *Cladonia cristatella* produce apothecia like structures in culture medium (Ahmadjian, 1966). The female reproductive structure of the Ascomycetous mycobiont is a filamentous organ called ascogonium, which usually develops on the upper region of the medulla.

The ascogonial cells are uninucleate or multinucleate, cylindrical or ellipsoid. They may originate singly or may be in groups (Awasthi, 2000).

1.5.2.1 Perithecia: These are typically flask shaped structure, 0.5- 2 mm in diameter immersed in the thallus. A pore of 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 (Fig-1.5).

1.5.2.2 Apothecia: A typical apothecium is a disc or cup-like structure situated on the thallus surface in a partially immersed or sessile condition or raised above by a stalk as a pelate structure. A fertile region of the apothecium with asci and paraphyses called hymenium is superficially often brown or black. The tissue lying below the hymenium and from which the asci and paraphyses arise has generally been called hypothecium. A protective tissue known as exciple surrounds the hymenium and hypothecium laterally outwards.

The apothecium in which exciple is soft, pale or lightly coloured and non-carbonized is called biatorine and the one which is tough, horny and usually carbonized is referred to lecideine. In the thalline exciple, tissues of the thallus are involved in the development and the apothecium is known as lecanorine (Fig-1.6).

1.5.2.3 Hymenium: The region of hymenium is the most important part of an ascocarp (perithecium/apothecium) as the sexual reproductive units, the ascospores,

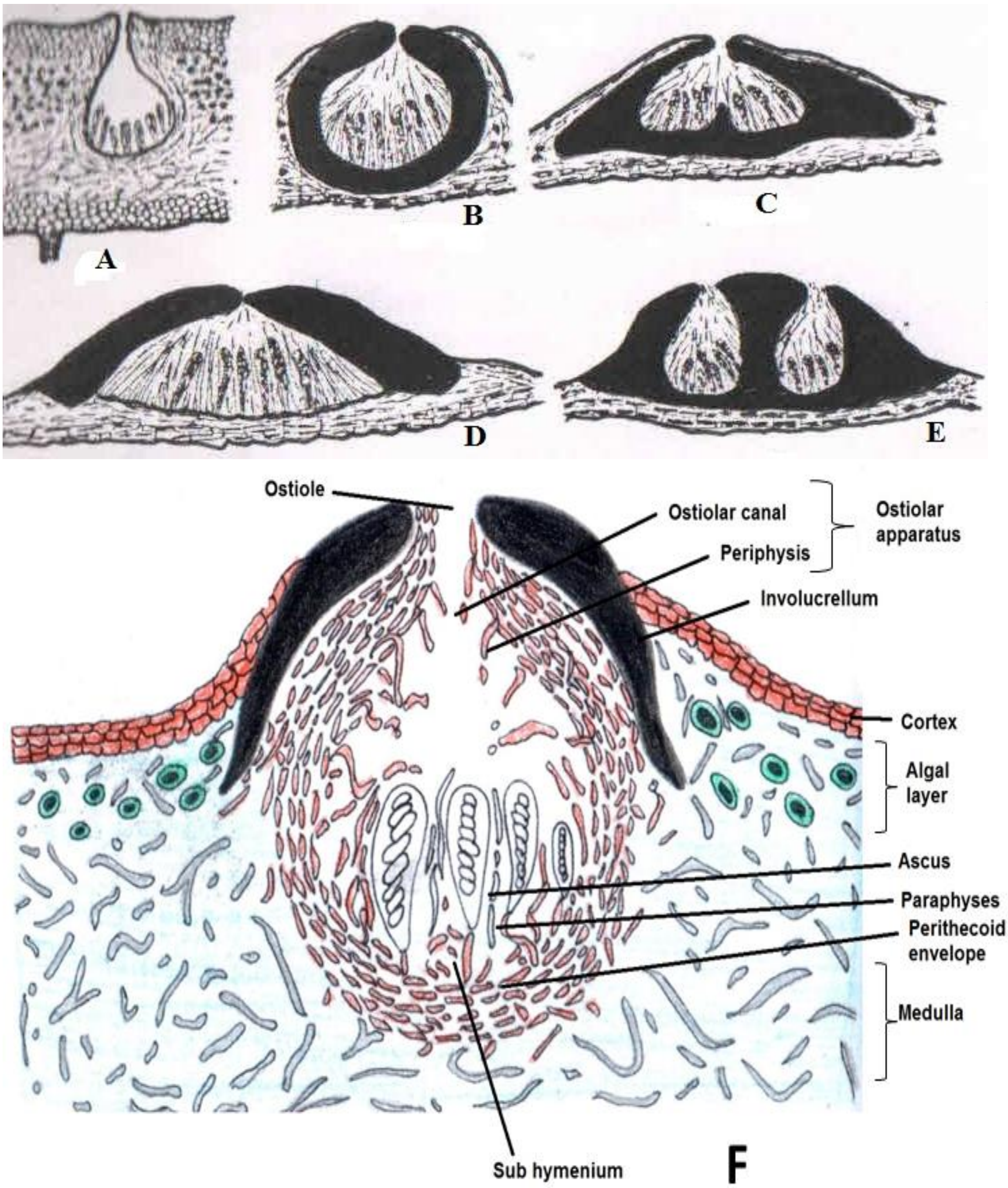


Fig-1.5: Types of Perithecia: (A) immersed perithecium with colourless, entire peridium in *Dermatocarpon vellereum*, (B) partially immersed perithecium with entire, carbonaceous peridium in *Pyrenula introducta*, (C) more or less emergent perithecium with entire carbonaceous peridium and a columella at the centre in *Pyrenula elegans*, (D) more or less emergent perithecium with dimidiate peridium, and carbonaceous exciple, (E) emergent perithecia in a stroma, peridia entire, carbonaceous in *Melanitheca leucotrypa* (Awasthi, 2000), (F) Anatomy of Perithecia

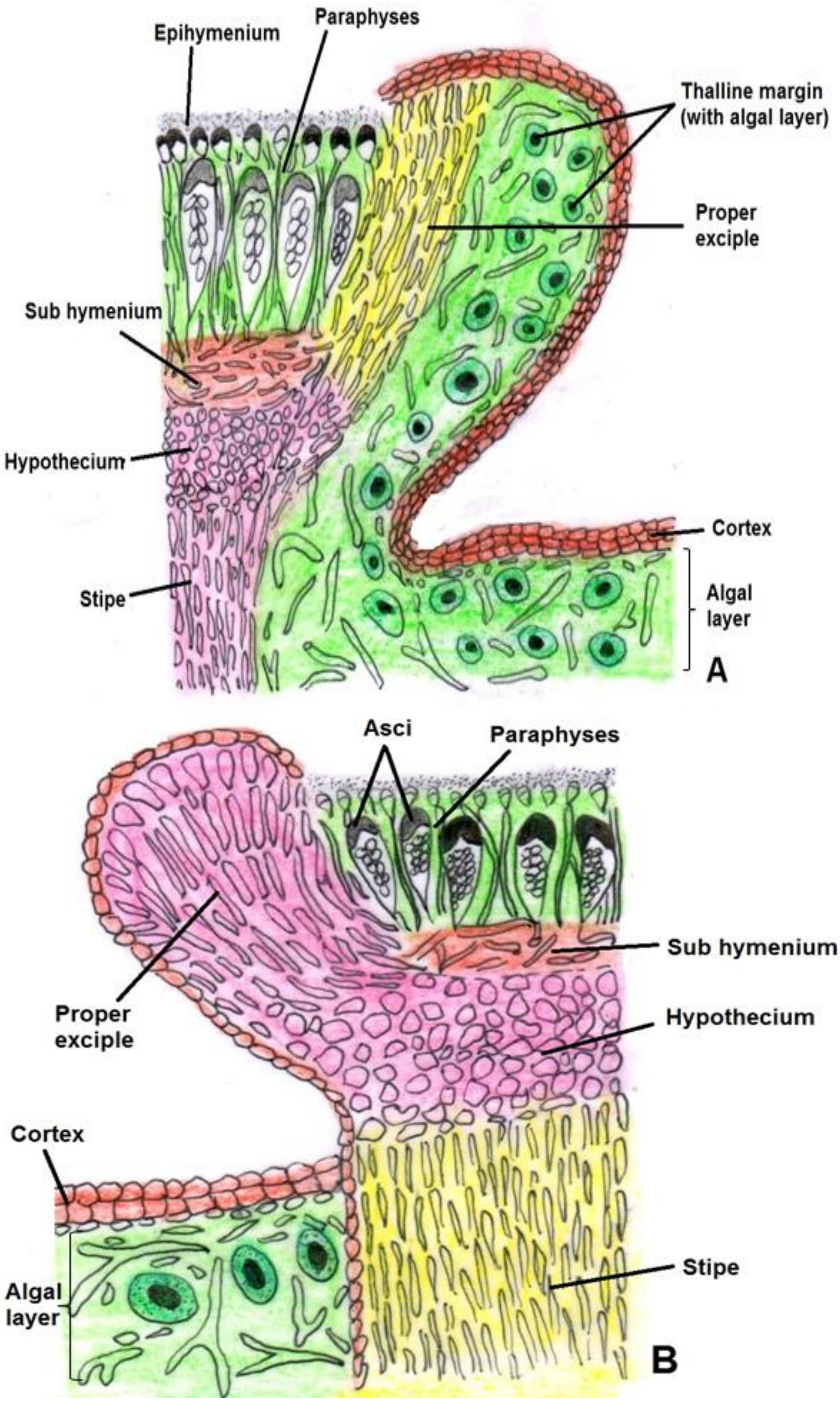


Fig-1.6: Anatomy of Apothecia- showing internal morphology: (A) Lecanorine margin and (B) Lecideine margin

are produced in this region. The fertile sacs or asci and the sterile protective hyphae, paraphyses/paraphysoids, constitute the hymenium. Ascus is the end art of the ascogenous hypha, and is variable in shape from cylindrical to clavate, claviform and pyriform to globose. This wall of ascus is generally of two types. In the majority of lichen taxa there is a single wall, and the ascus is called unitunicate. This wall is more or less uniformly thin, except at the apex where it is thickened and possesses a depression on the inner side of thallus. There are several variations in the detailed structure of thallus as indicated by reaction of iodine solution. The unitunicate asci are typically inoperculate and therefore the ascospores are released by a pore, rupture, break in or dissolution of the ascal wall.

1.5.2.4 Ascospores: The ascospores have generally been referred to ‘spores’ in lichenological literature. They are formed endogenously within the ascus as a consequence of two or more divisions of the diploid nucleus, the first division being meiotic. Usually their successive divisions take place resulting in the formation of eight ascospores.

Ascospores in Acarosporaceae are often as small as 2µm across, and in the single spored asci in some taxa of *Anthracothecium*, *Pertusaria*, *Varicellaria* and few others the ascospores are about 400 µm long and over 100 µm broad.

Shape of ascospores is variable i.e. oval, ellipsoid, oblong, fusiform, acicular and straight to spirally twist. There is considerable variation in their septation. They are simple, transversely 1-septate (2-celled) or multiseptate (many celled). The colour of ascospore is varies from hyaline to light brown, dark brown or black. Darkening of the ascospores takes place during maturation so that shades from hyaline to light brown ascospores may be seen in immature asci. In certain species of *Pertusaria*, the wall of ascospores is thickened into one, two or sometimes three distinct layers with concentric or radial zonation in each the end being more thickened (Fig-1.7)

Thus, there is a great diversity in the morphology of the ascospores in shape, size, colour, septation, thickness of wall and septa, ornamentation of the surface of ascospores wall and the number of ascospores per ascus, all of which are deceive taxonomic characters.

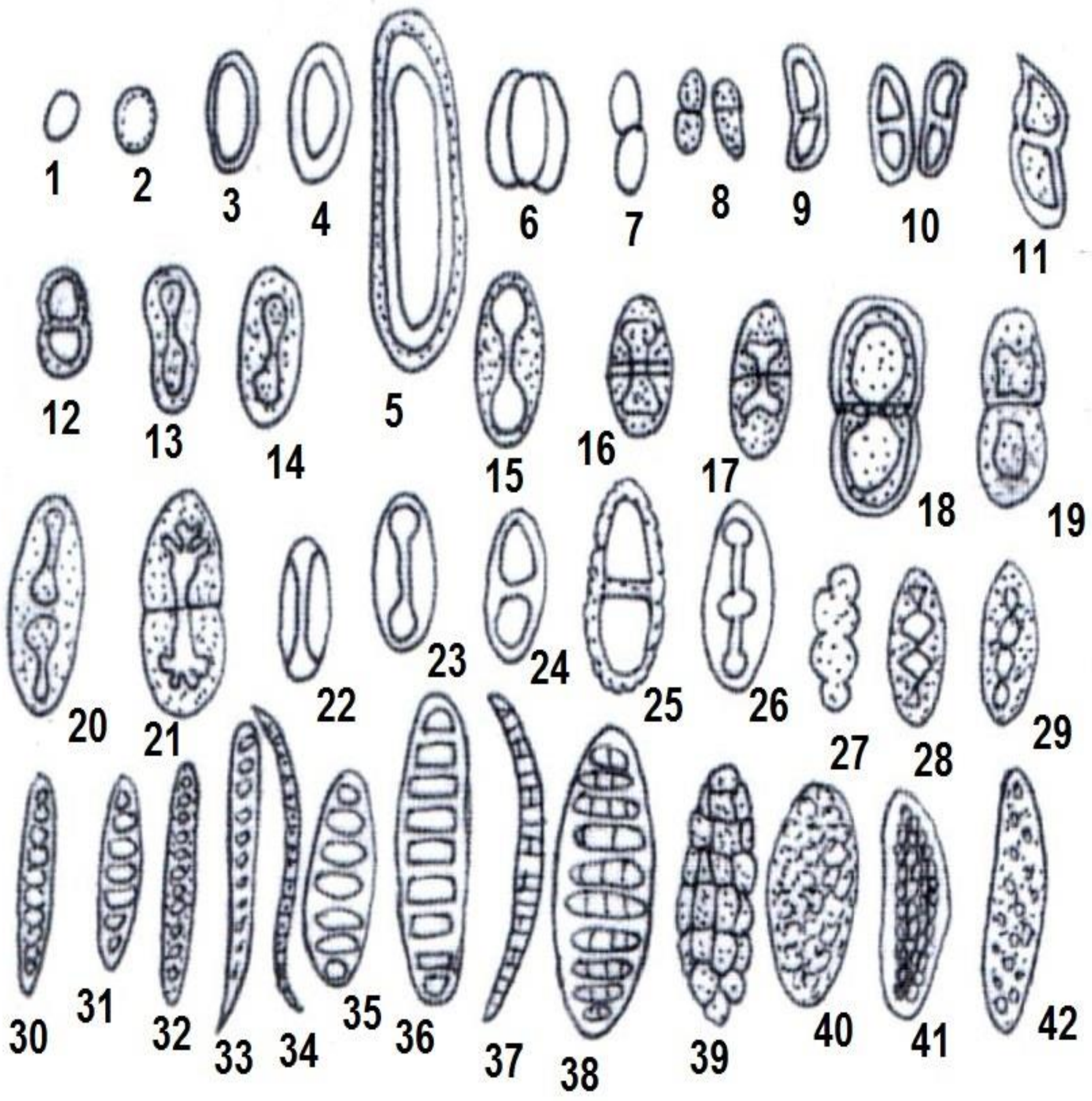


Fig-1.7: Different types of Ascospores met with in lichens: (1-6) Simple ascospores, (7-25) bicelled ascospores, (26) 3-celled ascospores, (27-29) 4-celled ascospores, (30-36) multicelled ascospores, (37-41) muriform ascospores (shaded ascospores are light brown, brown to brown-black) (Awasthi, 2000)

1.6 Physiology of lichens

Lichens are able to colonize in such environment that has extremes of humidity, temperature and light and they often occur in places where few other living things are able to survive. They have evolved a variety of ways to achieve this. One is their ability to switch off metabolic processes when that are dry and another is their limited need for nutrients. Lichens physiology varies according to the type of photobiont lichen morphology and the presence of lichen substances.

The physiology of lichen can be studied under following headings:

(a)Absorption of water- The lichens do not have special organ for absorbing and transpiring water. Absorption appears to be an entirely physical process. In general, water relation of lichens is similar to those of inert materials, such as agar, gel of cellulose. Mode of water absorption also depends on the form of the lichens. The crust forming lichens met their water requirement chiefly by the substratum, especially through the edges of areoles and partly through the general surface. The foliose leafy lichens absorb water through upper surface and through the hyphae, rhizines and tomenta, while fruiticose lichens absorb water through their general surface. The dimorphic lichens use their basal dead and decaying parts for the purposes.

Lichen thalli are able to withstand repeated witting and drying, and their tolerance to drying is much greater than in most other fungi studied. Substantial increase in water content is usually by the absorption of liquid water, although some species have a hydrophobic surface and occur in ecological niches where only water vapour (or liquid water from the substratum) is available. Absorption by general surface is followed by a quick penetration and distribution to different parts of the thallus. Lichen can absorb sufficient water from damp air to become physiologically active. Lichen can absorb water up to 4-13% and rarely up to 35% of their dry weight. *Ramalina misinforms*, a species of hot deserts, takes in sufficient humidity to 95%. CO_2 uptake is identical to that of a fully hydrated thallus. The process of absorption of water vapour and its accumulation in thallus is in much slower rate than by the process continues till the constant equilibrium value is reached.

(b) Respiration- Both the symbionts respire regularly under optimum condition at 20ºC; the rate of respiration in lichen has been reported to be 0.2 - 2.0 mg CO_2/gm dry weight/hour. An increase in water content in thallus increases the rate of respiration between photosynthesis and respiration. At high temperature when photosynthesis stops, respiration may continue and at extremely low temperature, photosynthesis continues, while respiration ceases. When an air-dried lichen is welted, there is an initial respiration rate, and this is accompanied by a rapid efflux of organic and inorganic solutes from the mycobiont.

(c) Nitrogen fixation metabolism- Nitrogen fixation in lichen is restricted to those containing cyanobacterial photobionts, either as the sole photobiont or in more complex three of four membered symbionts. All cyanobacteria containing lichens fix nitrogen, and there are reliable reports of other lichens showing this ability. Nitrogen fixation can only be obtained from the atmosphere by utilizing an abundant energy source, such as solar energy.

(d) Photosynthesis and Carbohydrate movement- The fixation of CO_2 in photobiont, photosynthesis provides the basis for lichen survival and development producing the carbohydrates needed for metabolism, structural components, osmotic regulation and cryo-and drought protection. The release of CO_2 in lichen respiration is subsequently related to the energy requirement of cell maintenance, nutrient acquisition and the potential for the growth of lichen.

The photosynthesis activity in lichen thallus is carried out by the photobiont. The three basic requirement- sunlight, water and carbon-dioxide are naturally available to the photobiont cell to synthesized organic food by the process of photosynthesis. The simple organic food synthesized by the photobiont is partially used by the photobiont itself and the other part is utilized by the mycobiont. The ratio is depending on the requirements of the symbionts. It is still not certain whether the role of fungus is active or passive because fungus maintains a low pH around the alga whose membranes are more permeable under this condition, fungus provides an enzyme hydrolyzing product which would normally form part of the algal wall and absorbs photosynthate which would be excreted until a particular external concentration had been developed. Fungus produces a factor or enzyme causing a direct increase in algal permeability.

The net rate of photosynthesis in lichens is reported to be 0.2-3.2 mg/CO_2/50cm^2/hour which is lower than in higher plant by being 1/3 to 1/6. The chlorophyll content in lichen photobiont is reported to be only 10-25% in comparison to that of the level of higher plant. The intake of atmospheric CO_2 varies in the wet and dry condition of thallus. Lichen growing in direct sunlight often darker in colour by the development of pigment in their cortical region. In CO_2 pathway, the nature and transfer of photosynthetic product can be demonstrated with the help of radioactive traces.

CO_2-----------------photobiont----------------X-----------------mycobiont

(H_2O+Light) (Photosynthetic product) (Unknown form) (Mannitol & other Fungal product)

The photosynthetic products such as glucose, ribitol, erythrol and sorbitol differ with photobiont. Glucose is the photosynthetic product in lichen with cyanobacterial photobionts. These compounds are first incorporated in the photobiont and then transfer to the mycobiont where they usually converted into mannitol.

1.7 Economic Uses of Lichens

The economic importance of plants and their utility is dependent on their abundance and capacity for quick renewal by high growth rate. In both these aspects lichens put up a poor show. In India, lichens are common in temperate and alpine regions of the Himalayas, hilly regions of peninsular India and along the sea coast. Lichens growing in nature, therefore, provide the basic raw material for economic utilization. Careful gathering of lichens at intervals of several years has to be resorted for their long-term utility. They have, thereby, been put to several uses like in dyes, pharmacology and medicines, perfumery, in food for human being and animals, indicators of air pollution, pioneers of colonization, Lichenometry (method of estimating the age of the substratum based on the age of lichens growing in it), absorption of radioactive nucleotides and other uses (Awasthi, 2000).

In view of their high chemical diversity and recent advancement in genetic engineering, potential of lichens clearly exists for the commercial exploitation of lichens, testified by the UK searching for novel pharmaceuticals and agrochemical.

1. Dyes of Lichens

Of all lichen dyes used by humans, none has attained greater historical and commercial significance than those of the coastal lichen commonly called orchalia weed or orchil belonging to the family *Rocellaceae.*

Dyes prepared from lichens have been in use for more than two hundred years. Woolen and silk have usually been dyed with lichen dyes as they are fast and make the fibers insect-proof, dye that are prepared are red, brown or yellow. Lichen was steeped in ammonia produced by distilling animals urine collected from the suburbs of Glasgow.

In addition, lichens containing gyrophoric acid and evernic acid can also be used for the some purposes. The usual method of obtaining the dye stuff is to spray ammonia (animal’s urine in older days) on the collected lichen materials and keep them for about a month for reactions to take place by ammonia and oxygen of the air. *Ochrolechia tararea* (cudbear dye), *Parmelia amphalodes* (red dye), *P. saxatilis* (yellow dye), *Cetraria juniperina* (yellow dye) and *Xanthoria parietina* (yellow dye) are the common dye yielding lichens used for dying from the ancient time.

An important use of the lichen dyes is in the preparation of litmus paper which is a sensitive indicator of acidity and alkalinity. It is prepared from lichens which contain the depsides erythrin, gyrophoric acid, evernic acid and ramalanolic acid.

2. Pharmacology and medicines

According to the 'doctrine of signatures' the creature marked those plants suitable for treating diseases by a resemblance to a specific part of the body. Thus, several lichens are illustrated in early herbals. *Labaria pulmonaria* which resembles the lobes of a lung was used for treating respiratory disorders, and hair moss was thought to be effective against disorders of the scalp. The *Xanthoria parietina* being yellow orange in colour used for treatment of Jaundice. The *Usnea species* being long hair like thalli used for strengthening hair. Lichens are still used by seminal Indians in Florida and Chinese herbal doctors.

3. Lichen used in perfumery

Evernia prunastri and *Pseudevernia furfuracea* are most frequently used lichens, being traded as 'oak moss' for perfumes. *E. mesomorpha*, *Prumastric, Lobaria pulmonaria* and *Ramalina* species are being used in the perfumery industry. Often extracts of lichens by methanol, benzene or petroleum ether are made and used along with other substances for scenting soaps and talcum powder.

4. Use of lichens as food

Lichen has got food value due to presence of lichen starch-lichenan. The polysaccharides present in lichens are used for brewing of beers and production of alcohol for human consumption. Many lichen species are considered as a good ingredient in popular dishes: *Everniastrum cirrhatum* and Ramalina spp., which grow in close proximity on three trunk and branches are collected, these are used for thickening of soups and in non-vegetation dishes. In Japan, *Umbilicaria esculenta* is used as a delicacy in the form of soup or part of salad. *Cetraria islandica* and *Cladonia* in Northern Europe are used in the preparation of soups, bread, porridge etc. The bitter content of lichen is removed by the treatment with potassium carbonate solutions.

5. Food for animals

Lichen acts a good material for both the categories of animals, that is the smaller one and the higher animals. The smaller animals comprising e.g. insects and mites feed on the apothecia of the thallus. Soredia are eaten up by snails, caterpillars and beetles etc. These insects can also develop a protective reason place to them, and this mimicry help these insects form being preyed upon.

Certain species of genera *Cladonia* forms a source of winter food. The reindeer and other cattle also feed on *Cladonia rengiferia*. This group of lichens is also known as reindeer moss.

6. Indicators of Air Pollution

Unlike other forms of plant life, lichen thallus is without cuticle and this type of structure makes the lichen as very much sensitive against the environmental pollution. Since industrialization, many species of lichen disappeared in great zones from the low-ground in Great Britain, an example being the foam of barb (beard moss) *Usnea orticulata.* It is mainly due to the SO_2 pollution, but the loss of habitat, in particular in the old wood areas, also led to the reductions of some species. The lichens are sensitive to the sulphur dioxide because their effective systems of absorption like consequence of sulphur once exposed the fast accumulation at the high levels of SO_2 pollution. Its partner, the alga, seems to be most affected by the sulphur; chlorophyll is destroyed and photosynthesis is blocked. The lichens also absorb sulphur di-oxide dissolved in water.

The lichens are largely used as environmental indicators or biological indicators. If the air is much polluted with SO_2, it is probable that no lichen is present, only green algae can be found. If the air is clean, the hairy and leafy lichens become abundant. Some species of lichens can tolerate high level pollution and are generally found on pavements, wall and barks of trees in urban zones. The most sensitive lichens are bulky and leafy, while the most tolerant lichens are curlier. Since industrialization several of the bulky and leafy lichens such as the species, *Ramalina*, *Usnea* and *Lobaria*, had ranges very limited, often confined to the areas of Great Britain with purer air such as the north and the west of Scotland.

One can observe a configuration of zone of lichen in large cities or around the industrial complexes, which corresponds at the average known SO_2 levels. The cartographic scale most generally sued is the scale of Hawksworth and Rose (1970), being composed of a scale of 1 to 10 (the lowest quality of the air), (the purest air) respectively. Certain species of lichen present on the bark of the trees can indicate the typical levels of dioxide of sulphur tested in a particular zone.

The method by which the index of atmospheric pollution (IAP) could be ascribed by the following formula:

$$\mathbf{IAP = 1/n\ (Q \times F)/\ 10}$$

Where, n = number of lichen spp. at a site

F = frequency (cover) of the species

Q = mean number of other species growing with the species in the area

7. Pioneers of colonization

Lichens have got special property to grow on any kind of substrate surface, of the rocks and boulders that are exposed by the receding glaciers, by landslides or by volcanic eruptions are broken down by lichens thalli. Crustose lichens gradually loosen the particles or crystals by a combined action of rhizines, hyphae, lichen acids and wetting and drying of lichen thalli. These continuous processes allow off or else accumulate to form soil with the growth of mosses.

Sometimes foliose and fruticose lichen may also grow on the rock surface. Example of the lichens growing foremost on bare rocks: *Acarospora*, *Aspicilia, Candelariella, Lecanora* and *Rhizocarpon.*

8. Lichenometry

Lichenometry is a method of estimating the age of the substratum based on the age of lichens growing on it. The slow growth of crustose lichen has been used in dating the rate of receding glaciers. These leave moraine rocks exposed which are colonized by *Rhizocarpon* species in the temperate alpine regions. *Rhizocarpon* species are known to live and grow for hundreds of years as they have very slow growth rate. An estimation of their growth rate per year as per a definite period is used to assess the total life span of the thallus growing at different distances from the mouth of the glacier. Time is calculated when the glacial ice may have receded exposing the rocks. Allowance for the time taken for the establishment of lichen, a slower growth of lichen at the initial stages, environment, and climatic changes that may have taken place and other adjustments are made for final calculation to interpret the movement of the glacier. Lichenometric methods have been successfully used in temperate alpine regions in northern countries of Europe and America.

9. Absorption of radioactive nucleotides

Lichens retain a higher percentage of radionuclides than other higher plants. Lichens have been found to accumulate three times more radionuclides as they have a high efficiency for retention of radionuclides for a long period of time. On the account of ability of lichens to retain radionuclides, they have been considered good meters of cumulative radioactive fallout. The harmful effect of the radio nuclides in lichens also has great importance in the food chain in the north boreal regions where reindeer is an important pet animal.

10. Miscellaneous uses

Lichen containing vulpinic and pinastric acid more known to cause toxicity in the central nervous system. Therefore has been used for poisoning wolves, e.g. of lichens *Letharia vulpina* and *Valpicidia pinastri*. The water extract of *Hypogymnia physodes* has been found useful against certain pathogenic fungi on higher plants. *Cetraria islandica* and *Lobaria pulmonaria* have been used for tannin leather. Species of *Cladonia* are often used for derivative purposes at homes.

There are many such uses of lichens which are quite difficult to enumerate, however along with their uses it should be kept in mind that their over harvesting may lead to the extinction of that particular species, hence, care should be taken before implementing them in any of such uses.

1.8 Air Pollution

Pollution is any undesirable change in the chemical, physical and biological properties of air, water and soil. The term "air pollution" is not a synonym of "air quality". Air pollution refers to the effect of pollutants on humans, animals, plants and inorganic artifacts as well as monuments. Air pollution has been the problem occur as countries become industrialized; growing cities, increasing traffic, rapid economic and industrialization. The urbanization is the increase in consumption patterns and unplanned urban and industrial development has led to the problem of air pollution. The surveys (i.e. on-site devices and analytical equipment in laboratories) are not necessary device to measure harmful pollutants.

Pollutant causes irreversible damage to living organisms. Damage can occur at all levels of biological organization, from the components of individual cells to ecosystems (Weinstein and Birk, 1989). Due to anthropogenic activities i.e. increasing population, increasing traffic, rapid economic growth, construction, unplanned developmental processes, vehicular emission and rapid growth of industrialization results in the increase in pollution level which ultimately cause deleterious impact on the living organisms. The places which have heavy tourist activity and vehicular activity are more susceptible to the increased concentration of pollutant as vehicular and anthropogenic activity result in emission of pollutant in the atmosphere. The major contribution in air pollution also includes a rapid immigration of population in urban areas, decrement in emigration, unplanned and management less developmental processes and higher degree of increasing consumer etc.

Apart from air pollution, lichen perfectly fits to monitor the environmental effects of global climate changes. The reaction of lichens to the stress is stronger and their intrinsic adaptability is weaker than that of most other organisms. The ecological niche of lichens is primarily determined by climatic factors such as precipitation, temperature and photosynthetic active radiation. As a result lichen communities mirror alteration in the global climate and pollution before most of other organism react (Upreti et al., 2009).

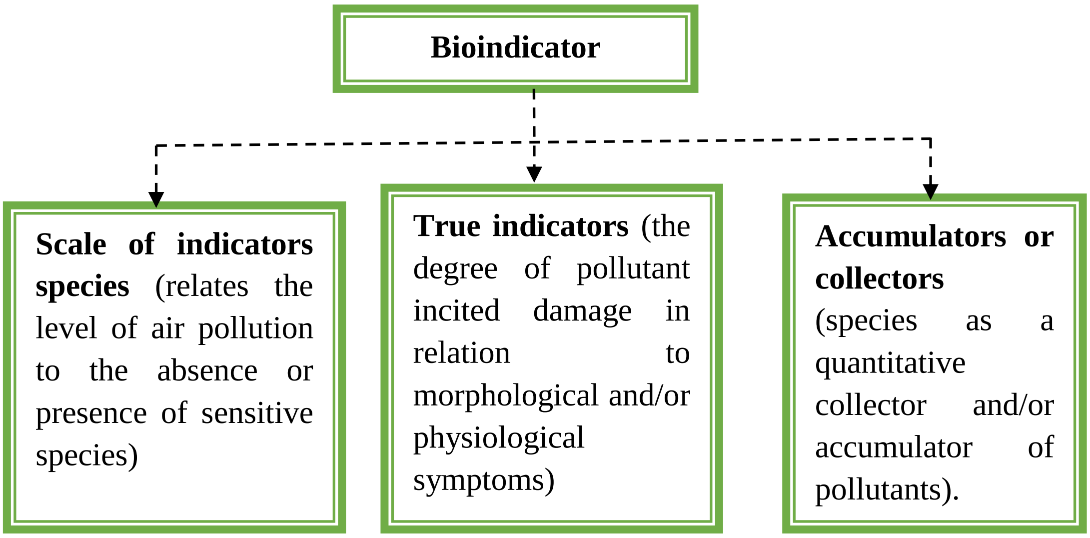
A large number of pollution monitoring studies with higher plants are available in India; however, such studies with utilizing lichens have been started recently. The primary sources of energy in India are renewable resources such as coal, wood etc. and its utilization in power generation is emerging as the biggest environmental problem. Because these emits fly ash, acid precursors, green house gases, non-combustible hydrocarbons, heavy metals and particulates matters. These pollutants can be carried to a long distance by wind and ultimately have a negative impact on both biotic and abiotic environment (Cicek et al., 2001).

Lichens are slow growing and assimilate metals at a rapid rate but release them at a low rate. Metal concentration in lichen thalli have been shown to correlate with atmospheric levels. Lichens are most valuable biomonitors of atmospheric pollution and also used as sensitive indicators to assess the effect of pollutants by measuring changes at community as well as population level (Loppi and Bonini, 2000) where decreasing metal concentration in species correlated with increasing distance from the source (Burton, 1986).

Lichens have a wide variety of growth forms but foliose lichens are better bioaccumulators with other growth forms (Swinscow and Krog, 1988). Lichens are peculiar plants in having special sensitivity for acidic gases but accumulate several organic compounds and elements in a large amount beyond their physiological needs and thus can be utilized as biological indicators of air quality. But there are several studies on pollution monitoring in which lichens are used as bioindicator (Conti and Cecchetti, 2001; Kircher and Daillant, 2002; Pirintsos and Loppi, 2008).

1.9 Biological Monitoring/Biomonitoring

The terms "bioindicator" and "biomonitors" are not interchangeable. The term "bioindicator" is related to the response of organisms to different types of pollution. It refers to the capability of the organism to indicate the presence and amount of atmospheric pollutants (Sloof et al., 1988; Nimis et al., 1993). According to Grodzinski and Yorks (1981), Bioindicator can be categorized into three main groups:



Bioindicator and/or bioaccumulator that provide quantitative information on levels of pollution and allow the identification of change in the course of time are defined as "biomonitors" (Manning and Feder, 1980; Martin and Coughtrey, 1982; Sloof et al., 1988; Nimis, 1992; Nimis et al., 1993). Biomonitoring is a complementary method or as an alternative method for the assessment on a long term pattern. The important characteristics of biomonitors are (a) The organism must have the capability to accumulate metals in measurable amounts; (b) The vegetative part of the organism must be readily available in terms of quality and distribution to make unbiased sampling possible; (c) The study must be repeatable; and (d) The cost of collection and analysis should be acceptable defined by Martin and Coughtrey (1982).

The first study on bioindicator date back to 1960s and the information related to the biomonitoring (eg. using plants or animals) is commonly decreased either changes in the behavioural pattern of the monitor organism (i.e. physiological and/or ecological, morphological) or the concentration of the particular substances in the monitor organisms. The biomonitoring approach is related to the common occurrence of the organism in the studied area and remote area, sampling methods and the necessary equipments.

Biological monitoring or Biomonitoring is the use of biological organisms to assess changes in the environment commonly due to anthropogenic causes. It involves the use of indicators, indicator species or indicator communities; and their presence or absence reflects the environmental conditions.

Biomonitoring is also used as a means to assess concentration of element and its deposition. Various monitor materials have been applied in pollution monitoring are lichens, mosses, ferns, grass, tree bark, tree rings etc. Lichens have the most common occurrence among all biological species used in it.

Lichens are the best indicators of atmospheric pollution and also exhibit the sensitivity to microclimatic changes. Lichens are excellent biomonitors of changes in air quality to their differential sensitivity to various air pollutants (Nash and Egan, 1988). Lichens have some remarkable feature that makes them standard biomonitoring organisms. The high capacity of lichens to collect pollutants of air, protest to the stress of environment and longevity are the other characteristics that make them most fitting organisms for the studies of biomonitoring. Amid various monitors of atmosphere, lichen have been broadly utilize for spatial and temporal accumulation of several pollutants (Freitas et al., 1999).

Lichens can be utilized as the monitors of pollution by three different ways: (a) by identifying and mapping of lichen species present in the area; (b) by transplant the healthy lichen from non- polluted area to the polluted area and measuring the decrement in the structure of thallus; and (c) sampling of an individual species and measuring contaminants collected in the thallus (Pfeiffer and Barclay-Estrup, 1992). Thus, the monitoring alteration in the distribution of lichens could be a serviceable tool to examine bioclimatic feature of an area.

The monitoring with lichens can be performed in any season as lichens are available throughout the year. Most of the lichens have large geographical area which allows the study of pollution gradient over large ranges (Fig-1.8). The sensitivity/tolerance together with their morphology and anatomical feature makes lichen useful for evaluation of pollutant collection in an area.

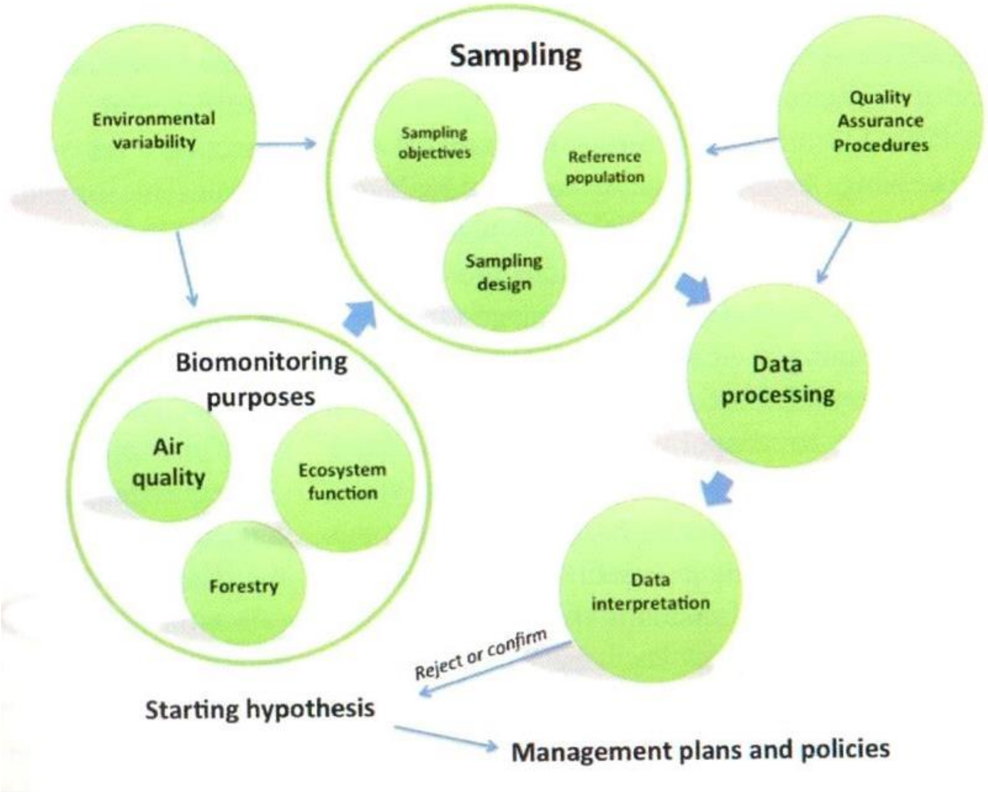


Fig-1.8: Representation of the operations for lichen biomonitoring program (Upreti et al., 2015a)

The role of lichens as a sensitive biomonitors of the atmospheric accumulation of inorganic metals can be enhanced or increased by the impact of different metal compounds and their physiological process. To assess the environmental changes, biological monitoring can be fruitfully utilized as timely caution/ notice system. The approach is based on the imagination that if any alteration occurring in micro-climate significantly harm the biota (Garty, 2001). The utilization of biomonitors permits monitoring of separate situation at low cost (Adriano, 2001).

1.9.1 Types of Monitoring

Due to their peculiar characteristics (i.e. morphological, anatomical and physiological), lichens are one of the most valuable biomonitors (Markert et al., 1999; Kircher and Darllant, 2002). The use of lichens to monitor metal deposition both as active (transplantation) and passive (lichen living *in situ*) monitors from a long time at various parts of the world are reviewed by Garty (2001).

Lichens can be used as sensitive indicators to estimate the biological effects of pollutants by recording changes at the community and as accumulative monitors of persistent pollutants which can be estimated by assaying their trace element contents (Pirintsos and Loppi, 2008). Lichens are used as passive pollution monitors because they accumulate a variety of pollutants in their thalli at levels well above environmental concentrations and their own physiological needs.

Both active (transplant) as well as passive biomonitoring studies utilizing lichen have been carried out in India in different regions against various pollution sources (Pandey and Upreti, 2000; Pandey et al., 2002; Bajpai et al., 2004; Saxena et al., 2007; Shukla and Upreti, 2007a, b; 2008; Bajpai et al., 2009; 2010a, d), but such studies around thermal power plant area are lacking.

The active monitoring and accumulation of substances are widely used in India but application of phyto-sociological methods in air pollution monitoring using plant communities rather than single indicator species. Air pollution alters community structure which is produced by changes in the community composition. Wirth (1988) defined the advantages and disadvantages of phyto-sociological approaches to monitoring temporal and spatial changes in air quality.

A number of studies have assessed the damage in transplanted lichens by using physiological parameters such as rate of respiration (Baddeley et al., 1972), decrease of ATP content, variations in respiration levels (Kardish et al., 1987), photosynthesis (Showman, 1972; Ronrn and Galun, 1984; Calatayud et al.,1999), chlorophyll content and degradation (Kardish et al., 1987; Ronrn and Galun, 1984; Garty et al., 1988; Balaguer and Manrique, 1991; Zaharopoulou et al., 1993), production of stress ethylene (Garty et al., 1997) and Malondialdehyde (MDA) content (González and Pignata, 1994).

1.9.2 Importance and relevance of biomonitors: The importance of biomonitors well evident by the statement that there is no better indicator of the status of a species or a system than a species or system itself (Tingey, 1989).

Biomonitoring is of great interest in cities having fast pace of urbanization and industrialization which encounter the serious problem of pollution. Recently, various researchers have monitored the heavy metal pollution using lichens in different geographic regions of the world (Godinho et al., 2008; Bergamaschi et al., 2004; Carreras and Pignata, 2002; Conti and Cecchetti, 2001; Upreti and Pandey, 2000; Loppi and Bonini, 2000) by using different growth forms of lichens in various climatic conditions.

Biomonitoring studies provide valuable information regarding the quantity and quality of pollutants in the atmosphere and can be very effective as an early warning system to detect environmental changes (Seaward, 2004). Different biomonitoring organisms have been used for the atmospheric air pollution monitoring (Steinnes, 1977; Coskun, 2006), among them lichens are first organisms used as bioindicator for assessment of air pollution (Garty, 1993).

Lichen flora have been used as indicators for monitoring sources of pollution at industrial levels (Sloof, 1995; Guidetti and Stefanetti, 1996) or by transplantation from uncontaminated areas to places devoid of lichen growth (Bajpai et al., 2004;

Garty et al., 1996; Jeran et al., 1995; Levin and Pignata, 1995). LeBlanc and Rao (1961) assessed the effect of air pollution on lichens by the transplantation technique for the first time.

1.10 Lichen as an Ecological Indicator

Indicators may be used for measuring a variety of ecosystem characteristics including the number of species grown in an area, the level of pollution in an area and changes in climate. Ecological indicator refers to the species which are highly sensitive to pollution, habitat fragmentation or other stresses. Lichens are very sensitive to the environment and the substances or element which can be used by several scientists as a way of measuring the health of the environment where lichens live. The indicator is changing only when we find that the monitor or indicator species which have high tolerance capacity of pollution.

The use of ecological indicator in air quality monitoring has some limiting factors such as space–time fluctuations could lead to sampling errors, low concentrations of several micro-contaminants could lead to difficulties in methodology, either the intermittent or the sporadic emission of contaminants is difficult to ascertain, the biological tolerance limits of the species concerned might not be taken into consideration and dose–effect response is not linear, and this may cause interpretation problems in evaluating damage to organisms and ecosystems (Conti and Cecchetti, 2001).

Lichens are also "traps" for environmental contaminants as the contaminants or pollution will collect in lichens thalli. The lichen thalli are influenced both by their present condition as well as by the condition that they are faced in the past. The advantage of using indicator species to assess the change in an environment and it is a better understanding to assess the lichen in an environment for the cumulative changes in pollution.

1.11 Lichen as a Biological Indicator of Pollution

Lichens are as widely spread throughout world for air pollution monitoring and it contributes to our understanding of environmental disturbances that are usually caused by pollutants and other environmental impacts. The lichens used as biomonitors of geothermal air pollution dates back to the beginning of the 20^{th} century when Bargagli- Pertucci (1915) reported the absolute absence of lichens in the geothermal area of Larderello (Italy) contrasting with their abundance in the surrounding regions.

The use of lichens in biomonitoring of particulate pollutants has gained increasing acceptance in recent years (Brodo, 1961). Lichens are highly sensitive to air pollution and for that purpose it is used as pollution indicators. There are three growth forms of lichen in which the fruticose and crustose forms are most and least vulnerable respectively, but foliose has intermediate vulnerability in reference to air pollution.

Lichens are highly diverse organisms offering a number of physiological and morphological characteristics which enable the assessment of several environmental and ecological factors. In the recent years there has been a great concern about the loss of lichen diversity in India (Upreti, 1995a).

Lichens cover 8% or more of the earth's terrestrial area (Ahmadjian, 1995). The pollutants (like SO_2 and O_3) which are absorbed by the lichens leads to loss of chlorophyll, reduced rate of photosynthesis and eventual plasmolysis of algal cells (Rao and deBlanc, 1965). In particular, sensitivity to SO_2 is a factor in most classifications. Another suggested classification is based on semi-quantitative characteristics or according to SO_2 sensitivity on a scale that distinguishes between acid and eutrophic bark (Conti and Cecchetti, 2001).

In general, the three mechanisms i.e. intercellular absorption through an exchange process; intercellular accumulation; entrapment of particles that contain metals have been put forward with regard to the absorption of metals in lichens. Heavy metal content in lichen thallus tends to alternate over time in phases of accumulation and subsequent release. Metal absorption in lichens is influenced by acid precipitation, geographical variations (e.g., altitude), temporal changes (e.g., seasonal variations), soil dust, local pollution sources and long range transport (Conti and Cecchetti, 2001).

The lichen can be defined as “permanent control system” for air pollution monitoring as they can be used to evaluate the effect of pollutants by measuring changes at community or population level or by assaying their trace element content (Upreti et al., 2009). According to Pfeiffer and Barclay-Estrup (1992) lichens are the one of the important constituents of the Indian flora and have vast topographical and climatic diversity of India has endowed it with a rich lichen flora, both in terms of luxuriance and species diversity.

1.11.1 Advantages of Lichen Biomonitoring

The lichens have diversified extensively during the last 600 years (Hawksworth and Hill, 1984). Lichen has been exploited by humans for several purposes since long among which most important use has been for dyeing textiles; exhibit a great diversity of biological effects, including antimicrobial, anti-inflammatory, analgesic, antipyretic, anti-proliferative and cytotoxic activities, and there has been a growing interest in the pharmaceutical properties of compound derived from lichens.

Lichens have been used for domestic purposes of Indians since ancient times and in various cultural events. The common condiments used in food dishes called ‘Garam Masala', ‘Meat Masala', ‘Sambar Masala' also contains lichen powder or whole plants as a major ingredient. *Parmotrema tinctorum* is used as spice and flavoring agent (Upreti et al., 2003). The major areas for lichen collection in India are the Himachal Pradesh and Uttaranchal hills while in the Central Indian region of Madhya Pradesh and certain localities of Western Ghats, few ethnic groups collect these plants (Upreti et al., 2005). However, the exploitation and excessive pollution by human has the major factor which are responsible for the existing lichen flora in the environment.

Although many natural lichens and cultured lichens have been screened for their biological activities and several novel compounds have been isolated and identified but lichens have been essentially ignored by the modern pharmaceutical industry because of their slow growth in nature (Yamamoto et al., 1998; Lauterwerwein et al., 1995).

Hypogymnia physodes is one of the most suitable bioindicators in the study of bioaccumulation of trace elements in view of its high tolerance capacities (Jeran et al., 1996). *Pyxine cocoes* (a foliose), most common epiphytic lichen species was found to be an excellent accumulator of different metals, as the elements such as Fe, Al, Zn, Ni and Cr tend to concentrate in noticeable amounts in this lichen (Bajpai et al., 2010a). Shukla and Upreti (2009) observed the maximum accumulation of PAHs in the lichens of Garhwal Himalaya. The substrate having high arsenic ranges also exhibit higher ranges of arsenic on lichens growing on them. Higher concentration of arsenic was found in lichens growing on site having mining activities (Bajpai et al., 2009).

Foliose lichens have efficient biomass and mainly of occurrence to the way of the urban regions but on the other hand, crustose lichens are highly resistant in the urban areas with slow growth pattern and abundance occurrence. However, the information about biomonitoring of pollutants using these crustose lichens in meager. The majority of these studies were conducted in natural and forest ecosystem or in urban environments.

Lichens have been used as accumulating indicators which provided information especially about the amount of different heavy metals absorbed in the lichen thalli. The epiphytic lichens have been used extensively to monitor air quality around urban areas, industrial sites and to document spatial distribution and accumulation of airborne pollutants (Garty, 2001; Carignan et al., 2002; Purvis et al., 2004). But the lichens are considered as the most suitable biomonitors due to their sensitivity to pollution and long life. Other characteristics feature of lichens which make them suitable for biomonitoring.

Studies regarding effect of NTPC on diversity of different plants are rarely available in India, except a single report by Bajpai et al. (2010a & b) on Biodiversity, bioaccumulation and physiological changes in lichens growing in the vicinity of coal-based thermal power plant at Raebareli, Uttar Pradesh, no reports of lichens growing around thermal power plants (NTPCs) are available from the country.

1.12 Aim of the study

The study will provide a complete list of different lichen species around of some selected thermal power plants of Uttar Pradesh together with their distribution. The distribution of lichens in 1×1 km grid around the thermal power plant clearly exhibit three distinct zones with different diversity levels of lichens and can be correlated with the status of urbanization and air pollution around thermal power plants of Uttar Pradesh. The diversity and distribution of lichens will act as a base line data for carrying out the future biomonitoring studies with the ambient air quality. The inventory of lichens available from the area will play vital role in the study of air pollution.

Study will also provide zone map of the area with different level of pollution occurring there. An assessment of the tolerant and sensitive lichen species will be available which can be use in future studies in the area.

No records of lichen diversity in relation with air pollution and monitoring were available from the thermal power plants of Uttar Pradesh, thus in the present research work an attempt has been made to provide the detail distribution of lichens around thermal power plant, together with estimation of chlorophyll and metal content in lichens of both polluted and unpolluted sites to evaluate the air pollution status of the area.

Chapter- 2

Objectives

The present research work is an attempt to provide a complete list of different lichen species around thermal power plants, Uttar Pradesh along with their distribution applying zone mapping technique, estimation of physiological parameter in lichens of both polluted and unpolluted sites to evaluate the impact of thermal power plant on the pollutant profile at spatial scale together with the level of different elements accumulated in lichens. The parameters considered for the study include physiological analysis, distribution pattern of heavy metals and abundance of lichens, accumulation of heavy metals and changes in pigment concentration in commonly occurring lichen species.

The present investigation was initiated with the following objectives-

1. To study lichen distribution around some selected thermal power plants of Uttar Pradesh.
2. Inventorization of sensitive and tolerant species and their diversity and distribution.
3. To study pollution induced/ incited physiological changes (i.e. Chlorophyll a, b, Chlorophyll degradation, Total chlorophyll, carotenoid and protein estimation) of commonly growing lichen taxa.
4. To assess the impact of thermal power plant emission on lichen community.
5. Profiling of heavy metal in lichens to distinguish polluted and non- polluted areas around selected thermal power plants.
6. To study lichen diversity using ecological parameters such as frequency %, density, abundance, relative frequency, relative density and Important Value Index (IVI).
7. SEM and FTIR analysis of commonly growing lichen taxa around thermal power plants.

Chapter-3 Review of Literature

"Treat literature is simply language changed with meaning to the almost possible degree".

It is estimated that there are about 13,500 to 17,000 lichen species (Hale, 1974; Hawksworth and Hill, 1984) throughout the world. India represented by 2450 lichen species (Singh and Sinha, 2010; Nayaka and Upreti, 2013) which represents 14% of the world lichen population. The cumulative information for macro-lichens and micro-lichens on over 1800 lichen taxa of India in the form of keys by Dr. D. D. Awasthi provide the information on utilization of lichens by the different ethnic groups of India and the current aspects of Indian Lichenology.

The Indian lichenology started with the account of lichens from Peninsular India. The initiation of taxonomic studies on Indian lichens dates back to the period of Linnaeus (1753) who mentioned a single lichen species *Rocella montagenii* in the publication "Species Plantarum" (Stockholm). It was in the year 1810 and 1814, the Father of Lichenology, Eric Acharius described four species of lichens from India. The first observation on sensitivity of lichens to air pollution dates back to 19th century (Nylander, 1866). This "city effect" popularly called as *lichen desert* was first systematically mapped by Sernander in the year 1926 in Stockholm.

Probably Quaraishi (1928) recorded 35 species of lichens occurring near Mussoorie in Western Himalayas as the first Indian worker. After that Prof. S. R. Kashyap started lichen sample collection from India along with his students. A. L. Smith determined the specimens, and the data were published in the form of a handbook by Chopra (1934).

Dr. D. D. Awasthi started studies on Indian lichens rather in a more systematic way in the early 1950s at the Department of Botany, University of Lucknow, Lucknow. During the last six decades, a large number of lichenological studies pertaining to monographic, revisionary and floristic account of different lichen taxa from the country are available. The use lichens in biomonitoring of particulate pollutants has gained increasing acceptance in the field of lichenology (Brodo, 1961). LeBlanc and Rao (1961) have used the transplantation technique for the first time to study the effect of air pollution on lichens. Several workers have suggested a possible role of lichens in pollution monitoring and biogeochemical studies (Tuominen and Jaakkola, 1973). Studies on lichens as biomonitors of metals and other element or on the uptake, accumulation, retention, localization, release, tolerance and toxicity of metal in lichens were thoroughly reviewed by Nieboer et al. (1972), James (1973), Richardson and Nieboer (1980), Puckett (1988), Tyler (1989), Frietas and Nobre (1997) and Garty (2000).

In recent years, the technique of chlorophyll fluorescence has become ubiquitous in plant ecophysiological studies. The accumulation of various air pollutants by lichens is well documented (Ferry et al., 1973; Nash and Sigal, 1978; Garty et al., 1983; Hawksworth et al., 2005). The photosynthetic response has been reported in lichens exposed to extreme temperature, light, water availability, air pollution and heavy metal concentration (Scheidegger and Schroeter, 1995). Recent studies suggested that there is a global contamination of air, water and soil by trace metals (Nriagu and Pacyna, 1988). Upreti (1995a, 2001) while discussing the factors responsible for the loss of diversity in Indian lichen flora, mentioned commercial and ethnobotanical utilization of lichens as the leading factor resulting in the loss of biodiversity of these plants in forest areas of India.

Lichens are highly diverse organisms offering a number of physiological and morphological characteristics which enable the assessment of several environmental and ecological factors. In the recent years there has been a great concern about the loss of lichen diversity in India (Upreti, 1995a).

Lichen communities are affected by various pollutants deposition which resulted alteration in their structure. The most sensitive species tend to disappear from the urban and industrial areas whereas tolerant species exist in moderately polluted areas (Sujetoviene, 2015). Biomonitoring studies on the physiological effects of pollution has often emphasized the inhibition of photosynthesis, respiration, fluorescence processes, chlorophyll content, membrane damage and oxidative stress (Garty et al., 2001a; Weissman et al., 2006; Bermudez et al., 2009; Bajpai et al., 2010a, b, c, d; Paoli et al., 2011; Majumder et al., 2013; Karakoti et al., 2014; Gupta, 2014; Gupta et al., 2015). The absorbed substances are stored for a long time and can be used for bioaccumulation studies. This allows to assess the different level of accumulated certain elements in an altered environment.

The air pollution studies with the help of lichens have been conducted by Das et al. (1986) in Kolkata city of West Bengal; Faizabad (Dubey et al., 1999; Gupta, 2014; Gupta et al., 2015; 2016a), Kanpur (Satya and Upreti, 2009; 2015; Satya et al., 2012); Lucknow (Bajpai, 2000; Bajpai et al., 2004; Mishra et al., 2003; Saxena et al., 2007; Upreti and Bajpai, 2002) and Raebareli (Bajpai et al., 2010 a, c) districts of Uttar Pradesh; Karakoti et al. (2014) reported a case study from Uttar Pradesh; Nayaka et al. (2003) in Bangalore city of Karnataka; Shukla and Upreti (2007a, b, 2008, 2009) in Garhwal Himalayas of Uttarakhand and in Madhya Pradesh especially metal accumulation studies on the lichens growing on monuments of Mandav city have been made by Bajpai et al. (2009). Upreti and Pandey (2000) monitored the heavy metal accumulation using different growth forms of lichens of East Antarctica. Therefore, many studies have been devoted to show the distribution of atmospheric air pollutants (Loppi and Bonini, 2000; Garty et al., 2002).

Though a large number of lichen monitoring studies were carried out in India devoted mostly to the cities and around highways, no reports of lichen biomonitoring studies are known around thermal power plant (NTPC) except Bajpai et al. (2010a, c).

3.1 Biomonitoring studies with lichens carried out in the World

In the mid-19th century, scientist and researchers became aware that lichens are scarce in the world and started to work on aspect of air pollution arising from residential, commercial and industrial areas. In 1790, Erasmus Darwin recognized that how lichen communities were affected by pollution and failed to grow near metal smelters on the island of Anglesey in North Wales. William Borrer (1812) observed that scarcely any lichen could exist where the air pollutants was present. In recent years, the technique of chlorophyll fluorescence has become ubiquitous in plant ecophysiological studies. The accumulation of major air pollutants by lichens is well defined by Garty et al. (1983) and Hawksworth et al. (2005).

A number of studies have assessed the response of lichen communities to air pollution and has been reviewed (Barkman, 1963; 1969; Skye, 1968; Rao and LeBlanc, 1967; Hawksworth and Rose, 1970; Will-Wolf, 1980; Wirth, 1988; van Haluwyn and Lerond, 1986; 1988; 1993; Wolterbeek, 2002). Especially, the epiphytic lichens have a great advantage in respect to other plants that there is there no possibility of uptake of metals from substratum and their morphology do not change with season. So, the techniques and elemental content in lichens of different regions were carried out by Le Blanc and Rao (1975); Hawksworth and Rose (1976); Richardson and Nieobar (1981); Nash and Wirth (1988); Nimis (1990); Rao et al. (1977); Garty et al. (1979); Garty (1988, 1993, 2000); Tuba and Csintalan (1993); Glenn et al. (1995); Leblanc et al. (1974); Freitas and Nobre (1997); Freitas et al. (1999); Branquinho et al. (1999) and Nimis et al. (1993; 2001).

Lichens have an ability to accumulate high variety of elements that are closely related with the environment and has led to their wide scale application as practical biomonitors of metal contamination. Many countries particularly France, Italy, Germany, Switzerland and USA are currently using lichens to assess the effects of air and metal pollution. This approach is based on the analytical determination of total concentration of elements or substances in lichen thalli and is mostly applied throughout the world.

The most popular methods to monitor the pollution are: distribution maps of single species / indicator species, (Nimis, 1985) or of parameters (injury) relative to single species, analysis of the whole flora (Wetmore, 1983), transplant method

(Brodo, 1961) or changes in photosynthetic performance (Christ and Türk, 1981) and Indices of Atmospheric Purity (IAP) by LeBlanc and De Sloover (1970). Recently the huge amounts of technical air quality baseline data in wide geographical areas are compared with various versions of the IAP (Herzig and Urech, 1991) to monitor large areas without expensive technical instrument. A test is also done out by Déruelle in 1978 which proved the validity of this index to assess SO_2 pollution in Western France.

Sernander (1912) termed the area in cities with lichen vegetation a 'struggle zone' and later Sernander (1926) also applied the zonation which followed the pattern of prevailing wind and assume an elliptic shape. Gilbert (1968) defined the two growth forms of lichen (i.e. crustose and leprose) have more tolerance capacity of air pollution followed by foliose and fruticose forms.

Rao and Le Blanc (1967) published a map of the area around an iron sintering plant at Wawa, Ontario on the basis of number of epiphytes and sulphate concentration of soil and showed how sulphur dioxide affect the vegetation up to a distance of 55 km north-east direction of the study area. These zones were mapped in numerous cities between 1930 and 1970 (Hawksworth, 1971; 1973; Skye, 1968) and identified 5 zones in Stockholm region on the basis of species combination and distribution of each zone having a specific level of pollution. Farkas et al. (1985) collected 50 lichen taxa from 84 sites and correlates with the dominating dust pollution and prepare lichen map of Kamaron (NW Hungary) by dividing whole area into two zones. These zones can be distinguished on the basis of lichen flora.

According to Goyal and Seaward (1982) morphological and histological characteristics especially of rhizine and medulla affect accumulation within the thallus. Richardson (1992) reviewed the active monitoring to assess air quality in urban environment and monitored contaminants in air and water. *Hypogymnia physodes,* a fairly pollution tolerant lichen distributed in the Pacific Northwest

(Holopainen, 1984; Gailey et al., 1985; Vestergaard et al., 1996; Sochting, 1995). In the tropical climate of India, *Pyxine cocoes, Phaeophyscia hispidula* and *Dirinaria applanata* belong to family Physciaceae having well known pollution tolerant character are the most suitable lichen taxa.

In last century of late 60's and early 70's people starting to use solid dots and open circles on the base maps to indicate presence or absence of lichens respectively. In lichens zone mapping the detail investigation of lichen thallus in particular area can be studied to divide the area in 3, 4 or more lichen zones.

Robinson and Robbins (1971) concluded that after emission, pollutants are dispersed both vertically and horizontally in the atmosphere. Seaward (1977) revealed the knowledge of lichens in relation to physical and biological compounds of environment. Hale (1979) and Gries (1996) used lichens for pollution monitoring in three ways by identifying and mapping all lichen species in an area: (i) to indicate the severity of pollution with reference to distance, as reflected by the number of species present, (ii) transplanting healthy lichens into polluted area and measuring thallus deterioration and (iii) sampling an individual lichen species from different areas with measuring contaminants accumulated within the thallus.

Ronrn and Galun (1984) described about the photosynthetic pigments from *Ramalina duriaei* extracted by immersion of the thalli in dimethyl sulfoxide (DMSO) stable in the dark at 4°C for 10 days and was measured by spectrophotometer in the ratio OD435/ 415 nm, was found to be a preferable parameter for estimating chlorophyll degradation. It is shown that Arnon's equation for quantification of total chlorophyll can be used with DMSO extract too (Arnon, 1949).

Seaward (1992) suggested that lichen thalli particularly those with soredia and isidia provide an effective surface for uptake. According to Garty (1993), mainly foliose and fruticose lichen species have been used as biomonitors for pollution studies. So, Epiphytic lichens can be used as a biomonitors on a national scale as well as around particular pollution to obtain information about the levels of trace elements in the atmosphere. Both natural as well as anthropogenic phenomenon used to enhance the deposition of elements in the lichens. The earliest approach to study the air pollution effects on lichens included the plotting of particular species, as well as its abundance, vitality and other qualitative and quantitative factors.

Loppi (2000) observed the Italian geothermal fields of Travale- Radicondoli and Mt. Amiata for possible effects due to the industrial exploitation of geothermal resources. In both areas, the mapping of lichen diversity showed that the zone of worst air quality does not extend more than about 500 m from the power plants and major injury to lichens might be due to release of hydrogen sulphide (H_2S) which is highly toxic gaseous pollutant. In both geothermal fields, lichen thalli indicated the presence of trace elements inside them (i.e. arsenic, boron and sulphur).

Nimis et al. (2001) used two foliose epiphytic lichens viz; *Parmelia caperata* and *Xanthoria parientina* as bioaccumulators of trace metals. Garty et al. (2002; 2003) studied the response of calcium oxalate and sulphate containing structure on the thalloid surface of the lichen *Ramalina lacera* and a biomonitor of air pollution (*R. maciformis)* in the Negev desert, Israel.

Jeran et al. (2002) concluded the results of lichen mapping with the quantitative levels of certain trace elements in *Hypogymnia physodes* (L.) Nyl., and Index of Atmospheric Purity (IAP) was calculated based on the assessment of the cover and frequency of growth form of lichens on different tree species.

Nájera et al. (2002) compared three foliose lichen biomonitoring methods by field tests in the tropical urban habitat of San José, Costa Rica. They recommend the 100 random point template (applied to four sides of trunk) for ecological studies and 50 random points template (applied to side with greatest lichen cover) for biomonitoring because it reduces time and costs by nearly 50% but still has acceptable reliability values.

Szczepaniak and Biziuk (2003) showed that lichens are good tools for air pollution monitoring because of the metal uptake and retention. For a complete data the biomonitors content should be compared with other parameters and evaluate the correlation between the amount of pollutants in the atmosphere and the human reaction to them.

Pinho et al. (2012) studied high-intensity land use gradients in Mediterranean ecosystems. However, they predicted higher diversity under an intermediate disturbances due to the co-existence of the species with contrasting ecological requirements. The overall conclusion of the study was based on lichens responded to low- levels of land use intensity and showed the possibility of using lichens as early indicator of the impacts of low intensity land-use.

Kularatne and Freitas (2013) assessed Auckland region of New Zealand at four different sites in which lichen *Parmotrema reticulatum* was used as air pollution biomonitors of four heavy metals (Cr, Cu, Pb and Zn). Three groups of lichens were monitored over a two-year period using active and passive biomonitoring to assess ‘on thallus’ and ‘in-thallus’ concentrations of heavy metals. Overall, the results showed that the lichens continuously accumulates pollutants from the air until equilibrium is reached and *P. reticulatum* was the successful species to monitor spatial and temporal pollution patterns.

Other developing countries are also engaged in biomonitoring studies with lichen but in Indian context, through a large number of pollution monitoring studies with higher plants are available yet such studies using lichens are largely neglected.

3.2 Biomonitoring studies with lichens carried out in India

In the sixties of the last century, Dr. D. D. Awasthi concluded the occurrence of about 1300 species from the Indian sub-continent. Later on Dr. Awasthi (1980, 1991), keyed out 1850 species of lichens which belongs to 700 of foliose to fruticose (macro-lichens) and 1150 of crustose to squamulose (micro-lichens). The checklist of lichen species from the Indian subcontinent have been proposed by Awasthi (2000) consist of 2450 lichen species belonging to 291 genera and 79 families.

Pollution monitoring studies using lichens were initiated in the 18^{th} century in India. But some records of such studies are available from different parts of India including the Lucknow city in Uttar Pradesh; Kolkata city, West Bengal; Bangalore city, Karnataka and Pune cities, Maharashtra, Mandav city in Dhar district.

Das et al. (1986) surveyed the lichens from 25 Kolkata streets revealed that the lichen species and their population could be an indicator for determining the air quality. Only the pollutant resistant lichen, *Parmelia caperata* was found to grow on the road side trees of Kolkata. In spite of low traffic load trees of several streets did not have any lichens, may due to the polluted air caused by nearby factories.

In Indian subcontinent, several studies regarding pollution monitoring with higher plants are carried out by Rao and Dubey (1992), Singh et al. (1995) and Singh and Sinha (1997). Upreti and Pandey (1994, 2000) studied the concentration of heavy metals in lichens growing in different ecological habitats in Schirmacher oasis and East Antarctica and concluded that all the lichen species had consistently higher amount of Fe and Cu, as their substratum were Fe and Cu mineralized rock.

Dubey et al. (1999) studied that the concentration of Pb in lichens decreases with increasing distance from the source of pollution at different sites in and around Faizabad city of Uttar Pradesh. Pandey et al. (2002) estimated the levels of metals in lichens collected in and Hetuda industrial area (HIA), Narayani zone, Makwanpur District, Nepal.

Nayaka et al. (2002a) enumerates the occurrence of 102 species of lichens (including *Pyxine cocoes*) in 12 forest sites of Solan District, Himanchal Pradesh campus, adds 25 species to the known lichen flora of the state. Nayaka et al. (2002b) enumerates 112 species of lichens belonging to 44 genera and 26 families in five reserve forest localities of Sirmaur District, Himanchal Pradesh. The family

Physciaceae is the common and highly diversed family in the studied area with 8 genera comprising 25 species of *Pyxine cocoes* present on the *Shorea robusta* tree.

Nayaka and Upreti (2002) estimated 143 species of lichens belonging to 50 genera and 26 families in semi- evergreen and deciduous forest of Sharavathi river basin. It was observed that the area was rich in crustose lichens represented by 108 species. The lichen collected was mostly corticolous. In this area, *Pyxine cocoes* was present in semi evergreen forest as well as in dry deciduous forest. Upreti and Bajpai (2002) conducted pollution monitoring studies in Lucknow city with the help of lichens transplant method.

Mishra et al. (2003) studied transplant technique in Lucknow city and found that samples transplanted towards the source of pollution showed higher concentration of metals as compared to leeward one.

Nayaka et al. (2003) studied 30 species of lichens belonging to 19 genera and 15 families from 12 localities of Bangalore city along with analysis of metal accumulation.

Bajpai et al. (2004) studied *Dirinaria consimillis* (Fr.) Awasthi (a foliose lichen) for the transplantation technique at some residential sites of Lucknow city, Uttar Pradesh, for monitoring the concentration of Cr, Zn, Pb, Cu and Cd metals at two vertical positions. But they found that the concentration of Cr and Cu were more at the higher vertical position than the lower one. The maximum Zn was at the lower vertical position than the upper one and lastly Pb and Cd were not detected in the study.

Saxena (2004) observed the lichen flora in and around Lucknow city in relation with air pollution with 1 x 1 km grid plotting and zone mapping. Saxena et al. (2004) reported the lichens growing on artifacts in the Indian subcontinent. In all those foliose species, *Pyxine cocoes* was universally on the monuments of Karnataka and Orissa regions. *P. cocoes* var. *cocoes* was equally frequent on the monuments of both the states whereas var. *prominula* was confined to southern India, while var. *pallid* had dominance on those of Orissa monuments. A yellow foliose lichen- *Candelaria concolor* formed a frequent association with these species of *Pyxine.*

Nayaka et al. (2005a) reported concentration of Mn is different lichen taxa in Chondak in Pithoragarh district, Uttarakhand. The mining area was heavily dusted and air quality was presumably poor because of the emission from the Mn smelter. Among the different lichens analyzed most of the lichen taxa exhibited the range of 40-50 μgg^{-1} Mn concentration. Again Nayaka et al. (2005b) reported that *Crytothecia punctulata,* a crustose lichen, collected from the Arecanut trees which was exposing them to fungicide Bordeaux mixture. The study revealed the accumulation of Cu, Ca and S in higher concentration of 575.4, 10,000 and 21,000μgg^{-1} respectively.

Nayaka and Upreti (2005) studied the lichen flora of Pune city, Western India with reference to air pollution. Out of the 20 sites of the Pune city surveyed, only 11 sites were mostly in the outskirt having thick tree cover together with less traffic activity showed luxuriant growth of lichen, while the city centre with scattered trees and high traffic activity has scarce or complete absence of lichens.

Upreti et al. (2005) compared the lichen flora of Indian Botanic Garden to an earlier enumeration of lichens collected by Kurz in 1865 and described by Nylander in 1867. It was interesting to note that in the last 140 years the lichen flora of the area has changed significantly as only three species out of 50 species (recorded earlier) were common between the two studies. The reason for the change in the lichen flora of the area may be attributed to the microclimate changes in the area due to fast pace of urbanization together with air pollution around the Indian Botanic Garden and Kolkata city.

Shukla et al. (2006) analyzed lichens from four localities of Dehradun city. The Clock Tower area situated in the entire city had maximum accumulation of most the metals emitted from higher vehicular activity in the area.

Saxena et al. (2007) studied the heavy metal accumulation in lichens growing on *Mangifera indica* in north side of Lucknow city, India. *Pyxine cocoes* accumulated Pb, Cr, Zn, Fe, Cu, Ni, Cd and Hg at Palka Village and revealed that the higher concentration of Pb (3.3- 15.6µg/g), Cr (25.6-137.5µg/g), Zn (49.4-219.7µg/g), Cu (10.2-66.6µg/g) and Fe (1748-19374µg/g) from the study area.

Shukla (2007) listed the sensitivity rating of some established pollution tolerant lichen species of the Garhwal Himalayas. *Candelaria concolor, Physcia biziana, Physconia enteroxantha, Punctelia subrudecta, Pyxine cocoes, P. subcinerea, Xanthoria elegans* and *X. fallax* belongs to pollution tolerant category, while *Phaeophyscia orbicularis* was moderately tolerant and *Rhizaplaca chrysoleuca* was sensitive lichen species.

Shukla and Upreti (2007a) studied the effect of increasing urbanization and traffic activity on the physiology of *Phaeophyscia hispidula* collected from 13 different localities, growing in their natural habitat in Pauri and Srinagar, two cities in the Himalayas enroute to a famous Hindu holy pilgrimage Badrinath. The study indicated that *P. hispidula* was pollutant tolerant (adaptation) and able to withstand local emission from vehicle exhausts.

Shukla and Upreti (2007b) analyzed the concentration of six heavy metals (Fe, Ni, Zn, Cr, Cu and Pb) in *Phaeophyscia hispidula* from five different sites of Pauri city, Garhwal Himalayas, Uttarakhand, India. The concentration of metals was correlated with the vehicular activity and urbanization. The total metal concentration was highest at circuit house on Pauri-Devprayag road which experienced heavy traffic throughout the year, while Kiyonkaleshwar area had less vehicular activity and minimum accumulation of the metals.

Bajpai et al. (2008) analyzed As in four different growth forms of lichens growing on old monuments in the city of Mandav, Dhar district of Madhya Pradesh and suggested that foliose lichen showed higher accumulation of As followed by leprose form.

Shukla and Upreti (2008) studied the damage caused by the metallic pollutants in the lichen *Pyxine subcinerea* Stirton by measuring Chl. a, Chl. b and Total Chl., Carotenoid and protein and OD 435/415 ratio. It was observed that Cu, Pb and Zn significantly affect the physiology of the lichen *P. subcinerea.* Multiple correlation analysis revealed significant correlation ($p < 0.001$) among the Fe, Ni, Cu, Zn and Pb metals analyzed.

Satya and Upreti (2009) estimated the accumulation of carbon, nitrogen and sulphur content and their influence on the photosynthetic pigments in *Rinodina sophodes*, crustose lichen growing naturally in and around six sites of Kanpur city. Maximum carbon concentration was recorded at highly polluted area, while higher nitrogen accumulation was at near village in the city having higher ammonia emission. The sulphur concentration was not detected except a single site with quite lower value (0.22%). Multiple correlation analysis concluded that Chl. a had highly significant correlation (1%) with Chl. b ($r = 0.9986$) and total chlorophyll ($r = 0.9307$). Carbon is directly correlated with nitrogen ($r = 0.3035$), sulphur ($r = 0.1743$) and chlorophyll degradation ($r = 0.2685$) while negatively correlated with Chl. a (-0.3323), Chl. b (- 0.3429) and total chlorophyll ($r = - 0.0824$). Nitrogen showed negative correlation between all photosynthetic pigments and chlorophyll degradation, while in case of sulphur it was highly positively correlated at 1% with chlorophyll degradation (0.9445).

Shukla and Upreti (2009) studied PAHs distribution and origin in the *Phaeophyscia hispidula* collected from nine different road crossing of Dehradun, Uttarakhand establishing the *Phaeophyscia hispidula* as an excellent biomonitoring of PAHs from foot hill to sub-temperate area of Garhwal Himalayas.

Bajpai et al. (2010a) concluded that the lichen diversity assessment carried out around a coal- based thermal power plant of Raibareily district of North India indicated that the lichen abundance increase with increase in distance from power plant. The physiological parameters were estimated in *Pyxine cocoes* (Sw.) Nyl. for further interference. Distribution of heavy metals from the source showed positive correlation with distance for all directions, but only the west directions has received better dispersion of pollutant. LSD analysis showed that wind speed and its direction played a major role in accumulation of heavy metals (Al, Cr, Fe, Pb and Zn) in the thallus. Further, the concentration of chlorophyll contents in *P. cocoes* increased with decreasing the distance from the power plant, while protein, carotenoid and phaeophytisation exhibited significant decrease.

Bajpai et al. (2010b) reported that Ca and Mg accumulated in seven lichen species growing on Monuments of Dhar district, Madhya Pradesh. Crustose and squamulose growth form exhibited higher accumulation and showed selectivity sequence as crustose> squanmulose> foilose> leprose. Among crustose, *Diploschistes candidissimum* had the maximum accumulation of Ca (314.45±1.30µg/g) and Mg (393.05±0.99µg/g). The higher accumulation of salt in lichen thallus clearly indicated the acceleration of biogeochemical deterioration of monuments.

Bajpai et al. (2010c) determined the accumulation of arsenic (As) and fluoride (F) in an epiphytic lichen *Pyxine cocoes* (Sw.) Nyl., collected from the vicinity of coal based thermal power plant of Raebareli, India. Both the elements were abundant in lichen thallus but their substrates contained negligible amount. The As ranged between 8.9±0.7 to 77.3±2.0 $\mu g g^{-1}$ dry weight in thallus and 1.0±0.0 to 9.7±0.2 $\mu g g^{-1}$ dry weight in substratum and it was increased with decreasing distance from the power plant whereas F ranged between 9.3±0.52 to 105.8±2.3 $\mu g g^{-1}$ dry weight in thallus. However, it was not present in the substratum but F showed an opposite trend. The distribution of As and F showed positive correlation with distance in all directions but better dispersion was only in west indicated by the concentration coefficient (R2). The analysis of variance and LSD indicated that As, F concentrations among lichen thallus was significant at p< 0.01% level.

Bajpai et al. (2010d) used *Lepraria lobificans* Nyl., a leprose lichen growing naturally on monuments and building in the city Mandav, Central India for passive monitoring of atmospheric metals. Among seven metals, Fe exhibited maximum accumulation both in thallus and substratum with the mean values of 2195.63µg/g.

Rout et al. (2010) investigated the pigment profile and chlorophyll degradation of lichen in Cachar district. Chlorophyll a, chlorophyll b, total chlorophyll and carotenoid were measured to estimate the possible damage caused by the metallic pollutants in the lichen, *Pyxine cocoes* collected from 25 sites of the study area. Total chlorophyll was highest in ecoforest (1.43 mg/l) whereas Carotenoid was lowest in Ecoforest (0.17 mg/l).

Shukla et al. (2010) concluded the utility of lichen diversity in the monitoring of air pollution and 85 lichen species were recorded from of Pauri and Srinagar, Garhwal Himalayas, Uttaranchal. It was observed that polluted sites had very low lichen diversity, mostly dominated by family Physciaceae. Kiyonkaleshwar area is the site with maximum lichen diversity (46 lichen taxa) located in a more or less pollution-free area of Pauri city.

Bajpai et al. (2011) assessed the level of atmospheric heavy metal pollution in Katni and Rewa cities of Madhya Pradesh, Central India. *Pyxine cocoes* and *Phaeophyscia hispidula*, used as bioindicators against seven heavy metals, were analyzed. The selectivity sequence of metals were Fe> Al> Zn> As> Cr> Pb> Cd in Katni city and Al> Fe> Zn> Cr> As> Pb> Cd in Rewa city.

Rai et al. (2011) examined the terricolous lichens community to identify potential elements as indicator of anthropogenic disturbances in Chopta Tungnath temperate- alpine grassland of Garhwal Himalaya. Terricolous lichens were sampled from 12 different sites distributed in three stratified macrohabitats, along increasing altitudinal gradient, were negatively correlated ($r = 0.70$; $p < 0.05$). A total of 20 soil lichen species belonging to 10 genera, 6 families and 4 morphological groups (i.e. leprose, foliose, dimorphic and fruticose) were identified. Among the four growth forms, fruticose growth form was indicator of grazing disturbances, distinguish low grazed high altitude (3400-4001 m asl) areas with highly grazed low altitude (2700-3000 m asl) to mid altitude (3000-3400 m asl) areas.

Rani et al. (2011) estimated nine heavy metals in lichen- *Phaeophyscia hispidula* (Ach.) Moberg collected it from 12 different sites of Dehradun, Uttarakhand to analyze the air quality. Total metal concentration was highest at Mohkampur Railway crossing, Hardwar road (42505µg/g). Among all heavy metals, Pb had higher concentration at all the sites.

Satya and Upreti (2011) studied Achanakmar-Amarkantak area, an interstate Biosphere Reserves falling in Madhya Pradesh and Chhattisgarh state, has been designated as 14th Biosphere Reserves by Govt. of India. Some morphological and anatomical characters of the lichen taxa of the Achanakmar– Amarkantak Biosphere Reserves, categorized into 11 lichen communities. The Biosphere Reserves exhibited maximum cover of Physcioid lichen communities represented by 18% followed by 16% Pertusaioid, 13% of Lecanoroid and 12% of Lecideoid communities.

Bajpai et al. (2012) investigated the physiological effects of arsenate on transplanted thallus of *Pyxine cocoes* and observed that it is as an excellent accumulator of arsenate suggesting it to be utilizing for active biomonitoring of As pollution.

Kholia et al. (2012) revealed the occurrence of 105 species of lichens belonging to 48 genera and 21 families from the different localities in and around Nainital city.

Bajpai and Upreti (2012) evaluated the lichen *Pyxine cocoes* (Sw.) Nyl., as an indicator to analyzed As and heavy metal rich sites in Chinsurah, West Bengal.

Significantly higher levels of Al, Cd, Cr, Cu, Fe, Pb and Zn were found from road sites while As concentration (48.1±2.1$\mu g g^{-1}$) was higher in the samples collected near the paddy field which indicated that the pesticide- herbicides as its source.

Ingle et al. (2012) studied the distribution pattern of 45 species (belonging to 22 genera and 13 families of lichens) from 35 localities in north, south, east and west of Bhopal City of Madhya Pradesh. The localities surveyed in all directions and divided into 0, 3, 6 and 12 kms radius from the city centre. The area dominated by crustose lichens (i.e. 25 species) followed by foliose, squamulose and leprose with 12, 6 and 2 species respectively. The lichens family Teloschistaceae with 10 species under a single genus *Caloplaca* dominates the area but genera *Hyperphyscia, Peltula* and *Pertusaria* are widely distributed in the area, while Physciaceae and Caliciaceae have 6 species each followed by Peltulaceae, Verrucariaceae, Pertusariaceae and Lacanoraceae with 4, 3, 3 and 3 species respectively. The diversity of lichens increased with increasing distance from the city centre. The outer zone bears luxuriant growth, while the city centre exhibited poor to scare growth of lichens. Despite heavy anthropogenic activity in and around the city centre presence of *Hyperphyscia adglutinata* and *Pyxine petricola* exhibited their toxitolerant nature against the pollution.

Satya et al. (2012) determined the possibility of PAHs using a crustose lichen *Rinodina sophodes* (Ach.) Massal. as bioaccumulator for evaluation of atmospheric pollution in Kanpur city of Uttar Pradesh, India. The limit of detection for different PAHs in *Rinodina sophodes* was found to be 0.008–0.050 $\mu g g^{-1}$. The total PAHs in different sites were ranged between 0.189 ± 0.029 and 0.494 ± 0.105 $\mu g g^{-1}$. PAHs were released from combustion of organic materials, traffic and vehicular exhaust (diesel and gasoline engine). So, the concentration of acenaphthylene and phenanthrene indicated road traffic as major source of PAH pollution in the city. Two-way ANOVA showed significant differences between all sampling sites (p<

1%). This study established the utility of *R. sophodes* in monitoring the PAHs accumulation as an effective tool and explored the most potential traits resistant to the hazardous environmental conditions in the tropical regions of north India.

Shukla et al. (2012a) concluded that the lichen suitability as biomonitors to distinguish urban from industrial PAHs. *Pyxine subcinera* collected from 12 sites varying from urban and periurban forest area of Haridwar in the foothills of Indian Himalayas. The result showed that the clear distinction between the urban and industrial PAHs profile showing higher concentration of PAH in later site comparatively to the former sites.

Shukla et al. (2012b) analyzed *Phaeophyscia hispidula* (Ach.) Moberg., foliose lichen, collected from Dehradun city of Garhwal Himalaya, to assess its tolerance to heavy metals. Among the biological parameters protein was significantly and negatively correlated with pigment concentrations (r= -0.3838, Chl. b); -0.5809 (Carotenoid); -0.5034(OD), however, it was significantly positively correlated with Cd (r= -0.6822, P<0,01). Among heavy metals, Cd was negatively correlated with Cu (r= -0.4639), Fe (r= -0.2676) and Zn (r= -0.0549). It was also observed that the chlorophyll and protein content increased parallel to the level of metallic pollutants indicating the mechanism of stress tolerance in *P. hispidula* (Himalayan region).

Das et al. (2013) analyzed the effect of a paper mill on epiphytic lichen communities in Barak Valley, Assam, India and thus used to study levels of pollution impact around a source of pollution.

Bajpai et al. (2013a) assessed the heavy metal and PAHs in the air as well as tourist rich area of Western Ghats by applying a most frequent lichen *Remototrachyna awasthii* as biomonitors. Total metal concentration ranged from 644 to 2277.5 µg/g^{-1} while PAHs concentration ranged between 0.193 to 54.78 µg/g^{-1}.

Bajpai et al. (2013b) assessed the level and possible sources of organic and inorganic pollutants in Mahabaleshwar city in Western part of India and their effect on lichen *Remototrachyna awasthii.* This lichen was collected from 8 different sites on the basis of anthropogenic activities detected in the area. The concentration of the most of the metal at different sites was significantly compared to control site ($p<0.001$).

Nayaka and Upreti (2013) analysed the diversity of lichens in Uttar Pradesh which revealed the occurrence of 135 species belonging to 46 genera and 25 families.

Shukla et al. (2013) enumerated seven heavy metals in *Pyxine subcinerea* Stirton collected from 12 sites in Haridwar city (Uttarakhand). The metal contents in lichen, bark and soil ranged from 1573 to 18793, 256 to 590 and 684 to 801µg/g respectively. Statistical analysis revealed that metal concentration in lichens did not show significant linear correlation with the bark or soil. Pearson's correlation coefficients revealed negative correlation of Pb ($r= -0.2245$) and Ni ($r= -0.0480$) content between lichen and soil.

The detailed account about lichens in ecosystem monitoring were published by Shukla et al. (2014); the book entitled "*Lichens to biomonitor the Environment*". Bajpai et al. (2014) compared three lichen species *Flavoparmelia caperata, Phaeophyscia hispidula* and *Pyxine sorediata* for interspecific comparison in metals and PAHs profile in different altitudinal gradients of the Western Himalayas. The study showed similar metal as well as PAHs profile under similar altitudinal gradients in the sequence of *F. caperata* (has a higher affinity for Al, Cr, Fe, Pb and Zn) >*P. hispidula* (has a significant positive affinity for Fe & Pb) >*P. sorediata.* The variation in pollutant concentrations within each species may be correlated with intrinsic attributes of the species.

Bajpai et al. (2015) used *Pyxine cocoes,* a toxitolerant lichen species, to evaluate the possible physiological, biochemical and genetic changes occurring due to Cr (+VI) stress. Different concentrations of Cr (+VI) (0, 10, 25, 50, 75 and 100 µM) for 10, 20, 30 and 45 days were employed on transplanted lichen species and result revealed that the exposure of Cr (+VI) caused a significant decline in physiological processes with increasing metal stress.

Bhat et al. (2014) used *Hyperphyscia adglutinata* for transplant technique in Rajouri town, Jammu & Kashmir. The samples exhibited higher concentration of Pb, Fe,Cu, Cr, Zn, Cd, Ni and Hg over control samples. Lichens transplanted nearer to the city centre showed maximum concentration of all heavy metal compared to those transplanted away from the city.

Karakoti et al. (2014) identified the relationship of the physiological parameters of the photosynthetic system with the elemental content of the naturally growing lichen *Pyxine cocoes.* The species was examined as biomonitoring indicator and effect of atmospheric pollutants on physiological integrity. Fv/Fm, chlorophyll degradation ratio and quantitative estimation of Al, As, Cd, Cr, Cu, Pb, Fe and Zn contained in the thallus were ascertained. The statistical analysis of the study showed significant correlations between Fv/Fm and element content (Al and Cr).

Mishra and Upreti (2014) analysed the effect of pollutants on foliose lichen *Pyxine cocoes* in Udham Singh Nagar. The samples of Bajpur and Tanda showed high concentration of heavy metal experiencing heavy traffic activity.

The book named "*Recent Advances in Lichenology-Vol. I & II*" published by Upreti et al. 2015a, b) describes the modern methods and approaches used in biomonitoring and bioprospection and also helps in knowing the various factors which influence the growth of lichens in natural conditions. Goni and Sharma (2015) revealed the addition of 44 species of lichen flora of Jammu & Kashmir state, India. Goni et al. (2015) enumerated an occurrence of 356 species belonging to 91 genera and 35 families from Jammu & Kashmir.

Gupta et al. (2015) assessed lichen diversity changes in one of the cultural centre of Uttar Pradesh, Faizabad city. Lichen zone mapping technique was employed to observe spatial trends of lichen diversity in a grid of 1x1 km within 0-5, 6-12 and

13-20 km distance from city centre in all the four directions. Overall 15 species were recorded from different directions but *Pyxine cocoes* and *Bacidia submedialis* were common in all directions. Changes in physiological parameters and metal profile with respect to distance from city centre to the outskirts of the city in *P. cocoes* and *B. submedialis* were analysed. It was observed that the physiological parameters varied from site to site and in different directions, but the metal profile clearly indicated decreasing trend of metal concentration with increasing distance from the city centre. The study provided the baseline data for future biomonitoring studies and confirms the lichen biomonitoring study as an effective tool to monitor changes in environmental condition.

Satya and Upreti (2015) assessed the seasonal variation in accumulation of macro-elements (C, N and S) and to elucidate influence of traffic load on accumulation pattern of micro elements (Mn, Cu, Zn, Cr, Fe, Ni and Pb) by lichen *Rinodina sophodes* in North India. The result indicated that during winter thalli gradually accumulated carbon and nitrogen.

Gupta et al. (2016a) documented lichen diversity pattern in Mango orchards of Gangetic plain including Faizabad, Ambedkar Nagar and Raebareli district.

Gupta et al. (2016b) utilized 13 bioindicator communities of lichen to assess the status of Badrinath, Uttarakhand and described that the sites with less anthropogenic activities is less polluted compared to the other sites with high anthropogenic having high pollution load.

Gupta and Sinha (2016) enumerated 44 lichen species belonging to 22 genera and 18 families from Tarai region of Uttar Pradesh (Pilibhit) with dominance of crustose and corticolous lichen. They recorded total 13 species out of which 3 species were new to Indian lichen mycota and 10 species new to the Tarai region of Uttar Pradesh.

Bajpai et al. (2016a) studied the fresh as well as herbarium specimens of lichens from foothills of Eastern Himalayas with respect to elements, PAHs accumulation and carbon isotope composition to explore the changes in climatic conditions and its impact on lichen flora. Study clearly demonstrated an increase in anthropogenic pollution and drastic decrease in precipitation while temperature showed abrupt changes during the past five decades resulting in significant change in lichen community structure.

Bajpai et al. (2016b) reported 122 lichen species belonging to 47 genera and 24 families from Tawang, Arunanchal Pradesh in order to access the long-term effect of climate change in alpine region of the area. The study presented that community structure and occurrence of individual species may be targeted for monitoring microclimatic changes in coming years.

Shukla et al. (2016) described lichens as a valuable proxy for monitoring microclimatic changes and proper coordination between geological, biological and environmental proxies which may be widely applied to predict the climatic changes, which is important for paleoclimatic studies, biological conservation and an extreme climate studies.

From the review of literature, it is evident that though, a number of studies regarding use of lichen community, or species in monitoring environmental conditions not only in European countries but are available from different parts of India including Uttar Pradesh. But, no reports of lichen biomonitoring studies are known around thermal power plant (NTPC) except Bajpai et al. (2010a, c), therefore, the present proposal aims to study the elemental load and its effect on lichens for assessment of environmental pollution.

Chapter- 4 Materials and Methods

"Use all methods analytical brig ever detail into play planning to the critical can cause the team to win their way".

The State of Uttar Pradesh is India's fourth largest state, comprising a total land area of 243,290 square km (93,935 sq mi) and lies between the coordinates 26.85°N and 80.91°E (Fig-4.1A, B). The state is divided in 75 districts and is highly populous state of India with 204.2 million (as 2012) population. It is situated on the northern spout of India and shares an international boundary with Nepal.

The state represented three distinct phyto-geographical regions. The transitional belt running along the entire length of the state of Uttarakhand and country of Nepal is called the "Terai" and "Bhabhar" area and have thick forest cover, swamps and marshes. The Gangetic plain elongates the area from east to west is the most fertile as well as agricultural land. The southern fringe of the Gangetic Plains is demarcated by the Vindhya Hills and Plateau exhibit strong ground and low hills. Most of the central region of the state of Uttar Pradesh is most fertile and utilized for agriculture from the ancient time. The mean annual rainfall ranges from 650 mm in the southwest corner of the state to 1000 mm in the eastern and southeastern parts of the state and the temperature varies between 0°C during winter and 50°C in summer.

Floristic Studies of Lichens of some selected Thermal Power Plants of Uttar Pradesh, India

4.1 Study Area, Collection and preservation of Lichen samples

Lichens were collected from nearby areas of some selected National thermal power plants situated in different parts of Uttar Pradesh. Lichen specimens were usually removed along with the substratum. The macro or micro- lichens on the bark, twig and tree trunks were collected using a sheath knife, geological hammer and iron chisels. The hand lens (x 10) was helpful to avoid overlooking tiny crusts.

Present study included some selected National thermal power plants of Uttar Pradesh, India (Table-4.1; Fig-4.1C) which were divided into three locations of sampling sites i.e. East and South-east; South-west and North-west; and Centre.

Table-4.1: Coal- based National Thermal Power Plant selected for the floristic survey

S. No	Thermal Power Plant Name	Location & District	Installed Capacity & Generation Unit	Primary fuel
1	**Panki Thermal Power Plant**	Panki, Kanpur	**210 MW** (5 x 105 MW)	Coal-fired
2	**Tanda thermal power Plant**	Vidyutnagar, Ambedkar Nagar	**440 MW** (4 x 110 MW) each	Coal-fired
3	**Feroze Gandhi Unchahar Thermal Power Plant Corporation**	Unchahar, Raebareli	**1050 MW** (5 x 210 MW) + 500MW (**2017 April)**	Coal-fired

National thermal power corporation (NTPC) is the largest Indian state owned electric utilities company based in New Delhi, India. It is listed in Forbes Global 2000 for 2011 ranked it 348th in the world. The total capacity of the company is 36,014 MW with 16 coal based and 7 gas based stations, located across the country. NTPC had been operating its plants at high efficiency levels. NTPC is lighting every third bulb in India. The primary reasons for the company foray into hydro and nuclear based power generation along with backward integration by coal mining.

4.1.1 Panki Thermal Power Plant, Kanpur

Kanpur city, with a population of about 3 million, is situated in North Central part of India at 88°22'E and 26°26'N in Gangetic Plain. Kanpur city is the second largest and most populated industrial city in the state of Uttar Pradesh, India. Panki thermal power station is situated in the Panki town of Kanpur district (Fig-4.1C), between co-ordinates 26º28'35"N and 80º14'31"E. Panki thermal power station has electricity production capacity of 210 MW (2 x 105 MW). The coal to all units is fed from coal mines of BCCL and ECL by means of railways. The study area is situated in the zone of humid subtropical climate and the year is divided into three seasons: the coal season (November- February), the hot season (March- June) and the monsoon season (July- October). Heavy rainfall (generally 70-80% of the total rainfall) occurs during the monsoon season in the months of July, August and September.

4.1.2 Tanda Thermal Power Plant, Ambedkar Nagar

Tanda is situated in Ambedkar Nagar district, located on North-Eastern part of Uttar Pradesh, India; lies between 26°09’ N to 26°40’ N latitudes and 82°12’ E to 83°05’ E longitudes (Fig-4.1C). The total area of the district is 2520 km² and the total length of the district from east to west is approximately 75 km and the breadth from north to south is about 42 km. Tanda thermal power plant coordinates between 26º33’00”N and 82º39’00”E and is surrounded by agriculture fields and mango orchards along with two National Highways 233A & 232 (India) also passes through the town. The coal for the power plant is sourced from North Karnpura Coal Fields, while source of water for the power plant is from Tanda Pump Canal of Saryu River. It has 4 units of 110 MW (4 x 110MW=440 MW) capacity of generation of electricity. The climate of the region is classified into three distinct seasons- Cold weather season (November to February), Hot weather season (March to mid-June) and Season of rains (mid-June to October). The reversal of winds takes place twice a year. The cold weather season lasts from November to February. In November, the belt of high pressure extends from north-west India and covers the whole of the Uttar Pradesh. The temperature beings to decline and the maximum and minimum are 32.15°C and 8.95°C respectively, in this month. The prevailing winds blow from west to east and are influenced by the pressure distribution and pattern of the Himalayas.

4.1.3 Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC) is situated in the Unchahar town of Raebareli district, Uttar Pradesh (Fig-4.1C), between coordinates 25º49 N to 26º36 N and 100º41 E to 81º34 E at an altitude of 120.4 m. FGUNTPC has the stack height of 130m with electricity production and the First unit was commissioned in November 1988. It has the installed capacity of 5×210MW (1050 MW) and 500 MW fourth stage commissioned on April, 2017. The coal for the plant is derived from North Karanpura mines. The water source is from Sarda Sahyak Canal. The climate of the region is tropical with eight months of dry period and four months of rain that ranges from 110 to 485 mm distributed between June to September, the temperature range that the area experiences is between 13.2ºC in winter and 45.2 ºC in summer.

4.2 Methodology

Equipments Used:

Hand lens (10x), field bag, knife, chisels and hammer, altimeter, compass, digital camera, Digi zoom binocular and Leica compound Microscope, Oven, UV chamber, TLC chamber, Glass sprayer, injection syringe, glass rod, test tube, micro test tube, capillary tube, needle, forceps, polythene bags, rubber band, tissue paper, white thick paper, naphthalene ball, pen, pencil, sharpener, scale, field notebook and other writing and labeling materials (Fig-4.2).

Chemicals:

Potassium hydrochloride, Calcium hypochlorite, *p*-phenylenediammine, Ethanol, Iodine, Potassium iodide, 10% Sulphuric acid, Lactic blue, Distilled Water, Liquid detergent, Merck 60F 254 precoated Aluminium TLC plates.

4.3 Exploration, Collection, Identification and Herbarium Preparation:

Present research work initiated with collection of lichen samples from area around thermal power plant of Uttar Pradesh, India. Lichens were periodically collected during the years 2012- 2017. Lichen samples were collected from four directions i.e. East, West, North and South around thermal power plants.

Hand lens (10x), camera, field bag for carrying samples, Global Positioning System (GPS or altimeter), a field notebook, pen, pencil, plant press, old newspapers

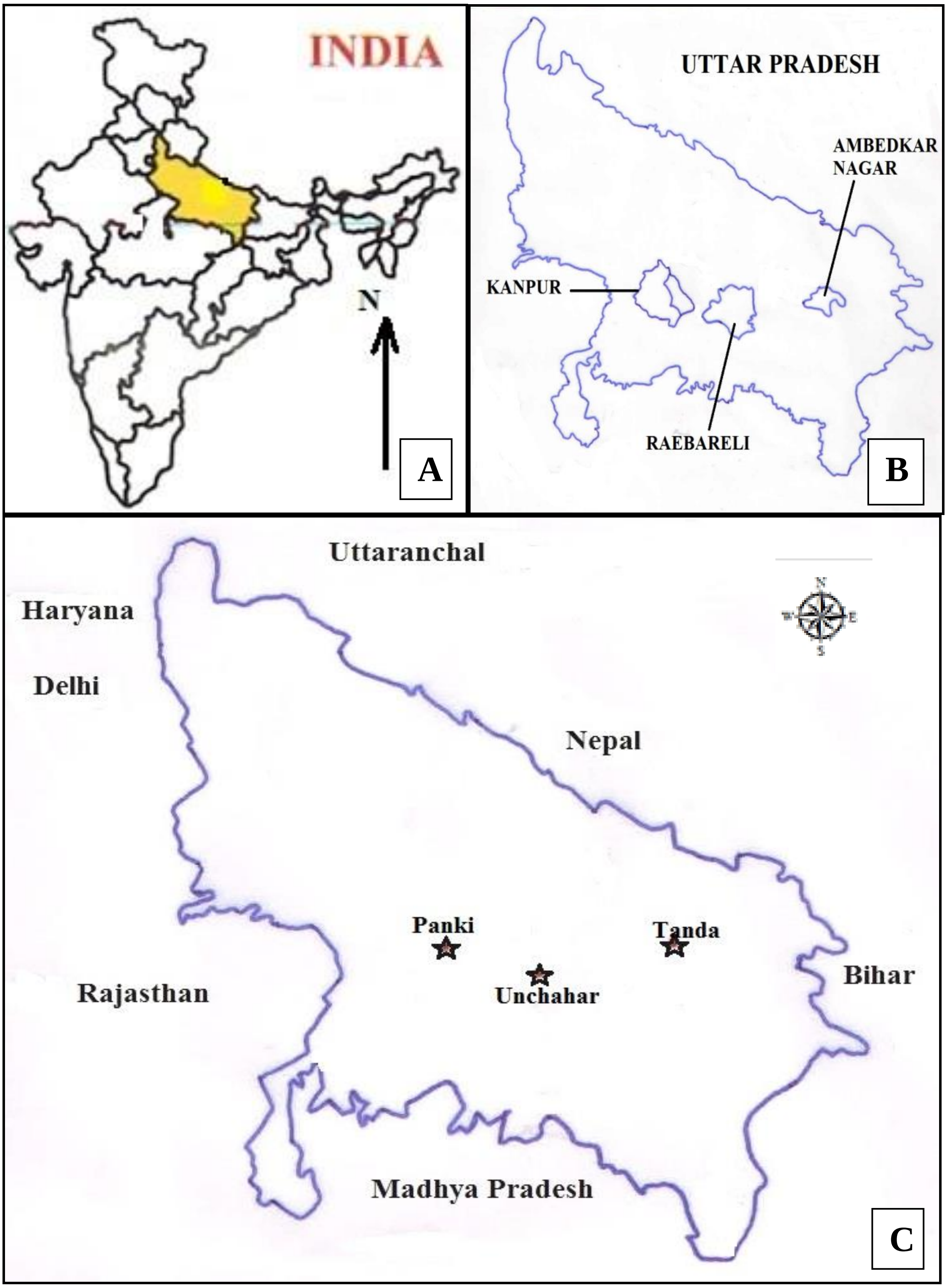


Fig-4.1: (A) Map of India showing Uttar Pradesh region; (B) Map of Uttar Pradesh showing Districts; (C) Map of Uttar Pradesh showing Location sites of selected Thermal Power Plants

or blotters, herbarium packets, sheath knife, chisels and hammer were the other necessary equipments used during lichens collection trip.

Sample Collection:

The lichen specimens were collected from all the available substrates (tree trunk, bark, dead wood and soil) with the help of hammer, knife and chisels and the attached specimens were usually scrapped out from the substrate. Additional protection was obtained by covering the specimen with a piece of tissue paper. Brittle or delicate lichens were protected by layers of cotton. Large macro-lichens were pressed flat and dried to fit into packets. However, for storage, lichens were directly placed in the herbarium packets. The method for collecting lichens depends on the objective of the study (Plate-4.1).

The collected specimens were placed in separate polythene bags (tightened with rubber bands), labeling stickers (together with the details of locality, substrate, ecological notes, voucher number, date of collection and also name of collector), These bags then brought to the laboratory (Fig-4.2). The lichen specimens were then dried at room temperature. Blotting paper was used for drying thick corticolous samples. The dried specimens were kept in herbarium packets (17cm x 13cm) of brown thick paper sheets so as to absorb the remaining moisture left in the samples after drying. These packets are ideal and handy for keeping the lichen specimens for a longtime. At the most, naphthalene balls or powder may be kept in boxes where lichens were stored.

In order to avoid spoiling of specimens due to crushing, large samples were distributed in two or more packets, however, all the specimens were given the voucher number of each species. One packet with good specimen was treated as original, while all others were marked as duplicate.

Plate-4.1: Collection of lichens (A) Location sites near Panki Thermal Power Plant; (B) Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli; (C) Location sites near Tanda Thermal Power Plant; (D) Collecting lichens from the bark of a tree using chisel and hammer; (E) *Bacidia* sp. (crustose lichen); (F) *Pyxine cocoes* (foliose lichen)

Fig-4.2: Identification kit of Lichen samples (Upreti, 2016)

4.3.1 Identification of Lichen Samples:

Identification of each lichen taxa collected from selected research sites was authenticated with the available relevant literatures i.e. checklist, floristic, monographic and revisionary studies (Awasthi, 1980, 1988, 1991, 2000, 2007; Singh and Sinha, 2010). Recently Nayaka and Upreti (2013) analyzed the status of lichen diversity in Uttar Pradesh which revealed the occurrence of 135 species belonging to 46 genera and 25 families.

The collected specimens were identified by their morphological, anatomical and chemical characters and specimens were preserved in the herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG) (Plate-4.2).

4.3.1.1 Morphological Parameter

For intensive and extensive studies of the specimens in east, west, north, south direction of the study area were collected. The number of species in each 1x1 sq km grid was recorded and distance from source of pollution was also recorded. A hand

Plate-4.2: Identification Process: (A) Drying lichen samples at room temperature; (B) Visual observation of lichens under Compound Microscope; (C) Preparation of packets for the herbarium record; (D) TLC preparation of the lichen samples; (E) FTIR unit: Model- NicoletTM 6700 (Thermo Scientific, USA) used for analysis; (F) Scanning Electron Microscope (SEM): Model-JSM 6490LV (JEOL, Japan) Unit used for analysis

lens (10x) and LABOMED dissecting microscope was used for external morphological study, while LEICA ATC 2000 compound microscope was used for microscopic anatomical details. The samples were mounted in water, 10% KOH and Lugol's solution. Measurement of asci and ascospores was made on material examined in KOH. The colour test and Thin layer chromatography (TLC) was done by solvent system A and C (Orange et al., 2001; Culberson, 1972; Walker and James, 1980) for identification of lichen with the usual reagent that is K (5% potassium hydroxide), C (Aqueous solution of calcium hypochlorite) and PD (*para*-phenylenediamine). Type of thallus including growth forms (crustose, foliose, leprose, squamulose, dimorphic etc.) with their shapes (circular/ irregular) and size were recorded. On the upper surface of the lichen thalli, colour, texture (smooth/wavy/rough/warty etc.), presence of isidia (finger like projection), soredia (granular form), pruina (fine powder), pycnidia (black dots) and pseudophyllae (white decorticated area) were noted.

In the case of foliose lichen, branching pattern, length and width of marginal lobes, presence of cilia and various features like colour, presence of cyphallae, pseudophyllae, rhizines with their colour, distribution, branching and abundance were noted.

Morphology of all fruiting bodies like in apothecia (shape, size, attachment organ, colour, texture of the margin and disc, presence of purina on the disc, shape of the disc i. e. convex or concave) and in perithecia (features like shape, size, opening position i.e. apical or lateral, single and/or grouped was observed (Plate -4.3).

4.3.1.2 Anatomical characters

Thin section of the particular lichen thalli were used for the anatomical study sections of the thallus were cut by a new razor blade. Sections were mounted in water and lactic blue (cotton blue + lacto phenol in glycerin) drying off the air by a drop of ethanol. The details of the hymenium were studied in squash preparations of sections mounted in aqueous KOH. The colour glass was gently tapped under observation till different parts get separated or loosened from each other. Under microscope, all observations included thickness of different layers (i. e. upper cortex, algal layer, medulla, lower cortex), algal distribution (homoiomerous or heteromerous), colour of ascocarp, no. of spore in ascus, exciple colour and position of crystals were studied (Plate-4.3).

4.3.1.3 Chemical Tests

(a) Colour Test- It is also known as "Spot Test". When certain chemicals were applied directly on the thallus or medulla, impart a change in colour were appeared. Presence or absence of lichen substances were detected with these spot test by applying minor amounts (Fig-4.3 & 4.4). A positive change is denoted by test solutions to thallus with a needle or micropipette. When the colour change in this test, it is positive (+) symbol, followed by the colour produced, and no change in colour is shown by a negative (-) symbol (Orange et al., 2001). The chemicals routinely used are as follows:

- **K-test-** 10-25% aqueous solution of potassium hydroxide (10mg KOH pellets in 100 ml distilled water) was used for K-test. K is useful reagent to find the difference between anthraquinones and pulvinic acid derivatives. It gives deep purple colour with orange or red anthraquinones, deep red with anthranorin followed by orange red with norstitic acid. Derivatives of pulvinic acid are either K- or give a very weak reddish reaction. It is also used as a clearing reagent for the thalli and its fruiting bodies.
- **C-test-** A freshly prepared aqueous solution of calcium hypochloride containing active chlorine was used. It gives a reddish pink colour with depsides and xanthone with two free hydroxyl groups at meta position.

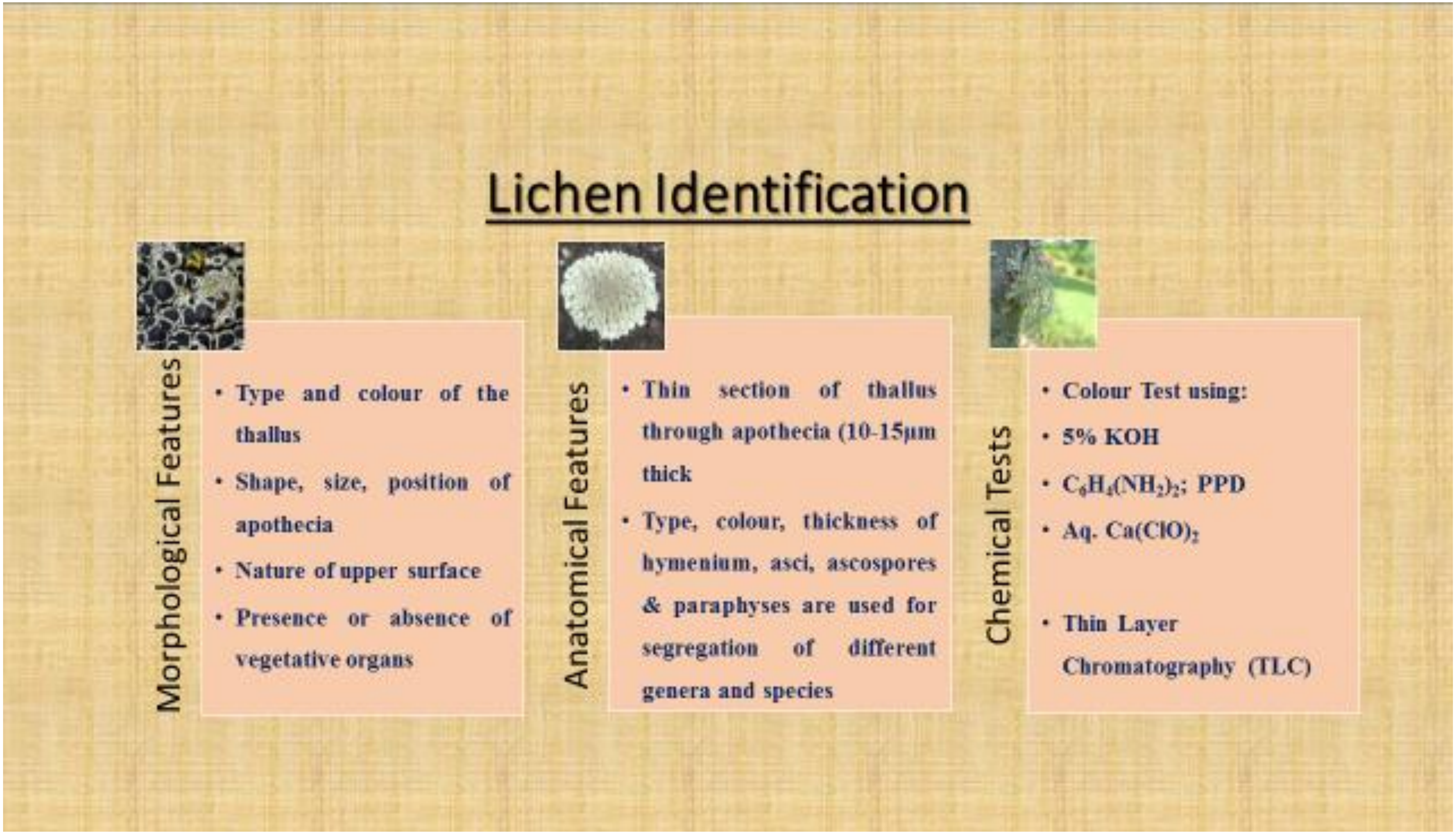
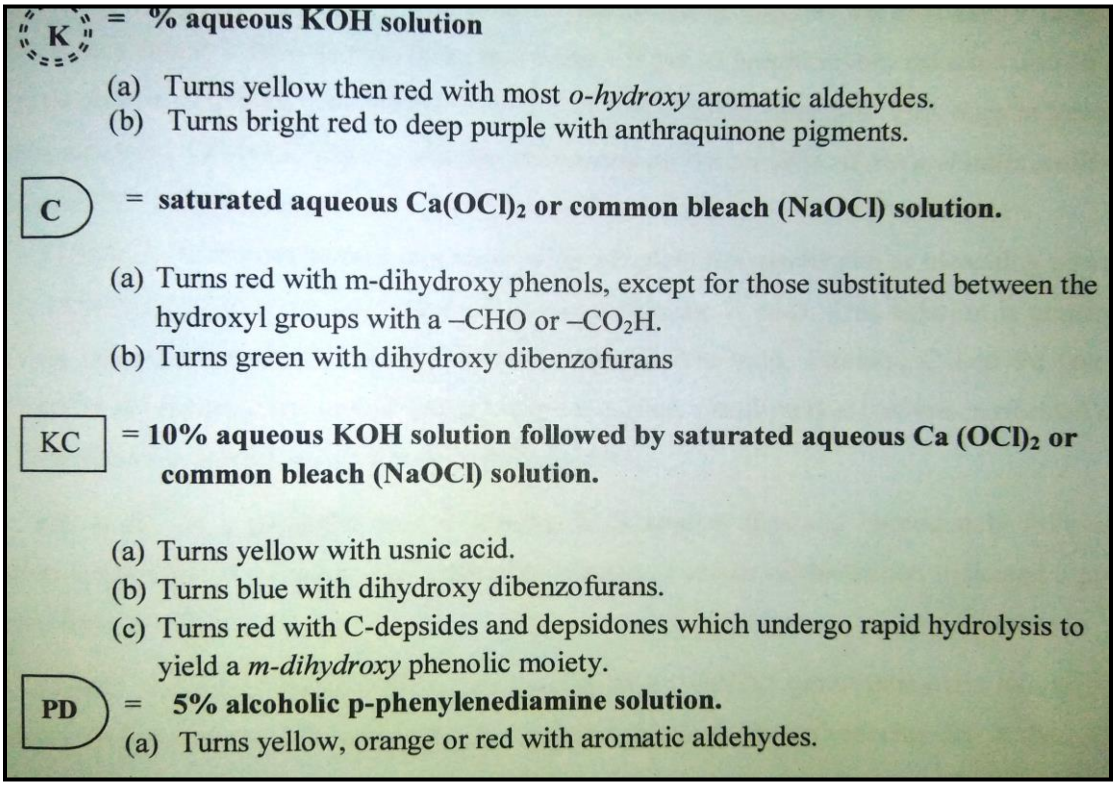


Plate-4.3: Characteristic features of lichen samples for identification process



K = % aqueous KOH solution

(a) Turns yellow then red with most *o-hydroxy* aromatic aldehydes.
(b) Turns bright red to deep purple with anthraquinone pigments.

C = **saturated aqueous $Ca(OCl)_2$ or common bleach (NaOCl) solution.**

(a) Turns red with m-dihydroxy phenols, except for those substituted between the hydroxyl groups with a –CHO or –CO_2H.
(b) Turns green with dihydroxy dibenzofurans

KC = **10% aqueous KOH solution followed by saturated aqueous Ca $(OCl)_2$ or common bleach (NaOCl) solution.**

(a) Turns yellow with usnic acid.
(b) Turns blue with dihydroxy dibenzofurans.
(c) Turns red with C-depsides and depsidones which undergo rapid hydrolysis to yield a *m-dihydroxy* phenolic moiety.

PD = **5% alcoholic p-phenylenediamine solution.**

(a) Turns yellow, orange or red with aromatic aldehydes.

Fig-4.3: The colour spot test reagents and their possible reactions (Nayaka and Upreti,2013)

Fig-4.4: Identification kit for Colour test for lichen samples (Upreti, 2016)

- **KC-test-** At a particular spot of thallus, K is applied first and immediately followed by C- test. Turns red with C- depsides and depsidones which undergo rapid hydrolysis to yield m-hydroxyl phenolic moiety, eg. Alectoronic acid.
- **P-test-** A stable solution called Steiner's P (1-5% solution of *p*-phenyleneamine) was prepared by dissolving 1 gm of para-phenylenediamine and 10 gm of sodium sulphite in 100 ml of distilled water with 1 ml of liquid detergent. It gives yellow to orange colour reactions with depsides and depsidones containing aldehyde group.
- **I-test-** The 2-5 gm of iodine was dissolved in water with 0.5 gm of potassium iodide. The reagent was kept in stoppered bottle. This solution does not react with lichen's secondary metabolites, but it react with starch-like polysaccharides in the thallus and fruiting body. It was renewed if brown colour faded away.

4.3.1.4 Ultra-violet (UV) Test: A number of secondary metabolites in lichens exhibit a characteristic fluorescence under UV- light. The response a (positive or negative) these metabolites plays a vital role in the lichens identification. Identification was done following comparison of the morphometric and biochemical test results with those in published literature and identification key given by Hale (1979) and Nash III (1996).

4.3.1.5 Microcrystallography

Microcrystallography was introduced by Asahina (1936 and 1938). The method elaborate equipment. A small fragment of lichen to be investigated is placed on the middle part of a microscopic glass slide and one-two drops of acetone or another organic solvent are dripped on to the fragment by means of dropper pipette. Lichens substances, if present, gets dissolve in the solvent and extracted on the slide as residue in a ring form around the fragment as soon as the solvent evaporates. The thallus fragment is blown off. A microcover glass is placed over the residue and a drop of one of the crystallizing fluids (detailed below) is placed as the edge of the cover glass.

The fluids gradually seep in. The slide is then heated gently over a spirit lamp. The residue dissolves in the fluids and lichen substances gradually crystallize into their characteristics shapes after cooling completely. These crystals observed under low power of microscope and identified by comparison with the photographs or line diagrams published by Asahina (1950; 1952), Hale (1967), Thomson (1967), Krog (1951). Identification of depsides and desidones and dibenzofurans can usually be confirmed by this method. The crystallizing fluids are as-

G. E. – Glycerol: acetic acid; 1:3 ratio

G. A. W.- Glycerol: ethanol: water ; 1:1:1 ratio

G.A. Ot- Glycerol: thanol: Ortho-toluidine; 2:2:1 ratio

G. A. An- Glycerol: ethanol: aniline; 2:2:1 ratio

G. A. O.-Glycerol: ethanol: quinoline; 2:2:1 ratio

4.3.1.6 TLC (Thin Layer Chromatography) (Fig-4.5; Plate-4.4)

Sometimes many lichen substances are not detectable in colour test and in such case TLC was performed. In TLC, various lichen substances present in the lichen thallus gets separated as spot on silica gel plate. The TLC is based in the principal that molecule having low molecular weight will move faster than the molecules having higher molecular weight.

<u>**Procedure:**</u>

1. Extraction of lichen substances: In micro test tubes, small pieces of lichen material were taken and 2-3 drops of acetone was added for extraction of lichen substances.

2. Preparation of TLC Plates: Commercially available Merck Silica gel 60F 254 precoated Aluminum TLC plates were used for performing TLC. The TLC plate was cut into appropriate dimension of 15x20 cm^2 and a fine line was drawn at 2 cm above from base of the plate. Depending upon the number of specimens to be identified, spots were marked on the baseline at uniform distance by keeping the control material on either sides of the plate.

3. Loading: Extracted material was loaded on the baseline with the help of capillary tubes and each spot was concentrated by repeated loading using capillary tubes.

4. Preparation of Solvent and TLC Tank

Following different solvent systems were used to separate lichen chemicals of which solvent A was frequently used for the routine identification process:

Solvent system A- (TDA) - Toluene (180ml): 1, 4-Dioxane (60ml): Acetic acid (8ml)

Solvent system B (HEF) – Hexane (140ml): Diethylether (72ml): Formic acid (18ml)

Solvent system C (TA) – Toluene (170ml): Acetic acid (30ml)

Solvent system G (TEF) – Toluene (139ml): Ethyl acetate (83ml): Formic acid (8ml)

Fig-4.5: Solvent System usually used for the Thin Layer Chromatography

Solvent 'A' is stable and reliable system for general use. Also very useful for separation of low Rf compounds such as β-orcinol depsidones, hopane terpinoids and fatty acids. It has an important role in routine analyses for most groups of compounds, for example, perlatolic acid and stenosporic acids can be separated in this solvent system (Fig-4.5; Plate-4.4). But, the common solvent system used for chromatography is- **T.D.A. – Toluene: 1-4 Dioxane: Acetic acid (180ml : 60ml : 8ml)**

Three dimensional TLC has also been used to find out and determine the lichen substances which are not detected by one dimensional TLC. Further sophistication has been achieved by the use of high performance liquid chromatography (HPLC) and spectrometry. Some common lichen substance with their Rf class is in solvent A were noted below for ready reference (Table-4.2).

5. Running: Loaded the TLC plate with extract and placed it in airtight TLC tank keeping baseline of the plate above solvent level in the tank. As the solvent reaches the top of the plate, the plate was taken out of TLC tank.

6. Spraying of Colouring Agent: For the identification of fatty acids, distilled water was sprayed over the TLC plate, but for other substances, 10% conc. H_2SO_4 (sulphuric acid) solution was sprayed.

7. Charring: After spraying with 10% H_2SO_4, TLC plate was allowed to air dried and then kept in preheated hot air oven at 110-120ºC for 7-10 minutes until spots at different levels were visible. Coloured spot on TLC plate were examined and identified by Rf (relative front) class or Rf value. The developed TLC plate was divided into seven equal parts from loading line to Atranorin spot to note Rf class of spots.

8. Identification of lichen substances: Lichen substance present in the sample was identified on the basis of position and colour of the spots appeared on the TLC plate and the distance they travelled from the loading point. Later, the spots were identified by noting their colour and measuring the distance travelled by them. *Parmellinela wallichiana* (Taylor) Emix & Hale was used as control, as it contains two secondary metabolites salazinic acid (at Rf class 2) and atranorin (at Rf class 7) (Culberson, 1972; Walker and James, 1980). (Table-4.2 & 4.3; Plate-4.4).

The Rf value was calculated by the using formula as under-

$$\textbf{Rf Value} = \frac{\text{Distance travelled by lichen substance (indicated by spot)}}{\text{Distance travelled by the solvent (Solvent front)}}$$

4.3.1.7 Other Colour Test- A dilute aqueous solution of nitric acid and an aqueous solution of ferric chloride are sometime used for identification of *Melanelia* and *Buellia* species. The spot tests were carried out on the thallus but comparatively younger parts give better results. Colour test is done to a small fragment of the desired part of lichen thallus eg. ascocarp. A definite colour comes showing the presence of lichenic acid.

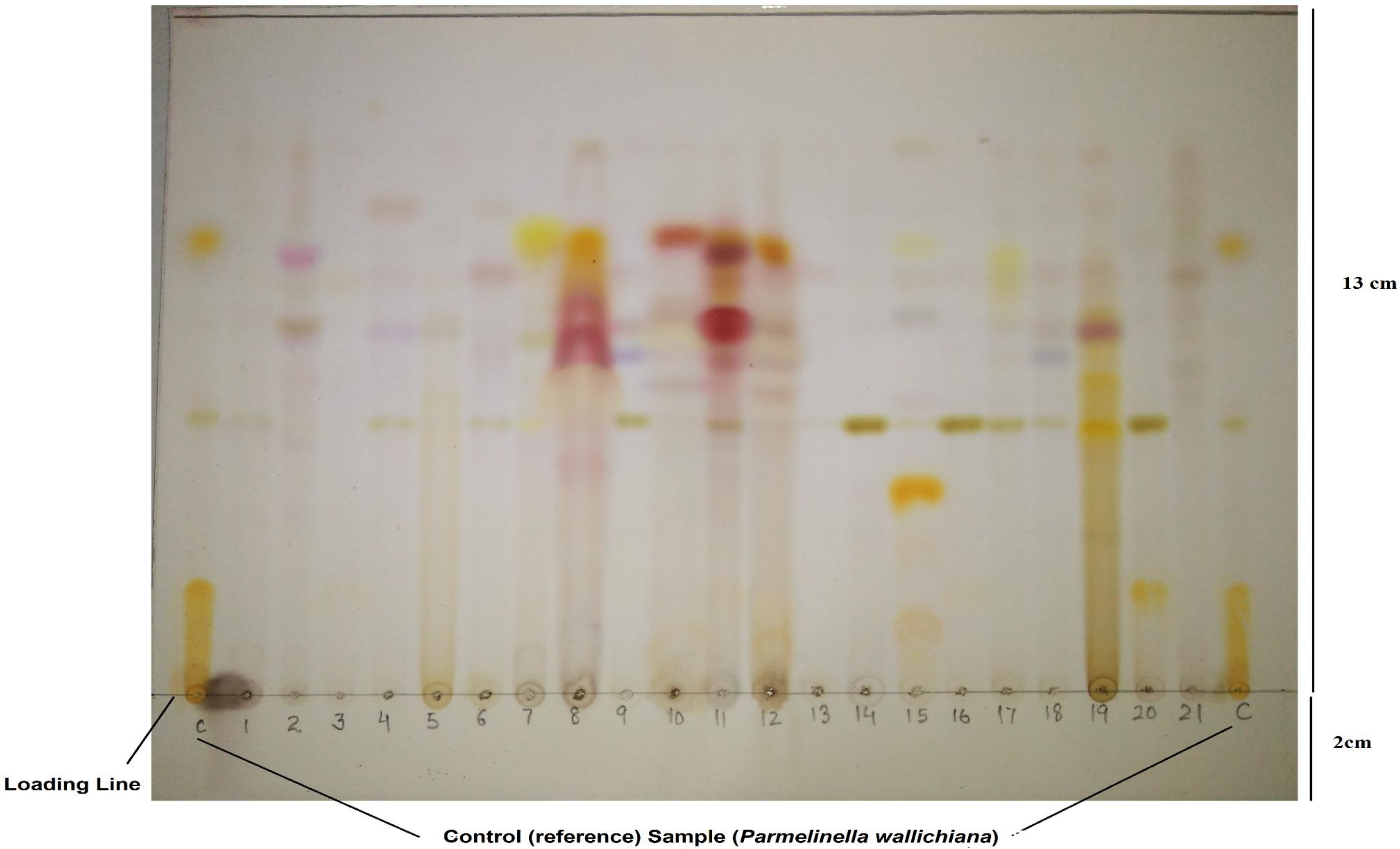


Plate-4.4: Lichen compounds analysed from different species of the study area

Table-4.2: Identification technique of Reference Classes by Thin Layer Chromatography, Colour spot, Colour test and substances

Rf Classes	Colour of Spot	Lichen Substances	Colour test
1 – 2	Dark grey	Fumarprotocetraric acid	PD+ yellow – red
1 – 2	Dark grey	Protocetraric acid	PD+ yellow – red
1 – 2	Grey – orange	Thamnolic acid	K+ yellow – orange PD+ orange
2	Yellow – orange	Salazinic acid	K+ yellow – orange PD+ red
2	Pale violet grey	Pannaric acid	C+ green
3	Orange	Stictic acid	K+ Yellow, PD+ Orange
3	Pale	Physodic acid	KC+ orange – red
3	Yellow or grey	Gyrophoric acid	C+ red
3	Yellow – grey	Lecanoric acid	C+ red
3	Pale green – grey	Lobaric acid	KC+ red
3	Dull yellow – brown	Psoromic acid	PD- yellow-red
3 – 4	Pale straw	Olivetoric acid	C+ red
4	Bright yellow	Norstictic acid	K+ red, PD+ orange
4	Orange	Sekikaic acid	--
4	Yellow	Barbatic acid	--
4 – 5	Yellow – orange	Perlatalic acid	--
5	Violet	Zeorin	--
6 – 7	Pale	Lichexanthone	UV+ yellow – orange
7	Greenish grey	Usnic acid	UV+ quench
7	Dark green	Pannarin	PD+ orange
7	Yellow – orange	Atranorin	K+ yellow

+ = Positive Reaction; - = Negative Reaction; ± = more or less

Table-4.3: Lichen chemicals substance present upon TLC plates

Sample No.	Lichen chemicals
1	Triterpene between Rf 6-7
2	Triterpene between Rf 6-7, dark blue brown unknown compound at Rf 5
3	Traces of triterpene at Rf 5-6
4	Traces of triterpene at Rf 5-6
5	Traces of triterpene at Rf 5-6, pale yellowish spot below Rf 4-5
6	Traces of triterpene at Rf 5-6
7	Pareitein between Rf 6-7, unknown bluish between Rf 4-5
8	Triterpene at Rf 5, 4-5, atranorin at Rf 7
9	Zeorin at Rf 5, triterpene below Zeorin
10	Atranorin + 2- methylperlatolic between Rf 4-5, Zeorin at 5 + unknown bluish at Rf 4
11	Atranoein at Rf 7 + Zeorin at Rf 5 + Yellow brown unknown between Rf 6-7 and Rf 4-5
12	Atranoein at Rf 7 + 2- methylperlatolic between Rf 4-5
13	Traces of triterpene between Rf 6-7
14	Pale brown spot of unknown compound at Rf 4
15	Stictic acid comple between Rf 1-3
16	Pale brown spot of unknown compound at Rf 4
17	Triterpenes at Rf 4, between Rf 4-5, yellow spot of lichenoxanthane between Rf 6-7
18	Triterpene at Rf 4-5, 5 and 6
19	Unknown substance of yellow spot at 4, 4-5; Zeorin at Rf 5 and 6
20	Traces of Salazinic at Rf 2, Pale brown unknown at Rf 4
21	Triterpene at Rf 6

4.4 Criteria for the identification of lichens groups and bio-indicator species:

Characteristics features of the lichens are used in segregation of the lichen taxa (Plate-4.5). The different morphological and anatomical characters employed for segregation of different lichen species in various lichen groups are as follows:

(i) Parmeloid taxa: Majority of Parmeloid taxa are segregated on the basis of their morphological characters as presence, absence, type and shape of pseudocyphellae,

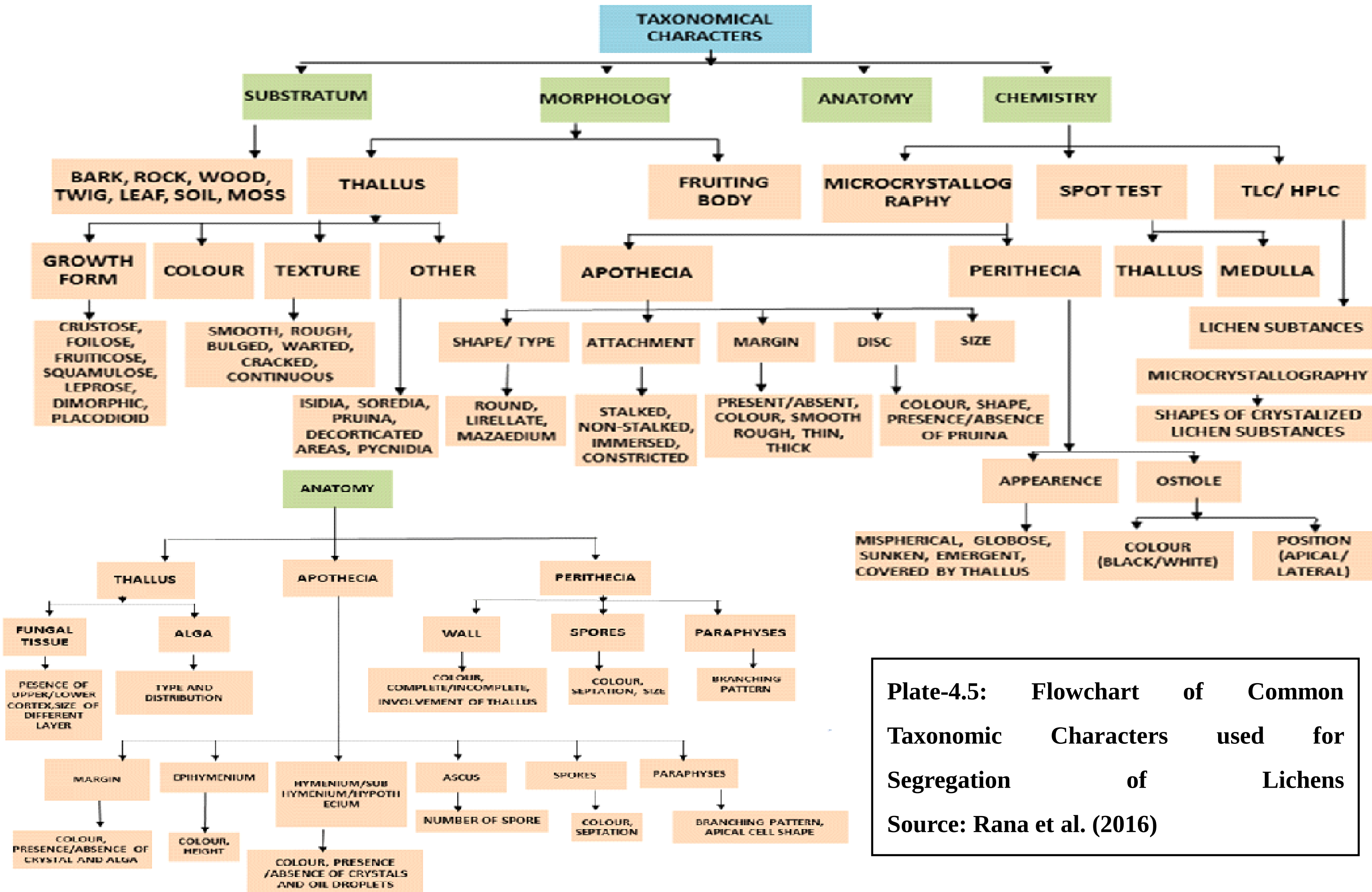


Plate-4.5: Flowchart of Common Taxonomic Characters used for Segregation of Lichens

Source: Rana et al. (2016)

maculae, cilia, rhizinae which also play an important role in segregation of different lichen taxa. The anatomical and ascomatal characters are not such a major characters for segregation of Parmeloid taxa.

(ii) Dimorphic taxa: The Dimorphic lichen consists of two types of thallus: a squamulose primary thallus bears upright secondary thallus called podetia which bears apothecia. The podetia may be hollow or solid (called pseudopodia). The lichen family Cladoniaceae and Strigulaceae belongs to this group. The colour, size and shape of primary thallus squamules are used in segregation of few taxa while majority of species are segregated on the basis of secondary thallus characters. The branching, presence or absence of longitudinal slits, colour of apothecia, presence or absence of cups, proliferation on cups are some major taxonomical characters used for segregation of Dimorphic taxa.

(iii) Lecanoroid taxa: Among Lecanoroid taxa, the thallus habit, substratum, type and colour of the thallus play an important role in segregation of different species. The habit of thallus may be crustose, squamulose or placodiod. The substratum maybe corticolous, saxicolous or musicolous. Colour of apothecial disc, pruinose or epruinose condition, presence or absence of crystal in epihymenium, the colour and K reaction, amphithecium type, hypothecium colour and size of calcium oxalate crystals in amphithecium are the major characters used for segregation of lecanoroid taxa.

(iv) Graphidioid taxa: The modified elongated structure of the ascocarp, called lirellae, is the only basic character for the identification of the taxa. The branching and position of lirellae, colour of exciple, ornamentation and shape of labia, number of spores in asci, size and septation of spore play an important role in the separation of graphidioid taxa.

(v) Pertusarioid taxa: The pertusarioid taxa are characterized by presence of thalline verrucae. The thallus colour, texture and habit together with the absence and presence of pseudophellae, isidia or soredia are used to segregate different species.

The apothecioid or pertusarioid nature of ascomatal, width of apothecia disc, colour, shape and size of fertile thalline verrucae, number, colour, position of ostiole, paraphyses branching, number of spores per ascus, shape and size of spore wall play an important role in segregation of particular taxa.

(vi) Lecideoid taxa: The segregation of this taxa is based on the type of thallus, nature and shape of areoles, colour of hypothallus along with position, colour and size of ascomata, pigmentation of exciple, hymenium and hypothecium, structure of paraphyses, shape, size of asci, paraphyses and spore. In this group of taxa, the ascocarp contains only fungal tissue with a proper exciple or rim similar in colour to the disc.

(vii) Pyrenuloid taxa: The less morphological variation in thallus structure limits the superficial identification of the taxa up to colour and nature of thallus, together with presence or absence of hypothallus and pseudocyphellae. The position, nature, size of ascomata, shape, ostiole and peridium, asi shaped, number of spore per ascus, ascus tip together with spore shape, thickness of spore wall, number of primary septa, size and orientation of cell chamber are the major characters used for segregation of pyrenuloid taxa.

(viii) Ascospores or Spore: Spore type plays an important role in species identification. Based on the type of septation, the spores may be aseptate, transversely septate, transversely and longitudinally septate, muriform or polaribilocular. Aseptate spores are usually simple, colourless and small in size are found in the lichen families Lecanoraceae, Lecidiaceae, Parmeliaceae, Pertusariaceae and Verrucariaceae. Transversely septate spores may be 1 to many septate. The members of Physciaceae family have one septate thick walled spores while, of Ramalinaceae have colourless bright-brown, transversely septate spores. Multiseptate spores are of thick or thin walled, colourless to brown are belong to the individuals of families Ramalinaceae, Chrysothriaceae, Graphidaceae and Arthoniaceae. Muriform spores are the characteristics features of the families Diploschistaceae and Pyrenulaceae. Polaribilocular spores consist of two locules connected by a thin canal found in the family Teloschistaceae (Fig-4.6). Multiseptate spores are of thick or thin walled, colourless to brown are belong to the individuals of families Ramalinaceae, Lecanoraceae, Caliciaceae, Teloschistaceae, Pertusariaceae, Opegrapaceae, Peltulaceae, Arthoniaceae and Physciaceae (Fig-4.7).

The main group of lichen bioindicator communities known from India and their predictive ability are described as follow (Upreti, 2011)-

***Calcioid* Group**: This group is also known as the "pin-head" lichens, are indicators of old growth forests and species dependent on snags and old trees with stable rough bark.

***Alectoroid* and *Usnioid* Group**: The hanging fruticose lichens are used as indicators for older forest with better air quality.

***Cyanophycean* Group**: The epiphytic cyanolichens are useful as an indicator of forest ecosystem function and plays an important role in forest nutrient cycle and indicate forest age and continuity (Mc Cune, 1993).

***Lobarian* Group**: This group is comprised of *Lobaria*, *Peltigera* and *Sticta* which are sensitive to air quality and reliable species which indicates rich old forest with long forest continuity (Gausala, 1995).

***Xanthoparmelioid* Group**: The yellow foliose lichen species of *Xanthoparmelia* is consistently correlated with stable productive landscape i.e. landscapes with no accelerated erosion (Eldridge and Koen, 1998).

***Graphidioid and Pyrenuloid* Group**: Both groups mostly prefer to grow on a smooth bark tree in evergreen forest (eg. Family Graphidaceous (*Graphis*, *Opergrapha*) and Pyrenocarpous (*Anthracothecium*, *Pyrenula*, *Porina*) influenced by the nature of bark.

***Lecanorioid* Group**: This group indicates well illuminated environmental condition of the forest with sunlight and wind and prefers to grow on trees with more open area (eg. *Lecanora*, *Lecidella* and *Biatora*).

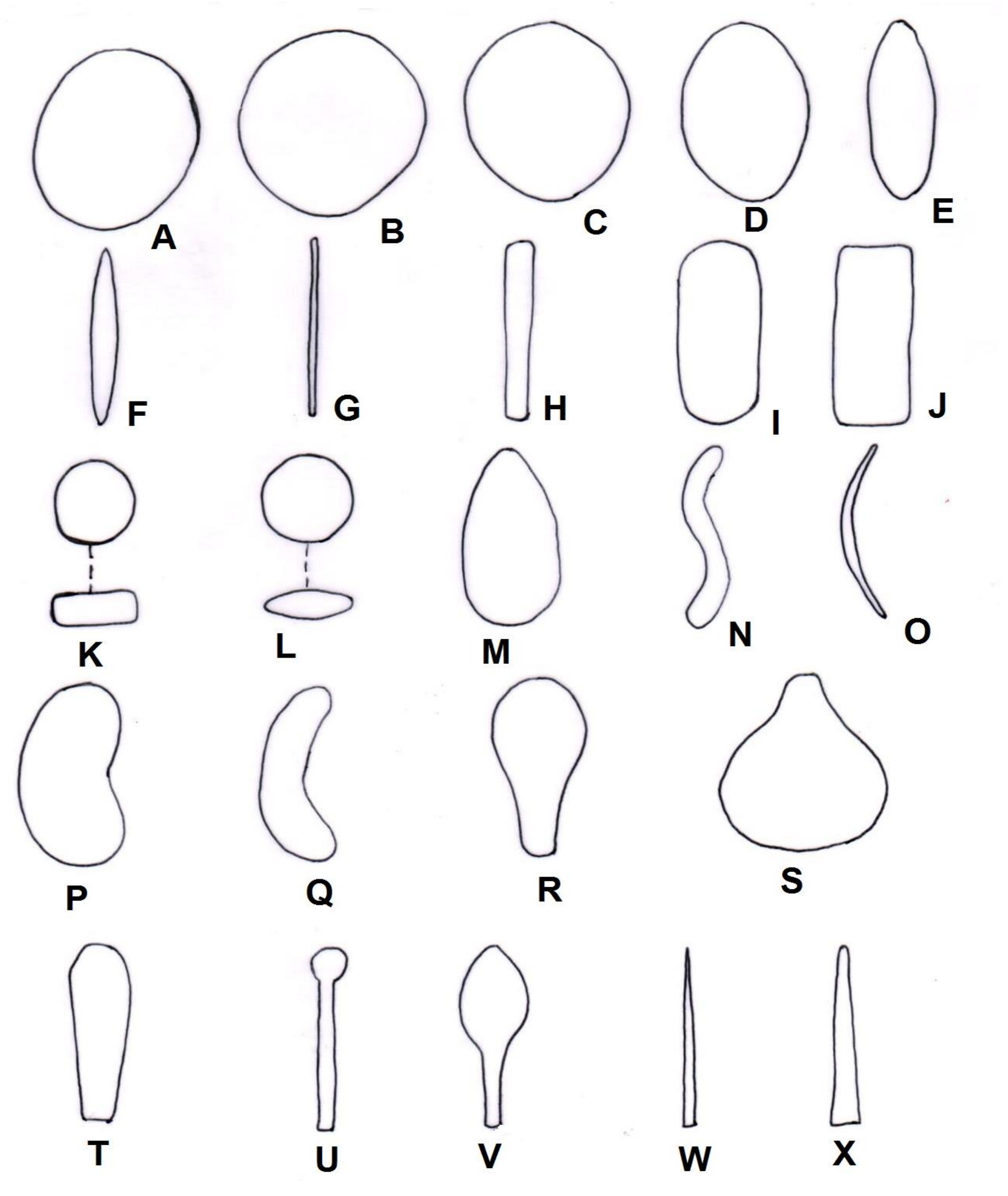


Fig-4.6: Spore shape terminology: (A) Globose; (B) Subglobose; (C) Broadly ellipsoid; (D) Ellipsoid; (E) Narrowly ellipsoid; (F) Fusiform; (G) Filiform; (H) Bacilliform; (I) Oblong rounded ends; (J) Oblong truncate ends; (K) Discoid; (L) Lenticular; (M) Ovoid; (N) Sigmoid; (O) Falcate; (P) Reniform; (Q) Allantoid; (R) Pyriform, (S) Ampulliform; (T) Clavate; (U) Capitate; (V) Spathulate; (W) Acicular and (X) Subulate

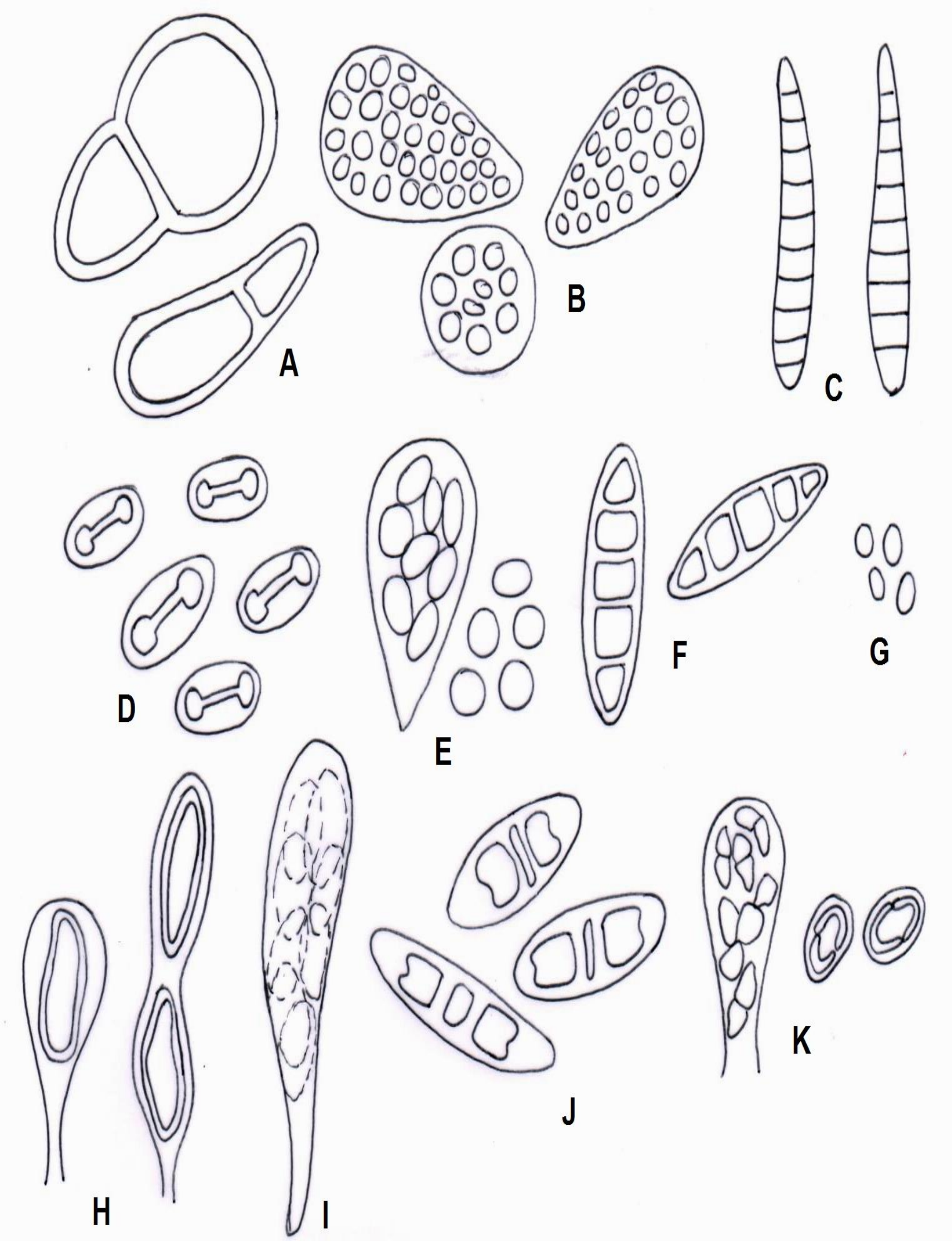


Fig-4.7: Different types of spores in different lichen species: (A) *Anisomeridium nidulans*; (B) *Arthothelium chiodectoides*; (C) *Bacidia* spp.; (D) *Caloplaca* spp.; (E) *Lecanora* spp.; (F) *Opegrapha astrae*; (G) *Peltula corticola*; (H) *Pertusaria* (1-2 spored); (I) *Pertusaria* (8-spored); (J) *Pyxine cocoes* and (K) *Rinodina sophodes*

***Parmelioid* Group** (Family Parmeliaceae): The forest with closed canopy and less sunlight support few species of Parmelioid genera to grow while the open thinned out forest with more sunlight exhibit dominance of Parmelioid lichens. eg. *Bulbothrix*, *Flavoparmelia*, *Parmotrema*, *Parmelia* and *Punctelia.*

***Pertusorioid* Group**: The group indicates old tree forest with rough-barked trees (eg. *Pertusaria* and *Shorea robusta* tree forest in the dry deciduous forest) appears excellent host for this group of lichens to colonize.

***Leprarioid* Group**: This group forms powdery thallus on the substrates indicates moist and dry vertical slopes, rough-barked trees of moist and dry habitats (eg. *Chrysothrix*, *Cryptothecia* and *Lepararia*).

***Physcioid* Group**: **(Pollution tolerant lichens)** This group of lichens has an ability to grow on varied substrates in both moist and dry habitats (eg. *Physcia*, *Pyxine*, *Dirinaria*, *Heterodermia*, *Phaeophyscia* and *Rinodina*).

Teloschistacean Group: This group of lichens has an ability to grow both on exposed and sheltered rocks. The dark orange pigment present on the upper cortex of the thallus act as a filter and to protects the lichens from high UV radiation (eg. *Caloplaca*, *Letroutia*, *Brigantiaea* and *Xanthoria*).

Lichinioid Group (Family Lichninaceae): mostly having cyanobacteria as their photobiont and prefers dry rocks and barks having higher concentration of calcium and indicate presence of calcareous substrate in the habitats.

Peltuloid Group: indicates a stable rock substratum like genera *Peltula.*

Different methods for Biomonitoring utilizing lichens-

In the present study, biomonitoring was performed through the following ways-

4.5 Lichen Zone Mapping- Occurrence of lichen species around thermal power plants of Uttar Pradesh indicated the severity of pollution in the area. On the basis of the impact of thermal power plants emission on lichen community within the radius of 21 km, the thermal power plants were zoned into three different categories- Zone A, Zone B and Zone C; on the basis of their pollution level from the centre of thermal power plants in all directions.

4.6 Ecological Methods or Community Analysis

Ecological Methods or Community analysis may be carried out in any given sites or location on the basis of their zones in the study area. In each study sites, 30 quadrats of 10 m X 10 m (100 sq m) or 50 quadrats of 1m X 1m (1sq m) size, which was suitable were randomly laid to study lichen species size randomly in each study site.

The important quantitative analysis such as density, frequency, and abundance of lichen species were determined as per Curtis and McIntosh (1950). The important parameters for describing community structure in precise quantitative terms are as follows:

4.6.1 Frequency

This term refers to the degree of dispersion of individual species in an area and is usually expressed in terms of percentage occurrence. It can be defined as the chance or probability of an individual of a given species to be present in a randomly placed quadrate. It was studied by sampling the study area at several places at random, and recording the names of species that occur in each sampling units. It is calculated by the equation:

$$\textbf{Frequency (F)} = \frac{\text{Total number of quadrates in which species occured}}{\text{Total number of quadrates sampled}} x100$$

A species most abundantly spread all over the area had chance of occurring in all the samplings and therefore, its frequency was hundred percent. When a poorly spread even with large number of species in one comer had a chance of occurrence in only few sampling has showed that low frequency value.

4.6.2 Density

Density is an expression of the numerical strength of a species where the total number of individuals of each species in all the quadrats is divided by the total number of quadrats studied. Density is calculated by the equation:

$$\textbf{Density } (D) = \frac{\text{Total number of individuals in all the quadrates}}{\text{Total number of quadrates studied}}$$

4.6.3 Abundance

Abundance is the study of the number of individuals of different species in the community per unit area. By quadrats method, samplings are made at random at several places and the number of individuals of each species was summed up for all the quadrats divided by the total number of quadrats in which the species occurred. It is represented by the equation:

$$\textbf{Abundance } (\mathbf{A}) = \frac{\text{Total number of individuals in the species}}{\text{Total number of quadrate used in sampling}}$$

4.6.4 Relative frequency

The degree of dispersion of individual species in an area in relation to the number of all the species occurred. Relative frequency is determined by the formula:

$$\textbf{Relative Frequency}(\mathbf{Rf}) = \frac{\text{Total number of individuals in the species}}{\text{Total number of quadrate used in sampling}}\ x100$$

4.6.5 Relative density

Relative density is the study of numerical strength of a species in relation to the total number of individuals of all species and can be calculated as:

$$\textbf{Relative density } (\mathbf{Rd}) = \frac{\text{Number of species in an area}}{\text{Total number of individuals}}\ x100$$

4.6.6 Importance Value Index (IVI)

This index is used to determine the overall importance of each species in the community structure. As it was not possible to measure the basal area of every lichen specimen encountered therefore, In calculating this index, the percentage values of the

Relative frequency (Rf) and Relative density (Rd) are summed up together and this value is designated as the Importance Value Index or IVI of the species (Pinokiyo et al., 2008). The relative frequency and relative density were determined following the standard methods (Phillips, 1959).

Importance Value Index = Relative frequency (Rf) + Relative density (Rd)

4.7 SEM (Scanning Electron Microscopy) and EDX (Energy Dispersive Microanalysis) Analysis

Required chemicals for SEM analysis:

25% Glutaraldehyde, Sodium di-hydrogen Orthophosphate (monobasic), Di Sodium hydrogen phosphate anhydrous (dibasic), Osmium tetroxide, Absolute Acetone, Anhydrous Copper, Distilled water, double-distilled water, Paraformaldehyde (optional).

Preparation of Solvents:

1. 0.2M Phosphate Buffer (Stock Solution):

a) 5.93gm of Sodium di-hydrogen Orthophosphate were added in 190ml of distilled water

b) 23gm of Di Sodium hydrogen phosphate anhydrous were added to 810ml of distilled water

Solution a and b were added to make 1000ml of 0.2ml Phosphate Buffer. For 0.1M Phosphate Buffer equal volumes of distilled water were added to 0.2M Phosphate Buffer.

2. 2% Osmium Terioxide (Stock Solution were stored at 4°C):

- Supplied as 1gm ampoules
- Dissolve 1gm OSO_4 in 50ml of double distilled water and allow overnight to completely dissolve it.

- Store at 4°C in tightly stopper, brown colour bottle.
- Working solution is 1% OSO_4; it is prepared by adding equals volumes of 0.2M Phosphate Buffer in 2% OSO_4 solution.

Sample Preparation for SEM analysis-

Lichen samples were cleaned and fixed into a eppendrof tube (2.5ml) which consisted of 2.5% glutaraldehyde (LobsChemi, India) in Millipore water for 1-2 hours at 4°C and washed in 0.1 M Phosphate buffer for changes each of 15 min. at 4°C. After that, the fixed lichen samples were washed twice with Millipore water and post-fixed with 2% Osmium tetroxide for 2 hrs. The fixed samples were dehydrated in 0.1 M Phosphate buffer using a series of 30%, 50%, 70%, 80%, 90%, 95% and 100% acetone (i.e. dry acetone; 30gm $CuSO_4$ add in 100ml absolute acetone). The samples were dried by air drying and critical point drying (i.e. 31.5°C at 1100p.s.i. Do not expose it in air while transferring from one medium to another. Then the dried samples were kept in desiccators for the removal of the moisture present in the sample. The dehydrated lichen samples were mounted on to the Aluminium stubs with double-sided carbon tape and coated with gold-palladium in a sputter coater (JFC 1600; JEOL, Tokyo, Japan) at 20 mA and equipped with an EDS 133, EV Dry Detector (INCAx-act) of OXFORD Instruments, UK and viewed under Scanning Electron Microscope (JSM-6490LV; JEOL, Tokyo, Japan) at different working distances and accelerating voltages. Each specimen was studied extensively and photographed at 500x, 1000x, 2000x and 5000x magnifications. Elemental composition of particulate matter present in the lichen thalli was analyzed by energy dispersive X-ray (EV Dry Detector) provides information on the electronic structural state of an element (Srivastava and Thakur, 2007).

The EDX spectra of individual aerosol particles were obtained by scanning an electron beam with an accelerating voltage of 15 kV for determination of the individual elemental composition of particles. The study provide rapid qualitative or adequate standards, and quantitative analysis of elemental composition with a sampling depth of 1–2 μm (Srivastava et al., 2009; Sielicki et al., 2011; Pipal et al., 2011) and EDX spectra of blank filter were also recorded and its composition was manually subtracted during the evaluation of the elemental composition of individual aerosol particles of different groups (USIC facility Babasaheb Bhimrao Ambedkar University Lucknow), India.

4.8 FTIR (Fourier Transform Infrared Spectroscopy) Analysis

Sample Preparation for FTIR (Fourier Transform Infrared Spectroscopy) Spectra measurement-

Since ordinary glass slides exhibit strong absorption in the wavelength range, used zinc selenide crystals which are highly transparent to IR radiation was used. Small amount of samples were picked up, suspended in 100 µl of saline, pelleted by centrifugation at 1000 rpm for 2 min. Each pellet was suspended with 20 µl of saline and a drop of 1 µl of the obtained suspension was placed on certain area on the zinc selenide crystal, air dried for 15 min at room temperature (or for 5 min by air drying in laminar flow) and examined by Fourier transform infrared spectroscopy (FTIR; Nicole 6700, Thermo Scientific, USA) and was used to determine the nature of associated biomolecules of lichen extracts with nanoparticles. The dried silver nanoparticles were compressed with KBr at 1:100 ratio by using hydraulic press at a pressure of 10 tons and spectra measured at the wavelength range from 4000 to 400 cm^{-1}. Spectra were monitored against KBr background and manipulated using the OMNIC software “automatic baseline correct” function.

4.9 Pigment Analysis

Photosynthetic pigments (chlorophyll a, chlorophyll b, Total chlorophyll, Carotenoid) were extracted by grinding 0.20 gm of fresh lichen samples with 0.25 gm of calcium carbonate and 5 ml of chilled 80% acetone (Merck, Analytical grade) in dark and centrifuged at 10,000 rpm for 10 min. The optical density of the supernatant was analyzed using Genesys 10 UV scanning Spectrophotometer.

Procedure:

- The identified lichen species from the study area were collected around thermal power plants of Uttar Pradesh, India from all the directions and were selected for their pigment analysis.
- The material was weighed and crushed into 80% acetone (5ml) and Calcium carbonate (a pinch) in mortar pestle.
- The crushed material were kept in tubes in the freezer for few minutes and centrifuged at (10,000 rpm/10 min/4ºC).
- The centrifuged solution was prepared by adding 10 gm NaOH in 250 ml distilled water.
- Supernatant of the centrifuged solution was poured in the test tube.
- The reading was taken with the help of Genesys 10 UV scanning Spectrophotometer and chlorophyll content was calculated from absorbance values at 663 and 645 nm according to the equation of Arnon (1949). The total carotenoid content was calculated from absorbance values at 480 and 510 nm according to Parsons et al. (1984).
- Left pellets of chlorophyll were filled with 1.5 ml NaOH overnight for further analysis.
- The test tubes were kept at room temperature and were centrifuged again.

4.10 Chlorophyll Degradation

The method developed by Ronrn and Galun (1984) was used to measure intensity of the photobiont chlorophyll. The chlorophyll was extracted overnight in the dark in 5 ml dimethyl sulfoxide (DMSO, Merck, AR grade). The ratio of chlorophyll a to phaeophytin (OD 435/415nm ratio) was determined using Genesys 10 UV scanning Spectrophotometer.

4.11 Protein Estimation

The protein content was measured using Folin's phenol as reagent with bovine serum albumin (BSA) as standard and calculations were made at 700 nm (Lowry et al., 1951).

4.12 Metal Analysis

The lichen thalli were removed from the bark with sharp knife. The samples (constant weight) were oven dried for 12 h at 90°C. The dried lichen samples (n=3) were grinded to power in a mortar (0.2 gm); each was digested in 5 ml mixture of concentrated HNO_3 and $HClO_4$ (v/v, 9:1) (beakers covered with watch glasses) for 1 hour and heated until close to dryness. Analysis was done with ICP MS (Perkin Elmer SCIEX ELAN DRCe). Stock standards were from Merck India and traceable to NIST (National Institute of Standards Technology). Working standards were prepared from the stock using deionised water.

4.13 Statistical Analysis

Differences in chlorophyll response to air pollution and elemental content in commonly occurring lichen thallus were compared by using One-way analysis of variance (ANOVA) together with mean, standard deviation, least significant difference (LSD) and coefficient of variance (CV%). Pearson coefficient correlation was performed to check the significant variation by using Statistical program SPSS 16.0.

Chapter- 5
Taxonomic Treatment

"Effort is nothing more than having a wishful dreams".

During the present work, systematic field survey and sample collection were conducted and collection of lichen species were made from all the directions of three selected thermal power plants i.e. Panki Thermal Power Station, Kanpur; Tanda Thermal Power Plant, Ambedkar Nagar and Feroze Gandhi Unchahar Thermal Power Plant Corporation, Unchahar, Raebareli. During the survey, lichens were collected from various substratum like barks, twigs, dead woods but mostly mango orchards were common around all thermal power plants. A total of more than 500 specimens were collected from more than 150 localities around thermal power plants.

After the complete identification of all the specimens, a total of 21 species belonging to 14 genera and 11 families were identified (Table-5.1). All the identified lichens were artificially keyed out first in families followed by genera and identified species were keyed out under their respective genera. All the three thermal power plants represents occurrence of about 25% of lichens known from the state of Uttar Pradesh (135 species) and 0.70% in India (2450 species) (Singh and Sinha, 2010; Nayaka and Upreti, 2013). The classification of Ascomycota by Lumbsch and Huhndorf (2010) was followed; relevant literature for taxonomic nomenclature were cited by Singh and Sinha (2010) and current name of species were validated using Awasthi (2007) and Lichen species *Pyxine sorediata*, new addition to Uttar Pradesh was recorded against the annotated checklist of Singh and Sinha (2010); Nayaka and Upreti (2013). Taxonomic description of all the species is as under:

Table-5.1: List of lichen species recorded from all the study area

S. No.	Name of Species	Family	Growth Form	Symbols used to map the species in grid
1	*Anisomeridium nidulans* (Müll. Arg.) R.C.Harris	Monoblastiaceae	Crustose	An
2	*Arthothelium chiodectoides* (Nyl.) Zahlbr.	Arthoniaceae	Crustose	Ar
3	*Bacidia incongruens* (Stirton) Zahlbr.	Ramalinaceae	Crustose	Bi
4	*Bacidia medialis* (Tuck.) Zahlbr.	Ramalinaceae	Crustose	Bm
5	*Bacidia rubella* (Hoffm.) A. Massal.	Ramalinaceae	Crustose	Br
6	*Bacidia submedialis* (Nyl.) Zahlbr.	Ramalinaceae	Crustose	Bs
7	*Caloplaca bassiae* (Willd. ex. Ach.) Zahlbr.	Teloschistaceae	Crustose	Cb
8	*Dirinaria consimilis* (Stirton) D. D. Awasthi	Caliciaceae	Foliose	Dc
9	*Hyperphyscia adglutinata* var. adglutinata (Flörke) H. Mayrhofer & Poelt	Physciaceae	Foliose	Ha
10	*Lecanora achroa* Nyl. In J. M. Crombie	Lecanoraceae	Crustose	La
11	*Lecanora helva* Stizenb.	Lecanoraceae	Crustose	Lh
12	*Lecanora tropica* Zahlbr.	Lecanoraceae	Crustose	Lt
13	*Opegrapha astraea* Tuck.	Opegraphaceae	Crustose	Oa
14	*Peltula corticola* Büdel & R. Sant.	Peltulaceae	Squamulose	Pc
15	*Pertusaria quassiae* (Fée.) Nyl.	Pertusariaceae	Crustose	Pq
16	*Phyllopeltula steppae* Kalb.	Peltulaceae	Squamulose to subfoliose	Ps
17	*Pyxine cocoes* (Sw.) Nyl.	Caliciaceae	Foliose	Pyc
18	*Pyxine sorediata* (Ach.) Mont.	Caliciaceae	Foliose	Pys
19	*Rinodina exigua* (Ach.) Gray	Physciaceae	Crustose	Re
20	*Rinodina sophodes* (Ach.) A. Massal.	Physciaceae	Crustose	Rs
21	*Strigula elegans* (Fée) Müll. Arg.	Strigulaceae	Follicolous	Se

5.1 Key to species

1. Thallus growing on leaves………………….…………..……..……***Strigula elegans***

1a.Thallus otherwise……………………………………………………..………..…….2

2. Thallus crustose ……………………………………………………………………...3

2a.Thallus otherwise……………………………………………………..………..…...16

3. Ascomata perithecia……………………..…………………***Anisomeridium nidulans***

3a.Ascomata otherwise…………………………………………………..………..………4

4. Ascomata unorganized……………………………..……***Arthothelium chiodectoides***

4a. Ascomata organized …………………..………………………………………………5

5.Apothecia lirellate……………………….……………………………..…***Opegrapha astraea***

5a. Apothecia otherwise…………………………………………………..………..…...6

6. Apothecia leceideine…………………..………………………………….…………7

6a. Apothecia otherwise ………………...………………..……………………..………10

7.Ascospores transversely 1-3 septate……………………….………***Bacidia incongruens***

7a. Ascospores more than 3 septate…………………………………………...……..8

8. Ascospores 3-5 septate……………………………………………………….***B. medialis***

8a. Ascospores more than 5 septate…………………………………………...……..9

9. Ascospores 7- septate …………………………………………………***B. submedialis***

9a. Ascospores upto 15 septate…………………………………………………..***B. rubella***

10. Thallus K+ purple……………..……………………………..……***Caloplaca bassiae***

10a. Thallus otherwise ...………………………………………………………..…….11

11. Thallus K+ yellow or yellowish, PD+ yellow……………………………………….12

11a. Thallus otherwise……………………………………..…………………….13

12.Thallus with true apothecia……………………..…………………***Lecanora achroa***

12a. Thallus with apothecioid perithecia…………………………..….***Pertusaria quassiae***

13.Ascospore brown, 1-septate……………………………………………………….14

13a. Ascospores colourless, simple………………………………………..……….15

14. Ascospores thin-walled, thallus grey to dark brown……………....***Rinodina sophodes***

14a. Ascospores thick-walled, pale grey to grey…………………………..……..***R. exigua***

15. Apothecial disc brown-dark brown……………………………..……...***Lecanora tropica***

15a. Apothecial disc light yellow-orange………………………………..………..***L. helva***

16.Thallus with cyanobacterial photobiont……………………………………………18

16a. Thallus with green photobiont……………………………………………………19

17.Thallus sorediate……………………………..…………..…………***Peltula corticola***

17a.Thallus esorediate…………………………………………..…...***Phyllopeltula steppae***

18.Thallus lobes small, adglutinate…………………..……..…..***Hyperphyscia adglutinata***

18a. Thallus lobes large more or less free……………………………………………..…19

19.Thallus without rhizinae on lower side………………..…………...***Dirinaria consmilis***

19a. Thallus with rhizinae on lower side………………………………………….….20

20.Thallus UV+ yellow……………………..……………………………***Pyxine cocoes***

20a. Thallus UV-…………………………………………………………***P. sorediata***

5.2 Taxonomic Description of lichen species from the study area:

ANISOMERIDIUM (Müll. Arg.) M. Choisy (Family: Monoblastiaceae)

Icon. Lich. Univ.: 3.1928

Thallus crustose, epi or ednophloeodal, whitish, pale grey to greenish; photobiont *Trentipohlia*. Ascomata perithecia, hemispheral to globose, simple to compound. Paraphyses slender, branched and anastomosed above; periphyses absent. Asci cylindrical to clavate, 8 spored; ascospores 1-3 septate, ovoid to clavate-fusiform, hyaline, smooth, uni to biseriate. Pycnidia immersed to sessile, black, ±globose or conical.

Worldwide 100 species; India 17 species (Upreti and Nayaka, 2006).

1. ***Anisomeridium nidulans*** (Müll. Arg.) R. C. Harris, *More Florida Lich*. Incl. 10 cent Tour Pyrenol. (New York):148. 1995. (Plate-5.1A**)**

≡ ***Arthopyrenia nidulans*** (Müll. Arg.) 1885.

Thallus corticolous, crustose, smooth, endophloeodal. Ascomata single or 2-3 aggregated, globose-ovoid, black, rough, ostiole distinct, whitish, peridium incomplete at base, globose, slightly laterally spreading. Ascospore spindle-shaped, 1-septate, 30-45×17-20 µm. Thallus K-, C-, KC-, PD-, Triterpene between Rf 6-7 detected upon TLC.

Remarks: This species is reported from Andaman and Nicobar Islands, Goa, Madhya Pradesh, Karnataka (Upreti and Pant, 1993), Uttar Pradesh (Gupta et al., 2016a) and Sri Lanka. The species is rare in Panki thermal power plant, but it is common at Unchahar Thermal power plant from the outskirts.

Specimen Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (North): Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near Choubepur Kalan near Tatiyaganj, on bark of *Mangifera indica,* 11th Oct., 2014, N. Gupta. 014-025384 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** near Bhagipur, Sarain Tula Ram, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031741 (LWG); Sarain Tula Ram, Gopapur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031742 (LWG); near Nababganj, Sanhoo Kuwan, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031727 (LWG); Sanhoo Kuwan, Thana-Bhodokhar, Harjanpurwa, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023725 (LWG). **Unchahar Thermal power plant (East):** Raghunathpur Paterwa, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031746 (LWG); **Unchahar Thermal power plant (South):** Ahmadganj, Murrassapur village, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023724 (LWG); Girdharpur Garhi, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031789 (LWG); Manikpur near Retahi, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031794 (LWG); Manikpur near Sangrampur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031796

(LWG); Allahabad-Lucknow road, Ahmedganj, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031798 (LWG).

ARTHOTHELIUM Massal. (Family: Arthoniaceae)

Ric. Auton. Lich. Crost: 54. 1852.

Thallus corticolous, photobiont a green alga; ascocarps sunken or adnate, round, irregular, stellate in outline; asci globular or oblong, thick walled, 2-8 spored; ascospores colourless or brown, transversely 1-9 septate.

Earlier reported from West Bengal and out of 24 species known from India, only one was found in the present collection.

1. ***Arthothelium chiodectoides*** (Nyl.) Zahlbr., *Cat. Lich. Univ*. 2: 122. 1922. (Plate-5.1B**)**

≡ ***Arthonia chiodectoides*** Nyl. *Flora*, 52: 72. 1869.

Thallus corticolous, crustose, most of the part endophloeodal, 88-166 µm thick; ascomata yellowish brown to dark blackish-brown, K-, punctuate, aggregated, covered with effuse thalline layer or naked; epithecium dark blackish-brown; hymenium pale brown 100-185 µm tall, I+ blue; hypothecium dark blackish-brown; asci butinicate, obovate to pyriform; paraphysoids profusely branched and anatomosed, strongly coherent; ascospore 8/ascus, hyaline, muriform, ovate to oblong, transversely 7 to 9-septate, vertically 1 to 3-septate, upper most cell larger, undivided, 28-36 × 3-5 µm. Triterpene between Rf 6-7, dark blue brown unknown compound at Rf 5 detected upon TLC.

Remarks: This species is reported from India (Arunachal Pradesh, Goa, Himachal Pradesh, Karnataka, Maharashtra, Sikkim and West Bengal). This species colonize on the bark of *Mangifera indica*, *Azadirachta indica* and *Litchi chinensis*. Now, for the first time it is reported from Uttar Pradesh (Gupta et al., 2016a).

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (West): Faizabad-Tanda road, Uparhar, Uniyarpur, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023767; 015-023768 (LWG).

BACIDIA De Not. (Family: Ramalinaceae)

Giorn. Bot. Ital. 2: 189. 1846.

Thallus crustose, effuse, ecorticated, corticolous; photobiont green alga; Ascomata apothecia, sessile, rounded, biatorine. Proper exciple para or prosoplectenchymatous; paraphyses sparingly branched with hyaline or pigmented apices, or branched and anastomosing. Asci 8-spored; ascospores colourless, transversely 1-2 many septate, acicular, ellipsoid or bacillary; pycnoconidia simple or septate, variously shaped.

Out of 28 species known from India, only 3 species were isolated from the present collection.

1. *Bacidia incongruens* (Stirton) Zahlbr. *Cat. Lich. Univ.* 4: 208. 1926. (Plate-5.1C**)**

≡ ***Lecidea incongruens*** Stirton, *Proc. Roy. Soc. Glasgow* 2: 314. 1879.

Thallus corticolous, crustose whitish grey to greenish grey; scurfy to granular. Apothecia frequent, 2-5 mm diam.,; margin prominent, smooth, biatorine, paler than the disc; disc yellow orange, plane to concave, rarely convex, epruinose. Exciple biatorine, hyaline, hyphae radiating, 44-64µm thick; epihymenium K-, KI+ blue, I+ blue, 14-18 µm thick; hymenium hyaline, KI+ blue, I+ blue, 55-89 µm thick; paraphyses simple to branched, apical cell slightly thickened. Ascus 8 spored, cylindrical to clavate, 42-56 x 10-13 µm; ascospores hyaline, rod shaped to fusiform, transversely 2-3 (-5) septate, 19.9-35.4 x 2.4-3.9 µm. Thallus K-, C-, KC-, P-, Traces of triterpene at Rf 5-6 detected upon TLC.

Remarks: This species is also known from India (Tamil Nadu, Karnataka and West Bengal plains) and Sri Lanka. It is most commonly found in the study area.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (East): Rajesultanpur road, Chintaura, on bark of *Mangifera* *indica,* 2nd April, 2015, N. Gupta. 015-031703 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031704 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031706 (LWG); Rajesultanpur road, Sulempur Persawa, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031715 (LWG); Rajesultanpur road, Sulempur Persawa, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031716 (LWG); Rajesultanpur road, Rampur Benepur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031718 (LWG). **Tanda Thermal power plant (West):** Faizabad-Tanda road, Pausara Uparhar, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023756 (LWG); Faizabad-Tanda road near Pausara, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023764; 015-023765 (LWG); Faizabad-Tanda road, Uparhar, Lalpur, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023772 (LWG). **Tanda Thermal power plant (North):** Kalwari road near Tahirpur roadside, on bark of *Artocarpous heterophyllus,* 5th April, 2015, N. Gupta. 015-023785 (LWG). Kalwari road near Kausara, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023789 (LWG). **Tanda Thermal power plant (South):** Akbarpur road, Mamrejpur, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023749 (LWG); Akbarpur road, Khetapur, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023753 (LWG); Akbarpur road, Ariya, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023755 (LWG). **Raebareli district, Unchahar Thermal power plant (East):** Umaran, on bark of *Mangifera indica,* 13th Aug., 2013, N. Gupta. 013-023710; 013-023713 (LWG); Manirampur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031744 (LWG); near Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031753 (LWG); Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031759 (LWG); near Amarupur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031767 (LWG); Salon dehat near meta merauli, on bark of *Mangifera* *indica*, 13th March, 2016, N. Gupta. 016-031768 (LWG); Autahiya, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031772 (LWG); **Unchahar Thermal power plant (South):** Ahmedganj, on bark of *Mangifera indica*, 13th Sep., 2013, N. Gupta. 013-023718 (LWG); Baharamaee village, on bark of *Mangifera indica*, 13th Sep., 2013, N. Gupta. 013-023736 (LWG); Arkha Mustakil, on bark of *Mangifera indica*, 13th Sep., 2013, N. Gupta. 013-023728 (LWG); near Arkha Mustakil, on bark of *Mangifera indica*, 13th Sep., 2013, N. Gupta. 013-023737 (LWG); Allahabad-Lucknow road, Barauliya Yakuvpur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029701 (LWG); Bramhauli, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029702 (LWG); near Arkha Mustakil, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029703 (LWG); Ganga-bridge road, Sultanpur Khwaja karak, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031783 (LWG); Bihamidpur near Deviganj, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031784 (LWG); Sounrai Buzurg, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031786 (LWG); Girdharpur Garhi, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031790 (LWG); Girdharpur Garhi near Bharpurwa, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031793 (LWG); Manikpur near Retahi, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031795 (LWG); Allahabad-Lucknow road, Ahmedganj, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031799 (LWG); Allahabad-Lucknow road, Milkipur Ahtimali, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031800 (LWG); **Unchahar Thermal power plant (West):** Baigaon, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029709 (LWG); Gaidhemau, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029713 (LWG); Airayan Sadat, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029715 (LWG); **Unchahar Thermal power plant (North):**

Sanhoo Kuwan, Thana-Bhodokhar, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029718 (LWG).

2. *Bacidia medialis* (Tuck. ex. Nyl.) Zahlbr., *Denskchr. Kaiserl. Akad. Wiss*., Wien, Math.- Naturwiss. Kl. 83: 127. 1909. (Plate-5.1D)

≡ ***Lecidea medialis*** Tuck. Zahlbr., *Cat. Lich. Univ*. 4: 221. 1863.

Thallus corticolous, crustose effuse, rough, cracked, granuolose-furfaraceous, greyish brown to grey, 50-70 µm thick, Apothecia constricted at base, 0.2-0.5 mm in diam., over mature apothecia sometimes split up into lobes, sometime glomerulose aggregation of 3-4 apothecia, disc yellow brown, brown to red brown, plane to convex, epruinose, margin entire, distinct, pale yellow to pale brown and later excluded exciple colourless to pale, 36-70 µm thick at margin, K- epithecium colourless to pale brown, 10-12 µm thick, K-; hymenium 40-70 µm thick, I+ blue than vinose red; hypothecium colourless to pale yellow, 16-30 µm thick, K; spores rod shaped with both end rounded, rarely one ends narrower than the other, transversely (1-)3-5 septate, 16-32×2.4-3.2 µm; paraphyses simple to branched, thickened at apices. Thallus K-, C-, KC-, P-, Traces of triterpene at Rf 5-6 detected upon TLC.

Remarks: This species is also known from India (Himanchal Pradesh, Kerala, Lakshadweep, Orissa, Tamil Nadu and West Bengal plains) and Sri Lanka. This species is new addition from Uttar Pradesh by Gupta et al. (2016a) and it is commonly present at Panki and Unchahar thermal power plant.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (East): Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica*, 2nd April, 2015, N. Gupta. 015-031708 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Artocarpous heterophyllus*, 2nd April, 2015, N. Gupta. 015-031709 (LWG); Rajesultanpur road, Rampur Benepur, on bark of *Artocarpous heterophyllus*, 2nd April, 2015, N. Gupta. 015-031719 (LWG). **Tanda Thermal**

power plant (West): Faizabad-Tanda road, Pausara Uparhar, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023757 (LWG); Faizabad-Tanda road, Mehbubganj, Bhitaura, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023775 (LWG). **Tanda Thermal power plant (North):** Kalwari road near Saraiya Khurd, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023791 (LWG). **Raebareli district, Unchahar Thermal power plant (West):** Gaidhemau, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029719 (LWG); Allipurbahera, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029722 (LWG); **Unchahar Thermal power plant (South):** Girdharpur Garhi, Ujiyari gaon, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029717 (LWG); Arkha Mustakil, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029703 (LWG).

3. ***Bacidia rubella*** (Hoffm.) A. Massal., *Ric. Auton. Lich. Crost.* (Verona). 118. 1852. (Plate-5.1E**)**

≡ ***Verrucaria rubella*** Hoffm., *Deutschl. Fl.* 2: 174. 1796.

Thallus crustose, corticolous, thin, rough, verruculose to scurfy, cracked areolate, greenish- grey. Apothecia frequent, sessile, mostly round, 0.2-0.3 mm diam.; margin biatorine, brown, moderately thick and darker when young, thinning and excluded at maturity; disc yellow to orange brown, plane to slightly convex. Exciple pale brown, 40-85 µm thick; epihymenium pale brown, 9-16 µm thick, K-; hymenium hyaline to yellowish, 50-70 µm thick; hypothecium yellowish to pale brown, 30-45 µm thick; paraphyses simple to branched, apical cell swollen and pigmented. Asci 8-spored, clavate 45-55 x 16-18 µm; ascospores hyaline, acicular, transversely 6-12 septate, 38.8-64.3 x 2.4-3.2 µm. Thallus K-, C-, KC-, P-, Traces of triterpene at Rf 5-6, pale yellowish spot below Rf 4-5 detected upon TLC.

Remarks: This species is also known from India (Himanchal Pradesh, Madhya Pradesh, Sikkim, Tamil Nadu, Uttarakhand and West Bengal). It is rarely found but in the present study, it is single reported from Unchahar thermal power plant.

Specimens Examined: India, Uttar Pradesh, Raebareli district, Unchahar Thermal power plant (South): Lalaganj-Kalakanpur road, Rampur Garauli near Barabigah, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029721 (LWG).

4. ***Bacidia submedialis*** (Nyl.) Zahlbr., *Cat. Lich. Univ.* 4: 243. 1926. (Plate-5.1F**)**

≡ ***Lecidea submedialis*** Nyl., *Acta Soc. Sci. Fenn.* 26 (10): 14. 1900.

Thallus crustose, corticolous, greenish- green, granular; apothecia yellow orange to brownish, biatorine, 0.1-0.5 mm wide in diam.; margin excluded; hymenium hyaline, not inspired, without oil globules, I^+ blue; hypothecium hyaline to slightly yellowish; epihymenium yellowish to yellow brown; asci *Bacidia*-type, 8-spore; ascospores 3-7 septate, 25-40 µm long, fusiform. Thallus K-, C-, KC-, P-, Traces of triterpene at Rf 5-6 detected upon TLC.

Remarks: This species is also known from India (Arunanchal Pradesh, Goa, Karnataka, Maharashtra, Tamil Nadu, Uttar Pradesh and West Bengal plains) and Sri Lanka. It is very common species at Tanda and Unchahar thermal power plant.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (East): Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica*, 2nd April, 2015, N. Gupta. 015-031712 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Artocarpous heterophyllus*, 2nd April, 2015, N. Gupta. 015-031713 (LWG). **Tanda Thermal power plant (West):** Faizabad-Tanda road, Pausara Uparhar, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023758; 015-023759 (LWG); Faizabad-Tanda road, Pausara, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023760 (LWG); Faizabad-Tanda road, Mehbubganj, Bhitaura, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023777

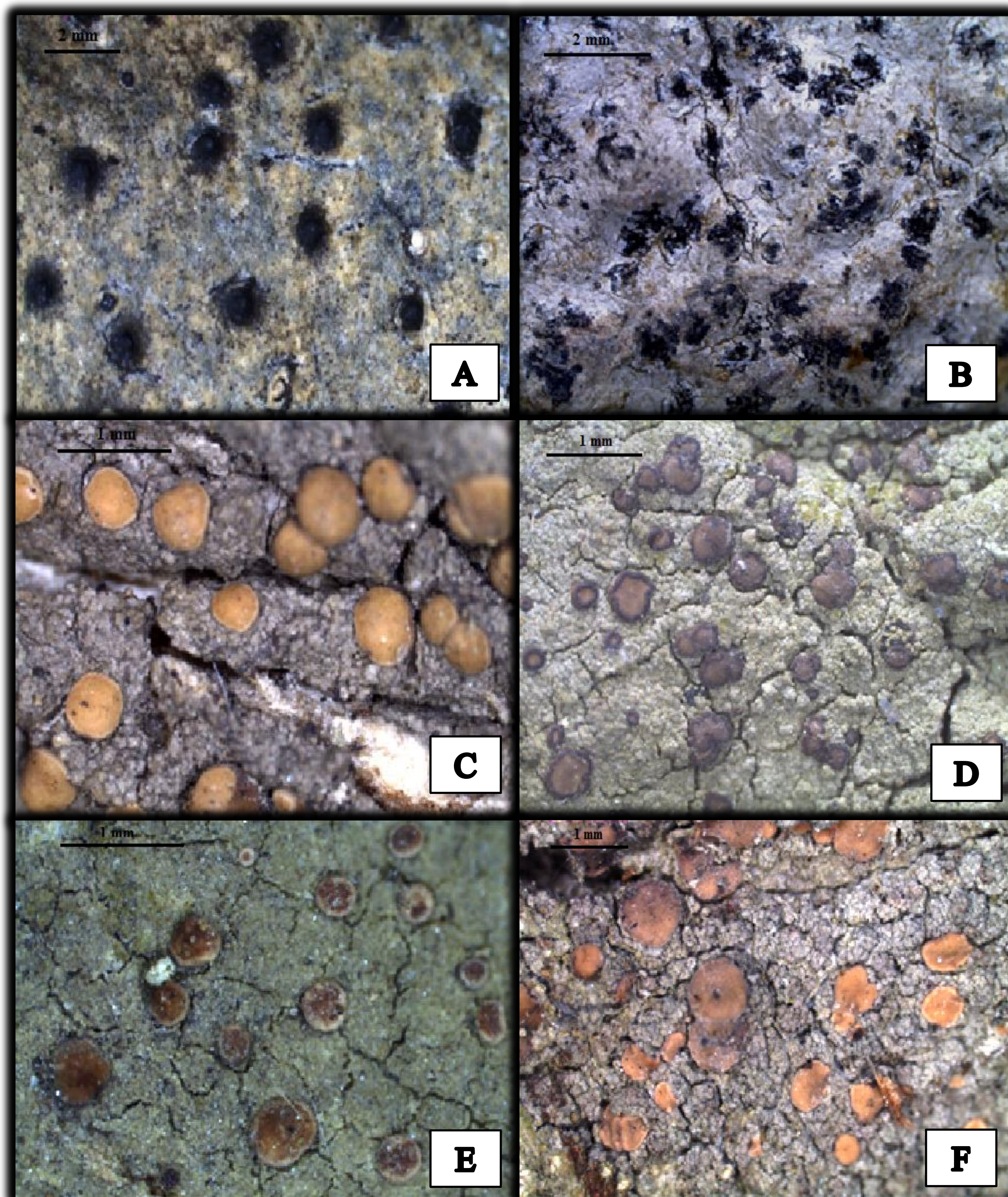


Plate-5.1: Thallus of Lichen Species: (A) *Anisomeridium nidulans* (Müll. Arg.) R.C. Harris; (B) *Arthothelium chiodectoides* (Nyl.) Zahlbr.; (C) *Bacidia incongruens* (Stirton) Zahlbr.; (D) *Bacidia medialis* (Tuck.) Zahlbr.; (E) *Bacidia rubella* (Hoffm.) A. Massal.; (F) *Bacidia submedialis* (Nyl.) Zahlbr.

(LWG); Faizabad- Tanda road, Mehbubganj, Ruhiyawa, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023778 (LWG). **Tanda Thermal power plant (North):** Kalwari road near Kusaura, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023795 (LWG); Kalwari road, Pakri Chhabar, on bark of *Mangifera indica*, 5th April, 2015, N. Gupta. 015-023797 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Chandrai, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031743 (LWG); near Nababganj, Sanhoo Kuwan, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031728 (LWG); **Unchahar Thermal power plant (East):** Salon near Bhawanipur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031764 (LWG); near Salon bazaar, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031766 (LWG); near Lawana, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031774 (LWG); Umaran near Hanumant Nagar, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029720 (LWG); **Unchahar Thermal power plant (South):** Lalganj-Kalakanpur road, Rampur Garauli near Barabigah, on bark of *Artocarpous heterophyllus,* 13th March, 2016, N. Gupta. 016-031779 (LWG); Lalganj-Kalakanpur road, Rampur Garauli near Barabigah, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031780 (LWG); Lalganj-Kalakanpur road, Rampur Garauli near Ramnagar, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031781 (LWG); **Unchahar Thermal power plant (West):** Kand Rawan, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029706 (LWG); Allipurbahera, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029711 (LWG); Airayan Sadat, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029716 (LWG).

***Bacidia* sp. (sterile form)**

Thallus crustose, effuse, ecorticated, corticolous; photobiont green alga; Ascomata apothecia, sessile, rounded, biatorine. Proper exciple para or prosoplectenchymatous; paraphyses sparingly branched with hyaline or pigmented apices, or branched and anastomosing. Acicular, ellipsoid or bacillary; pycnoconidia simple or septate, variously shaped.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (North): Bithur road near IIT gate, Kalyanpur, Gooba Garden above 3 m from ground, on bark, 7th May, 2013, N. Gupta. 013-019826 (LWG); Aligarh-Kanpur road, Bagdudi Bazar, Amiliha near Choubepur Kalan near Tatiyaganj, on bark of *Mangifera indica,* 11th Oct., 2014, N. Gupta. 014-025383 (LWG); **Panki Thermal power plant (West):** near power plant, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016690 (LWG); **Panki Thermal power plant (South):** near Panki thermal power plant, Rampur, Bhimsen, on bark of *Mangifera indica,* 11th Oct., 2014, N. Gupta. 014-025387 (LWG); **Raebareli district, Unchahar Thermal power plant (South):** Arkha Mustakil, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023720 (LWG); Matehullapur, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023721; 013-023726 (LWG); near thermal power plant (0-5km), on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023723 (LWG); Chandapur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031776 (LWG); **Unchahar Thermal power plant (South):** Saray Mohd. Sarif, on bark, 13th Aug., 2013, N. Gupta. 013-023703 (LWG).

CALOPLACA Th. Fr. (Family: Teloschistaceae)

Lich. Arct.: 218. 1860.

Thallus crustose to squamulose, placodioid or crustose- effigurate at margins, yellowish-orange, red, brown red to blackened, K+ purple or K-; photobiont green alga; ascomata apothecia, lecanorine or biatorine, round, orange, orange-red, rust brown to black. Exciple biatorine or lecidine, sometime lecanorine; hypothecium usually hyaline; paraphyses simple, septate, capitates. Asci 8-spored; ascospores hyaline, thick walled, poalribilocular or rarely 3-loculed. Pycnoconidia short or long.

Out of 65 species known from India, only single species were found in the present collection.

1. *Caloplaca bassiae* (Willd. ex. Ach.) Zahlbr., *Cat. Lich. Univ.* 7: 78. 1930. (Plate-5.2G**)**

≡ ***Lepraria bassiae*** Willd. ex. Ach., *Methodus*: 5. 1803.

≡ ***Isidium bassiae*** Ach., 1810.

Thallus corticolous, crustose, thin, yellowish to greenish yellow, isidiate; isidia simple, rarely branched and coralloid, sometimes thallus appears completely granular due to minute isidia. Apothecia rare, most of the time thallus sterile, apothecia when present round, sessile, 0.3-0.5 mm diam.; margin thick, biatorine, paler than the disc, yellow isidiate; disc yellow-orange, plane to concave. Exciple biatorine, sometimes with algal cells, 55-73 µm thick; epihymenium yellowish to golden, K+ pink, 21-28 µm thick; hymenium hyaline, inspired with oil globules, 51-64 µm thick; hypothecium hyaline, inspersed, 53- 92 µm thick; paraphyses, simple to sparingly branched. Ascus 8 spored, clavate; ascospore hyaline, ellipsoid to oblong, transversely 1 septate, locules polarbilocular, 14.5-16.5×10.6-11.0 µm. Thallus K± yellow purple, C-, KC-, P-. Parietin between Rf 6-7, unknown bluish between Rf 4-5 detected upon TLC.

Remarks: *Caloplaca bassiae* is a most common species and widely distributed species in Uttar Pradesh; found growing on the variety of trees including *Azadirachta indica*, *Mangifera indica* and *Artocarpus heterophyllus* in orchard as well as on tree trunk. It is earlier reported from India (Andaman & Nicobar Islands, Arunachal Pradesh, Assam, Himanchal Pradesh, Jammu & Kashmir, Madhya Pradesh, Orissa, Rajasthan, Sikkim and Tamil Nadu). In the present study, it is commonly found at Tanda and Unchahar thermal power plant only on the bark of *Mangifera indica.*

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (West): Faizabad-Tanda road, Pausara, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023761 (LWG); Faizabad-Tanda road, Uparhar, Uniyarpur, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023766 (LWG); Faizabad-Tanda road, Mehbubganj, Bhitaura, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023774 (LWG); Faizabad-Tanda road, Uparhar near Uniyarpur, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023769 (LWG). **Tanda Thermal power plant (South):** Akbarpur road, Fathe Jahoorpur, on bark of *Mangifera indica*, 3rd April, 2015, N. Gupta. 015-023747; 015-023748 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Rojhaia Gokulpur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031736 (LWG). **Unchahar Thermal power plant (South):** Bihamidpur near Deviganj, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029730 (LWG).

DIRINARIA (Tuck.) Clem. (Caliciaceae)

Clement, Gen. Fungi: 84. 1909.

Thallus foliose, adnate, lobes dichotomously to pinnately divided, usually flabellateplicate, confluent in centre, grey to darker grey, with or without isidia and soredia; heteromerous; corticated on both sides; lacking rhizines; upper cortex paraplectenchymatous; photobiont a green alga; medulla white or pigmented. Ascomata, apothecia, laminal, thalline, usually black, pruinose or not. Exciple lecanorine; epithecium pale brownish, K-; hypothecium brown to brown black; asci 8-spored; ascospores brown, 1 septate, thick walled. Atranorine present in upper cortex.

Out of about 25 species known from the World, 6 species reported from India, Earlier reported from West Bengal and single species was found in the present collections.

1. *Dirinaria consimilis* (Stirton) D. D. Awasthi, in Awasthi & Agarwal, *J. Indian Bot. Soc.,* 49: 135 (1970). (Plate-5.2H**)**

≡ ***Physcia consimilis*** Stirton, 1879.

Thallus corticolous, foliose, upper side grey, sorediata, sorelia capitates. Apothecia to 1.5mm in diameter; ascoapores 14-24 x 6-8 µm. Medulla K-, C-, KC-, PD-; Triterpene at Rf 5, 4-5, atranorin at Rf 7 present upon TLC.

Remarks: This species is widely distributed species in India (Arunachal Pradesh, Assam, Himanchal Pradesh, Kerala, Madhya Pradesh, Manipur, Nagaland, Sikkim, Tamil Nadu, Uttar Pradesh and West Bengal plains). But it is very rare species and reported from single locality of the study area.

Specimens Examined: Thermal power plant: Raebareli district, Unchahar Thermal power plant (East): Umaran (around 5-10 km area), on tree trunk of *Mangifera indica*, 13^{th} Aug., 2013, N. Gupta. 013-023717 (LWG).

HYPERPHYSCIA Müll. Arg. (Family: Physciaceae)

Bull. Herb. Boiss. 2 Apt. 1:10. 1894.

Thallus foliose, closely adnate, small and narrowly lobate; lobes grey- brown; lower side often agglutinated to substratum, with short rhizines or rhizines absent. Thallus hereteromerous, usually corticated on both sides; photobiont a green alga. Ascomata apothecia, laminal, margin thalline, disc dark brown. Exciple lecanorine, hypothecium hyaline; paraphyses branched. Asci with amyloid thallus, 8-spored; ascospores brown, 1 septate, *Pachysporaria*- or *Physcia* type. Pycnoconidia filiform, more than 10 µm long.

Four species so far reported from India (Uttaranchal), Nepal and Sri Lanka.

1. *Hyperphyscia adglutinata* var. adglutinata (Flörke) H. Mayrhofer & Poelt., in Hafellner & al., *Herzogia* 5 (1-2): 62. 1979. (Plate-5.2I**)**

≡ ***Lecanora adglutinata*** Flörke, *Deutsche Lich. Gessam. Anmerk.* 4, *Lief Rostoch.*: 7. 1819.

Thallus foliose, corticolous, orbicular, small, 0.6-2.4 cm across, greenish grey to brownish, sorediata; lobes minute, 0.2-0.4 mm wide, slightly pruinose, free from substratum; lower surface pale, yellowish white to grey white, rhizinate, rhizines dark grey with white tips; soralia capitate; soredia granular, greenish; medulla white to greenish. Apothecia not seen. Cortex and medulla K-, C-, KC-, P-. Zeorin at Rf 5, triterpene below Zeorin present upon TLC.

Remarks: This species is widely distributed species in India (Himanchal Pradesh, Jammu & Kashmir and Uttarakhand), Australia, Bhutan, North America. But it is rarely found from the present study.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (East): Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031714 (LWG). **Raebareli district, Unchahar Thermal power plant (East):** near Raghunathpur Paterwa, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031749 (LWG); Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031754 (LWG); Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031760 (LWG); Samaspur Khalsa, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031763 (LWG); Mohammabad, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031771 (LWG).

LECANORA Ach. (Family: Lecanoraceae)

Luyken, Kongl. Vetensk. Acad. Nya Handl. 31: 66. 1809.

Thallus crustose, saxicolous or corticolous, granular, areolate or placodioid; photobiont green alga. Ascomata apothecia, sessile or shortly stipitate, margin thin to thick, concolours with the thallus. True exciple poorly developed; thalline exciple prominent; epihymenium greenish brown to dark brown, hymenium hyaline. I+ blue; hypothecium hyaline; paraphyses sim ple to septate, apices slightly swollen. Asci elongate- clavate, Lecanora type; ascospores ellipsoid to subglobose, hyaline, simple, smooth walled.

Worldwide 552 species; India 90 species; Literature: Nayaka, 2004; Lumbsch, 1994; Saag et al., 2009. Only two species were collected in the present study.

1. *Lecanora achroa* Nyl. in J. M. Crombie. *J. Bot. Lond.* 14: 263. 1876. (Plate-5.2J**)**

Thallus corticolous, crustose, continuous to rimose areolate, slightly verruculose, grey to yellowish grey, greenish grey, shiny; prothallus brownish black. Apothecia numerous, sessile, 0.2-1.0 mm in diam.; margin thick, thalline, smooth, entire to verruculose, persisting or becoming excluded at maturity, concolours with the thallus; disc orange to orange brown, epruinose. Exciple with algal cells, large crystals in groups, 18-35 µm thick; epihymenium yellowish brown, granular, pigmentation dissolving in K, 10-15 µm thick; hymenium hyaline, 45-60 µm thick; hypothecium hyaline, 20-30 µm thick; paraphyses sparingly branched, apical cell swollen, hyaline. Asci 8 spored, clavate, 40-50 x 8-12 µm; ascospores hyaline, simple, allipsoidal to broadly ellipsoidal, 9.5-17.1 x 6.2- 9.1 µm. Thallus K+ yellow, C- or + orange, KC-, P+ yellow. Atranorin + 2- methylperlatolic between Rf 4-5, Zeorin at 5 + unknown bluish at Rf 4 were detected present upon TLC.

Remarks: This species is widely distributed species in India (Himanchal Pradesh, Manipur, Sikkim and Uttar Pradesh); New Zealand, America, Indian Ocean Islands, Antarctica. *Lecanora achroa* is common species and widely distributed species in Uttar Pradesh. BuTbin the present study, it is only growing on the bark of *Mangifera indica.*

Specimens Examined: India, Uttar Pradesh, Raebareli district, Unchahar Thermal power plant (North): near Nababganj, Sanhoo Kuwan, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031729 (LWG); Rojhaia Gokulpur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031737 (LWG); Bhikh, Harjanpurwa, on bark of *Mangifera indica*, 13th Aug., 2013, N. Gupta. 013-023702 (LWG); **Unchahar Thermal power plant (South):** Girdharpur Garhi, Ujiyari Gaon, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031792 (LWG); Girdharpur Garhi, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031791 (LWG).

2. ***Lecanora helva*** Stizenb., *Ber. Tat. St Gall. Naturw, Ges,:* 218 (1890). (Plate-5.2K**)**

≡ ***Lecanora albellaria*** Müll. Arg., *Bull. Herb. Boissier.* 3: 632. (1895)

≡ ***Lecanora alligata*** Stirt., in Bailey, *Queensland Agric. J*. 5: 38 (1899)

Thallus corticolous, crustose, continuous or areolate, smooth to verruculose, yellowish white to yellowish green or greenish grey. Apothecia numerous, crowded, immersed when young, becoming sessile, 0.3-0.9 mm diam.; margin thin, entire, smooth to verruculose, thalline, concolours with the thallus; disc pale brown to orange, epruinose or slightly pruinose. Exciple with algal cells, large crystals in groups, 25-40 µm thick; epihymenium pale yellowish to brown, granular, pigmentation dissolving in K, 10-15 µm thick; hymenium hyaline, 60-85 µm thick; hypothecium hyaline, 30-45 µm thick; paraphyses sparingly branched, apical cell not or slightly swollen. Asci 8-spored, clavate, 40-70 x 15-20 µm; ascospores hyaline, simple, ellipsoidal, 13.3-18.0 x 5.9-7.8 µm. Thallus K+ yellow, C-, KC-, PD+ pale orange to orange. Atranorin at Rf 7 + Zeorin at Rf 5 + Yellow brown unknown between Rf 6-7 and Rf 4-5 were detected upon TLC.

Remarks: This species is widely distributed species in India (Assam, Goa, Himanchal Pradesh, Madhya Pradesh, Kerala, Maharashtra, Tamil Nadu and Uttar Pradesh) and Thailand, Africa, Central and South America. But it is very rare species and found at five localities of the study area.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (North): Airport road Kataraghan Shyam west to thermal power plant near Sachendi, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016696 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Rojhaia Gokulpur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029723 (LWG); Bhikh, Jog Magdipur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029724 (LWG); **Unchahar Thermal power plant (South):** Lalaganj-Kalakanpur, Pariyawan, on bark of *Artocarpous heterophyllus,* 13th March, 2016, N. Gupta. 016-029725 (LWG); **Unchahar Thermal power plant (East):** near Raghunathpur Paterwa, on bark of *Artocarpous heterophyllus*, 13th March, 2016, N. Gupta. 016-029729 (LWG);

3. ***Lecanora tropica*** Zahlbr., *Cat. Lich. Univ*. 5: 589 (1928). (Plate-5.2L**)**

≡ ***Lecanora subfusca*** var. subcrenulata Nyl., *Ann. Sci. Nat., Bot., Ser*. 5, 7: 310. 1867.

≡ ***Lecanora lecanactina*** sensu Upreti, *Feddes Report*, 108: 192. 1997.

Thallus corticolous, crustose, rough, verrucose to verruculose, continuous to areolate, whitish grey to yellowish grey. Apothecia numerous, crowded, sessile, 1.3-3.2 mm diam.; margin thick, verrucose to verruculose, entire, thalline, concolours with the thallus; red brown to dark brown, epruinose, plane to concave. Exciple with algal cells, with large and small crystals, 25-45 µm thick; epihymenium reddish brown, agranular, lacking crystals, pigmentation not dissolving in K, 10-15 µm thick; hymenium hyaline, 60-70 µm thick; hypothecium hyaline, 20-30 µm thick; paraphyses sparingly branched, apical cell ± swollen, hyaline. Asci 8 spored, clavate, 45-55 x 20-25 µm; ascospores hyaline, simple, ellipsoidal, 8-17 x 6-9 µm. Thallus K+ yellow, C-, KC-, P+ yellowish. Atranorin at Rf 7 + 2- methylperlatolic between Rf 4-5 detected upon TLC.

Remarks: This species is widely distributed species in India (Himanchal Pradesh, Karnataka, Madhya Pradesh, Orissa, Sikkim, Tamil Nadu, Uttarakhand, Uttar Pradesh and West Bengal plains); Australia, Japan, Nepal. It is commonly present at fourteen localities from the study area.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (East): Rajesultanpur road, Chintaura, on bark of *Mangifera indica*, 2nd April, 2015, N. Gupta. 015-031701 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Artocarpous heterophyllus*, 2nd April, 2015, N. Gupta. 015-031707 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Artocarpous*

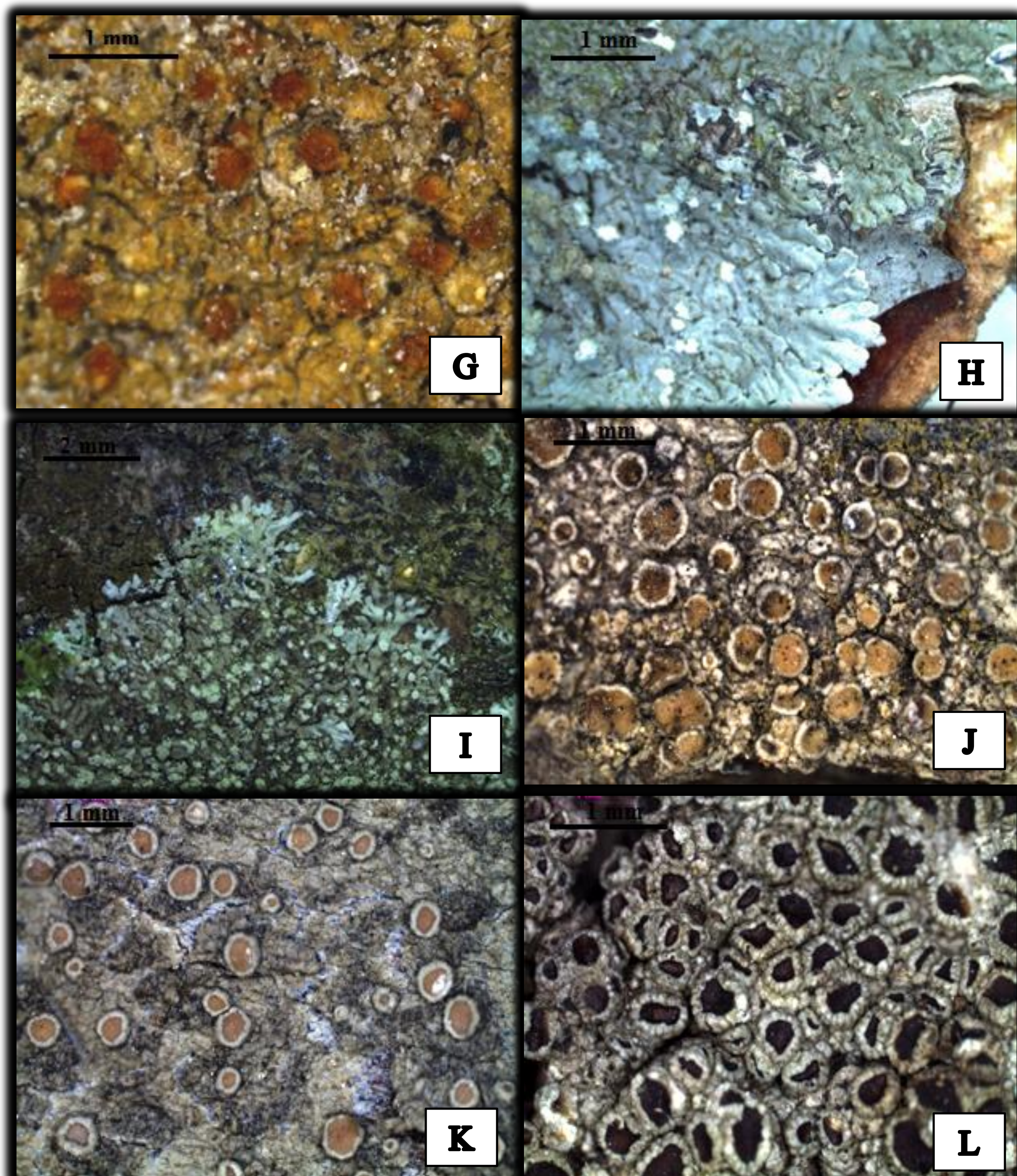


Plate-5.2: Thallus of Lichen Species: (G) *Caloplaca bassiae* (Willd. ex. Ach.) Zahlbr.; (H) *Dirinaria consimilis* (Stirton) D. D. Awasthi; (I) *Hyperphyscia adglutinata var. adglutinata* (Flörke) H. Mayrhofer & Poelt; (J) *Lecanora achroa* Nyl. In J. M. Crombie; (K) *Lecanora helva* Stizenb.; (L) *Lecanora tropica* Zahlbr.

heterophyllus, 2nd April, 2015, N. Gupta. 015-031710 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica*, 2nd April, 2015, N. Gupta. 015-031711 (LWG); Rajesultanpur road, Rampur Benepur, on bark of *Mangifera indica*, 2nd April, 2015, N. Gupta. 015-031720 (LWG). **Tanda Thermal power plant (West):** Faizabad-Tanda road, Mehbubganj, Bhitaura, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023776 (LWG); **Tanda Thermal power plant (North):** Kalwari road, Pakri Chhabar, on bark of *Mangifera indica*, 5th April, 2015, N. Gupta. 015-023800 (LWG). **Tanda Thermal power plant (South):** Akbarpur road, Khetapur, on bark of *Mangifera indica*, 3rd April, 2015, N. Gupta. 015-023752 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Itaura Buzurg, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031739 (LWG); **Unchahar Thermal power plant (East):** Umaran, on tree trunk of *Mangifera indica*, 13th Aug., 2013, N. Gupta. 013-023715 (LWG); **Unchahar Thermal power plant (South):** Girdharpur Garhi, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031787 (LWG); Allahabad- Lucknow Road, Alapur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029726 (LWG); Bihamidpur near Deviganj, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029727 (LWG); Ganga Bridge road, Sounrai buzurg, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029728 (LWG).

OPEGRAPHA Ach. (Family: Opegraphaceae)

Kongl. Vetensk. Acad. Nya Handl. 30: 97. 1809.

Thallus crustose, uniform, ecorticate, corticolous; photobiont green alga. Ascomata sunken or sessile, round to elongate, exciple black carbonaceous, disc narrow or widened. Exciple carbonized; hypothecium dark or hyaline; paraphyses branched and anastomosing, hymenium I+ blue, vinose or vinose red. Asci bituicate, globular-elongate (4) 8 spored; ascospores hyaline to pale brown, ellipsoid to elongate, straight or curved.

Worldwide 361 species; India 20 species; Literature: Awasthi, 1991; Ertz, 2009. Only single species was collected in the present study.

1. ***Opegrapha astraea*** Tuck., *Lichens of California (Berkeley)*: 33 (1866). (Plate-5.3M**)**

Thallus corticolous, crustose, whitish grey, smooth, ecorticate, determinant; prothallus absent or distinct. Lirellae flexuose, simple to forked or branched, acute to blunt ends, scattered uniformly or sometimes 2-3 in grouped and or asteroid; disc white, slightly to wide open, white pruinose. Exciple black, carbonaceous, convergent, discontinuous below hymenium, broad at base, 43-37 µm thick; epihymenium lower part hyaline, upper part (with deposition) olive green to yellow green, granular, K-. I+ blue, KI+ blue; hymenium; hymenium hyaline to pale brown, I+ blue,KI+ blue, 61-75 µm high; hypothecium hyaline, 38-40 µm high; praphysoids branched, slightly anastomosing. Ascus 8 spored, cylindrical – clavate, I+ red to vinose, tip pale blue, KI+ red, tip blue, 60-68 × 9-12 µm; ascospores hyaline, acicular to fusiform, transversely 4-5 septate, all cells are mostly equal size, cells broader than long, 12.3-15.7 × 4.4-4.8 µm.

Thallus K-, C-,KC-,P-. Traces of triterpene between Rf 6-7 were present upon TLC.

Remarks: This species is widely distributed species in Uttar Pradesh as well as new record for India and it is a pantropical species, earlier reported from Africa, Asia and Australia. It is reported from single locality of the study area.

Specimens Examined: India, Uttar Pradesh, Raebareli district, Unchahar Thermal power plant (East): near thermal power plant, Manirampur, on bark of *Mangifera indica*, 13th Aug., 2013, N. Gupta. 016-029731 (LWG).

PELTULA Nyl. (Family: Peltulaceae)

Anni. Sci. Nat. Bot. ser. 3, 20: 316. 1853.

Thallus areolate, squamulose-peltate or subfruticose; rhizinate or umbilicate; upper side olive-brown to brown, upper cortex absent; lower cortex well developed; medulla loose; photobiont a cyanobaterium; apothecia initially immersed, later emergent; disc brown, red or orange brown; thalline exciple as a rim; hymenium I^+ blue or vinose; hypothecium coloueless; asci unitunicate-rostarte with gelatinous sheath around the apex, multispored (16-100 or more); ascospores colourless, simple; pycnoconidia bacilliform to fusiform.

World wide 40 species; India 10 species; Literature: Awasthi, 2007; Upreti and Büdel, 1990.

1. *Peltula corticola* Büdel & R. Sant. in Büdel, *Biblithca Lichenol.* 23: 79. 1987. (Plate-5.3N**)**

Thallus corticolous, squamulose; squamules greenish brown, black, gelatinous when wet, imbricate, 0.4-0.6 mm, marginally sorediate, sometimes soredia arising from lower syrface; soredia granular, labriform. Apothecia absent. Thallus K± yellow purple, C-, KC-, P-. Pale brown spot of unknown compound at Rf 4 were present upon TLC.

Remarks: It grows on mango tree trunk, completely camouflaged with the colour of the bark deposited with algal mat. It can be distinguishable after wetting the bark. It is earlier reported from Eastern Africa (Büdel, 1987), Arabian Peninsula, SW North America (Wetmore, 1970), Sonoran Desert (Büdel et al., 2013). It is commonly present around the study area.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (west): Airport road Kataraghan Shyam west to thermal power plant near Sachendi, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016691 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Bhikh, Harjanpurwa, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023732 (LWG); Bhikh, Harjanpurwa, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023734 (LWG); Bairihat, on bark, 13th Aug., 2013, N. Gupta. 013-023705 (LWG); Bhikh, Harjanpurwa, on bark, 13th Sep., 2013, N. Gupta. 013-023731

(LWG); **Unchahar Thermal power plant (East):** near Raghunathpur Paterwa, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031750 (LWG); Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031755 (LWG); **Unchahar Thermal power plant (West):** Harjanpurwa village, on bark, 13th Sep., 2013, N. Gupta. 013-023733 (LWG); Ashok Nagar (around 0-5 km), on bark of *Acacia Nilotica,* 13th Aug., 2013, N. Gupta. 013-023708 (LWG).

PERTUSARIA DC. (Family: Pertusariaceae)

Fl. Franc., ed. 3, 2: 319. 1805.

Thallus crustose, granular or verrucose, fissured or areolate, corticated, usually corticolous or on plant remains; photobiont a green alga. Ascomata apothecia, generally elevated or innate in fertile verrucae, single or several in each verrucae; disc wide, lecanorine or small, punctiform. Paraphyses branched and variously reticulately anastomosing. Asci thick walled, 1-8 spored; ascospores hyaline, oval ellipsoid, spore wall thick, single, double or triple layered, often constulate and rarely laminate.

World wide 525 species; India 54 species; Literature: Awasthi, 1991; Archer, 1997. Reported from Eastern and North West Himalayas, Andhra Pradesh, Madhya Pradesh, Maharastra, Andaman Islands, Nepal and Sri Lanka.

1. ***Pertusaria quassiae*** (Fée) Nyl., *Ann. Sci. Nat., Bot., ser.* 4, 15: 45. 1861. (Plate-5.3O**)**

≡ ***Porina quassiae*** Fée, *Essai Crypt. Ecorc*.: 81. 1824.

Thallus corticolous, crustose, verrucose, cracked, greyish white; prothallus prominent, white. Ascomata apothecia, perthecioid, fertile verrucae hemispherical, constricted at base, 0.4-0.6 mm, verrucose to tubercled at top near the ostiole; ostiole black, slightly wider. Exciple 32-45 µm thick, covered thalline layer; hymenium conical to U-shaped, 177-279 µm across. Ascus 2 spored, rarely 4 spored, up to 193 x 41 µm; ascospores oblong, hyaline, 71.3-100.0 x 32.3- 40.9 µm, double walled, walls radially consulate, up to 5.5 µm thick. Thallus K+ red, C-, KC-, P+ yellow orange. Stictic acid comple between Rf 1-3 were present upon TLC.

Remarks: This species is widely distributed species in India (Arunachal Pradesh, Andaman and Nicobar Islands, Andhra Pradesh, Himanchal Pradesh, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Nagaland, Sikkim and Uttar Pradesh); Nepal and Sri Lanka; tropical regions of the world. It is rarely found around thermal power plant.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (west): Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near Choubepur kalan near Tatiyaganj, on bark of *Mangifera indica,* 11th October, 2014, N. Gupta. 014-025382 (LWG); **Raebareli district, Unchahar Thermal power plant (East):** near thermal power plant, Umran (5-10 km), on bark of *Mangifera indica,* 13th Aug., 2013, N. Gupta. 013-023716 (LWG); **Unchahar Thermal power plant (North):** Itaura Buzurg near Chandrai, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031740 (LWG); **Unchahar Thermal power plant (South):** Allahabad-Lucknow road, Jagroop nagar, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029732 (LWG).

PHYLLOPELTULA Kalb. (Family: Peltulaceae)

Biblioth. Lichenol. 23: 40. 1987.

Thallus squamulose, subfoliose to foliose, heteromerous, paraplectenchymatous, comprising ± globose hyphal cells, attached to the substratum (bark) by fascicles of rhizohyphae; photobiont a cyanobacteria. Ascomata apothecia, laminal, 0.3-1.0 mm diam. Exciple rudimentary; hymenium hyaline; paraphyses not or rarely branched with few anastomosing, apices slightly swollen. Asci clavate, with 0.32-128 spores; ascospores globose, 3-4 µm diam.

World wide 1 species; India 1 species; Literature: Kalb, 2001; single species are reported from study area.

1. *Phyllopeltula steppae* Kalb. *Biblioth. Lichenol.* 78:159. 2001. (Plate-5.3P**)**

Thallus corticolous, squamulose to subfoliose, olive brown, 1-3 cm across; marginally lobate; lobes concave, 1-2 mm long, 0.5-1.0 mm wide; upper surface ecorticate. Medulla and algal layer inseparaba; lower cortex distinct, consist of 3-4 rows of isodiametric cells; lower surface attached by bundles of rhizohyphae. Ascomata not seen. Thallus K-, C-, KC-, P-. Pale brown spot of unknown compound at Rf 4 detected upon TLC.

Remarks: It is a common lichen species in Uttar Pradesh, found growing on bark of *Mangifera indica* tree trunk. It is characterized by squamulose to subfoliose. This species is earlier known from Neotropics. It is reported from single locality at Panki thermal power plant.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (west): Airport road Kataraghan Shyam west to thermal power plant near Sachendi, on tree trunk of *Mangifera indica*, 20th Feb., 2013, N. Gupta. 013-016695 (LWG).

PYXINE Fr. (Family: Caliciaceae)

E. Fries, *Syst. Orb. Veget. I*: 267. 1925.

Thallus foliose; lobes radiating, branched; upper side pale grey, dark grey to brownish grey, often pruinose and white-maculate; photobiont a green alga; apothecia laminal; disc black; margin and exciple variable; thalline exciple persisitent or becoming black at maturity; or exciple black; brown black part of exciple K^+ violet-purple; epithecium K^+ purple; hypothecium brown; asci 6-8-spored; ascospores brown, 2-celled. Atranorin usually present in upper cortex (K^+ yellow), or upper cortex UV^+ yellow (lichexanthone).

Out of over 60 species distributed primarily in the pantropical regions of the world, 29 species reported from India, Nepal and Sri Lanka. Literature: Awasthi, 2007. Only two species are reported from the study area.

1. *Pyxine cocoes* (Sw.) Nyl., *Mem. Soc. Imp. Sci. Nat. Cherbourg*. 5: 108. 1857. (Plate-5.3Q**)**

≡ ***Lichen cocoes*** Sw., *Nov. Gen. Sp. Pl.*: 146. 1788.

Thallus corticolous, foliose, whitish grey, orbicular, 1.8-6.0 cm across, UV+ yellow, maculate, sorediata; lobes rotund, pruinose, 0.4-1.3 mm wide; medulla white to off-white; maculate laminal and marginal, sometimes forming pseudocyphellae; sorelia laminal to submarginal, linear, soredia granular; lower surface pale yellow to brown, rhizines brownish. Ascomata apothecia, rare, 0.3-1.2 mm diam.; margin thin, thalline, entire, concolours with the thallus, gradually darkening and becoming lecidine; disc black, plane to concave, epruinose of slightly white pruinose. Exciple hyaline, with algal cell when young, brownish at maturity, 20-35 µm thick; epihymenium brown, K+ purple, 10-18 µm thick; hymenium hyaline to slightly yellowish, 45-60 µm thick; hypothecium brown, 25- 35 µm thick; paraphyses simple to branching, apical cell swollen and brown pigmented. Ascus 8 spored, clavate, 40-50 x 18-22 µm; ascospores brown, transversely 1 septate, mischoblastiomorphic, oblong, 15.3-22.1 x 7.6-9.1 µm. Thallus K+ yellow, C-, KC-, P-. Triterpenes at Rf 4, between Rf 4-5, yellow spot of lichenoxanthane between Rf 6-7 were present upon TLC.

Remarks: This species is widely distributed species in India (Assam, Goa, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Manipur, Orissa, Tamil Nadu, Uttarakhand, Uttar Pradesh and West Bengal) and Sri Lanka. In the present study, this species is widely distributed around the study area and collected at 54 localities of all the thermal power plant.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (west): Airport road Kataraghan Shyam west to thermal power plant, on tree trunk of *Mangifera indica*, 20th Feb., 2013, N. Gupta. 013-016689 (LWG); Airport road near Sachendi, on tree trunk of *Mangifera indica*, 20th Feb., 2013, N. Gupta. 013-016693 (LWG); Airport road Kataraghan Shyam west to thermal power plant, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016697 (LWG); **Panki Thermal power plant (North):** Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj, on bark of *Mangifera indica,* 11th October, 2014, N. Gupta. 014-025381 (LWG). **Panki Thermal power plant (South):** Canel road Meharavan Singh Purwa, Patarsa near Mardanpur, on the bark of Mangifera indica, 11th Oct., 2014, N. Gupta. 014-023738 (LWG); **Ambedkar Nagar near Tanda Thermal power plant (East):** Rajesultanpur road, Chintaura, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031702 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031705 (LWG); Rajesultanpur road, Rampur Benepur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031717 (LWG); Rajesultanpur road, Prithivipur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031722 (LWG); Rajesultanpur road, Pretampur Narayanpur, Rasoolpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031724 (LWG); Rajesultanpur road, Pretampur Narayanpur, Rasoolpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031725 (LWG); Rajesultanpur road, Pretampur Narayanpur, Rasoolpur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031726 (LWG). **Tanda Thermal power plant (West):** Faizabad-Tanda road, Uparhar near Uniyarpur, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023762 (LWG); Faizabad-Tanda road, Uparhar near Uniyarpur, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023763; 015-023769 (LWG); Faizabad-Tanda road, Uparhar, Uniyarpur, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023770; 015-023771 (LWG); Faizabad-Tanda road, Mehbubganj, Bhitaura, on bark of *Mangifera indica,* 4th April, 2015, N. Gupta. 015-023773 (LWG); Faizabad-Tanda road, Mehbubganj, Bhitaura, on bark of *Pongamia pinnata,* 4th April, 2015, N. Gupta. 015-023779 (LWG). **Tanda Thermal power plant (North):** Kalwari road, Kalwari Ahtimali, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023781 (LWG); Kalwari road, Kalwari must, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023782 (LWG); Kalwari road, Tahirpur, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023783 (LWG); Kalwari road near Tahirpur roadside, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023784 (LWG); Kalwari road near Saraiya Khurd, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023786 (LWG); Kalwari road, Kusauri, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023787 (LWG); Kalwari road near Kusaura, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023788 (LWG); Kalwari road, Pakri Chhabar, on bark of *Mangifera indica,* 5th April, 2015, N. Gupta. 015-023790 (LWG); Kalwari road near Kusauri, on bark of *Pongamia pinnata,* 5th April, 2015, N. Gupta. 015-023792 (LWG); Kalwari road, Pakri Chhabar, on bark of *Litchi chinensis,* 5th April, 2015, N. Gupta. 015-023799 (LWG); **Tanda Thermal power plant (South):** Akbarpur road, Fathe Jahoorpur, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023746; 015-023748 (LWG); Akbarpur road, Mamrejpur, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023750 (LWG); Akbarpur road, Khetapur, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023751 (LWG); Akbarpur road, Ariya, on bark of *Mangifera indica,* 3rd April, 2015, N. Gupta. 015-023754 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Bhikh, Jog Magdipur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031731 (LWG); Rojhaia Gokulpur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031735 (LWG); **Unchahar Thermal power plant (East):** near Raghunathpur Paterwa, on bark of *Mangifera indica,* 13th Aug., 2013, N. Gupta. 013-023712 (LWG); near power station, Umaran (5-10 km), on bark of *Mangifera indica,* 13th Aug., 2013, N. Gupta. 013-023714; 013-023717 (LWG); Raghunathpur Paterwa, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031747 (LWG); near Raghunathpur Paterwa, on twig of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031751 (LWG); near Raghunathpur Paterwa, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta.

016-031752 (LWG); Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031756 (LWG); near Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031757 (LWG); Paksarwan near Usraina, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031761 (LWG); Umaran near Hanumant Nagar, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031762 (LWG); Lawana, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031773 (LWG); **Unchahar Thermal power plant (South):** Girdharpur Garhi, Ujiyari Gaon, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031792 (LWG); Chandapur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031777 (LWG); Sounrai Buzurg, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031785 (LWG); Girdharpur Garhi, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031788 (LWG); Allahabad-Lucknow road, Alapur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031797 (LWG); **Unchahar Thermal power plant (West):** near power plant (0-5km), on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029704 (LWG); Unchahar dehat near Mustafabad, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-029705 (LWG); Kharauli Mustakil, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029708 (LWG); Baigaon, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029710 (LWG); Allipurbahera, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029712 (LWG); Gaidhemau, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029714 (LWG).

2. ***Pyxine sorediata*** (Ach.) Mont. in Sagra, *Hist. phys. Cuba*, *Bot. Pl. Cell.* 2: 188. 1842. (Plate-5.3R**)**

≡ ***Lecidea sorediata*** Ach., *Syn. Meth. Lich.* 54. 1814.

Thallus corticolous, foliose; lobes 1.0-2.0 mm broad, pearl- white to light grey or dull yellow, branching sub dichotomous, tightly or loosely adnate to the substrate; pseudo-cyphellae well developed along the margins but rare on the lamina; pruina restricted

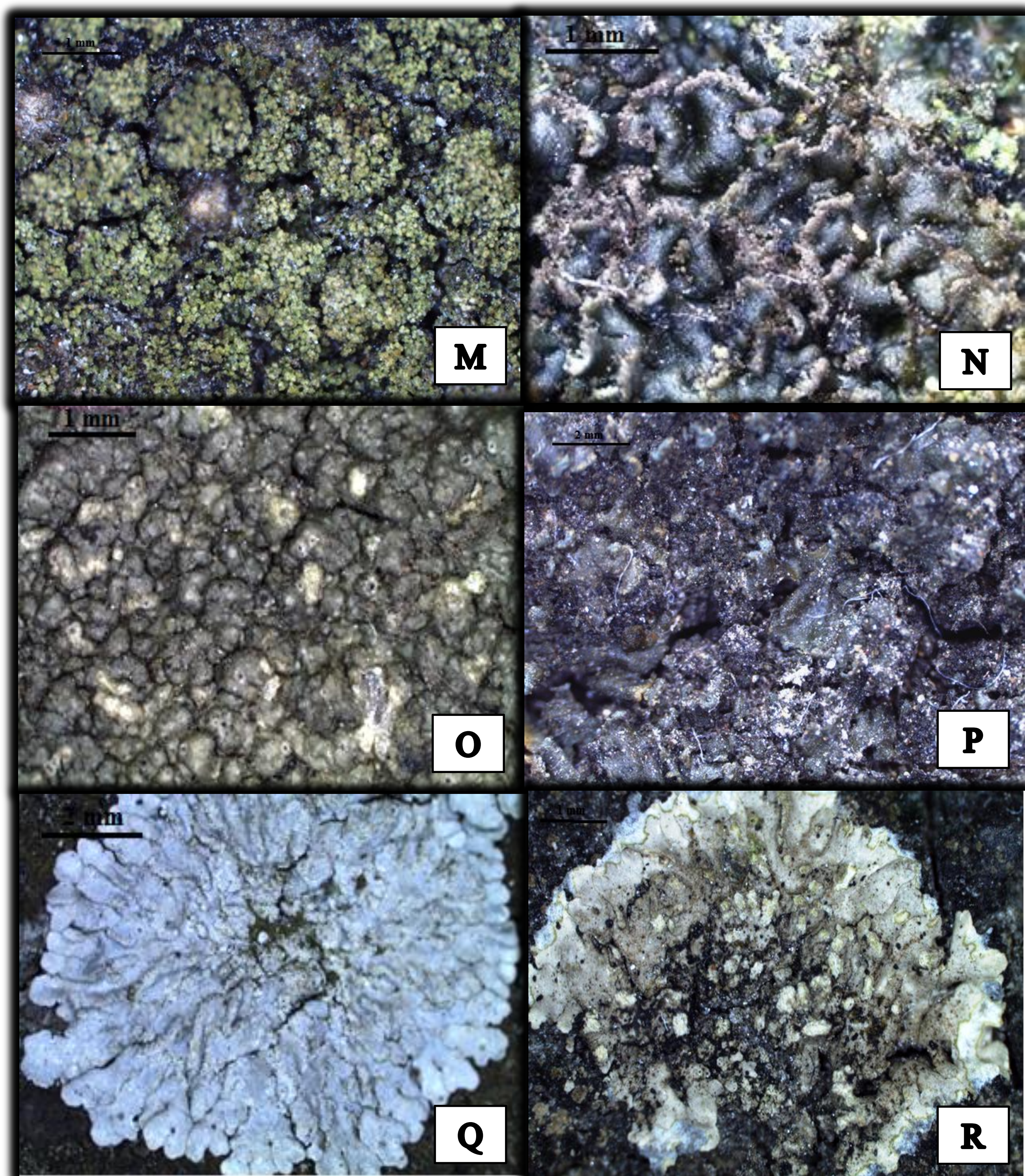


Plate-5.3: Thallus of Lichen Species: (M) *Opegrapha astraea* Tuck.; (N) *Peltula corticola* Büdel & R. Sant.; (O) *Pertusaria quassiae* (Fée.) Nyl.; (P) *Phyllopeltula steppae* Kalb.; (Q) *Pyxine cocoes* (Sw.) Nyl.; (R) *Pyxine sorediata* (Ach.) Mont.

to the lobe tips; soredia coarse, grey. Medulla yellow or light yellow, the soralia which may be on marginal isidia- like lobules. Apothecia very rare, internal stipe colourless to pale brown, K-; ascospores 12-17 × 6-8 µm. Thallus K+ yellow; medulla, K-, Pd-, Triterpene at Rf 4-5, 5 and 6 were detected upon TLC.

Remarks: The species is known from India (Arunachal Pradesh, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Manipur, Nagaland, Sikkim, Tamil Nadu, Uttarakhand and West Bengal hills) and Sri Lanka. The species is rare as it is known from two different localities in the outskirts of Tanda and near to Unchahar thermal power plants growing on *Mangifera indica*.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (East): Rajesultanpur road, Ismailpur beldaha, Heerapur, on bark of *Mangifera indica*, 02nd April, 2015, N. Gupta. 015-031723 (LWG); **Raebareli district, Unchahar Thermal power plant (East):** Manirampur, on tree trunk of *Mangifera indica*, 13th Aug., 2013, N. Gupta. 013-023711 (LWG).

RINODINA (Ach.) Gray (Family: Physciaceae)

Nat. Arr. Brit. Pl. 1: 448. 1821.

Thallus crustose to subsquamulose, continuous, rimose or areolate, pale to dark grey, yellow, yellow to brown or dark brown. Ascomata apothecia, immersed to sessile, disc brown to black, rarely pruinose, plane to convex; margin concolours with the thallus, lecanorine or sometome lecidine. Exciple usually hyaline, rarely brown; hymenium hyaline, amyloid; hypothecium hyaline to pale brown; paraphyses septate, simple or with short branches near the apices, apices. Asci, clavate, (4) 8 spored; ascospores olive- green or pale or dark brown, 1-5 septate, mainly double walled, the walls variously thickened, ellipsoidal, septa well developed at maturity.

Reported 265 species all over the world; from India (Kolkata, Manipur and Sri Lanka) 11 species; Literature: Awasthi, 1991.

1. *Rinodina exigua* (Ach.) Gray, *Nat. Arr. Brit. Pl.* (London). 1: 450. 1821. (Plate-5.4S**)**

≡ ***Lichen exiguus*** Ach., *Lich. Suec. Prodrom*. 69. 1799.

Thallus corticolous, crustose, rough, verruculose, cracked areolate, yellowish grey to greenish grey. Ascomata apothecia, numerous, round, 0.2-0.6 mm diam.; margin promonent, smooth, thalline, concolours with the thallus; disc dark brown to black, epruinose, plane to rarely convex. Exciple with algal cell, 39-66 µm thick; epihymenium brown, 12-18 µm thick; hymenium hyaline, 34-50 µm thick; hypothecium pale brown, 46-70 µm thick; paraphyses simple, apical cell swollen and pigmented. Asci 8 spored, clavate, 40-52 x 9.8-14.4 µm; ascospores brown, transversely 1 septate, oblong, locules mischoblastiomorphic, 11.7-22.2 x 5.0-10.8 µm. Thallus K+ yellow, C-, KC-, P-. Unknown substance of yellow spot at 4, 4-5; Zeorin at Rf 5 and 6 were present upon TLC.

Remarks: It is widely distributed in India (Manipur and Uttar Pradesh) and Sri Lanka. It is reported from single locality of Tanda Thermal power plant.

Specimens Examined: India, Uttar Pradesh, Ambedkar Nagar near Tanda Thermal power plant (West): Faizabad-Tanda road near Ruhiyawa, on bark of *Artocarpous heterophyllus,* 4th April, 2015, N. Gupta. 015-023780 (LWG).

2. Rinodina sophodes (Ach.) A. Massal., *Ric. auton. lich. crost.* (Verona). 14. 1852. (Plate-5.4T**)**

≡ ***Lichen sophodes*** Ach., *Lichenogr. Suec. Prodr*. 67. 1799.

Thallus corticolous, crustose, smooth, thin, ecorticate, greyish green to brownish green. Ascomata apothecia, common, sessile, constricted at base or closely adpressed, 0.8 – 3.0 mm diam.; margin lecanorine, thick, concolours with the thallus; disc brown, dark brown to black, plane to concave, epruinose. Exciple with algal cells, 60 – 73 µm thick; epihymenium yellow brown to dark brown, 18 – 20 µm high, K-, I+ blue; hymenium hyaline, 85 – 95 µm high, I+ blue; hypothecium hyaline to pale brown, I-, 78 – 95 µm high, praphyses sparingly branched, , apical cells slightly swollen and pigmented. Ascus 8 spored, cylindrical to clavate, 65 – 72 × 5 – 8 µm; ascospores brown, ellipsoid to oblong, transversely 1 septate, locules simple, round, 12.8 – 14.7 × 5.4 – 6.7 µm. Thallus K+ yellow, C-,KC-,P-. Traces of Salazinic at Rf 2, Pale brown unknown at Rf 4 were detected upon TLC.

Remarks: This species is widely distributed species in India (Arunachal Pradesh, Himanchal Pradesh, Madhya Pradesh, Sikkim, Uttar Pradesh and West Bengal). It is a most common species and widely distributed species in present study.

Specimens Examined: India, Uttar Pradesh, Kanpur district, Panki Thermal power plant (West): Airport road Kataraghan Shyam west to thermal power plant, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016688 (LWG); Airport road Kataraghan Shyam west to thermal power plant near Sachendi ,on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016690 (LWG); Airport road near Sachendi, on bark of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016692 (LWG); Airport road Kataraghan Shyam west to thermal power plant, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016694 (LWG); Airport road Kataraghan Shyam west to thermal power plant, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016698 (LWG); Airport road Kataraghan Shyam west to thermal power plant, on tree trunk of *Mangifera indica,* 20th Feb., 2013, N. Gupta. 013-016699 (LWG); **Panki Thermal power plant (North):** Aligarh-Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj, on bark of *Mangifera indica,* 11th October, 2014, N. Gupta. 014-025379; 014-025380 (LWG); **Panki Thermal power plant (South):** near Panki thermal power plant, Rampur, Bhimsen, on bark of *Mangifera indica,* 11th October, 2014, N. Gupta. 014-025385; 014-025386 (LWG); Canel road Meharavan Singh Purwa, Patarsa near Mardanpur, on bark of *Mangifera indica,* 11th October, 2014, N. Gupta. 014-025388; 014-025389

(LWG). **Ambedkar Nagar near Tanda Thermal power plant (East):** Rajesultanpur road, Prithivipur, on bark of *Mangifera indica,* 2nd April, 2015, N. Gupta. 015-031721 (LWG); Rajesultanpur road, Mubarakpur, on bark of *Artocarpous heterophyllus,* 2nd April, 2015, N. Gupta. 015-031707 (LWG); **Tanda Thermal power plant (West):** Faizabad-Tanda road, Uparhar near Uniyarpur, on bark of *Mangifera indica*, 4th April, 2015, N. Gupta. 015-023763 (LWG); **Raebareli district, Unchahar Thermal power plant (North):** Taghan near Ganganahar, on bark, 13th Aug., 2013, N. Gupta. 013-023701 (LWG); Taghan, Bairihat, on bark of *Azadirachta indica,* 13th Aug., 2013, N. Gupta. 013-023704 (LWG); Bairihat, on bark, 13th Aug., 2013, N. Gupta. 013-023705, 013-023706 (LWG); Harpurhalla, on bark, 13th Aug., 2013, N. Gupta. 013-023705, 013-023719 (LWG); Taghan near Ganganahar, on bark of *Azadirachta indica*, 13th Sep., 2013, N. Gupta. 013-023722 (LWG); Bhikh, Harjanpurwa, on bark, 13th Sep., 2013, N. Gupta. 013-023727; 013-023731(LWG); near Nababganj, Sanhoo Kuwan, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031730 (LWG); Bhikh, Jog Magdipur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031732 (LWG); Bairihat, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031733 (LWG); near Bairihat, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031734 (LWG); Rojhaia Gokulpur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031738 (LWG); **Unchahar Thermal power plant (East):** Raghunathpur Paterwa, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031745 (LWG); near Raghunathpur Paterwa, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031748 (LWG); near Umaran, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031758 (LWG); near Amaraupur, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031769 (LWG); Amaraupur, on bark of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031770 (LWG); near Lawana, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031775 (LWG); **Unchahar Thermal power plant (South):** Chandapur, on bark of

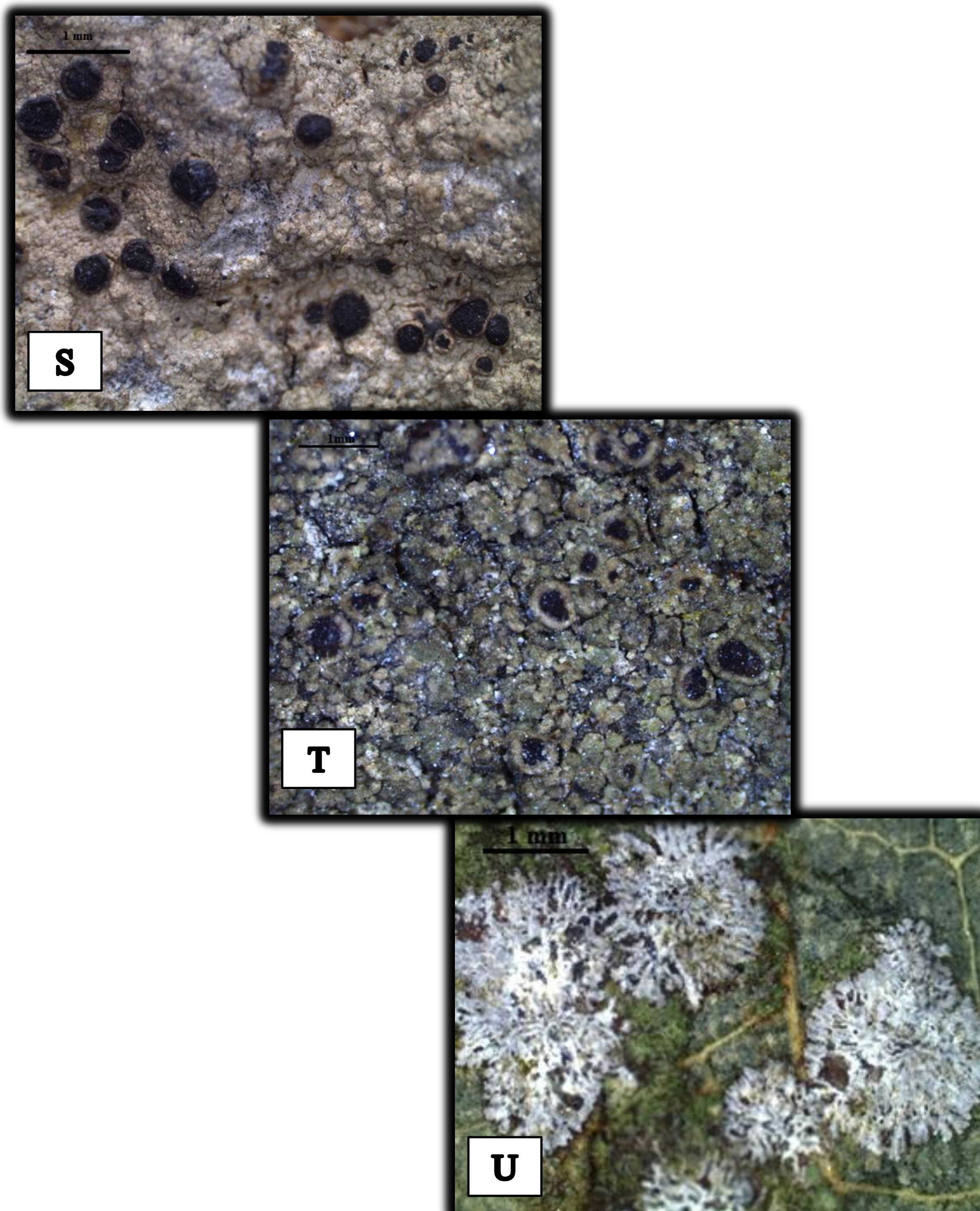


Plate-5.4: Thallus of Lichen Species: (S) *Rinodina exigua* (Ach.) Gray; (T) *Rinodina sophodes* (Ach.) A. Massal.; (U) *Strigula elegans* (Fée) Müll. Arg.

Mangifera indica, 13th March, 2016, N. Gupta. 016-031778 (LWG); Ganga-bridge road, Sultanpur Khwaja karak, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-031782 (LWG); **Unchahar Thermal power plant (West):** Ashok Nagar (0-5 km), on bark of *Acacia nilotica,* 13th Aug., 2013, N. Gupta. 013-023707 (LWG); near power plant, Ashok Nagar (0-5 km), on bark of *Acacia nilotica,* 13th Aug., 2013, N. Gupta. 013-023708 (LWG); Unchahar Junction, Ashok Nagar (0-5 km), on bark of *Azadirachta indica,* 13th Aug., 2013, N. Gupta. 013-023709 (LWG); near power plant (0-2 km), on bark, 13th Sep., 2013, N. Gupta. 013-023729 (LWG); near power plant (0-2 km), on bark, 13th Sep., 2013, N. Gupta. 013-023730 (LWG); Allipurbahera, on bark of *Mangifera indica,* 13th Sep., 2013, N. Gupta. 013-023735 (LWG); Kand Rawan, on bark of *Mangifera indica,* 13th March, 2016, N. Gupta. 016-029707 (LWG).

STRIGULA Fr. (Family: Strigulaceae)

Kongl. Vet. Akad. Handl. 1821: 323. 1821.

Thallus crustose, subcuticular, ecorticate, effigurate, lobes distinct or confluent, foliicolous; photobiont. Ascomata perithecia, convex to conical, partially immersed in thallus or totally covered by thallus. Exciple complete to dimidiate; usually differentiated into an outer brown or black involucrellum and an inner brown- black or hyaline wall; paraphyses simple. Asci thin walled, 8 spored; ascospores hyaline, transversely 1-3 septate. Pycnidia convex, macro conidia 1-7(-9) septate, filiform or bacillary, micro conidia simple, ellipsoid or fusiform.

Reported 265 species all over the world; from India (Kolkata, Manipur and Sri Lanka) 17 species; Literature: Awasthi, 1991.

1. ***Strigula elegans*** (Fée) Müll. Arg., *Flora.* Regensburg. 63 (9): 41. 1880. (Plate-5.4U**)**

≡ ***Phyllocharis elegans*** Fée. 1825.

One cell of spores slightly larger than other, thallus green to grey-green, perithetia 0.25-0.4 mm diam., immersed in thallus, upper part exposed, involucrellum separated from inner wall at base and laterally, spores 1-septate, rarely 3-septate, with construction at septa, ends acute, 14-22(-24) x 4-5.5µm. Thallus K-, C-, KC-, P-. Triterpene at Rf 6 were detected upon TLC.

Remarks: *Strigula elegans* is rare lichen species in Uttar Pradesh, found growing on the leaves of *Mangifera indica* tree. Earlier reported from Assam, Nepal and Sri Lanka but in the present study, it is single reported from Unchahar thermal power plant.

Specimens Examined: India, Uttar Pradesh, Raebareli district, Unchahar Thermal power plant (East): Salon near Bhawanipur, on leaves of *Mangifera indica*, 13th March, 2016, N. Gupta. 016-031765 (LWG).

Chapter- 6
Ecological Studies

6.1 Ecological Assessment of Lichen Diversity (Appendix-III: 6.4.1 & 6.4.2; 6.5.1 & 6.5.2; 6.6.1 to 6.6.4)

Ecological assessment of diversity was made by laying quadrates in the study area to determine the frequency %, density, abundance, relative frequency and relative density along with Important Value Index (IVI). The relative importance of organisms in a community is not determined by its taxonomic position but rather by the number, size and other relationships. The degree of an importance of a species is usually termed as an index of dominance. The ratio between the numbers of individuals in a community is termed as species diversity. This is related to the stability of the environment and it varies with different communities. Species diversity is of great importance in assessing the extent of damage done to natural system by human interference (Negi and Upreti, 2000; Pinokiyo et al., 2008).

Species diversity is denoting the number of species in a given area or as the number of species among the total number of individuals of all species present. This relationship may be expressed as diversity index. A great diversity also indicates the availability of a large number of niches.

Studies on lichens

With the help of sampling techniques like transect, quadrate, bisect, etc. the group and structure of communities can be studied and expressed and quantitatively, both in absolute terms of species and with respect to all other plants species of the area. In present study, different growth forms of lichens on different substratum were recorded (Table-6.1, 6.2 & 6.3).

Lichen communities encompass a major contribution in forest’s biomass together with ecological roles such as nitrogen fixation, nutrient cycling and provision of food and nesting materials for birds in the ecological systems. The nature of bark, pH and moisture retaining capacity of bark plays a vital role in determining the composition and structure of epiphytic communities.

Table-6.1: Overall distribution, growth forms (GF) and preferred substrate of lichens as observed around selected Thermal Power Plants

S. No.	Family	Genus	Species	Growth Form	Substrate	Localities		
						1	2	3
1	**Arthoniaceae**	*Arthothelium*	*Arthothelium chiodectoides* (Nyl.) Zahlbr.	Crustose	bark of *Mangifera indica*	-	+	-
2	**Caliciaceae**	*Dirinaria*	*Dirinaria consimilis* (Stirton) D. D. Awasthi	Foliose	bark of *Mangifera indica*	-	-	+
		Pyxine	*Pyxine cocoes* (Sw.) Nyl.	Foliose	bark of *Mangifera indica*	+	+	+
			Pyxine sorediata (Ach.) Mont.	Foliose	bark of *Mangifera indica*	-	+	+
3	**Lecanoraceae**	*Lecanora*	*Lecanora achroa* Nyl. In J. M. Crombie	Crustose	bark of *Mangifera indica*	-	-	+
			Lecanora tropica Zahlbr.	Crustose	bark of *Mangifera indica, Artocarpous heterophyllus*	-	+	+
			Lecanora helva Stizenb.	Crustose	bark of *Mangifera indica*	+	-	+
4	**Monoblastiaceae**	*Anisomeridium*	*Anisomeridium nidulans* (Müll. Arg.) R.C.Harris	Crustose	bark of *Mangifera indica*	+	-	+
5	**Opegraphaceae**	*Opegrapha*	*Opegrapha astraea* Tuck.	Crustose	bark of *Mangifera indica*	-	-	+
6	**Peltulaceae**	*Peltula*	*Peltula corticola* Büdel & R. Sant	Squamulose	bark of *Mangifera indica*	+	-	+
		Phyllopeltula	*Phyllopeltula steppae* Kalb.	Squamulose to subfoliose	bark of *Mangifera indica*	+	-	-
7	**Pertusariaceae**	*Pertusaria*	*Pertusaria quassiae* (Fée.) Nyl.	Crustose	bark of *Mangifera indica*	+	-	+
8	**Physciaceae**	*Hyperphyscia*	*Hyperphyscia adglutinata* var. adglutinata (Flörke) H. Mayrhofer & Poelt	Foliose	bark of *Mangifera indica*	-	+	+
		Rinodina	*Rinodina exigua* (Ach.) Gray	Crustose	bark of *Mangifera indica*	-	+	-
			Rinodina sophodes (Ach.)	Crustose	bark of *Mangifera*	+	+	+

			A. Massal.		*indica, Azadirachta indica, Acacia nilotica, Artocarpous heterophyllus*			
9	**Ramalinaceae**	*Bacidia*	*Bacidia* sp.	Crustose	bark of *Mangifera indica*	+		+
			Bacidia incongruens (Stirton) Zahlbr.	Crustose	bark of *Mangifera indica*	-	+	+
			Bacidia medialis (Tuck.) Zahlbr.	Crustose	bark of *Mangifera indica, Artocarpous heterophyllus*	-	+	+
			Bacidia rubella (Hoffm.) A. Massal.	Crustose	bark of *Mangifera indica*	-	-	+
			Bacidia submedialis (Nyl.) Zahlbr.	Crustose	bark of *Mangifera indica, Artocarpous heterophyllus*	-	+	+
10	**Strigulaceae**	*Strigula*	*Strigula elegans* (Fée) Müll. Arg.	Follicolous	bark of *Mangifera indica*	-	-	+
11	**Teloschistaceae**	*Caloplaca*	*Caloplaca bassiae* (Willd. Ex. Ach.) Zahlbr.	Crustose	bark of *Mangifera indica*	-	+	+

1= Panki Thermal Power Plant, Kanpur; 2= Tanda Thermal Power Plant, Ambedkar Nagar; 3= Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli; += present; -= absent

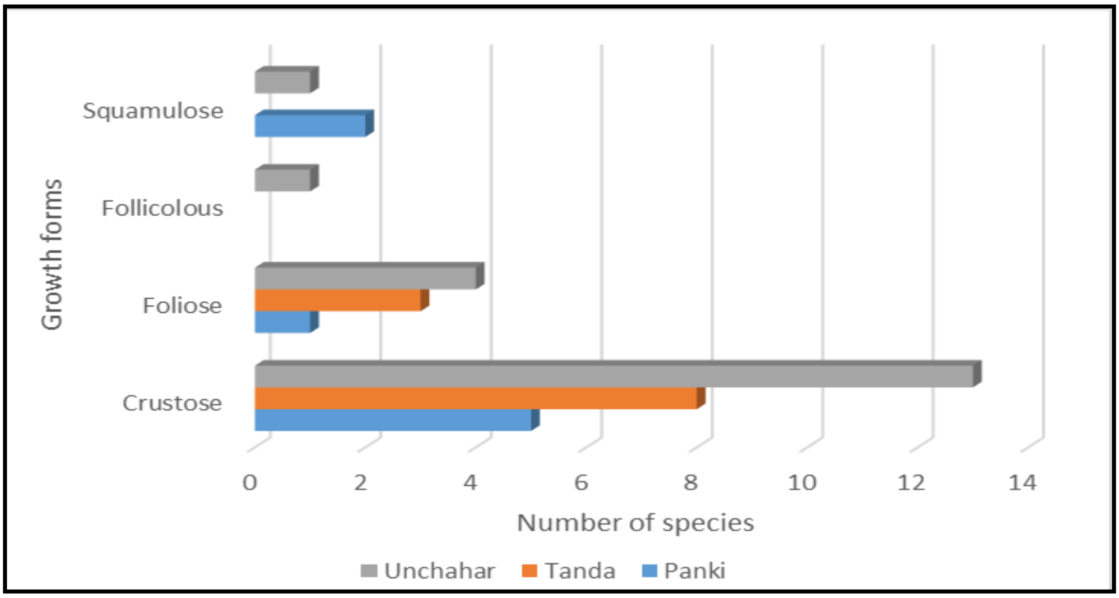


Fig-6.1: Representation of different growth forms (GF) of lichens observed around selected Thermal Power Plants of Uttar Pradesh

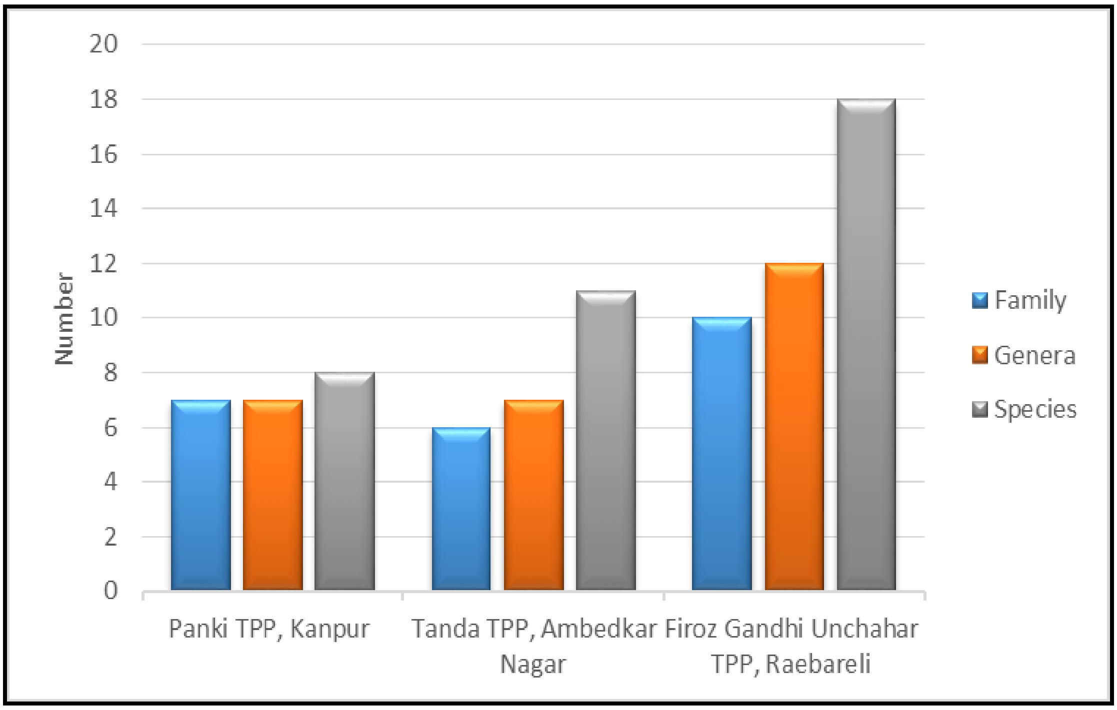


Fig-6.2: Family/ Genera/ Species wise distribution of lichens around selected Thermal Power Plants of Uttar Pradesh

Table-6.2: Representation of growth forms (GF) of lichens observed around selected Thermal Power Plants

S. No.	Sites	Growth Forms				
		Crustose	Foliose	Follicolous	Squamulose	Total
1	**Panki Thermal Power Plant, Kanpur**	5	1	-	2	**8**
2	**Tanda Thermal Power Plant, Ambedkar Nagar**	8	3	-	-	**11**
3	**Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli**	13	4	1	1	**18**

Table-6.3: Family/ Genera/ Species wise distribution of lichens around selected Thermal Power Plants

S. No.	Sites	Family	Genera	Species
1	**Panki Thermal Power Plant, Kanpur**	7	7	8
2	**Tanda Thermal Power Plant, Ambedkar Nagar**	6	7	11
3	**Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli**	10	12	18
	Total No.	**21**	**26**	**37**

The bark of *Mangifera indica* tree provides an excellent substrate for the luxuriant growth of lichens around thermal power plants. The members of lichen family Ramalinaceae, Physicaceae, Lecanoraceae and Calciaceae are the dominant lichen family around the study area (Fig-6.1 & 6.2). The soil around power plants may also provide a suitable substrate for crustose lichen genera such as *Anisomerium nidulans, Arthothelium chiodectoides, Bacidia* sp., *Caloplaca bassiae, Lecanora* sp., *Opegrapha astraea, Pertusaria quassiae, Rinodina exigua, Rinodina sophodes.*

Assessment of diversity, distribution together with frequency %, abundance, relative frequency, relative density, Important Value Index (IVI) around thermal power plants was estimated. Number of quadrates laid down were varied with the locality at each study area to record the ecological parameters with their relative values were also determined. The ecological parameters such as frequency percentage, density, abundance and IVI of lichen of each locality studied around power plants and exhibit more or less similar variation as following-

6.1.1 Frequency: The frequency of lichen species ranged from 55.88% to 166.25% around all the three selected thermal power plants. Among all the species encountered

Bacidia incongruens, *Pyxine cocoes* and *Rinodina sophodes* are the common species from all the study area with maximum frequency showing their wide range of diversity and distribution along with dispersion. *Rinodina sophodes* (Panki Thermal Power Plant), *Pyxine cocoes* (Tanda Thermal Power Plant) and *Bacidia incongruens* (Unchahar Thermal Power Plant) exhibit the highest the maximum frequency observed around thermal power plants. Other lichen species have less frequency percentage in comparison to above lichen species (Table-6.4 to 6.6).

6.1.2 Density: Density represents the numerical strength of the particular community around selected thermal power plant of Uttar Pradesh. Total density of lichen species ranged from 0.57 to 1.67 in all the study area. In Panki Thermal Power Plant, *Rinodina sophodes* exhibit maximum density of 0.18 followed by *Bacidia incongruens* and *Pyxine cocoes* with 0.12 density each. In Tanda Thermal Power Plant, *Pyxine cocoes* has the maximum density of 0.55 followed by *Bacidia incongruens* and *Bacidia submedialis* with 0.29 and 0.17 respectively. Unchahar Thermal Power Plant has the maximum density of *Bacidia incongruens* with density of 0.38 followed by *Pyxine cocoes* and *Rinodina sophodes* represented by 0.28 and 0.26 respectively. Among all the study area *Pyxine cocoes* showed its maximum density (0.55) in Tanda Thermal Power Plant (Table-6.4 to 6.6).

6.1.3 Abundance: The lichen species ranged between 0.76-1.92 around all the selected thermal power plant. *Bacidia incongruens*, *Pyxine cocoes* and *Rinodina sophodes* are the most abundant taxa in lichens. *Pyxine cocoes* exhibit its abundance in Tanda Thermal Power Plant i.e. 0.690 followed by *Bacidia incongruens* (Unchahar Thermal Power Plant) and *Rinodina sophodes* (Panki Thermal Power Plant) with abundance of 0.425 and 0.353. The abundance of lichen species varies amongst in different localities around thermal power plants (Table-6.4 to 6.6).

6.1.4 Relative Frequency (Rf): Relative frequency ranged between 98.47% and 100% around all the three thermal power plants. The maximum relative frequency was observed by *Pyxine cocoes* which is 35.39% growing in Tanda Thermal Power Plant, whereas the other lichen species in Panki and Unchahar Thermal Power Plants have *Bacidia incongruens* (31.58%) and *Rinodina sophodes* (22.56%) respectively. Other lichen species in all the study area have less relative frequency (Table-6.4 to 6.6).

6.1.5 Relative Density (Rd): The maximum relative density ranged between 98.32% and 100.15% around all the three thermal power plants. The maximum relative frequency was observed by *Pyxine cocoes* which is 35.33% growing in Tanda Thermal Power Plant, whereas the other lichen species in Panki and Unchahar Thermal Power Plants have *Rinodina sophodes* (31.51%) and *Bacidia incongruens* (22.59%) respectively. Other lichen species have more or less similar to each other in all the study area with relative frequency (Table-6.4 to 6.6).

6.1.6 Important Value Index (IVI): The total IVI of all the lichen species ranged from 196.75-200.11 in all the study area. The maximum IVI is recorded in *Pyxine cocoes* with 70.72 in Tanda Thermal Power Plant followed by *Rinodina sophodes* (63.09%) in Panki Thermal Power Plant and *Bacidia incongruens* (45.15%) in Unchahar Thermal Power Plant have and respectively. Other lichen species have more or less similar IVI to each other in all the study area (Table-6.4 to 6.6).

After estimation of the values of ecological parameters at each study area, it was concluded that the lichen diversity around Unchahar Thermal Power Plant showed maximum value in comparison to Panki and Tanda Thermal Power Plants.

Table-6.4: Ecological parameters estimated for lichen taxa around Panki Thermal Power Plant, Kanpur (Total Sampling sites=34) (Appendix-III: 6.4.1 & 6.4.2)

S. No.	Lichen Taxa	Ecological Parameters					
		Frequency%	Density	Abundance	Relative Frequency	Relative Density	Important Value Index (IVI)
1	*Anisomeridium nidulans*	0.00	0.00	0	0.00	0.00	0.00
2	*Arthothelium chiodectoides*	0.00	0.00	0	0.00	0.00	0.00
3	*Bacidia incongruens**	11.76	0.12	0.117	21.05	21.01	42.06
4	*Bacidia medialis*	0.00	0.00	0	0.00	0.00	0.00
5	*Bacidia rubella*	0.00	0.00	0	0.00	0.00	0.00
6	*Bacidia submedialis*	0.00	0.00	0	0.00	0.00	0.00
7	*Caloplaca bassiae*	0.00	0.00	0	0.00	0.00	0.00
8	*Dirinaria consimilis*	0.00	0.00	0	0.00	0.00	0.00
9	*Hyperphyscia adglutinata*	0.00	0.00	0	0.00	0.00	0.00
10	*Lecanora achroa*	0.00	0.00	0	0.00	0.00	0.00
11	*Lecanora tropica*	0.00	0.00	0	0.00	0.00	0.00
12	*Lecanora helva*	2.94	0.03	0.029	5.26	5.25	10.52
13	*Opegrapha astraea*	0.00	0.00	0	0.00	0.00	0.00
14	*Peltula corticola*	2.94	0.03	0.029	5.26	5.25	10.52
15	*Pertusaria quassiae*	2.94	0.03	0.029	5.26	5.25	10.52
16	*Phyllopeltula steppae*	2.94	0.03	0.029	5.26	5.25	10.52
17	*Pyxine cocoes*	11.76	0.12	0.147	21.05	21.01	42.06
18	*Pyxine sorediata*	0.00	0.00	0	0.00	0.00	0.00
19	*Rinodina exigua*	0.00	0.00	0	0.00	0.00	0.00
20	*Rinodina sophodes*	17.65	0.18	0.353	31.58	31.51	63.09
21	*Strigula elegans*	0.00	0.00	0	0.00	0.00	0.00
	Total	**55.88**	**0.56**	**0.765**	**100.00**	**99.79**	**199.79**
	Average	**2.66**	**0.03**	**0.036**	**4.76**	**4.75**	

**Bacidia* sp. (sterile form) merged with this species

Table-6.5: Ecological parameters estimated for lichen taxa around Tanda Thermal Power Plant, Ambedkar Nagar (Total Sampling sites=42) (Appendix-III: 6.5.1 & 6.5.2)

S. No.	Lichen Taxa	Ecological Parameters					
		Frequency%	Density	Abundance	Relative Frequency	Relative Density	Important Value Index (IVI)
1	*Anisomeridium nidulans*	0.00	0.00	0	0.00	0.00	0.00
2	*Arthothelium chiodectoides*	2.38	0.02	0.047	1.54	1.54	3.07
3	*Bacidia incongruens*	28.57	0.29	0.357	18.46	18.43	36.89
4	*Bacidia medialis*	11.90	0.12	0.143	7.69	7.68	15.37
5	*Bacidia rubella*	0.00	0.00	0	0.00	0.00	0.00
6	*Bacidia submedialis*	16.67	0.17	0.214	10.77	10.75	21.52
7	*Caloplaca bassiae*	9.52	0.10	0.143	6.15	6.14	12.30
8	*Dirinaria consimilis*	0.00	0.00	0	0.00	0.00	0.00
9	*Hyperphyscia adglutinata*	2.38	0.02	0.024	1.54	1.54	3.07
10	*Lecanora achroa*	0.00	0.00	0	0.00	0.00	0.00
11	*Lecanora tropica*	14.29	0.14	0.190	9.23	9.22	18.45
12	*Lecanora helva*	0.00	0.00	0	0.00	0.00	0.00
13	*Opegrapha astraea*	0.00	0.00	0	0.00	0.00	0.00
14	*Peltula corticola*	0.00	0.00	0	0.00	0.00	0.00
15	*Pertusaria quassiae*	0.00	0.00	0	0.00	0.00	0.00
16	*Phyllopeltula steppae*	0.00	0.00	0	0.00	0.00	0.00
17	*Pyxine cocoes*	54.76	0.55	0.690	35.39	35.33	70.72
18	*Pyxine sorediata*	2.38	0.02	0.024	1.54	1.54	3.07
19	*Rinodina exigua*	2.38	0.02	0.024	1.54	1.54	3.07
20	*Rinodina sophodes*	7.14	0.07	0.071	4.62	4.61	9.22
21	*Strigula elegans*	0.00	0.00	0	0.00	0.00	0.00
	Total	**152.38**	**1.52**	**1.93**	**98.46**	**98.31**	**196.77**
	Average	**7.256**	**0.072**	**0.092**	**4.689**	**4.681**	

Table-6.6: Ecological parameters estimated for lichen taxa around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (Total Sampling sites=80) (Appendix-III: 6.6.1 & 6.6.4)

S. No.	Lichen Taxa	Ecological Parameters					
		Frequency%	Density	Abundance	Relative Frequency	Relative Density	Important Value Index (IVI)
1	***Anisomeridium nidulans***	12.50	0.13	0.125	7.52	7.53	15.05
2	***Arthothelium chiodectoides***	0.00	0.00	0	0.00	0.00	0.00
3	***Bacidia incongruens****	37.50	0.38	0.425	22.56	22.59	45.15
4	***Bacidia medialis***	5.00	0.05	0.062	3.01	3.01	6.02
5	***Bacidia rubella***	1.25	0.01	0.013	0.75	0.75	1.50
6	***Bacidia submedialis***	13.75	0.14	0.15	8.27	8.28	16.55
7	***Caloplaca bassiae***	2.50	0.03	0.025	1.50	1.51	3.01
8	***Dirinaria consimilis***	1.25	0.01	0.013	0.75	0.75	1.50
9	***Hyperphyscia adglutinata***	6.25	0.06	0.062	3.76	3.77	7.52
10	***Lecanora achroa***	7.50	0.08	0.075	4.51	4.52	9.03
11	***Lecanora tropica***	6.25	0.06	0.062	3.76	3.77	7.52
12	***Lecanora helva***	5.00	0.05	0.05	3.01	3.01	6.02
13	***Opegrapha astraea***	1.25	0.01	0.013	0.75	0.75	1.50
14	***Peltula corticola***	6.25	0.06	0.1	3.76	3.77	7.52
15	***Pertusaria quassiae***	3.75	0.04	0.037	2.26	2.26	4.51
16	***Phyllopeltula steppae***	0.00	0.00	0	0.00	0.00	0.00
17	***Pyxine cocoes***	27.50	0.28	0.3	16.54	16.57	33.11
18	***Pyxine sorediata***	1.25	0.01	0.013	0.75	0.75	1.50
19	***Rinodina exigua***	0.00	0.00	0	0.00	0.00	0.00
20	***Rinodina sophodes***	26.25	0.26	0.35	15.79	15.81	31.60
21	***Strigula elegans***	1.25	0.01	0.013	0.75	0.75	1.50
	Total	**166.25**	**1.66**	**1.887**	**100.00**	**100.15**	**200.15**
	Average	**7.92**	**0.08**	**0.089**	**4.76**	**4.77**	

**Bacidia* sp. (sterile form) merged with this species

6.2 Comparison of Lichen types with respect to Air Pollution levels: The distribution of each lichen species within 156 sampling sites of the study area is given in Table-6.7.

Table-6.7: Distribution of lichens within 156 sampling sites around all the study area

S. No.	Species	GF	Substrate	Localities			Total No. of sites	Sites Characteristics
				1	2	3		
1	***Anisomeridium nidulans***	Cr	On bark of *Mangifera indica*	1	-	10	**11**	Moist any shady places; observed away from the road sides
2	***Arthothelium chiodectoides***	Cr	On bark of *Mangifera indica*	-	1	-	**1**	Open and sunny areas receiving ample sunlight, Away from road
3	***Bacidia* sp. + *Bacidia incongruens***	Cr	On bark of *Mangifera indica*	4	14	31	**49**	Thick forest of *Mangifera indica;* both along as well as far from roadsides
4	***Bacidia medialis***	Cr	On bark of *Mangifera indica, Artocarpous heterophyllus*	-	6	4	**10**	observed in moist and dense forest towards sunlight
5	***Bacidia rubella***	Cr	On bark of *Mangifera indica*	-	-	1	**1**	In moist places; away from roadsides
6	***Bacidia submedialis***	Cr	On bark of *Mangifera indica, Artocarpous heterophyllus*	-	8	12	**20**	Along the roadsides and also at places situated away from the roads
7	***Caloplaca bassiae***	Cr	On bark of *Mangifera indica*	-	5	2	**7**	Away from roads i.e. locations free from any vehicular source of pollution
8	***Dirinaria consimilis***	F	On bark of *Mangifera indica*	-	-	1	**1**	Moist, shady and pollution free areas
9	***Hyperphyscia adglutinata***	F	On bark of *Mangifera indica*	-	1	5	**6**	Along the roadsides as well as in thick forest with low sunlight
10	***Lecanora achroa***	Cr	On bark of *Mangifera indica*	-	-	5	**5**	Away from roads i.e. locations free

								from any vehicular source of pollution
11	***Lecanora tropica***	Cr	On bark of *Mangifera indica, Artocarpous heterophyllus*	-	8	6	**14**	Along the road sides
12	***Lecanora helva***	Cr	On bark of *Mangifera indica*	1	-	4	**5**	Observed as small patches in areas neither very close nor very far from the road sides
13	***Opegrapha astraea***	Cr	On bark of *Mangifera indica*	-	-	1	**1**	away from road side;
14	***Peltula corticola***	Sq	On bark of *Mangifera indica*	1	-	8	**9**	Growing away from road sides in pollution free areas
15	***Pertusaria quassiae***	Cr	On bark of *Mangifera indica*	1	-	3	**4**	Both sunny and shady areas; at a small distance from road sides
16	***Phyllopeltula steppae***	Sq	On bark of *Mangifera indica*	1	-	-	**1**	away from road side
17	***Pyxine cocoes***	F	On bark of *Mangifera indica*	5	26	23	**54**	Observed abundantly in the forest around power plant, also along the road side
18	***Pyxine sorediata***	F	On bark of *Mangifera indica*	-	1	1	**2**	Rarely observed in east direction of both the power plant
19	***Rinodina exigua***	Cr	On bark of *Mangifera indica*	-	1	-	**1**	Scattered forest, close to agricultural fields; away from roadside
20	***Rinodina sophodes***	Cr	On bark of *Mangifera indica, Azadirachta indica, Acacia nilotica, Artocarpous heterophyllus*	9	3	26	**38**	Both sunny and shady areas; at a small distance from road sides
21	***Strigula elegans***	Fo	On leaves of *Mangifera indica*	-	-	1	**1**	Away from roads i.e. location free from any vehicular source of pollution

1= Panki Thermal Power Plant, Kanpur; 2= Tanda Thermal Power Plant, Ambedkar Nagar; 3= Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli; - = absent; GF= Growth Form; Cr= Crustose; F= Foliose; Fo= Follicolous lichen

Chapter-7
Results and Discussion

"Research is a very good world and the meaning is certainly plain, when results are still quite absurd, it literally means search again".

The identification of more than 500 specimens were collected from different localities around three Thermal Power Plants, revealed the occurrence of 21 species belonging to 14 genera and 11 families of lichens. Out of 20,000 species of lichens known from World, but India represents more than 10% of the species. The state Uttar Pradesh is represented by 135 species of lichens (Nayaka and Upreti, 2013) of which the Thermal Power Plants represents only less than 20% of the species (Fig-7.1).

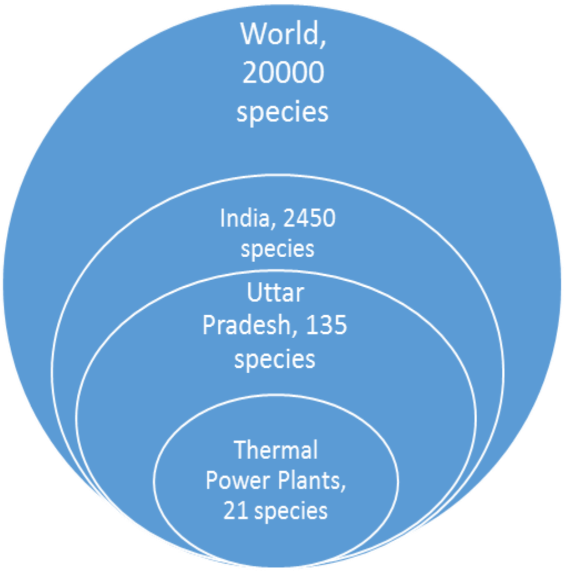


Fig-7.1: Representation of number of lichen species recorded from World, India, Uttar Pradesh and selected Thermal Power Plants

Table-7.1: **Representation of species in various regions**

S. No.	**Region**	**Area (km^2)**	**Species Present**
1	World	51,00,72,000	20000
2	India	3.287 million	2450
3	Uttar Pradesh	2,43,286	135
4	Thermal Power Plants	-	21

The area shows dominance of crustose lichen represented by 14 species followed by 4 species of foliose lichen and 2 species of squamulose lichen and single species of follicolous lichens.

(a) Substrate specificity of lichens: The *Mangifera indica* tree bears the maximum growth of lichen species on their trunks and branches, followed by *Artocarpous heterophyllus*, *Azadirachta indica*, *Litchi chinensis* and *Pongamia pinnata* respectively. *Pyxine cocoes*, *Bacidia incongruens* and *Rinodina sophodes* are the most commonly occurring lichen taxa around selected Thermal Power Plants of Uttar Pradesh. *Arthothelium chiodectoides, Bacidia rubella, Dirinaria consimilis, Opegrapha astraea*, *Phyllopeltula steppae*, *Rinodina exigua* and *Strigula elegans* recorded from the single locality of the study area.

The overall substrate properties specificity of lichens not only depend on the phorophytes species but also on the condition of the particular area where they have present and accumulate several environmental factors (Okasnen, 1988; Bates et al., 2001; Humphery et al., 2002). In the study area, the crustose growth form of lichens grow luxuriantly and have highest representation in Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli with 13 species followed by Tanda and Panki Thermal Power Plant with 8 and 5 species respectively (Table-7.1). The dominance of corticolous species can also be attributed to the heterogenecity of substratum provided by different species of phorophytes as compared to the soil and rock; their dominance also reflects the importance of tree bark of the area as a major lichen habitat (Pinokiyo et al., 2008).

(b) Dominant Toxitolerant and Sensitive Families and Genera (Fig-7.2): Most of the pollution tolerant lichen species belongs to the members of the lichen family Ramalinaceae together with Physciaceae, Caliciaceae and Lecanoraceae are well known for their toxitolerant nature. Taxonomic treatment of each lichen species indicates that the species such as *Pyxine cooces* (54 sites); *Bacidia incongruens* (40 sites); *Rinodina sophodes* (38 sites); *B. submedialis* (20 sites); *Lecanora. tropica* (14 sites); *Anisomeridium nidulans* (11 sites); *B. medialis* (10 sites); *Peltula corticola* (9 sites); *Caloplaca bassiae* (7 sites); *Hyperphyscia adglutinata* (6 sites); *Lecanora achroa* (5 sites); *L. helva* (5 sites); *Pertusaria quassiae* (4 sites); *P. sorediata* (2 sites); whereas *Arthothelium chiodectoides*, *Bacidia rubella*, *Dirinaria consimilis*, *Opegrapha astraea*, *Phyllopeltula steppae*, *Rinodina exigua* and *Strigula elegans* are more sensitive to the existing pollution and found growing only at single sites of the selected thermal power plants. The sensitive species exhibit their absence in the areas facing heavy traffic pollution.

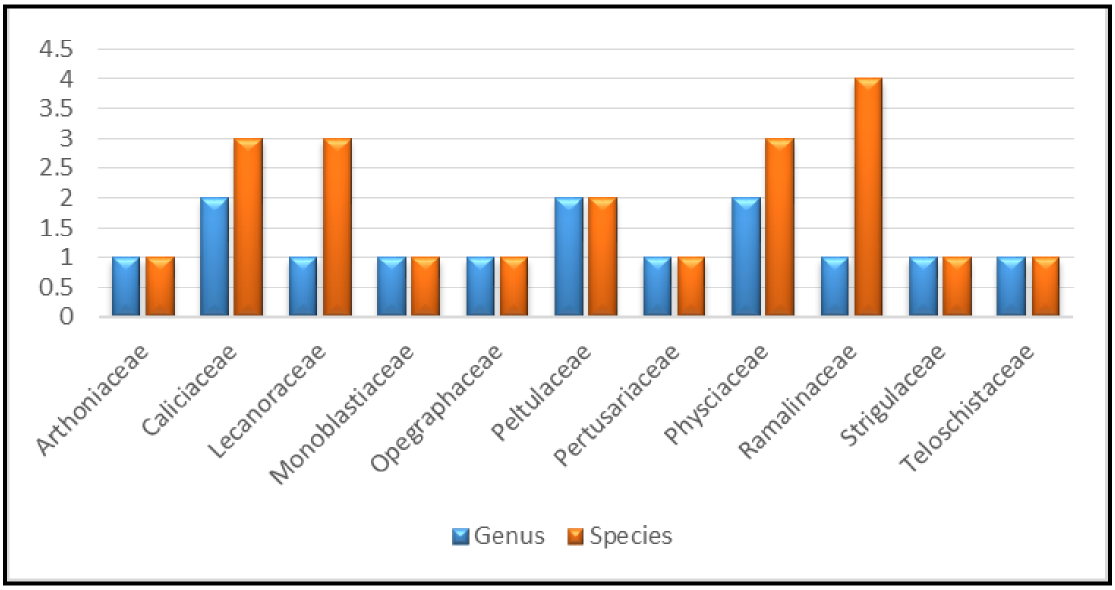


Fig-7.2: Representation of dominant family of lichens observed around the study area

(c) Distribution of Lichens around the study area: Distribution of lichens has been observed to be affected by the environmental factors such as biotic and abiotic factors. Urbanization, deforestation, forest fires, grazing, tourisms and developmental activities have been identified as the major threats to the lichens flora in the study area also (Upreti, 1995a; Canters et al., 1991).

The localities situated on outskirts of the thermal power plant exhibited normal growth of most of the lichen species. Few sites within the thermal power plant have dense patches of trees which also provides favorable habitat for normal growth of lichens. The avenue trees planted on the outskirts of the thermal power plant also exhibited good growth of most of the lichen species, while the localities between 0-6 km exhibited poor growth of lichens. Most of the species collected from the trunks and barks of *Mangifera indica* trees record between vertical heights of 3-12 feet.

It is interesting to note that, out of 156 localities *Pyxine cocoes* and *Bacidia incongruens* were recorded from 54 and 40 sites respectively followed by *R. sophodes, B. submedialis, L. tropica* with 38, 20 and 14 sites respectively. Most of the sites within the range of 0-6 km in the study area all around the thermal power plant were devoid of epiphytic lichen growth which clearly indicate the presence of few toxi-tolerant species (i.e. *Pyxine cocoes* and *Rinodina sophodes*) in the area because of urbanization and anthropogenic activities.

The localities situated between the distances of 6-12 km from the thermal power plant exhibited increased trend of species indicated more or less moderate pollution. The localities between distances of 13-21 km in all around thermal power plant had luxuriant and normal growth of lichens. The normal and rich lichen diversity of both sensitive and tolerant species in the outskirts of the thermal power plant clearly indicate more or less pollution free area. The probable reason for luxuriant growth of lichen in the outskirts of the thermal power plant may be attributed due to the large number of orchards with dense canopy having moist and shady condition which supports good growth of varied lichen taxa.

Similar to the studies carried out in Kolkata city (Upreti et al., 2005); Lucknow by Saxena et al. (2004); Bhopal city (Ingle et al., 2012) and De Witt (1976) in Netherlands, and Bajpai et al. (2010a) concluded that Feroze Gandhi Unchahar Thermal Power plant exhibit decline in lichen diversity and disappearance of sensitive species in the study area. The nearby area of thermal power plant exhibited dominance of crustose lichen because of their tolerant nature against air pollution while foliose and fruticose lichen due to their sensitive nature disappears from the area.

Urbanization and human activities affects the lichen diversity of an area upto a greater extends. Similar to most of the Indian cities, the thermal power plant also undergone fast pace of urbanization resulted into removal and destruction of forest and orchards thus leads to decline in epiphytic lichens of the area. The thermal power plant i.e. sources of air pollution varied according to sites of the study area. Vehicular activity together with machines operated for generating electricity and growth of urban areas are the main sources of pollution in the area.

Distribution and diversity of lichen growth forms is known to reflect the conditions including availability of substrate, precipitation, temperature, light and elevation. Among all the growth form of lichens, crustose lichen together with foliose lichen showed their dominance around selected thermal power plants. Larger numbers of foliose forms were collected from Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli with the representation of 4 species followed by Tanda and Panki Thermal Power Plants with 3 species and only one species respectively. Crustose forms were represented by 13 species and only few squamulose form of lichen were reported from the study area (Fig-6.1).

Of the identified taxa, Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli has the highest representation as it exhibits the occurrence of 18 species belonging to 12 genera and 10 families; Panki Thermal Power Plant exhibit least diverse showing the occurrence of only 8 species belonging to 7 genera and 7 families. This may be attributed to less diversity of substrates and thinned out forest around thermal power plants. Highest number of species recorded around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli is most probably because of its large forest area as compared to Panki and Tanda Thermal Power Plants as well as its altitudinal range, ample amount of moisture and shade, all of which allow many lichens to colonize on trees, trunks and twigs (Rawat et al. 2009; Kholia, 2012). Occurrence of family, genera and species is given in Fig-7.3.

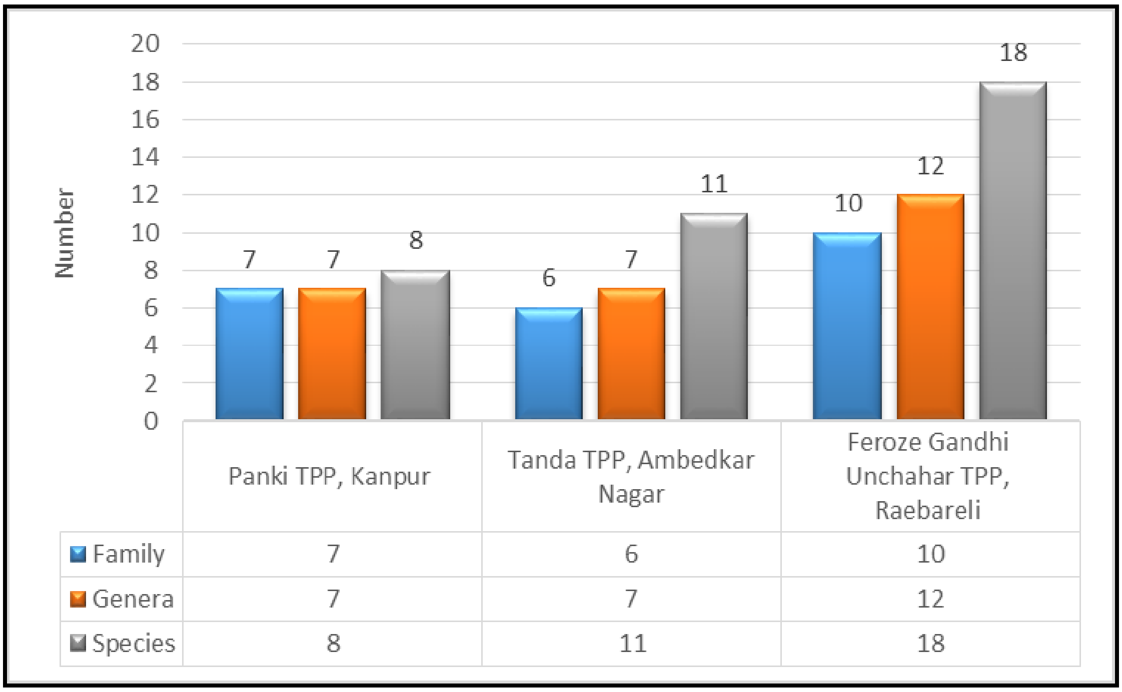


Fig-7.3: Representation of distribution of Family/ Genera/ Species around selected Thermal Power Plants of Uttar Pradesh

(d) New taxa recoded from the area: Out of about 20,000 species known from the world, India which is considered a centre of high lichen diversity has recorded 2450 species (Singh and Singh, 2015). Himalayas are among the most exhaustively explored regions of the country. These are said to be the centres of high lichen diversity (Awasthi, 1988, 1991, 2000, 2007).

Of the various states in the region, only three viz; Himanchal Pradesh, Uttarakhand (Nayaka and Upreti, 2008) and Uttar Pradesh (Nayaka and Upreti, 2013) have been worked out significantly for their lichen collection with 501, 613 and 135 species respectively. The present study also resulted addition of one lichen taxa in lichen flora of Uttar Pradesh i.e. ***Pyxine sorediata*** **(from Tanda and Unchahar Thermal Power Plants)** are the **new addition to the lichens flora of Uttar Pradesh** (Gupta, 2014; Gupta et al., 2016a) as these species are not listed by Nayaka and

Upreti (2013) in the book entitled, ***'Lichens of Uttar Pradesh'.*** But, with the addition of only one species from two thermal power plants and 4 species from Faizabad district (Gupta et al., 2016a), as enumerated in the present compilation, the number of lichens recoded from Uttar Pradesh state is now raised to more than 140 species.

7.1 Determination of tolerant and sensitive lichen species

On the basis of the observations of diversity and distribution pattern of lichens in the present study, thermal power plants were divided into three zones/ regions. It is clear from the study that air pollution is not equally spread throughout the thermal power plant. The areas near thermal power plant have higher vehicular activity and lack of vegetation leads to more pollution than the outskirts areas of the thermal power plants. Distribution data of lichen taxa collected from the thermal power plants indicates the separation of the thermal power plant into three distinct zones. **Zone A** having poor lichen growth indicates more polluted zone. **Zone B** is characterized by moderate growth of few crustose lichens on some scattered trees of mango and it is transitional zone of the thermal power plant and corresponding to the area of the moderate pollution. **Zone C** of the thermal power plant exhibits normal growth of different epiphytic lichen taxa on trees of *Mangifera indica* (mango), *Azadirachta indica* (neem) and *Artocarpus heterophyllus* (kathal), *Litchi chinensis* and *Pongamia pinnata* etc.

The sampling sites shown in all three distribution maps indicates that the species *Bacidia rubella, Dirinaria cosmilis, Lecanora helva, Opegrapha astrae, Strigula elegans, Rinodina exigua* are more sensitive to the existing pollution observed growing only at few sites of thermal power plants, mostly exhibit their absence in the areas facing heavy traffic pollution.

It is clearly evident from the distribution map of lichens around thermal power plants that the entire central part of the thermal power plants are lacking lichen vegetation, followed by the areas with moderate lichen growth. Distribution maps of

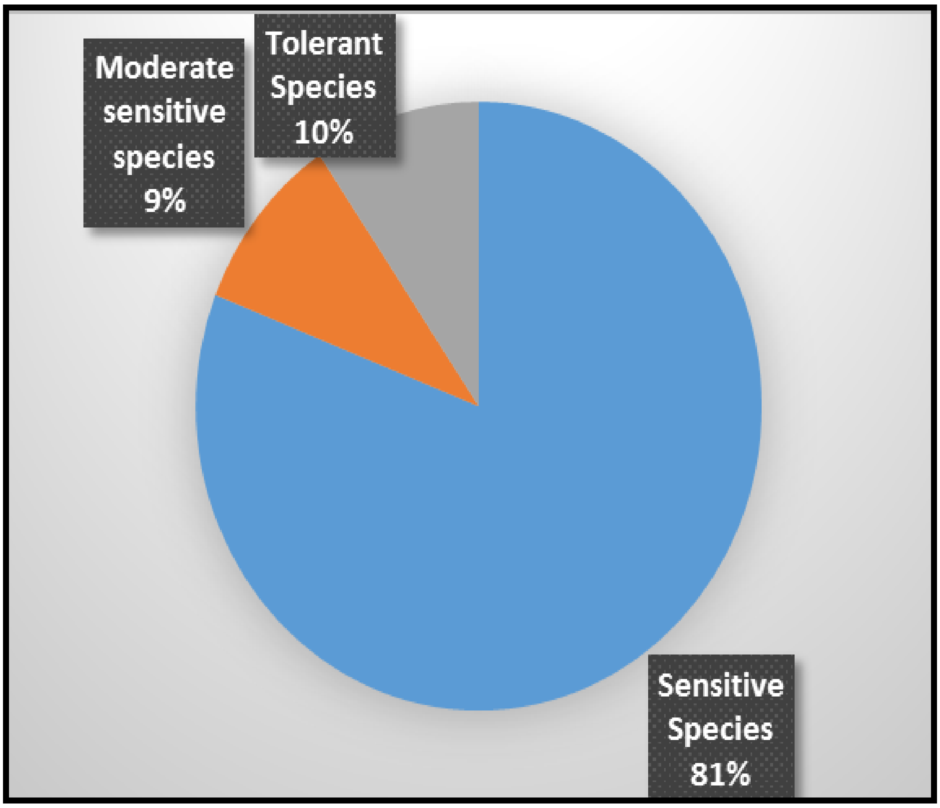


Fig-7.4: Share of tolerant, moderate sensitive and sensitive lichen species vis-à-vis air pollution level in the study area

all the three selected thermal power plants (Plate-7.1, 7.2, 7.3 & 7.4) clearly indicates the luxuriant growth in the thermal power plants as categorized into sensitive and tolerant groups. The species mostly growing in polluted areas are the tolerant species such as *Pyxine cocoes* and *Rinodina sophodes.* The genus *Bacidia, Lecanora, Arthothelium, Pertusaria, Peltula, Caloplaca, Opegrapha* and *Anisomeridium* collected from more or less pollution free or moderately polluted areas are the pollution sensitive species of lichens recorded from the study area.

On the basis of sites, their occurrence and distribution, lichen species were categorized as tolerant, moderately sensitive and sensitive species with respect to air pollution (Table-7.2; Fig-7.4).

Table-7.2: List of Sensitive and tolerant lichen species recorded growing around Thermal Power Plants vis a vis air pollution levels

Sensitive Species	Moderate sensitive species	Tolerant Species
Anisomeridium nidulans	*Pyxine sorediata*	*Pyxine cooces*
Arthothelium chiodectoides	*Rinodina exigua*	*Rinodina sophodes*
Bacidia incongruens		
Bacidia medialis		
Bacidia rubella		
Bacidia submedialis		
Caloplaca bassiae		
Dirinaria consimilis		
Hyperphyscia adglutinata		
Lecanora achroa		
Lecanora tropica		
Lecanora helva		
Opegrapha astraea		
Peltula corticola		
Pertusaria quassiae		
Phyllopeltula steppae		
Strigula elegans		

7.2 Panki Thermal Power Plant, Kanpur

The study area showed occurrence of 8 epiphytic lichens species belonging to 7 genera and 7 families found growing at 34 monitoring sites upto a distance of 21 km in west, north and south directions of the Panki Thermal Power Plant (Table-7.3 & 7.5; Fig-7.5; Plate-7.1). *Pyxine cocoes* and *Rinodina sophodes* showed their dominance over other species in the area surveyed (Table-7.4).

It is clear from the observation that the diversity of lichens increased with increasing distance from the source of pollution. Panki Thermal Power Plant is located about 21 kms from the Kanpur railway station and has the agricultural land and canals as well as flyash dumping sites around the power plant. *P. cocoes* and *R. sophodes* exhibit their presence in west, north and south directions and it is observed that the number of lichen thalli increases with increasing distance from the power plant of which west direction exhibited the maximum number of lichens (Plate-7.1).

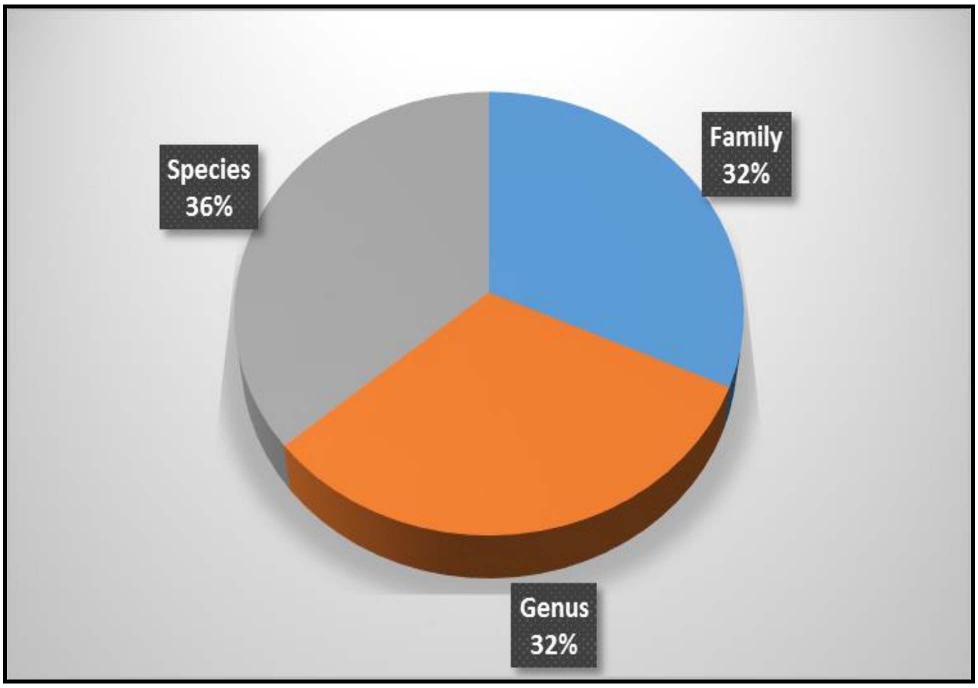


Fig-7.5: Share of family, genus and species of all the lichens reported from Panki Thermal Power Plant, Kanpur

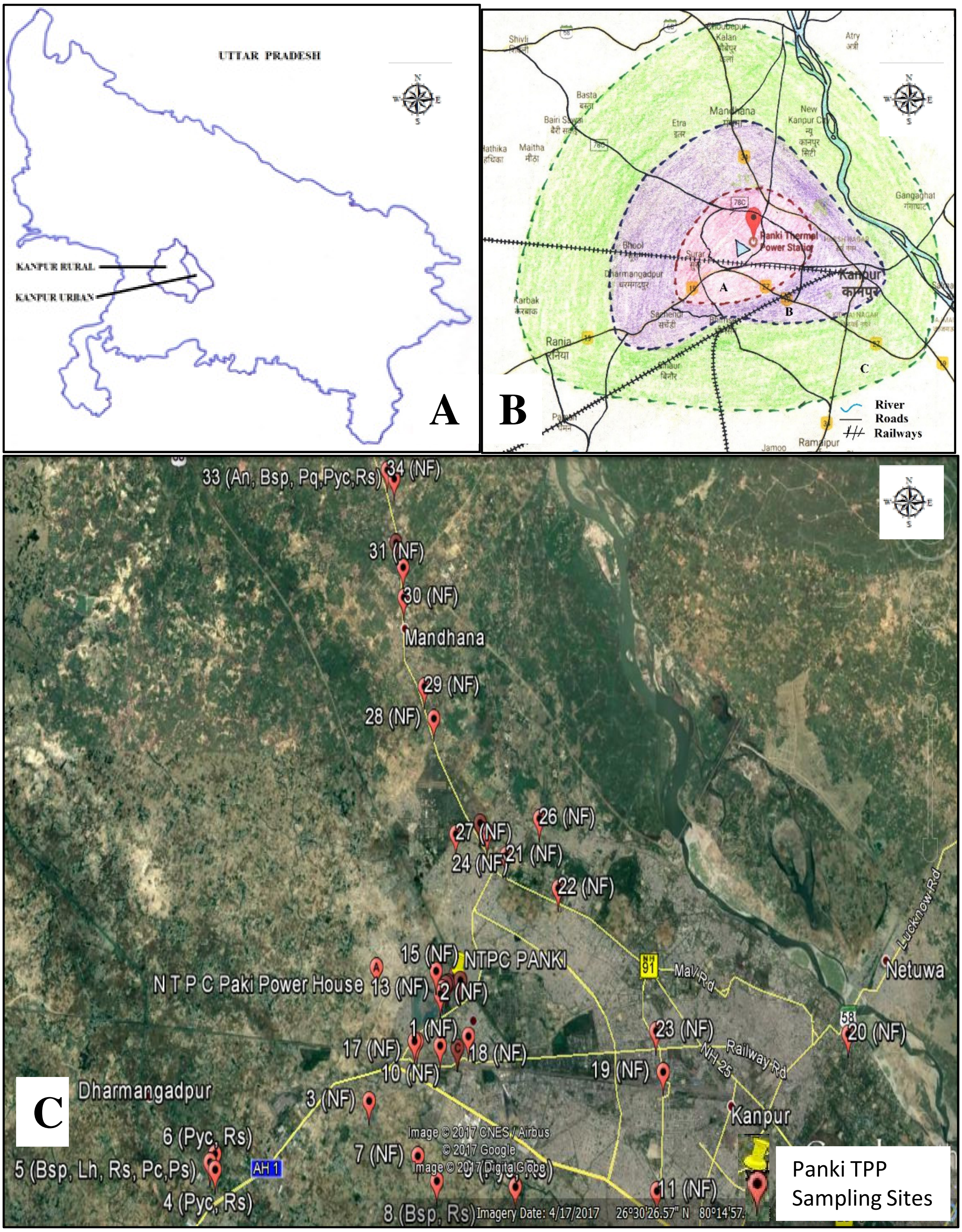


Plate-7.1: Panki Thermal Power Plant, Kanpur: (A) Uttar Pradesh Region Showing Kanpur district; (B) Zone Map showing distribution pattern of lichen taxa around Panki Thermal Power Plant, Kanpur: Zone A: Poor lichen growth- Polluted; Zone B: Moderate lichen growth- Moderate Pollution; Zone C: Normal lichen growth- More or less Pollution free area; (C) Sampling site around Panki Thermal Power Plant, Kanpur (refer Table- 7.3 & 7.4) (Source: Google Earth)

Table-7.3: Localities surveyed for collection of lichens around Panki Thermal Power Plant, Kanpur, Uttar Pradesh

Panki Thermal Power Plant, Kanpur					
S. No.	**Localities**	**Longitude (N)**	**Latitude (E)**	**Altitude**	**Sp. Occ.**
1	Ishwariganj-Palara road, Saraimita	26°27′22.8″	80°12′56.4″	111m	NF
2	Near Bhautipratappur	26°26′53.6″	80°12′48.3″	121m	NF
3	Near Bhautipratappur	26°26′47.2″	80°12′47.8″	126m	NF
4	Airport road Kataraghan Shyam west to thermal power plant	26°25′56.2″	80°09′49.5″	123.7 ± 15.7m	Pyc, Rs
5	Airport road Kataraghan Shyam west to thermal power plant near Sachendi	26°26′01.7″	80°09′43.3″	124.0 ± 41.3m	Bsp, Lh, Rs, Pc,Ps
6	Airport road near Sachendi	26°26′07.7″	80°09′48.6″	87.5 ± 16.3m	Pyc, Rs
7	Near Chhitepur	26°26′06.3″	80°13′45.6″	120m	NF
8	near Panki thermal power plant, Rampur, Bhimsen	26°25′48.0″	80°14′08.0″	110m	Bsp, Rs
9	Canel road Meharavan Singh Purwa, Patarsa near Mardanpur	26°25′43.7″	80°15′39.4″	127m	Pyc, Rs
10	Kalpi road, Saraimita near power plant	26°27′32.2″	80°13′40.6″	176.4 ± 15.0m	NF
11	Barra Bypass road, Barra	26°25′40.6″	80°18′23.8″	128m	NF
12	Shatabdi road, near flyash dumping site	26°28′16.9″	80°14′19.9″	185.9 ± 25.7m	NF
13	Ishwariganj-Palara road, Panki Katra near Hanuman Mandir	26°28′12.1″	80°14′13.3″	228.0 ± 21.7m	NF
14	Ishwariganj-Palara road, Shahpur	26°28′15.7″	80°14′17.6″	184.1 ± 22.6m	NF
15	Shatabdi road, Ratanpur colony near Panki TPP	26°28′26.0″	80°14′05.7″	139.8 ± 10.6m	NF
16	Panki road near Panki TPP	26°28′18.7″	80°14′34.8″	134m	NF
17	Jhansi-Kanpur highway, Pandu river near Hariom Industries Limited	26°27′31.2″	80°13′40.4″	176.4 ± 15.0m	NF
18	Kalpi road, Panki power house, Swaraj Nagar	26°27′35.9″	80°14′44.5″	117m	NF
19	Govind nagar road near	26°27′08.9″	80°18′34.6″	127m	NF

	Govindpuri station, Govind Nagar				
20	Havelock lane, Kanpur Cantoment	26°27′37.3″	80°22′15.7″	138m	NF
21	Grand trunk road near Kalyanpur	26°29′56.8″	80°15′30.0″	139m	NF
22	Panchwati, Sharda nagar	26°29′30.8″	80°16′33.1″	134m	NF
23	Govind nagar road, Shakti market, Fazalganj, Shastri Nagar	26°27′39.9″	80°18′27.3″	135m	NF
24	Grand trunk road, NSI Gate near NSI, Kalyanpur	26°30′15.5″	80°15′06.9″	152m	NF
25	Bithur road near IIT gate, kalyanpur gooba garden above 3m from ground	26°30′23.0″	80°14′58.5″	120.9m	Bsp
26	Patrakarpuram-Indira nagar road, Khyora	26°30′26.6″	80°16′11.0″	126m	NF
27	Dwivedi market road, Gooba garden, Kalyanpur	26°30′14.1″	80°14′28.7″	361m	NF
28	Aligarh- Kanpur road, Kalyanpur	26°31′48.6″	80°14′01.0″	121m	NF
29	Aligarh- Kanpur road, Kalyanpur, Biritiyan Bithoor	26°32′15.3″	80°13′48.9″	133m	NF
30	Aligarh- Kanpur road, Bagdudi Bazar, Mandhana	26°33′30.7″	80°13′21.9″	136m	NF
31	Aligarh- Kanpur road, Bagdudi Bazar, Bhavanipur	26°33′56.7″	80°13′20.8″	135m	NF
32	Aligarh- Kanpur road, Bagdudi Bazar, Hardaspur	26°34′18.0″	80°13′11.3″	138m	NF
33	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	26°35′14.2″	80°13′08.0″	128m	An, Bsp, Pq,Pyc,Rs
34	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan	26°35′22.1″	80°12′58.8″	143m	NF

An= *Anisomeridium nidulans;* Bsp= *Bacidia* sp.; Lh= *Lecanora helva;* Pc= *Peltula corticola;* Pq= *Pertusaria quassiae;* Ps= *Phyllopeltula steppae;* Pyc= *Pyxine cocoes;* Rs= *Rinodina sophodes;* NF= Not Found; Sp. Occ.= Species Occurred

Table-7.4: List of lichen taxa observed around Panki Thermal Power Plant, Kanpur, Uttar Pradesh

Name of Species	Family	Localities	Substrate	Field No.	Accession No.
WEST DIRECTION					
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Airport road Kataraghan Shyam west to thermal power plant	on *Mangifera indica* bark	013-016689	10265
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Airport road Kataraghan Shyam west to thermal power plant	on *Mangifera indica* bark	013-016697	10260
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Airport road Kataraghan Shyam west to thermal power plant	on *Mangifera indica* bark	013-016688	10269
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Airport road Kataraghan Shyam west to thermal power plant	on *Mangifera indica* bark	013-016694	10266
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Airport road Kataraghan Shyam west to thermal power plant	on *Mangifera indica* bark	013-016698	10267
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Airport road Kataraghan Shyam west to thermal power plant	on *Mangifera indica* bark	013-016699	10268
Bacidia sp. + *Rinodina sophodes* (Ach.) A. Massal.	Ramalinaceae + Physciaceae	Airport road Kataraghan Shyam west to thermal power plant near Sachendi	on *Mangifera indica* bark	013-016690	10261
Lecanora helva Stizenb.	Lecanoraceae	Airport road Kataraghan Shyam west to thermal power plant near Sachendi	on *Mangifera indica* bark	013-016696	10262
Peltula corticola Budel & R. Sant.	Peltulaceae	Airport road Kataraghan Shyam west to thermal power plant near Sachendi	on *Mangifera indica* bark	013-016691	10263
Phyllopeltula steppae Kalb.	Peltulaceae	Airport road Kataraghan Shyam west to thermal power plant near Sachendi	on *Mangifera indica* bark	013-016695	10264

Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Airport road near Sachendi	on *Mangifera indica* bark	013-016693	10270
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Airport road near Sachendi	on *Mangifera indica* bark	013-016692	10271
NORTH DIRECTION					
Bacidia sp.	Ramalinaceae	Bithur road near IIT gate, kalyanpur gooba garden above 3m from ground	on bark	013-019826	10272
Anisomeridium nidulans (Mull. Arg.) R.C. Harris	Monoblastiaceae	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	on bark	014-025384	31518
Bacidia sp.	Ramalinaceae	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	on bark	014-025383	31517
Pertusaria quassiae (Fee.) Nyl.	Pertusariaceae	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	on *Mangifera indica* bark	014-025382	31516
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	on *Mangifera indica* bark	014-025381	31515
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	on *Mangifera indica* bark	014-025379	31513
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj	on *Mangifera indica* bark	014-025380	31514

SOUTH DIRECTION					
Bacidia sp.	Ramalinaceae	near Panki thermal power plant, Rampur, Bhimsen	on *Mangifera indica* bark	014-025387	31521
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near Panki thermal power plant, Rampur, Bhimsen	on *Mangifera indica* bark	014-025386	31520
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near Panki thermal power plant, Rampur, Bhimsen	on *Mangifera indica* bark	014-025385	31519
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Canel road Meharavan Singh Purwa, Patarsa near Mardanpur	on *Mangifera indica* bark	014-023738	34931
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Canel road Meharavan Singh Purwa, Patarsa near Mardanpur	on *Mangifera indica* bark	014-025388	31522
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Canel road Meharavan Singh Purwa, Patarsa near Mardanpur	on *Azadiracthta indica* bark	014-025389	31523

Table-7.5: Comprehensive list of all the lichens reported around Panki Thermal Power Plant, Kanpur

S. No.	Family	Genus	Species
1	Lecanoraceae	*Lecanora*	*Lecanora helva* Stizenb.
2	Monoblasticeae	*Anisomeridium*	*Anisomeridium nidulans* (Mull. Arg.) R. C. Harris
3	Peltulaceae	*Peltula*	*Peltula corticola* Büdel & R. Sant *Phyllopeltula steppae* Kalb.
4	Pertusariaceae	*Pertusaria*	*Pertusaria quassiae* (Fee.) Nyl.
5	Caliciaceae	*Pyxine*	*Pyxine cocoes* (Sw.) Nyl.
6	Physciaceae	*Rinodina*	*Rinodina sophodes* (Ach.) A. Massal.
7	Ramalinaceae	*Bacidia*	*Bacidia* sp.

7.2.1 Analysis of Lichens by Fourier- Transform Infrared Spectroscopy (FTIR) around Panki Thermal Power Plant, Kanpur

Biosorption is defined as the property of organisms to accumulate metal ions by the cells. The two different lichen species were determined by FTIR microscopy in order to find specific spectroscopic biomarkers for rapid identification and discrimination between two different lichen growth forms as well as species. Developing specific biomarkers by FTIR microscopy could be highly important for future rapid and reliable detection and identification of functional groups present in the species.

7.2.1.1 FTIR spectra measurement of *P. cocoes* around Panki Thermal Power Plant, Kanpur

The spectra of *P. cocoes* showed the stretching of bonded N-H/ O-H and the presence of alcohol and phenol groups (Table-7.6; Fig-7.6A) at a strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3418.6 cm^{-1} (north), 3419.1 cm^{-1} (west), 3417.1 cm^{-1} (south) (Ramrakhiani et al., 2011). The spectral band observed between 3300-2500 cm^{-1} due to symmetrical stretching of bonded O-H showed the presence of carboxylic acid. The absorbance bands observed at ranged between 1760-1665 cm^{-1} due to stretching of C=O showed the presence of carbonyl group.

The wave numbers observed 1450-1400 cm^{-1} due to symmetric stretch vibration of C=O at 1413.5 cm^{-1}, 1405.1 cm^{-1} and 1423.4 cm^{-1} respectively showed the presence of C=O symmetric stretching (Naumann, 2000). The spectra observed at 1320.6 cm^{-1}, 1323.3 cm^{-1} and 1319.0 cm^{-1} showed components of α- helix protein. The absorbance bands ranged between 1250- 1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters at 1275.0 cm^{-1} (north), 1277.0 cm^{-1} and 1207.9 cm^{-1} (south) respectively. The range of wave number 1080-1010 cm^{-1} showed asymmetric stretching and C-O bonding due to polysaccharides (Das and Guha, 2007) at 1039.6 cm^{-1} (north), 1050.9 cm^{-1} (west) and 1036.5 cm^{-1} (south) respectively. The wave number 666.9 cm^{-1} showed O-CH_2 stretching of methoxy groups (Movasaghi et al., 2008) only in south direction. The peaks range between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides at 566.5 cm^{-1} (north), 577.4 cm^{-1} and 587.5 cm^{-1} (south) respectively. The peaks observed at 468.4 cm^{-1}, 464.2 cm^{-1} and 470.5 cm^{-1} showed the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated) (Tarte, 1962; 1964).

7.2.1.2 FTIR spectra measurement of *R. sophodes* around Panki Thermal Power Plant, Kanpur

For lichen *R. sophodes* (Table-7.6; Fig-7.6B), the strong absorbance bands ranged between 3500-3300 cm^{-1} and observed at 3417.1 cm^{-1} (north), 3416.1 cm^{-1} (west) and 3411.9 cm^{-1} (south) showed the stretching of bonded N-H/ O-H and the presence of alcohol and phenol groups (Ramrakhiani et al., 2011). The spectral band observed between 3300-2500 cm^{-1} due to O-H stretching in the presence of carboxylic acid. The absorbance bands observed at due to bending of N-H with the presence of primary amines at 1634.4 cm^{-1} (north), 1618.3 cm^{-1} (west) and 1627.5 cm^{-1} (south). The range of wave numbers 1560-1530 cm^{-1} showed the presence of C-N stretching, N- H bending with the presence of secondary amines only at 1514.0 cm^{-1} in south direction (Jilie and Shaoning, 2007). The bonded C=O symmetric stretching (Naumann, 2000) absorbed infra-red at 1419.5 cm^{-1}, 1421.1 cm^{-1} and 1421.7 cm^{-1}. The absorbance bands observed at 1317.9 cm^{-1} in west and 1320.0 cm^{-1} in south direction showed components of α- helix (Adriana and Gabi, 2011). The absorbance bands ranged between 1250- 1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters in all three directions (Naumann, 2000). The range of wave number 1080-1010 cm^{-1} showed SO_3 asymmetric stretching (Cirik et al., 2012); and C-O bonding due to polysaccharides (Das and Guha, 2007) at 1034.6 cm^{-1} (north), 1050.8 cm^{-1} (west) and 1046.0 cm^{-1} (south) respectively. The range of wave number 900-600 cm^{-1} showed O-CH_2 stretching of methoxy groups (Movasaghi et al., 2008) only in west direction at 779.6 cm^{-1}. The peaks range between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides. The observations are useful to detect rapidly and characterized the occurrence of lichen *R. sophodes* with different level of metal accumulation around thermal power plant.

The results are presented in Table-7.6; Fig-7.6, showed the spectra of two different lichen species (i.e. *Pyxine cocoes* and *Rinodina sophodes*). It can be also seen, both the lichen species have more or less similarity in the spectra. Presence of both secondary metabolites and primary metabolites in *P. cocoes* enhances the probability of detection of IR bands in 3500-3300 cm^{-1} and in 3300-2500 cm^{-1} region due to the presence of more N-H and O-H groups. While bands in 3500-3300 cm^{-1} which lacks the secondary metabolites the number of band detected are less than *P. cocoes.* The FTIR analysis provides spectroscopic evidence of the role of chemicals in

Table-7.6: Transmittance frequencies of FTIR spectra of *P. cocoes* and *R. sophodes* around Panki Thermal Power Plant, Kanpur

S. No.	Range of wave number (cm^{-1})	*P. cocoes* Band Position (in cm^{-1})			*R. sophodes* Band Position (in cm^{-1})			Band Assignment
		North	West	South	North	West	South	
1	3500-3300	3418.6	3419.1	3417.1	3417.1	3416.1	3411.9	N-H stretching Amide- A, O-H stretching of hydroxyl groups (primary, secondary, amines and amides) (Ramrakhiani et al., 2011)
2	3300-2500	2922.2	2922.1	2923.0	2921.7	2918.3	2920.6	O-H stretching (carboxylic acid)
					2853.3	2850.3	2852.4	
3	1760-1665	1626.3	1615.0	1625.0				C=O stretching (Carbonyls group)
4	1650-1580				1634.4	1618.3	1627.5	N-H bending (primary amines)
5	1560-1530				-	-	1514.0	Amide- II, CN stretching, NH bending (Jilie and Shaoning, 2007)
6	1450-1400	1413.5	1405.1	1423.4	1419.5	1421.1	1421.7	C=O symmetric stretching $–COO^-$ (Naumann, 2000)
7	1350-1300	1320.6	1323.3	1319.0	-	1317.9	1320.0	components of α- helix proteins (Adriana and Gabi, 2011)
8	1250-1220	1275.0	-	1277.0	1261.0	1268.0	1265.1	P=O stretching (asym.) of PO_2^- phosphodiesters (Naumann, 2000)
		-	-	1207.9				
9	1080-1010	1039.6	1050.9	1036.5	1034.6	1050.8	1046.0	SO_3 asymmtric (Cirik et al., 2012); C-O bonding due to polysaccharides (Das and Guha, 2007)
10	900-600	-	-	666.9	-	779.6	-	$O-CH_3$ stretching of methoxy groups (Movasaghi et al., 2008)
11	690-515	566.5	577.4	587.5	-	587.2	582.1	C-Br stretching (alkyl halides)
					531.9	-	-	
12	530-400	468.4	464.2	470.5	466.2	471.0	468.8	Al-O stretching (AlO_8 Octahedral, isolated) (Tarte, 1962; 1964)

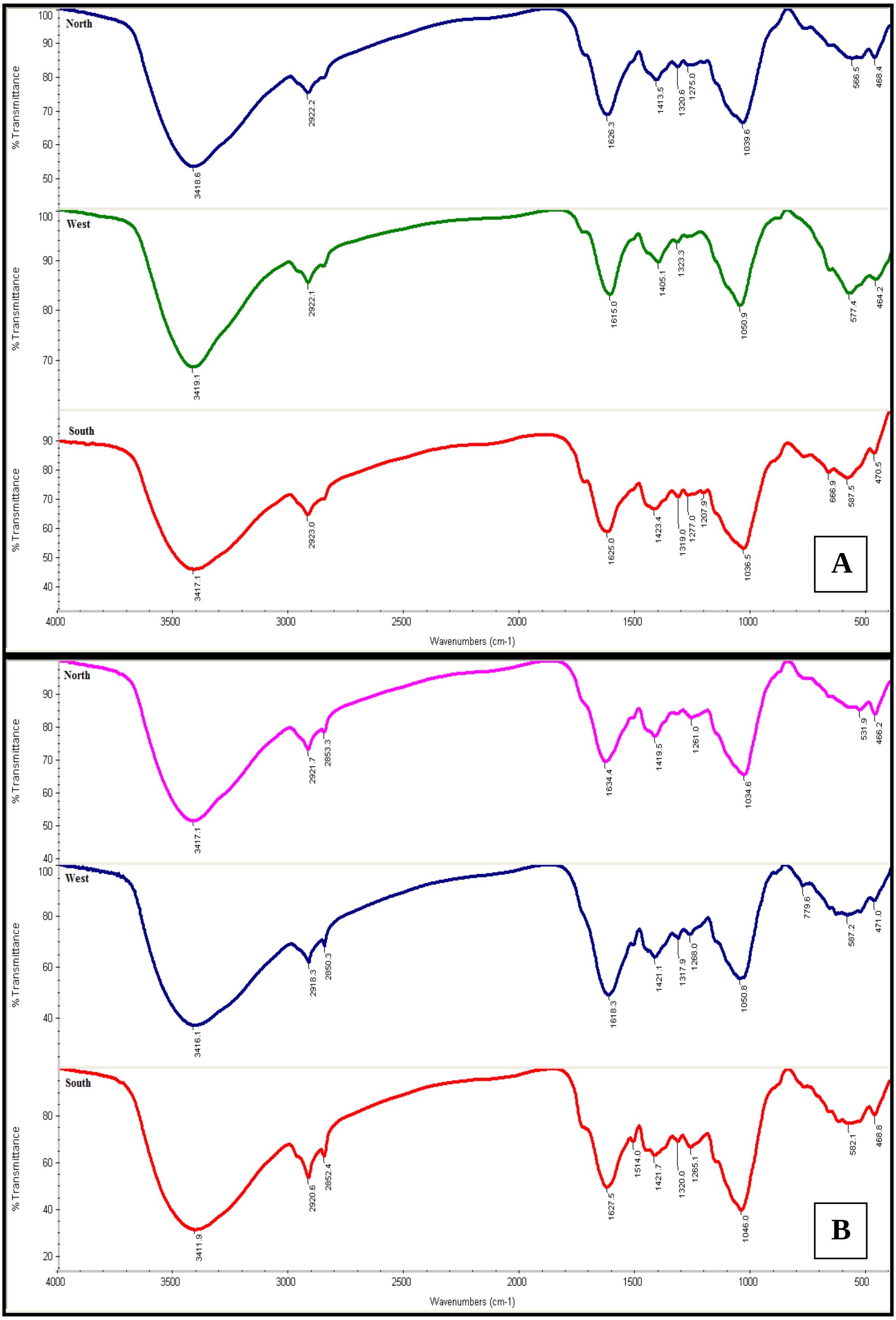


Fig-7.6: Direction-wise FTIR spectra of lichen species around Panki Thermal Power Plant, Kanpur; (A) *P. cocoes*, (B) *R. sophodes*

metal absorption as the variation in the frequency is affected by bond dissociation and bond formation which plays important role in metal chelation. The variation in the functional group bands in IR region shows the effect of pollutant on the functional group chemistry of the species. This phenomenon is principally involved in metal absorption by formation of chelates or bond dissociation due to the presence of phytotoxic gases mainly SO_2. The biodeterioration of granite monuments was done by Prieto et al. (1999; 2000) are available using FT Raman Spectroscopic studies on a number of lichens.

7.2.2 Comparative physiological response of *P. cocoes* and *R. sophodes* around Panki Thermal Power Plant, Kanpur (Appendix-IV: 7.7.1 to 7.7.12)

The morphology and anatomy of lichen play an important role in the accumulation of metals (Goyal and Seaward, 1982). *P. cocoes* (foliose) and *R. sophodes* (crustose) lichen commonly occurring around the study area, were selected for photosynthetic pigment analysis and metal concentration. In *P. cocoes,* chlorophyll a showed minimum concentration at 0.01±0.002 $\mu g g^{-1}$ in west whereas maximum concentration at 0.02±0.003 $\mu g g^{-1}$ in south direction. Chlorophyll b content ranged from 0.00±0.001 $\mu g g^{-1}$ (in west) to 0.01±0.002 $\mu g g^{-1}$ (in south) in the outskirts of thermal power plant. The total chlorophyll (chlorophyll a + chlorophyll b) ranged from 0.01±0.003 $\mu g g^{-1}$ in west to 0.02±0.004 $\mu g g^{-1}$ in south direction respectively. All the above three photosynthetic parameters showed similar trend of concentration in settling of pigment in lichen thalli.

Highest concentration of carotenoid was detected in *P. cocoes* with accumulation of 0.01±0.002 $\mu g g^{-1}$, while lowest accumulation of 0.01±0.001 $\mu g g^{-1}$ was detected in each north and west directions. Chlorophyll degradation ranged from 0.77±0.015 $\mu g g^{-1}$ in west to 1.00±0.011 $\mu g g^{-1}$ in north direction, whereas protein content ranged from 1.31±0.089 $\mu g g^{-1}$ in west to 1.54±0.088 $\mu g g^{-1}$ in south direction respectively. The samples collected from the west showed lower concentration values of all parameters, while samples from south direction showed higher concentration of all parameters except chlorophyll degradation (Table-7.7). The east direction showed complete absence of lichens as the sites has residential and commercial areas together with roads with high traffic activity. LSD analysis in *P. cocoes* showed highly significant difference only in chlorophyll degradation at $p < 0.01$ level whereas total chlorophyll and carotenoid showed significant differences at $p < 0.05$ level. Chlorophyll a and b along with protein estimation showed non-significant difference (Table-7.7; Fig-7.7).

Chlorophyll content and its degradation are often used as one of the cheapest and most accurate methods of biomonitoring. *R. sophodes* showed minimum chlorophyll a concentration (0.49±0.07 μgg^{-1}) whereas maximum concentration (0.79±0.02 μgg^{-1}) followed by Chlorophyll b content (0.16±0.02 μgg^{-1} to 0.44±0.06 μgg^{-1}) and total chlorophyll (chlorophyll a + chlorophyll b) ranged from 0.65±0.09 μgg^{-1} to 1.23±0.08 μgg^{-1} which showed each chlorophyll content with lower concentration in west and higher concentration in north direction respectively. According to Carreias et al. (1998), the concentration of total chlorophyll is governed by the ambient environment, anthropogenic sources, vehicular traffic pollution and urban emission. Lowest concentration of carotenoid was detected in samples of *R. sophodes* in west (0.24±0.05 μgg^{-1}), while highest concentration was detected in north direction (0.55±0.02 μgg^{-1}). The ratio of optical density of chlorophyll samples read at 435 and 415nm is the most frequently used parameter for chlorophyll degradation (Garty et al., 2000). Chlorophyll degradation concentration was highest in north decreased with increasing distance in west and south direction from NTPC and it ranged from 0.70±0.01μgg^{-1} in west to 1.05±0.01 μgg^{-1} in north direction. All the photosynthetic parameters (chl. a, b, total chlorophyll, carotenoid and chlorophyll degradation) showed the same pattern of variation in higher and lower concentration which might be due to effect of wind direction and pollution loads.

Protein concentration ranged from 1.50±0.17 μgg^{-1} in south to 7.19±0.12 μgg^{-1} in west direction. The increased level of protein in the present study, at most contaminated sites corresponds with the findings of Gonzaléz et al. (1996) for the *Ramalina ecklonii.* The area Airport road Kataraghan Shyam west to thermal power plant; Airport road Kataraghan Shyam west to thermal power plant near Sachendi; Airport road near Sachendi; Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj; near Panki Thermal Power Plant, Rampur, Bhimsen and Canel road Meharavan Singh Purwa, Patarsa near Mardanpur showed lichen diversity in the areas.

In the present study, the ratio was highly affected at 10km to 15 km radius of Panki Thermal Power Plant in *R. sophodes*, the highest amount of degradation was observed at outskirt of the point sources. LSD analysis in *R. sophodes* at $p < 0.01$ level showed significant difference in chl. a, total chlorophyll, carotenoid, chlorophyll degradation and protein content, while only chl. b showed significant differences at level of 0.05 (Table-7.7; Fig-7.8).

Correlations of various physiological parameters (Table-7.8) showed significant correlation of total chlorophyll content with chlorophyll b ($p<0.01$) in *P. cocoes* but *R. sophodes* showed significant correlation of chlorophyll b with chlorophyll a and total chlorophyll with chlorophyll a and chlorophyll b at $p<0.05$ level while protein had negative correlation with chlorophyll a (-0.981), chlorophyll b (-0.97), total chlorophyll (-0.976), carotenoid (-0.935) and chlorophyll degradation (-0.994) respectively. Increase in protein due to stressed condition has been reported in higher plants by Neumann et al. (1994). Overall pattern showed the concentration varied with the wind direction of the area as well as increasing trend with the increasing distance from the thermal power plant. In the area with fly ash dumping sites, vehicular exhausts are the main source of metals that can alter the biosynthesis of protein.

Table-7.7: Photosynthetic pigment and protein content analysis of lichens around Panki Thermal Power Plant, Kanpur (Appendix-IV: 7.7.1 to 7.7.12)

Directions	*P. cocoes* (concentration in µgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
North	0.01±0.003	0.01±0.001	0.02±0.003	0.01±0.001	1.00±0.011	1.35±0.230
West	0.01±0.002	0.00±0.001	0.01±0.003	0.01±0.001	0.77±0.015	1.31±0.089
South	0.02±0.003	0.01±0.002	0.02±0.004	0.01±0.002	0.97±0.016	1.54±0.088
CV%	21.70	22.01	18.83	17.42	1.54	10.81
LSD (p< 0.05)	0.005^{NS}	0.002^{NS}	0.006*	0.003*	0.025**	0.269^{NS}
Directions	*R. sophodes* (concentration in µgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
North	0.79±0.02	0.44±0.06	1.23±0.08	0.55±0.02	1.05±0.01	1.53±0.12
West	0.49±0.07	0.16±0.02	0.65±0.09	0.24±0.05	0.70±0.01	7.19±0.12
South	0.73±0.10	0.37±0.12	1.10±0.22	0.44±0.13	1.01±0.01	1.50±0.17
CV%	10.92	23.87	14.52	19.05	1.15	14.10
LSD (p< 0.05)	0.146**	0.155*	0.288**	0.157**	0.021**	0.279**

Mean±S.D., n=3 in µgg^{-1} Fresh weight; S. D.= Standard Deviation
** Significance at the level of 0.01
* Significance at the level of 0.05

Table-7.8: Values of correlation matrix between the physiological parameters around Panki Thermal Power Plant, Kanpur

P.cocoes	Chl.a	Chl.b	Total Chl.	Carotenoid	Chl. deg.	Protein
Chl.a	1	0.5	0.5	.a	0.392	0.987
Chl.b		1	1.000**	.a	0.993	0.634
Total Chl.			1	.a	0.993	0.634
Carotenoid				.a	.a	.a
Chl. deg.					1	0.537
Protein						1
R. sophodes	**Chl.a**	**Chl.b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
Chl.a	1	.999*	1.000*	0.986	0.996	-0.981
Chl.b		1	1.000*	0.993	0.99	-0.97
Total Chl.			1	0.99	0.994	-0.976
Carotenoid				1	0.968	-0.935
Chl. deg.					1	-0.994
Protein						1

a. Cannot be computed because at least one of the variables is constant.
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

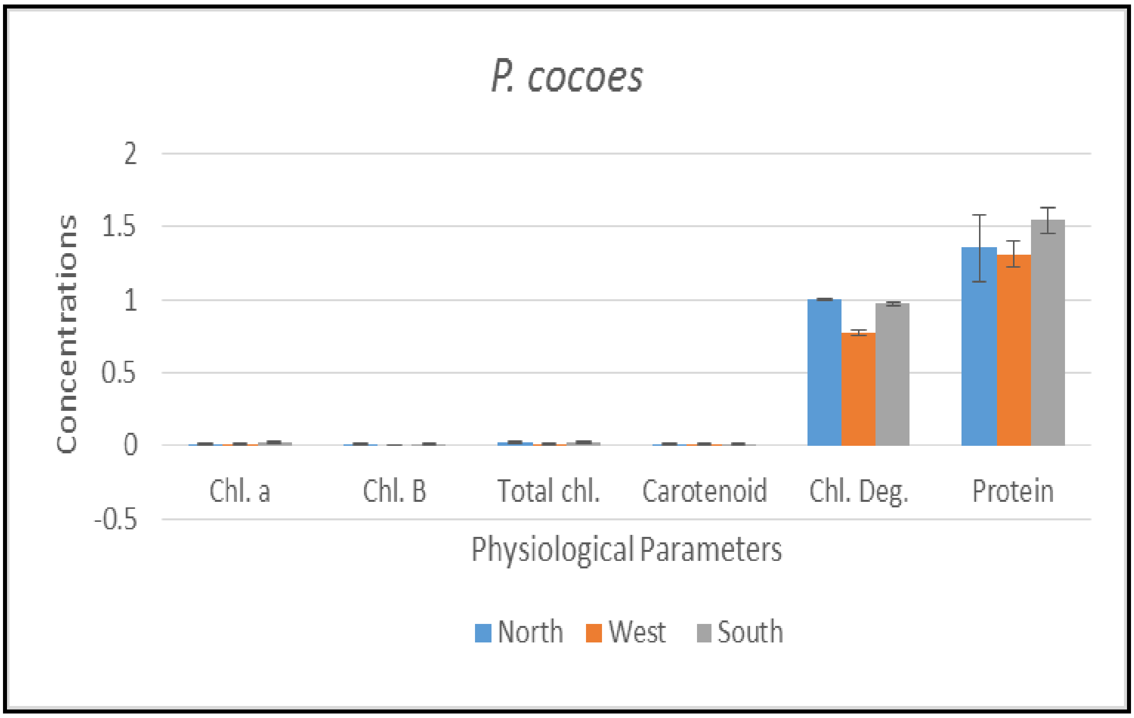


Fig-7.7: Graphical representation of photosynthetic pigments in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

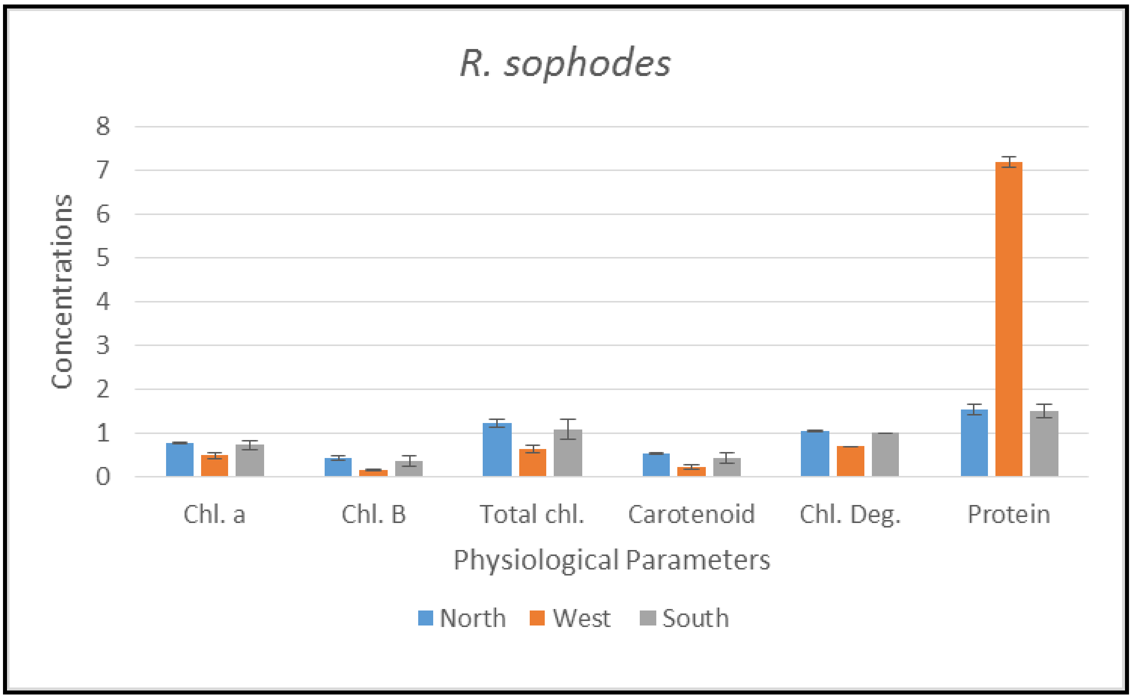


Fig-7.8: Graphical representation of photosynthetic pigments in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

7.2.3 Comparative response of metal accumulation in *P. cocoes* and *R. sophodes* around Panki Thermal Power Plant, Kanpur (Appendix-IV: 7.9.1 to 7.9.22)

Accumulation of eleven metals viz; Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Selenium (Se), Cadmium (Cd) and Lead (Pb) were estimated in thalli of both lichens in all three directions from the Panki Thermal Power Plant to compare the bioaccumulation of metals (Table-7.9). Both the species exhibited dissimilar sequence of concentration for all metals. Enhanced level of Fe clearly indicates vehicular activity as the originator (Pirintsos and Loppi, 2008). The study area showed higher accumulation of Fe> Mn> Zn> Pb metals, while Cr> Cu> Ni> As> Co> Se> Cd accumulated in lower concentration in both the species.

Lichens *P. cocoes* and *R. sophodes* showed accumulation of all the heavy metal within the ranges between 0.49 to 34703.04 µgg^{-1} dry weight as total metal contents. Both the species accumulated Fe in higher concentration followed by the selectivity sequence of Mn> Zn> Pb> Cr> Cu> Ni> As> Co> Se> Cd with concentration of 58826.08, 943.48, 374.82, 217.09, 109.77, 81.76, 77.81, 33.56, 24.01, 10.17 and 3.32 µgg^{-1} dry weight in *P. cocoes* (Fig-7.9). More or less similarly *R. sophodes* exhibit metal concentration sequence of Fe> Mn> Pb> Zn> Cr> Cu> Ni> As> Co> Se> Cd as 68882.62, 2462.54, 886.07, 469.44, 169.63, 139.73, 122.35, 67.15, 41.03, 14.17 and 5.99 µgg^{-1} dry weight (total metal) respectively (Fig-7.10). The Pb, Cr, Ni and Cd metals showed clear increasing trend of their concentrations in areas associated with high vehicular activities as well as coal burning.

Higher accumulation of Fe with concentration of 32603.04±0.78 µgg^{-1} in west site and minimum concentration of 26223.04±0.46 µgg^{-1}in south clearly indicates that the wind direction may be the probable reason for the settling of this metal in south direction. Loppi et al. (1998a, b) and Bajpai et al. (2010b) also reported that Fe in the earth's crust are strongly correlated in lichens and environmental contamination and lichens have an especially affinity for Fe.

Manganese (Mn) ranged between (456.04±0.25 μgg^{-1} in west to 487.44±0.47 μgg^{-1} in south) in lichen thalli. Arsenic (As) is a ubiquitous element and it ranged from 14.0±0.37 μgg^{-1} to 19.56±0.19 μgg^{-1} in the air around thermal power plant in west and south directions respectively. As is also released by anthropogenic activities like smelting, industrial applications and with combustion of fossil fuels. Rapid leaching of As has been observed by Al and Blowes (1999); Madhwan and Subramanian (2000) in case of exposed wastes of ores and mining, as well as soil erosion.

Zinc had maximum accumulation (206.18±0.05 μgg^{-1}) in west and minimum in south direction (168.64±0.46 μgg^{-1}). Higher concentration of Zn around the thermal power plant may be due to the high vehicular activity involved in the disposal of coal waste. Lubricant oil often contains Cd, Cu and Zn. Zinc may be emitted by automobile tires and brake pads (Berry and Wallace, 1981; Ward, 1989).

Lead (Pb) is released in the air by automobile fuel, batteries industries and their use in pesticide manufacturing. In this study the Pb accumulation reported by Bajpai et al. (2011) at Katni and Rewa cities respectively. Lead (Pb) content with traffic volume by a lichen *Hypogymnia physo*des reported by Takala and Okkonen (1981) and concluded that traffic load is directly proportional to Pb accumulation in lichen thallus. Lead (Pb) and Cd showed their presence only in west direction with concentration of 217.09±0.49 μgg^{-1} and 3.32±0.23 μgg^{-1} respectively. According to Hardiman and Jacoby (1984), the absorption of Cd by plant root was reduced in the presence of other cations of increasing valency or ionic radii.

Nriagu and Pacyana (1988); Shtiza et al. (2008) described that Cr is emitted to the air due to combustion of coal and oil especially by diesel-fed vehicles, refuge incineration as well as by stainless steel production. Chettri et al. (1997) reported that chromium concentration in non-polluted environments is to be quite low and Cr uptake occurs as hexavalent chromate ($CrO4^{2-}$) which is rapidly reduced to Cr^{3+} in soil. Streit and Stumm (1993) described that the trivalent form of Cr is absorbed minimally by root and its translocation from root to other parts is low. In the present study, Cr showed range of accumulation from 49.7±0.95 μgg^{-1} to 60.07±0.17 μgg^{-1} in the study area which indicated its mixed sources such as automobile exhaust, incineration of waste and agricultural applications.

Copper (Cu) and Ni showed range of accumulation of 28.53±0.11 μgg^{-1} to 53.23±0.23 μgg^{-1} and 28.36±0.08 μgg^{-1} to 49.45±0.21 μgg^{-1} respectively. Some of the metals lighter in weight dispersed to long range while, according to Loppi et al. (1994), Cu is large particle metal emitted from the source are incapable of long-range dispersion. The concentration of metals of Co ranged between (10.09±0.05 μgg^{-1} to 13.11±0.67 μgg^{-1}); Se (4.42±0.37 μgg^{-1} to 5.75±0.28 μgg^{-1}) in south and west directions respectively. In *P. cocoes*, total metal concentration was highest in west (33681.23 μgg^{-1}) and lowest in south direction (27020.59 μgg^{-1}) of the study area but north direction showed all metals below detection limit (BDL). *P. cocoes* had metal selectivity sequence as Fe> Mn> Zn> Pb> Cr> Cu> Ni> As> Co> Se> Cd. LSD analysis (at $p< 0.01$ level) showed highly significant difference in all the photosynthetic parameters (Table-7.9).

R. sophodes exhibit higher concentration of total metals accumulated in north direction (36850.07 μgg^{-1}) followed by west direction (35975.7 μgg^{-1}) and south direction (434.95 μgg^{-1}). Thalli of *R. sophodes* around Panki Thermal Power Plant concentrated lower accumulation of metals in only south direction: Cd (1.48±0.28 μgg^{-1}); Se (2.03±0.03 μgg^{-1}); Co (0.49±0.05 μgg^{-1}); As (2.04±0.07 μgg^{-1}); Ni (3.88±0.13 μgg^{-1}); Cu (26.07±0.07 μgg^{-1}); Cr (1.11±0.13 μgg^{-1}); Zn (108.78±0.21 μgg^{-1}); Pb (39.09±0.04 μgg^{-1}); Mn (93.44±0.55 μgg^{-1}) and Fe (156.54±0.49 μgg^{-1}) respectively while higher metals accumulation were showed in maximum accumulation in north direction i.e. Se (6.62±0.17 μgg^{-1}); As (36.19±0.08 μgg^{-1}); Ni (61.91±0.31 μgg^{-1}); Cu (57.33±0.15 μgg^{-1}); Cr (87.13±0.52 μgg^{-1}); Pb (441.09±0.41 μgg^{-1}); Mn (1281.04±0.58 μgg^{-1}) and Fe (34703.04±0.57 μgg^{-1}) but Cd (2.37±0.16 μgg^{-1}); Co (21.34±0.30 μgg^{-1}) and Zn (206.28±0.08 μgg^{-1}) were setteled in west direction. *R. sophodes* had metal selectivity sequence as Fe> Mn> Pb> Zn> Cr> Cu> Ni> As> Co> Se> Cd (Table-7.9).

Cadmium (Cd) content was very less in both the lichen thallus when compared to other heavy metals. According to Nimis et al. (1990), the burning of fossil fuel, incineration of solid waste, paint and phosphate fertilizers are the main source of the Cd in the atmosphere. In the present study, the lowest concentration of Cd showed its origin from vehicular as well as agricultural applications. According to Garty (2001), Dispersion and distribution of metals depend on wind speed and direction as well as the density of the element under consideration. LSD analysis at $p< 0.01$ level showed significant difference in chlorophyll estimation as well as protein content, while only chl. b showed significant differences at level of 0.05 (Table-7.9).

Correlation coefficients were calculated for concentration in paired element and for the element content in the lichen in different directions (Table-7.10). The possible source of element may be indicated by significant correlation between elements in the lichen thallus. The correlations (all significant at $p<0.01$ level) of Co and Cr, Zn and Cr, Zn and Fe, Zn and Co, Pb and Cr in *P. cocoes* but the correlations of Cu and Fe, Pb and Ni in *R. sophodes* indicates motor vehicles as possible originators (Table-7.10). Nickel is found in car metal using plating in welded plates (Ward, 1989) and in tires (Sadiq et al., 1989). Among the eleven metals analysed, Cu, Pb and Zn seems to cause extensive damage to the biological apparatus by causing alteration in the vital physiological process (Shukla and Upreti, 2008).

Both *P. cocoes* and *R. sophodes* at all the sites showed more or less similar selectivity sequence of metals and similar chlorophyll degradation with positive

Table-7.9: Metal accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur (Appendix-IV: 7.9.1 to 7.9.22)

Directions	*P. cocoes* (concentration in µgg^{-1} Dry weight)											Total metal
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**	
North	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
West	60.07±0.17	456.04±0.25	32603.04±0.78	13.11±0.67	49.45±0.21	53.23±0.23	206.18±0.05	14.0±0.37	5.75±0.28	3.32±0.23	217.09±0.49	**33681.28**
South	49.7±0.95	487.44±0.47	26223.04±0.46	10.9±0.05	28.36±0.08	28.53±0.11	168.64±0.46	19.56±0.19	4.42±0.37	BDL	BDL	**27020.59**
Total metal	**109.77**	**943.48**	**58826.08**	**24.01**	**77.81**	**81.76**	**374.82**	**33.56**	**10.17**	**3.32**	**217.09**	
CV%	1.515	0.097	0.002	4.849	0.501	0.527	0.212	2.125	7.900	12.201	0.392	
LSD(p< 0.05)	0.924**	0.508**	0.875**	0.647**	0.216**	0.239**	0.443**	0.396**	0.446**	0.225**	0.473**	
Directions	***R. sophodes* (concentration in µgg^{-1} Dry weight)**											**Total metal**
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**	
North	87.13±0.52	1281.04±0.58	34703.04±0.57	19.2±0.19	61.91±0.31	57.33±0.15	154.38±0.17	36.19±0.08	6.62±0.17	2.14±0.15	441.09±0.41	**36850.07**
West	81.39±0.38	1088.06±0.41	34023.04±0.90	21.34±0.30	56.56±0.23	56.33±0.09	206.28±0.08	28.92±0.30	5.52±0.16	2.37±0.16	405.89±0.21	**35975.7**
South	1.11±0.13	93.44±0.55	156.54±0.49	0.49±0.05	3.88±0.13	26.07±0.07	108.78±0.21	2.04±0.07	2.03±0.03	1.48±0.28	39.09±0.04	**434.95**
Total metal	**169.63**	**2462.54**	**68882.62**	**41.03**	**122.35**	**139.73**	**469.44**	**67.15**	**14.17**	**5.99**	**886.07**	
CV%	0.673	0.063	0.023	1.499	0.577	0.226	0.102	0.811	2.850	6.744	0.089	
LSD(p< 0.05)	0.634**	0.860**	9.078**	0.341**	0.392**	1.756**	0.267**	0.302**	0.224**	0.224**	0.441**	

Mean±S.D., n=3 in µgg^{-1} dry weight, S. D.= Standard Deviation; BDL= Below Detection Limit

** Significance at the level of 0.01

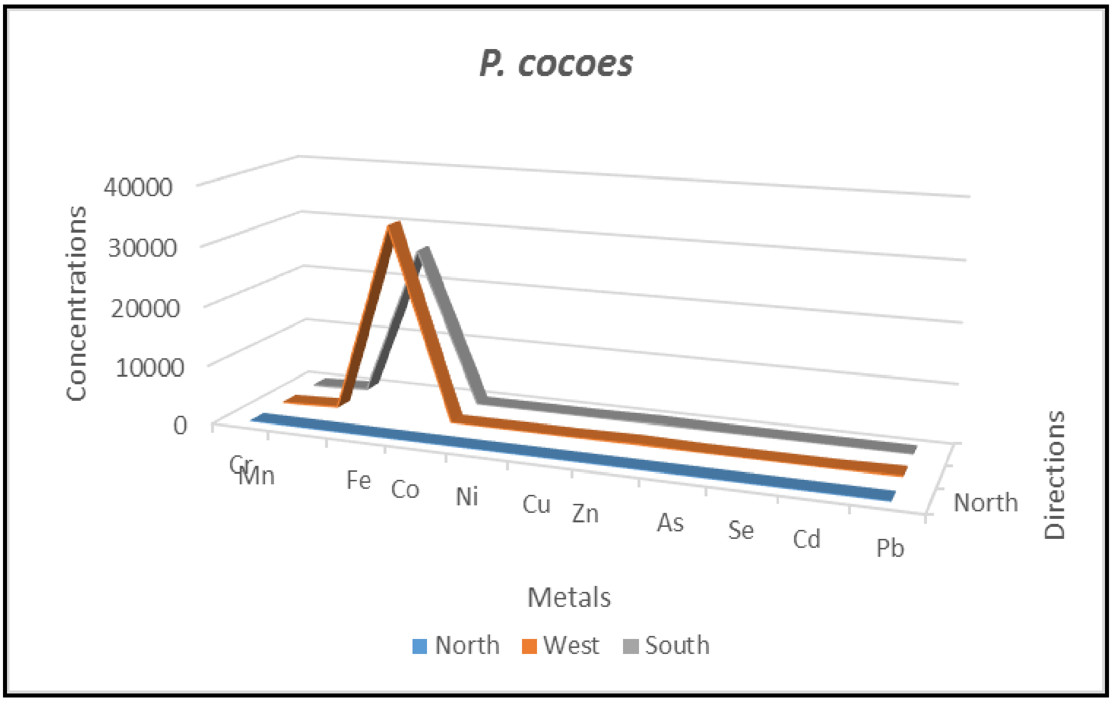


Fig-7.9: Graphical representation of metal accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

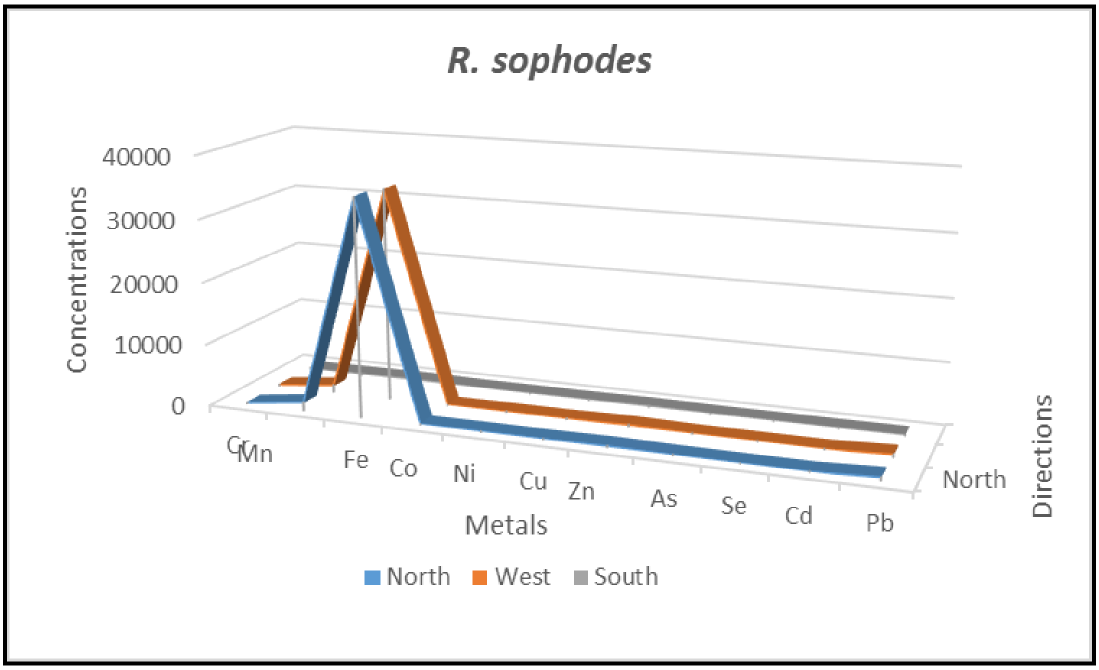


Fig-7.10: Graphical representation of metal accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Table-7.10: Values of correlation matrix between the elements around Panki Thermal Power Plant, Kanpur

P.cocoes	Cr	Mn	Fe	Co	Ni	Cu	Zn	As	Se	Cd	Pb
Cr	1	0.976	1.000*	1.000**	0.962	0.949	1.000**	0.904	.998*	0.633	0.633
Mn		1	0.971	0.977	0.879	0.858	0.974	0.975	0.961	0.449	0.449
Fe			1	1.000*	0.968	0.956	1.000**	0.894	.999*	0.651	0.651
Co				1	0.961	0.948	1.000**	0.906	.998*	0.63	0.63
Ni					1	.999*	0.965	0.753	0.977	0.821	0.821
Cu						1	0.952	0.724	0.967	0.845	0.845
Zn							1	0.9	.999*	0.641	0.641
As								1	0.877	0.242	0.242
Se									1	0.679	0.679
Cd										1	1.000**
Pb											1
R.sophodes	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**
Cr	1	0.996	.999*	0.988	1.000*	1.000*	0.814	0.99	0.985	0.952	1.000*
Mn		1	0.991	0.97	.998*	0.992	0.756	.999*	0.997	0.92	.997*
Fe			1	0.994	.998*	1.000**	0.838	0.983	0.977	0.964	.998*
Co				1	0.984	0.993	0.893	0.956	0.948	0.988	0.985
Ni					1	.998*	0.799	0.993	0.989	0.944	1.000**
Cu						1	0.831	0.985	0.979	0.961	.999*
Zn							1	0.722	0.702	0.953	0.802
As								1	1.000*	0.898	0.992
Se									1	0.886	0.988
Cd										1	0.946
Pb											1

**. Correlation is significant at the 0.05 level (2-tailed).*
***. Correlation is significant at the 0.01 level (2-tailed).*

correlation matrix; whereas protein content had positively correlated in *P. cocoes* and negatively correlated with all photosynthetic parameters in *R. sophodes*. The level of concentration of different metal present in the lichens provides information about the risk to the population living in the vicinity of the power plant together with long-term hazard due to metal accumulation. The reason for the higher accumulation of metals may be due to anthropogenic activities together with pollutants emerging from thermal power due to coal burning.

Since the area is close to Panki Thermal Power Plant, therefore, the probable source of metals in species may be attributed to the emission of thermal power plant. The study provided an understanding about the mechanisms adopted by different growth form of lichens for bioaccumulation of metals emitted by thermal power plant and indicates that the particulate bound adsorption is the major factor responsible for bioaccumulation in lichens irrespective of their growth form.

The physiological studies carried out on lichens together with metal accumulation, degradation of chlorophyll and change in protein and carotenoid will help to understand the damage caused by the pollutants to the living organisms around thermal power plant.

7.3 Tanda Thermal Power Plant, Ambedkar Nagar

The study area revealed the occurrence of 11 species of lichens belonging to 7 genera and 6 families from 42 monitoring sites upto a distance of 21 km, indicates poor lichen diversity in the area not suitable for the colonization of lichens (Table-7.11, 7.12 & 7.13; Fig-7.11). Among them *Pyxine cocoes* and *Bacidia incongruens* were found growing luxuriantly on trunks and branches of *Mangifera indica* tree in all four directions (i.e. east, west, north and south) (Plate-7.2).

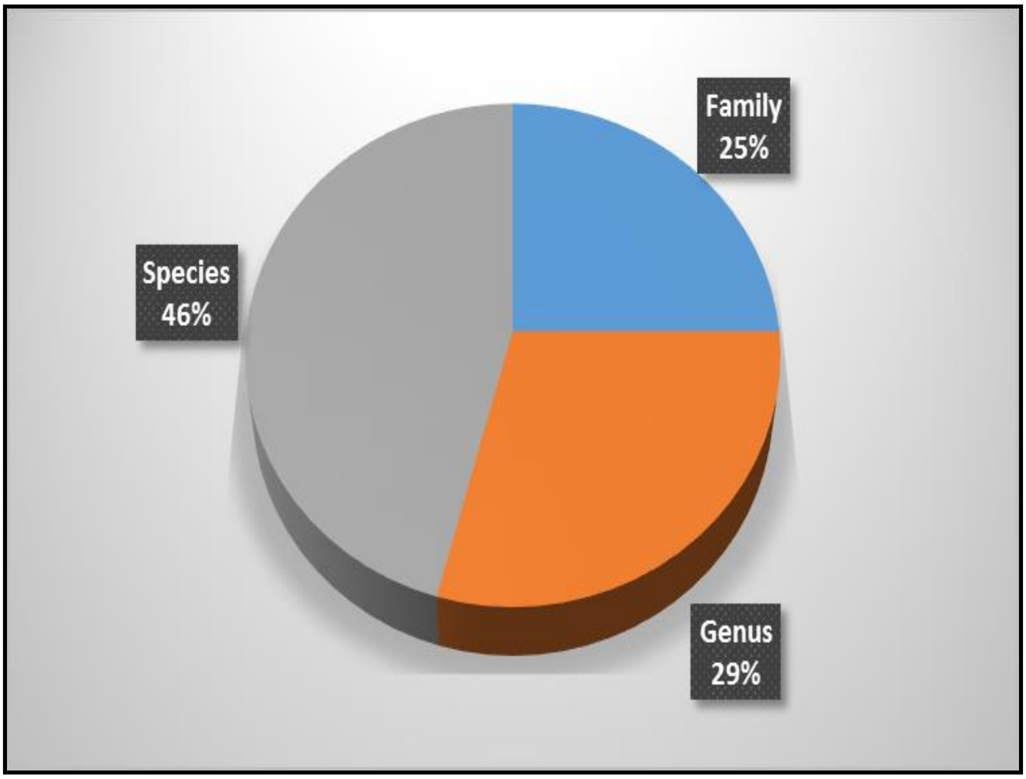


Fig-7.11: Share of family, genus and species of all the lichens reported around Tanda Thermal Power Plant, Ambedkar Nagar

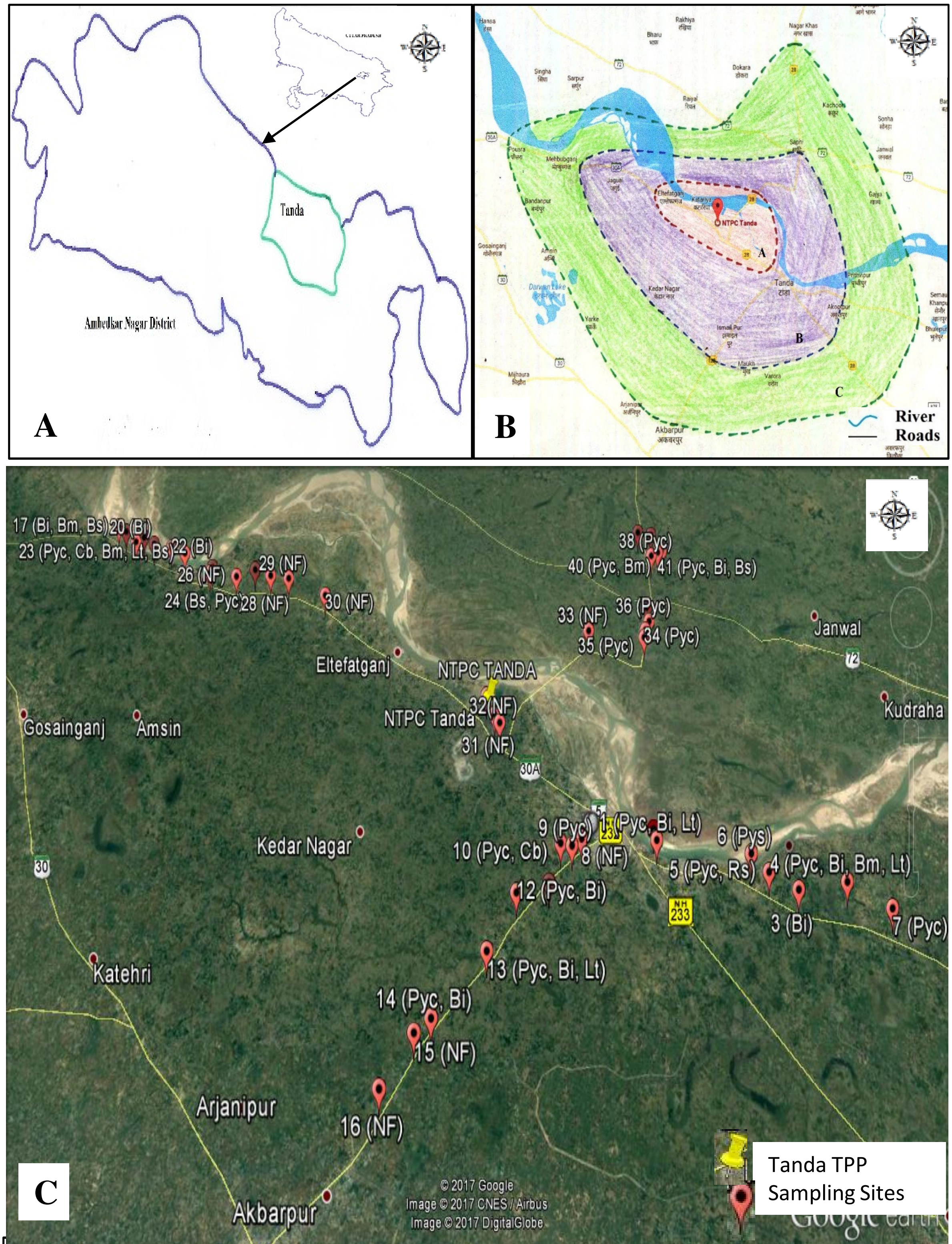


Plate-7.2: Tanda Thermal Power Plant, Ambedkar Nagar: (A) Uttar Pradesh Region Showing Ambedkar Nagar district; (B) Zone Map showing distribution pattern of lichen taxa around Tanda Thermal Power Plant, Ambedkar Nagar: Zone A: Poor lichen growth- Polluted; Zone B: Moderate lichen growth- Moderate Pollution; Zone C: Normal lichen growth- More or less Pollution free area; (C) Sampling sites around Tanda Thermal Power Plant, Ambedkar Nagar (refer Table-7.11 & 7.12) (Source: Google Earth)

Table-7.11: Localities surveyed for collection of lichens around Tanda Thermal Power Plant, Ambedkar Nagar, Uttar Pradesh

Tanda Thermal Power Plant, Ambedkar Nagar					
S. No.	**Localities**	**Latitude (N)**	**Longitude (E)**	**Altitude**	**Sp. Occ.**
1	Rajesultanpur road, Chintaura	26°32'27.18"	82°40'43.04"	93.30m	Pyc, Bi, Lt
2	Rajesultanpur road, Mubarakpur	26°32'39.68"	82°40'38.71"	92.42m	Pyc, Bi, Lt, Rs,Bm,Bs, Ha.
3	Rajesultanpur road, Sulempur Persawa	26°31'46.33"	82°44'16.65"	89.0m	Bi
4	Rajesultanpur road, Rampur benepur	26°32'0.35"	82°45'32.35"	89.32m	Pyc, Bi, Bm, Lt
5	Rajesultanpur road, Prithvipur	26°32'3.03"	82°43'34.01"	89.30m	Pyc, Rs
6	Rajesultanpur road, Ismailpur beldaha, Heerapur	26°32'22.09"	82°43'9.13"	90.87m	Pys
7	Rajesultanpur road, pretampur Narayanpur, Rasoolpur	26°31'35.74"	82°46'35.01"	90.97m	Pyc
8	Akbarpur Road, Chak makdoom nagar	26°32'20.43"	82°38'45.53"	88.07m	NF
9	Akbarpur Road, Fathe Jahoorpur	26°32'11.19"	82°38'30.66"	89.00m	Pyc
10	Akbarpur Road near Fathe Jahoorpur	26°32'12.84"	82°38'12.89"	92.93m	Pyc, Cb
11	Akbarpur Road, Alampur Shekhpur	26°31'26.67"	82°37'56.23"	93.98m	NF
12	Akbarpur Road, Mamrejpur	26°31'12.40"	82°37'7.00"	92.10m	Pyc, Bi
13	Akbarpur Road, Khetapur	26°30'7.16"	82°36'27.04"	90.48m	Pyc, Bi, Lt
14	Akbarpur Road, Ariya	26°28'54.83"	82°35'13.32"	92.86m	Pyc, Bi
15	Akbarpur Road, Daherpur	26°28'39.22"	82°34'50.84"	96.72m	NF
16	Akbarpur Road, Vijay gaon	26°27'44.47"	82°34'10.06"	96.79m	NF
17	Fzd-Tanda Road, Pausara Uparhar	26°38'38.72"	82°24'3.66"	95.00m	Bi, Bm, Bs
18	Fzd-Tanda Road, Pausara	26°38'31.82"	82°24'20.33"	96.16m	Bs, Cb
19	Fzd-Tanda Road, Uparhar near Uniyarpur	26°38'24.10"	82°24'57.38"	95.32m	Pyc, Rs
20	Fzd-Tanda Road near	26°38'16.29"	82°24'44.87"	94.20m	Bi

	Pausara				
21	Fzd-Tanda Road, Uparhar, Uniyarpur	26°38'14.56"	82°25'20.27"	99.50m	Pyc, Ac, Cb
22	Fzd-Tanda Road, Uparhar, Lalpur	26°38'10.84"	82°25'54.86"	95.03m	Bi
23	Fzd-Tanda Road, Mehbubganj, Bhitaura	26°38'3.93"	82°26'22.66"	97.63m	Pyc, Cb, Bm, Lt, Bs
24	Fzd-Tanda Road, Mehbubganj, Ruhiyawa	26°37'35.76"	82°27'18.59"	97.18m	Bs, Pyc
25	Fzd-Tanda Road near Ruhiyawa	26°37'44.40"	82°27'20.74"	96.74m	Re
26	Fzd-Tanda Road, Ishapur	26°37'33.35"	82°28'8.94"	95.23m	NF
27	Fzd-Tanda Road near Ishapur	26°37'46.48"	82°28'40.62"	94.38m	NF
28	Fzd-Tanda Road, Mahuari	26°37'39.08"	82°29'11.50"	98.23m	NF
29	Fzd-Tanda Road near Mahuari	26°37'37.28"	82°29'45.49"	97.10m	NF
30	Fzd-Tanda Road, Anwa, Laxmanpur	26°37'15.74"	82°30'57.79"	96.80m	NF
31	Kalwari Road, Husainpur Sudhana	26°34'45.30"	82°36'17.44"	91.84m	NF
32	Kalwari Road, Husainpur Sudhana	26°34'35.34"	82°36'26.92"	92.51m	NF
33	Kalwari Road, Majha Khurd	26°36'55.42"	82°38'55.23"	86.41m	NF
34	Kalwari Road, Kalwari Ahtimali	26°36'52.58"	82°40'33.06"	90.23m	Pyc
35	Kalwari Road, Kalwari Must	26°37'3.49"	82°40'35.37"	88.38m	Pyc
36	Kalwari Road, Tahirpur	26°37'17.44"	82°40'42.79"	87.00m	Pyc
37	Kalwari Road near Tahirpur roadside	26°37'38.16"	82°40'39.24"	93.37m	Pyc, Bi
38	Kalwari Road, Kusauri	26°39'1.57"	82°40'50.98"	91.18m	Pyc
39	Kalwari Road near Kusauri	26°39'36.18"	82°40'51.70"	91.89m	Pyc
40	Kalwari Road near Saraiya Khurd	26°39'10.36"	82°41'10.70"	87.74m	Pyc, Bm
41	Kalwari Road near Kusaura	26°39'7.92"	82°41'3.18"	86.84m	Pyc, Bi, Bs
42	Kalwari Road, Pakri chhabar	26°39'38.85"	82°40'27.34"	90.00m	Pyc, Bs, Lt

Ac= *Arthothelium chiodectoides;* Bi= *Bacidia incongruens;* Bm= *Bacidia medialis;* Bs= *Bacidia submedialis;* Cb= *Caloplaca bassiae;* Ha= *Hyperphyscia adglutinata;* Lt= *Lecanora tropica*; Pyc= *Pyxine cocoes;* Pys= *Pyxine sorediata;* Re= *Rinodina exigua*; Rs= *Rinodina sophodes;* NF= Not Found; Sp. Occ.= Species Occurred

Table-7.12: List of lichen taxa observed around Tanda Thermal Power Plant, Ambedkar Nagar

Name of Species	Family	Localities	Substratum	Field No.	Accession no.
EAST DIRECTION					
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, Chintaura	on *Mangifera indica* bark	015-031702	33601
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Rajesultanpur road, Chintaura	on *Mangifera indica* bark	015-031703	33602
Lecanora tropica Zahlbr.	Lecanoraceae	Rajesultanpur road, Chintaura	on *Mangifera indica* bark	015-031701	33600
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031705	33642
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031704	33599
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031706	33597
Lecanora tropica Zahlbr. + *Rinodina sophodes* (Ach.) A. Massal.	Lecanoraceae+Physciaceae	Rajesultanpur road, Mubarakpur	on *Artocarpus heterophyllus* bark	015-031707	33596
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Rajesultanpur road, Mubarakpur	on *Artocarpus heterophyllus* bark	015-031709	33598
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031708	33595
Lecanora tropica Zahlbr.	Lecanoraceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031711	33593
Lecanora tropica Zahlbr.	Lecanoraceae	Rajesultanpur road, Mubarakpur	on *Artocarpus heterophyllus* bark	015-031710	33594
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031712	33592
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Rajesultanpur road, Mubarakpur	on *Artocarpus heterophyllus* bark	015-031713	33591
Hyperphyscia adglutinata var. adglutinata (Florke) H. Mayrhofer & Poelt	Physciaceae	Rajesultanpur road, Mubarakpur	on *Mangifera indica* bark	015-031714	33590
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Rajesultanpur road, Sulempur Persawa	on *Mangifera indica* bark	015-031715	33613
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Rajesultanpur road, Sulempur Persawa	on *Mangifera indica* bark	015-031716	33616

Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, Rampur benepur	on *Mangifera indica* bark	015-031717	33621
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Rajesultanpur road, Rampur benepur	on *Mangifera indica* bark	015-031718	33620
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Rajesultanpur road, Rampur benepur	on *Artocarpus heterophyllus* bark	015-031719	33617
Lecanora tropica Zahlbr.	Lecanoraceae	Rajesultanpur road, Rampur benepur	on *Mangifera indica* bark	015-031720	33614
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, Prithvipur	on *Mangifera indica* bark	015-031722	33619
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Rajesultanpur road, Prithvipur	on *Mangifera indica* bark	015-031721	33615
Pyxine sorediata (Ach.) Mont.	Caliciaceae	Rajesultanpur road, Ismailpur beldaha, Heerapur	on *Mangifera indica* bark	015-031723	33618
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, pretampur Narayanpur, Rasoolpur	on *Mangifera indica* bark	015-031724	33622
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, pretampur Narayanpur, Rasoolpur	on *Mangifera indica* bark	015-031725	33640
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rajesultanpur road, pretampur Narayanpur, Rasoolpur	on *Mangifera indica* bark	015-031726	33641
SOUTH DIRECTION					
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Akbarpur Road, Fathe Jahoorpur	on *Mangifera indica* bark	015-023746	33603
Caloplaca bassiae (Willd.ex. Ach.) Zahlbr.	Teloschistaceae	Akbarpur Road, Fathe Jahoorpur	on *Mangifera indica* bark	015-023747	33607
Pyxine cocoes (Sw.) Nyl. + *Caloplaca bassiae* (Willd.ex. Ach.) Zahlbr.	Caliciaceae + Teloschistaceae	Akbarpur Road, Fathe Jahoorpur	on *Mangifera indica* bark	015-023748	33608
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Akbarpur Road, Mamrejpur	on *Mangifera indica* bark	015-023749	33611
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Akbarpur Road, Mamrejpur	on *Mangifera indica* bark	015-023750	33609
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Akbarpur Road, Khetapur	on *Mangifera indica* bark	015-023751	33610
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Akbarpur Road, Khetapur	on *Mangifera indica* bark	015-023753	33605
Lecanora tropica Zahlbr.	Lecanoraceae	Akbarpur Road, Khetapur	on *Mangifera indica* bark	015-023752	33606

Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Akbarpur Road, Ariya	on *Mangifera indica* bark	015-023754	33612
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Akbarpur Road, Ariya	on *Mangifera indica* bark	015-023755	33604
WEST DIRECTION					
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Pausara Uparhar	on *Mangifera indica* bark	015-023756	33623
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Pausara Uparhar	on *Mangifera indica* bark	015-023757	33625
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Pausara Uparhar	on *Mangifera indica* bark	015-023758	33626
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Pausara Uparhar	on *Mangifera indica* bark	015-023759	33631
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Pausara	on *Mangifera indica* bark	015-023760	33627
Caloplaca bassiae (Willd.ex.Ach.) Zahlbr.	Teloschistaceae	Fzd-Tanda Road, Pausara	on *Mangifera indica* bark	015-023761	33628
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Fzd-Tanda Road, Uparhar near Uniyarpur	on *Mangifera indica* bark	015-023762	33629
Rinodina sophodes (Ach.) A. Massal.+ *Pyxine cocoes* (Sw.) Nyl.	Physciaceae + Caliciaceae	Fzd-Tanda Road, Uparhar near Uniyarpur	on *Mangifera indica* bark	015-023763	33630
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Fzd-Tanda Road near Pausara	on *Mangifera indica* bark	015-023764	33633
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Fzd-Tanda Road near Pausara	on *Mangifera indica* bark	015-023765	33624
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Fzd-Tanda Road, Uparhar, Uniyarpur	on *Mangifera indica* bark	015-023771	33643
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Fzd-Tanda Road, Uparhar, Uniyarpur	on *Mangifera indica* bark	015-023770	33637
Arthothelium chiodectoides (Nyl.) Zahlbr.	Arthoniaceae	Fzd-Tanda Road, Uparhar, Uniyarpur	on *Mangifera indica* bark	015-023768	33644
Arthothelium chiodectoides (Nyl.) Zahlbr.	Arthoniaceae	Fzd-Tanda Road, Uparhar, Uniyarpur	on *Mangifera indica* bark	015-023767	33639
Caloplaca bassiae (Willd.ex.Ach.)	Teloschistaceae	Fzd-Tanda Road, Uparhar,	on *Mangifera indica* bark	015-023766	33648

Zahlbr.		Uniyarpur			
Pyxine cocoes (Sw.) Nyl. + *Caloplaca bassiae* (Willd.ex.Ach.) Zahlbr.	Caliciaceae +Teloschistaceae	Fzd-Tanda Road, Uparhar, Uniyarpur	on *Mangifera indica* bark	015-023769	33646
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Uparhar, Lalpur	on *Mangifera indica* bark	015-023772	33650
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Fzd-Tanda Road, Mehbubganj, Bhitaura	on *Mangifera indica* bark	015-023773	33469
Caloplaca bassiae (Willd.ex.Ach.) Zahlbr.	Teloschistaceae	Fzd-Tanda Road, Mehbubganj, Bhitaura	on *Mangifera indica* bark	015-023774	33638
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Mehbubganj, Bhitaura	on *Mangifera indica* bark	015-023775	33647
Lecanora tropica Zahlbr.	Lecanoraceae	Fzd-Tanda Road, Mehbubganj, Bhitaura	on *Mangifera indica* bark	015-023776	33636
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Mehbubganj, Bhitaura	on *Mangifera indica* bark	015-023777	33645
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Fzd-Tanda Road, Mehbubganj, Ruhiyawa	on *Pongamia pinnata* bark	015-023778	33635
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Fzd-Tanda Road, Mehbubganj, Ruhiyawa	on *Pongamia pinnata* bark	015-023779	33634
Rinodina exigua (Ach.) Gray	Physciaceae	Fzd-Tanda Road near Ruhiyawa	on *Artocarpous heterophyllus* bark	015-023780	33632
NORTH DIRECTION					
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road, Kalwari Ahtimali	on *Mangifera indica* bark	015-023781	33575
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road, Kalwari Must	on *Mangifera indica* bark	015-023782	33576
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road, Tahirpur	on *Mangifera indica* bark	015-023783	33589
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road near Tahirpur roadside	on *Mangifera indica* bark	015-023784	33585
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Kalwari Road near Tahirpur roadside	on *Artocarpous heterophyllus* bark	015-023785	33578

Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road, Kusauri	on *Mangifera indica* bark	015-023787	33584
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road near Kusauri	on *Pongamia pinnata* bark	015-023792	33580
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road near Saraiya Khurd	on *Mangifera indica* bark	015-023786	33509
Bacidia medialis (Tuck.) Zahlbr.	Ramalinaceae	Kalwari Road near Saraiya Khurd	on *Mangifera indica* bark	015-023791	33577
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road near Kusaura	on dead wood of *Mangifera indica* bark	015-023788	33579
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Kalwari Road near Kusaura	on *Mangifera indica* bark	015-023789	33587
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Kalwari Road near Kusaura	on *Mangifera indica* bark	015-023795	33582
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road, Pakri chhabar	on *Mangifera indica* bark	015-023790	33581
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Kalwari Road, Pakri chhabar	on *Mangifera indica* bark	015-023797	33586
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Kalwari Road, Pakri chhabar	on *Litchi chinensis* bark	015-023799	33583
Lecanora tropica Zahlbr.	Lecanoraceae	Kalwari Road, Pakri chhabar	on *Mangifera indica* bark	015-023800	33588

Table-7.13: Comprehensive list of all the lichens recorded around Tanda Thermal Power Plant, Ambedkar Nagar

S. No.	Family	Genus	Species
1	Arthoniaceae	*Arthothelium*	*Arthothelium chiodectoides* (Nyl.) Zahlbr.
2	Lecanoraceae	*Lecanora*	*Lecanora tropica* Zahlbr.
3	Physciaceae	*Hyperphyscia*	*Hyperphyscia adglutinata* var. adglutinata (Florke) H. Mayrhofer & Poelt
		Rinodina	*Rinodina exigua* (Ach.) Gray
4	Caliciaceae		*Rinodina sophodes* (Ach.) A. Massal.
		Pyxine	*Pyxine cocoes* (Sw.) Nyl.
			***Pyxine sorediata* (Ach.) Mont.**
5	Ramalinaceae	*Bacidia*	*Bacidia incongruens* (Stirton) Zahlbr.
			Bacidia medialis (Tuck.) Zahlbr.
			Bacidia submedialis (Nyl.) Zahlbr.
6	Teloschistaceae	*Caloplaca*	*Caloplaca bassiae* (Willd.ex. Ach.) Zahlbr.

*New Addition to Uttar Pradesh

7.3.1 Scanning Electron Microscopy and Energy Dispersive X-ray analysis around Tanda Thermal Power Plant, Ambedkar Nagar

The morphological assessment and quantification of elements of *P. cocoes* (Fig-7.12) and *B. incongruens* (Fig-7.13) in comparison to standard was performed by Scanning Electron Microscopy (SEM) (Fig-7.12 & 7.13) and Energy Dispersive X-ray analysis (EDX) analysis (Fig-7.14 & 7.15).

7.3.1.1 SEM Studies on *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar (Fig-7.12): Lichens depend partly on the chemical characters of the substrate such as the calcium content. The whitish purina (powdery substance) deposited on the upper surface of lichen thalli appears as crystals which are composed of calcium oxalate (Büdel and Scheidegger, 2008).

The calcium oxalate crystals especially the weddellite crystals which contains zeolitic water which can leave the crystals when they dry and are implied as a possible source of water in the lichen. (Wadsten and Moberg, 1985). The size of the crystals and their proximity to the algal cells have important factors in the mechanism (Clark et al., 2001) and the weddellite crystals alternately trap and release zeolitic water. The algal cells in the lichens have the capacity to use water vapor for photosynthesis (Nash, 2008). Besides their role in trapping water for the lichen, calcium oxalate crystals also provide mechanical protection, serve as deterrents against herbivores (Reutimann and Scheidegger, 1987) and provide protection against excessive light by deflecting some light rays from reaching the lichens (Purvis, 2000).

The study provide rapid qualitative or adequate standards, and quantitative analysis of elemental composition with a sampling depth of 1–2 μm (Srivastava et al., 2009; Sielicki et al. 2011; Pipal et al. 2011) and EDX spectra of blank filter were also recorded and its composition was manually subtracted during the evaluation of the elemental composition of individual aerosol particles of different groups. EDX spectra in *P. cocoes* showed the weight percentage of elements in all directions in which oxygen as oxides is the most abundant element (41.1 to 53.53%) followed by carbonaceous element (14.8-33.35%) and Ca (20.8-23.82%) from the study area (Table-7.14).

7.3.1.2 SEM studies on *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar: The crustose thallus of *B. incongruens* attached to the tightly substrate. The upper surface is warty, smooth or/ and is marked off into many-sided areas or areoles called as areolate. The adsorption of particulate matter is more prominent in *P. cocoes* as compared to *B. incongruens.* Scanning Electron Microscopy coupled with Energy Dispersive X-ray analysis (SEM-EDX) was used to determine the distribution of element, weight percent and atomic percent during analysis (Fig-7.12, 7.13, 7.14 &7.15).

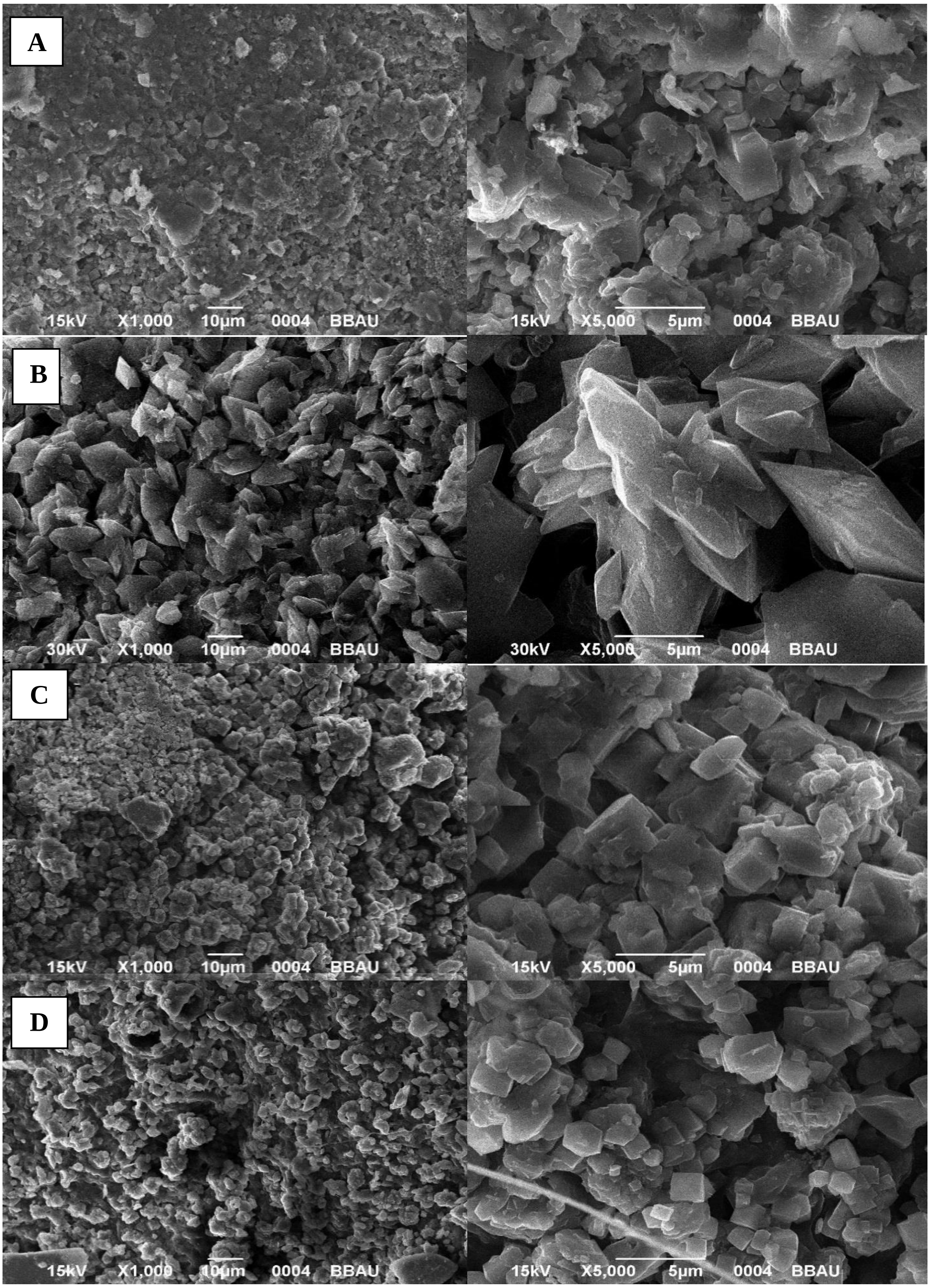


Fig-7.12: Scanning Electron Microscope images of lichen species *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar*;* (A) East direction, (B) South direction, (C) West direction and (D) North direction

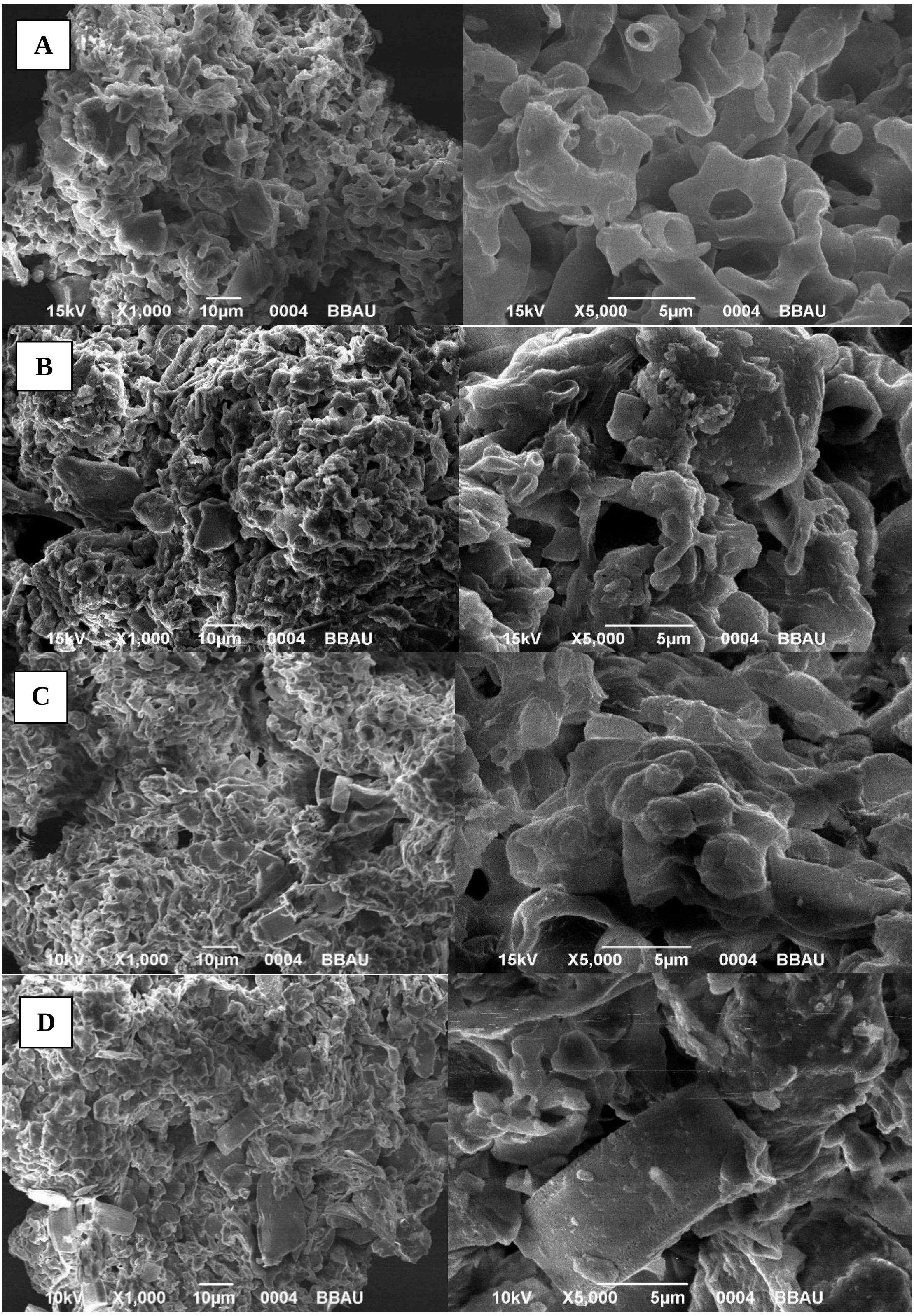


Fig-7.13: Scanning Electron Microscope images of lichen species *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar; (A) East direction, (B) South direction, (C) West direction and (D) North direction

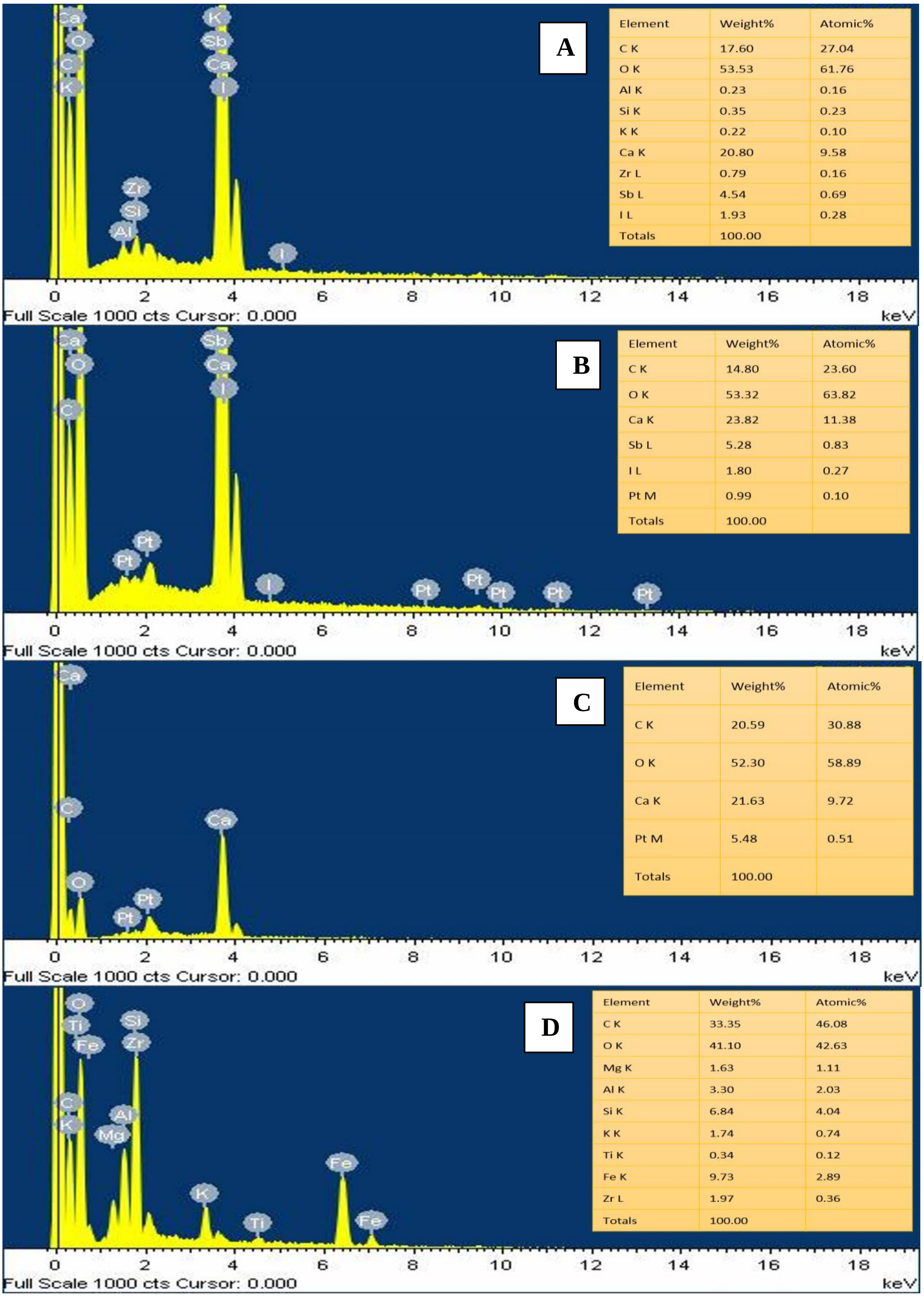
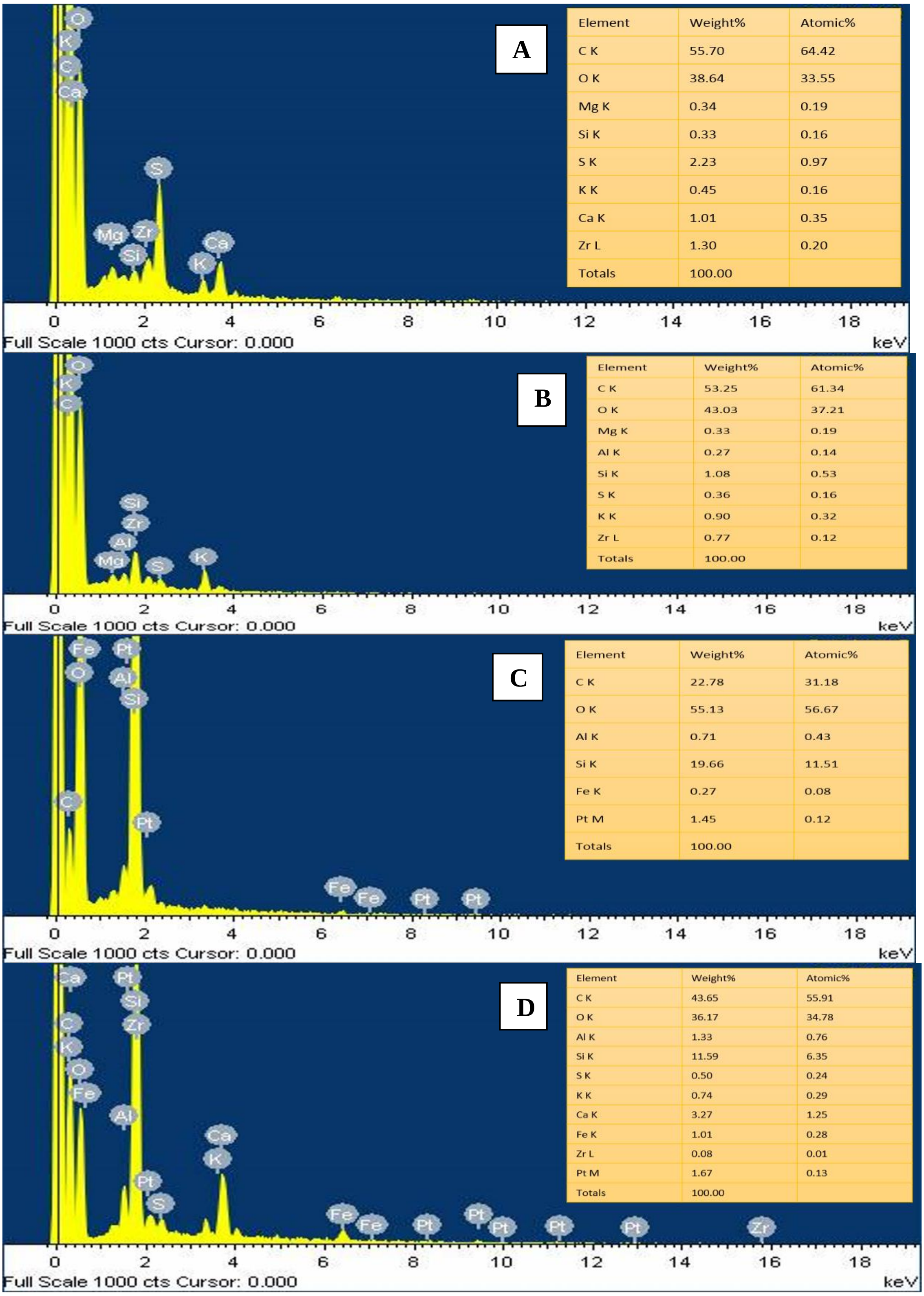


Fig-7.14: Energy Dispersive X-ray analysis of the lichen species *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar; (A) East direction, (B) South direction, (C) West direction and (D) North direction



A

Element	Weight%	Atomic%
C K	55.70	64.42
O K	38.64	33.55
Mg K	0.34	0.19
Si K	0.33	0.16
S K	2.23	0.97
K K	0.45	0.16
Ca K	1.01	0.35
Zr L	1.30	0.20
Totals	100.00	

B

Element	Weight%	Atomic%
C K	53.25	61.34
O K	43.03	37.21
Mg K	0.33	0.19
Al K	0.27	0.14
Si K	1.08	0.53
S K	0.36	0.16
K K	0.90	0.32
Zr L	0.77	0.12
Totals	100.00	

C

Element	Weight%	Atomic%
C K	22.78	31.18
O K	55.13	56.67
Al K	0.71	0.43
Si K	19.66	11.51
Fe K	0.27	0.08
Pt M	1.45	0.12
Totals	100.00	

D

Element	Weight%	Atomic%
C K	43.65	55.91
O K	36.17	34.78
Al K	1.33	0.76
Si K	11.59	6.35
S K	0.50	0.24
K K	0.74	0.29
Ca K	3.27	1.25
Fe K	1.01	0.28
Zr L	0.08	0.01
Pt M	1.67	0.13
Totals	100.00	

Fig-7.15: Energy Dispersive X-ray analysis of the lichen species *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar; (A) East direction, (B) South direction, (C) West direction and (D) North direction

EDX spectra of *B. incongruens* (Table-7.15) showed the weight percentage of elements i.e. carbon (22.78-55.7%) and oxides (36.17-55.13%) are dominating in east and west directions respectively. Si (0.33-19.66%) is also present in lower concentration in the thallus. The sources of carbonaceous elements indicate the biomass burning and dominance of soot particle from biomass burning similar to the studies by Zhang et al. (2010) and Posfai et al. (2003).

Table-7.14: Elemental composition of particulate matter by EDX in *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Element	East	South	West	North
C	17.6	14.8	20.59	33.35
O	53.53	53.32	52.3	41.1
Al	0.23	ND	ND	3.3
Si	0.35	ND	ND	6.84
K	0.22	ND	ND	1.74
Ca	20.8	23.82	21.63	ND
Zr	0.79	ND	ND	1.97
Sb	4.54	5.28	ND	ND
I	1.93	1.8	ND	ND
Pt	ND	0.99	5.48	ND
Mg	ND	ND	ND	1.63
Ti	ND	ND	ND	0.34
Fe	ND	ND	ND	9.73

Table-7.15: Elemental composition of particulate matter by EDX in *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Element	East	South	West	North
C	55.7	53.25	22.78	43.65
O	38.64	43.03	55.13	36.17
Al	ND	0.27	0.71	1.33
Si	0.33	1.08	19.66	11.59
K	0.45	0.9	ND	0.74
Ca	1.01	ND	ND	3.27
Zr	1.3	0.77	ND	0.08
Pt	ND	ND	1.45	1.67
Mg	0.34	0.33	ND	ND
Fe	ND	ND	0.27	1.01
S	2.23	0.36	ND	0.5

7.3.2 Analysis of Lichens by Fourier- Transform Infrared Spectroscopy (FTIR) around Tanda Thermal Power Plant, Ambedkar Nagar

FTIR analysis of both the species around Tanda Thermal Power Plant listed in Table-7.16; Fig-7.16 and the typical functional groups present on the surface of both the species were amino, carboxylic, phosphate and carbonyl. These result indicated the involvement of these functional groups in biosorption process.

7.3.2.1 FTIR spectra measurement of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

The spectra of *P. cocoes* showed the stretching of bonded N-H/ O-H and the presence of alcohol and phenol groups (Table-7.16; Fig-7.16A) at a strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3408.3 cm^{-1} (east), 3435.0 cm^{-1} (south), 3436.0 cm^{-1} (west), 3443.7 cm^{-1} (north). The spectral band observed between 3300- 2500 cm^{-1} due to symmetrical stretching of bonded O-H showed the presence of carboxylic acid. The absorbance bands observed at ranged between 2200-2000 cm^{-1} due to NH_3^+ torsional vibration (Mohan, 2005). The wave numbers observed at 1725.9 cm^{-1} due to C=O ester stretching showed the presence of carbonyl group (Sandt et al., 2003).

The minor absorption bands ranged between 1680- 1640 due to C=O showed the presence of primary amines. The wave numbers observed 1560-1530 cm^{-1} due to asymmetric stretch vibration of N-O at 1548.7 cm^{-1} and 1555.8 cm^{-1} respectively showed the presence of nitrogen compounds in the isolates. The bonded C-H bending in alkanes observed at 1457.6 cm^{-1} and bonded C=O symmetric stretching absorbed infra-red at 1416.1 cm^{-1} and 1419.3 cm^{-1}. The spectra observed at 1368.6 cm^{-1} showed stretching of C-H and presence of alkanes.

The absorbance bands ranged 1350-1300 cm^{-1} showed components of α- helix protein. The absorbance bands ranged between 1250- 1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters. The range of wave number 1080-

1010 cm^{-1} showed asymmetric stretching and C-O bonding due to polysaccharides. The wave number 897.9 cm^{-1} showed O-CH_2 stretching of methoxy groups (Movasaghi et al., 2008). C-H stretching vibration (Jilie and Shaoning, 2007) represents 800-640 cm^{-1} absorbance band.

The bands range 770-620 cm^{-1} represents N-H bending with the presence of amine- V**.** The peaks range between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides. The peaks observed at 469.2 cm^{-1} and 467.0 cm^{-1} showed the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated) (Tarte, 1962; 1964).

7.3.2.2 FTIR spectra measurement of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

For lichen *B. incongruens* (Table-7.16; Fig-7.16B), the strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3431.6 cm^{-1} (east), 3410.2 cm^{-1} (south), 3378.4 cm^{-1} (west), 3386.5 cm^{-1} (north) showed the stretching of bonded N-H/ O-H and the presence of alcohol and phenol groups. The spectral band observed between 3000-2800 cm^{-1} due to asymmetrical vibration of C-H showed the presence of protein and phospholipids (Ramrakhiani et al., 2011). The absorbance bands observed at 2033.9 cm^{-1} due to NH_3^+ torsional vibration (Mohan, 2005). The wave numbers observed at 1728.9 cm^{-1} due to C=O ester stretching showed the presence of carbonyl group (Sandt et al., 2003).

The minor absorption bands observed at 1654.1 cm^{-1} due to C=O stretching with the presence of primary amines. The wave numbers observed at 1650-1580 cm^{-1} range due to bending of N-H with the presence of primary amines. The range of wave numbers 1560-1530 cm^{-1} showed the presence of C-N stretching, N- H bending with the presence of secondary amines. The bonded C=O symmetric stretching (Naumann, 2000) absorbed infra-red at 1408.4 cm^{-1} and 1407.6 cm^{-1}. The spectra observed at

1368.5 $cm^{-1,}$ and 1367.3 cm^{-1} showed stretching of C-H rocks as well as the presence of alkanes.

The absorbance bands observed at 1293.5 cm^{-1} showed components of α- helix (Adriana and Gabi, 2011). The absorbance bands ranged between 1250-1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters (Naumann, 2000). The range of wave number 1080-1010 cm^{-1} showed SO_3 asymmetric stretching (Cirik et al., 2012); and C-O bonding due to polysaccharides (Das and Guha, 2007). The range of wave number 900-600 cm^{-1} showed O-CH_2 stretching of methoxy groups (Movasaghi et al., 2008) and wave number 770-620 cm^{-1} showed the presence of amines-V with out of plane NH bending (Jilie and Shaoning, 2007). The peaks range between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides.

The peaks observed at 469.2 cm^{-1} and 467.0 cm^{-1} showed the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated) (Tarte, 1962; 1964). The observation are useful to detect rapidly and characterized the occurrence of lichen *B. incongruens* with different level of metal accumulation around thermal power plant.

Presence of both secondary metabolites and primary metabolites in *P. cocoes* enhances the probability of detection of IR bands in 3500-2800 cm^{-1} region due to the presence of more COOH and OH groups. While *B. incongruens* which lacks the secondary metabolites the number of band detected are less than *P. cocoes.*

The SEM and FTIR studies carried out on the production of calcium oxalate by lichens exhibited that the calcium oxalate production of different lichen taxa are associated with their effective biodeterioration activities (Edwards et al., 1997) or adaptation to the air pollution (Garty et al., 2002).

Table-7.16: Absorption frequencies of FTIR spectra of *P. cocoes* and *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

S. No.	Range of wave number (cm^{-1})	*P. cocoes* Band Position (in cm^{-1})				*B. incongruens* Band Position (in cm^{-1})				Band Assignment
		East	South	West	North	East	South	West	North	
1	3500-3300	3408.3	3435.0	3436.0	3443.7	3431.6	3410.2	3378.4	3386.5	N-H stretching Amide- A, O-H stretching of hydroxyl groups (primary, secondary, amines and amides) (Ramrakhiani et al., 2011)
2	3300-2500	2923.2	2923.5	2923.9	2944.0					O-H stretching
		-	2856.3	-	2891.6					(carboxylic acid)
3	3000-2800					2927.4	2925.5	2924.0	2927.4	Asymmetric vibration C-H of CH_2, protein and phospholipids (Ramrakhiani et al., 2011)
4	2200-2000	-	2040.0	2117.5	2135.3	-	2033.9	-	-	NH_3^+ torsional vibration (Mohan, 2005)
5	1760-1665	1725.9	-	-	-	-	-	-	1728.9	C=O ester stretching (Carbonyls group) (Sandt et al., 2003)
6	1680-1640	1643.8	1643.1	1646.3	1644.6	-	-	-	1654.1	Amide- I, C=O stretching (Jilie and Shaoning, 2007)
7	1650-1580					1637.8	1634.2	1639.2	-	N-H bending (primary amines)
8	1560-1530	-	-	1548.7	1555.8	1554.2	1553.4	1548.8	1547.0	Amide- II, CN stretching, NH bending (Jilie and Shaoning, 2007)
9	1470-1450	-	1457.6	-	-					C-H bending (alkanes)
10	1450-1400	1416.1	-	-	1419.3	-	1408.4	1407.6	-	C=O symmetric stretching $–COO^-$ (Naumann, 2000)
11	1370-1350	-	1368.6	-	-	1368.5	-	-	1367.3	C-H rock (alkanes)
12	1360-1290					1293.5	-	-	-	components of α- helix proteins
13	1350-1300	1322.3	1323.6	1322.7	1327.4					(Adriana and Gabi, 2011)
14	1250-1220	1247.0	1242.6	-	1214.7	1240.8	1229.0	-	1210.2	P=O stretching (asym.) of PO_2^- phosphodiesters (Naumann, 2000)
15	1080-1010	1036.7	1075.7	1033.6	1078.6	1077.5	1036.7	1032.6	1080.5	SO_3 asymmtric (Cirik at al., 2012); C-O bonding due to polysaccharides (Das and
					995.6	994.9	-	-	-	Guha, 2007)
16	900-600	-	-	-	897.9	-	774.7	776.7	790.2	$O-CH_3$ stretching of methoxy groups (Movasaghi et al., 2008)
17	800-640	770.9	-	777.5	750.9					C-H out of plane bending vibrations (Jilie and Shaoning, 2007)
18	770-620	689.6	-	691.1	689.8	689.9	691.6	691.7	691.7	Amide- V, Out of plane NH bending (Jilie and Shaoning, 2007)
19	690-515	527.7	523.3	524.3	518.7	-	527.2	524.7	525.0	C-Br stretching (alkyl halides)
20	530-400	469.2	-	467.0	-	472.3	467.0	467.1	466.8	Al-O stretching (AlO_8 Octahedral, isolated) (Tarte, 1962; 1964)

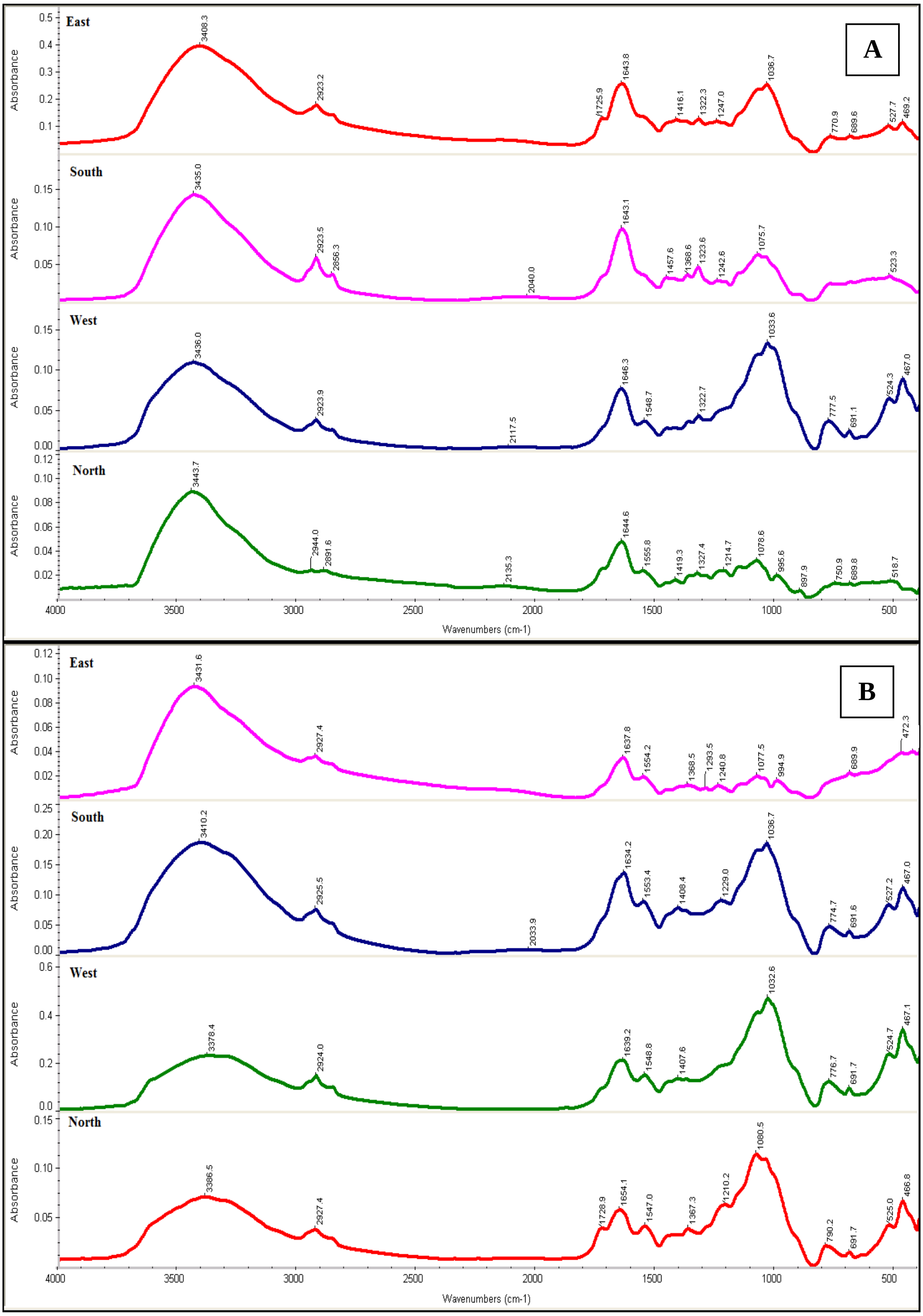


Fig-7.16: Direction-wise FTIR spectra of lichen species around Tanda Thermal Power Plant, Ambedkar Nagar; (A) *P. cocoes*, (B) *B. incongruens*

The present study illustrates the influence of prolonged exposure of emission of coal-based thermal power plant on lichen diversity and metal accumulation pattern in two commonly occurring lichen species i.e. *P. cocoes* and *B. incongruens* in the area. The study indicates that the concentration of metal increases with decreasing distance from thermal power plant and provide direct evidence about the air quality status. Both the lichen species growing in all the four directions showed more or less similar concentration of metal accumulation. FTIR spectra showed variation in the functional groups O-H, C-H, C=O and C-O indicating the role of metabolites in sequestration of metals, (absorption phenomenon) while SEM analysis showed adsorption of particulate bonded matter on the surface of lichen thallus which is responsible for bioaccumulation of most of the metals mainly Fe and Al, detected in high concentration in both the species. Based on the observation it is clear that surface adsorption is the key phenomenon of bioaccumulation of metals in both the lichen species studied.

7.3.3 Comparative physiological response of *P. cocoes* and *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar (Appendix-IV: 7.17.1 to 7.17.12)

P. cocoes (foliose) and *B. incongruens* (crustose) lichen commonly occurring within the contaminated and non-contaminated area were selected for photosynthetic pigment analysis and metal concentration. Concentration values for chlorophyll a in *P. cocoes* showed minimum concentration (0.40±0.05 μgg^{-1} Fresh weight) in east direction whereas maximum concentration (0.79±0.05 μgg^{-1}) in south direction. Chlorophyll b content also varied in different directions and it ranged from 0.16±0.04 μgg^{-1} (east) to 0.38±0.08 μgg^{-1} (south). According to Ronrn and Galun (1984); Chapin et al. (1987); concentration of Chl. a + b is altered by vehicular traffic pollution. The total chlorophyll (chlorophyll a + chlorophyll b) ranged from

0.56±0.09 μgg^{-1} in east to 1.17±0.13 μgg^{-1} in south direction respectively. Carreias et al. (1998) assessed that concentration of total chlorophyll is altered by the vehicular activity and urban emission. Photosynthetic parameters (chl. a, chl. b and total chlorophyll) showed the same pattern of variation in higher and lower concentration which might be due to effect of wind direction and pollution loads. Chlorophyll content are often utilized as one of the most accurate methods of biomonitoring in the study.

Highest concentration of carotenoid was detected in samples of *P. cocoes* in north (0.22±0.14 μgg^{-1}), while lowest concentration was detected in west direction (0.58±0.10 μgg^{-1}). Carotenoid and protein contents of *P. cocoes* have significantly decreased with the increasing distance from thermal power plant. Chlorophyll degradation concentration was highest in east decreased with increasing distance in west, south and north direction from NTPC and it ranged from 0.70±0.02 μgg^{-1} in north to 1.08±0.04 μgg^{-1} in east direction.

Protein concentration ranged from 1.15±0.13 μgg^{-1} in north to 1.54±0.06 μgg^{-1}in east direction. The values of chlorophyll degradation and protein content were minimum in north and maximum in east direction (Table-7.17). The increased level of protein in the present study, at most contaminated sites corresponds with the findings for the *Ramalina ecklonii* (González et al., 1996). LSD analysis at $p< 0.01$ level showed significant difference in chl. a, total chlorophyll, carotenoid and chlorophyll degradation at different directions, while chl. b and protein may vary significantly at the level 0.05 (Table-7.17; Fig-7.17).

In case of *B. incongruens,* chlorophyll a, chlorophyll b and total chlorophyll content similar variation in concentration in north (lowest concentration) and highest trend in chlorophyll b and total chlorophyll. Chlorophyll a ranged between (0.27±0.05 μgg^{-1} to 0.68±0.10 μgg^{-1}) while chlorophyll b and total chlorophyll were minimum concentration in north direction having values 0.22±0.01 μgg^{-1} and 0.48±0.06 μgg^{-1}

but maximum in east having values 0.31±0.07 μgg^{-1} and 1.06±0.10 μgg^{-1} respectively. Carotenoid content of *B. incongruens* was opposite to the trend of photosynthetic pigments i.e. maximum (0.53±0.07 μgg^{-1}) in north and minimum (0.42±0.01 μgg^{-1}) in west. Chlorophyll degradation concentration ranged from 0.56±0.01 μgg^{-1} in north to 1.13±0.09 μgg^{-1} in east direction. Chlorophyll content and its degradation are cheapest and most accurate methods of biomonitoring. Optical density values of pigment samples examine at 435 and 415 nm is valuable parameter for chlorophyll degradation (Garty et al., 2000). Protein content of *B. incongruens* ranged from 1.34±0.09 μgg^{-1} in west to 2.10±0.29 μgg^{-1} in south direction (Table-7.17; Fig-7.18). LSD studies showed that directions from sources of pollution (NTPC) play an important role in pigment concentration of lichen thalii and exhibit significant difference at 0.01 level in total chlorophyll and chlorophyll degradation in particular. While, only chl. a showed significant difference at $p< 0.05$ level but Chl. b, carotenoid and protein showed non-significant differences (Table-7.17; Fig-7.18).

Overall pattern for east and south direction showed more or less concentration in species *P. cocoes* while *B. incongruens* showed opposite trend in photosynthetic pigment analysis in north and west part of the study area; mostly variation in Zone b and c from the study area. Both the species of the study area having dissimilar pattern of concentration of chlorophyll a, chl.b, total chl. Photosynthetic pigment analysis varied with the direction as well as species and it showed increasing trend with the increasing distance from the thermal power plant. Levin and Pignata (1995); Silberstein et al. (1996) reported a ratio of 1.4 indicates that chlorophyll is unchanged; any reduction in this value indicates chlorophyll degradation with ensuring stress to the organism. Babula et al. (2008) concluded the tolerance mechanism adapted by plant to with still air pollution, which includes synthesis of stress metabolite and protein. In the area with fly ash dumping sites, vehicular exhausts are the main source of metals that can alter the biosynthesis of protein.

Table-7.17: Photosynthetic pigment and protein content analysis of lichens in all directions around Tanda Thermal Power Plant, Ambedkar Nagar (Appendix-IV: 7.17.1 to 7.17.12)

Directions	*P. cocoes* (concentration in μgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
East	0.40±0.05	0.16±0.04	0.56±0.09	0.40±0.04	1.08±0.04	1.54±0.06
West	0.77±0.07	0.37±0.11	1.13±0.18	0.58±0.10	1.02±0.02	1.28±0.17
North	0.59±0.02	0.23±0.01	0.82±0.03	0.22±0.14	0.70±0.02	1.36±0.16
South	0.79±0.05	0.38±0.08	1.17±0.13	0.53±0.09	1.06±0.01	1.15±0.13
CV%	7.814	24.614	12.85	22.70	2.640	10.179
LSD(p< 0.05)	0.099**	0.141*	0.237**	0.197**	0.051**	0.271*
Directions	*B. incongruens* (concentration in μgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
East	0.59±0.31	0.31±0.07	1.06±0.10	0.46±0.11	1.13±0.09	1.54±0.47
West	0.68±0.10	0.27±0.06	0.95±0.15	0.42±0.01	1.12±0.01	1.34±0.09
North	0.27±0.05	0.22±0.01	0.48±0.06	0.53±0.07	0.56±0.01	1.40±0.31
South	0.66±0.01	0.25±0.03	0.91±0.04	0.45±0.01	1.01±0.06	2.10±0.29
CV%	29.693	17.283	11.553	13.63	5.595	20.097
LSD(p< 0.05)	0.327*	0.091 NS	0.197**	0.127 NS	0.107**	0.640NS

Mean±S.D., n=3 in μgg^{-1} Fresh weight; S. D.= Standard Deviation; NS= Non-Significant
** Significance at the level of 0.01
* Significance at the level of 0.05

Table-7.18: Values of correlation matrix between the physiological parameters around Tanda Thermal Power Plant, Ambedkar Nagar

P. cocoes	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
Chl. a	1	.985*	.998**	0.595	0.072	-.958*
Chl. b		1	.994**	0.722	0.241	-0.933
Total Chl.			1	0.639	0.133	-.956*
Carotenoid				1	0.813	-0.485
Chl. deg.					1	-0.042
Protein						1
B. incongruens	**Chl. a**	**Chl. b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
Chl. a	1	0.621	0.904	-.973*	0.944	0.377
Chl. b		1	0.891	-0.598	0.842	-0.065
Total Chl.			1	-0.858	.987*	0.247
Carotenoid				1	-0.927	-0.175
Chl. deg.					1	0.19
Protein						1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

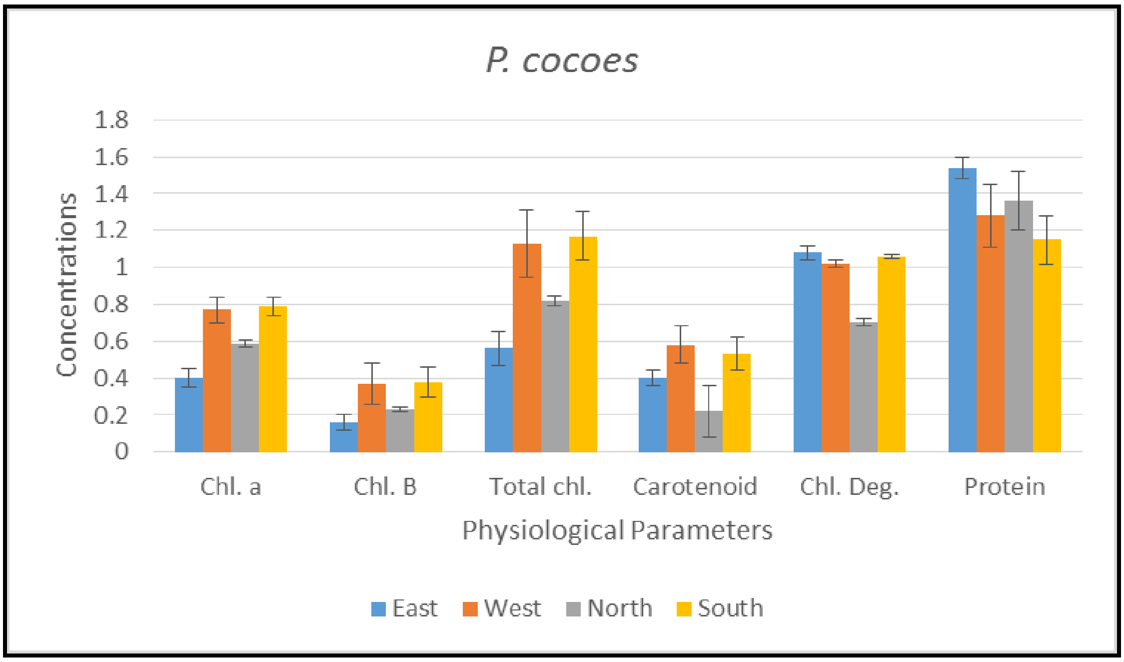


Fig-7.17: Graphical representation of photosynthetic pigments in the thalli of *P. cocoes* in all directions around Tanda Thermal Power Plant, Ambedkar Nagar

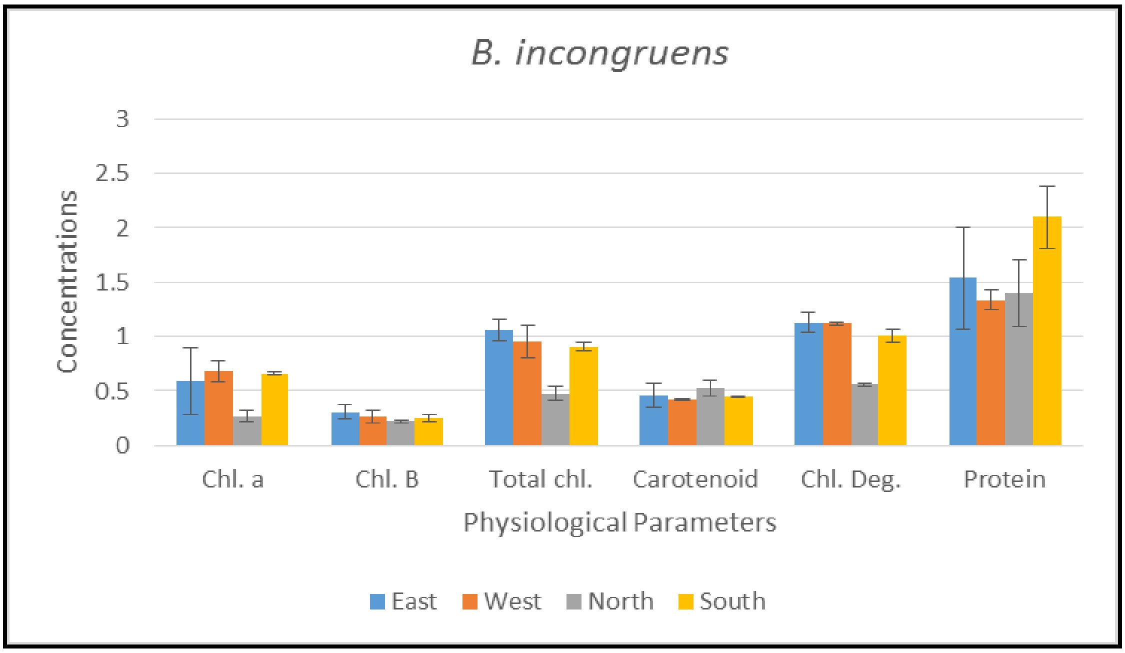


Fig-7.18: Graphical representation of photosynthetic pigments in the thalli of *B. incongruens* in all directions around Tanda Thermal Power Plant, Ambedkar Nagar

Correlations of various physiological parameters in lichen *P. cocoes* (Table-7.18) showed significant correlation (at $p<0.05$) of chlorophyll a with chlorophyll b (0.985) and negatively correlated with protein content (-0.958) while total chlorophyll content also negatively correlated with protein (-0.956). Besides that total chlorophyll showed highly significant correlations (at $p<0.01$ level) with chlorophyll a (0.998) and chlorophyll b (0.994); protein also showed the negative correlation with all physiological parameters in *P. cocoes*; whereas in *B. incongruens,* carotenoid showed negative significant correlation with chlorophyll a (-0.973) at $p<0.05$ level and negative significant with chlorophyll b (-0.598) as well as total chlorophyll (-0.858). Total chlorophyll showed significant correlation at $p<0.05$ level (0.987) while carotenoid had negatively correlated with chlorophyll degradation (-0.927). In *B. incongruens,* protein content showed negative correlation with chlorophyll b (-0.065) and carotenoid (-0.175).

7.3.4 Comparative response of metal accumulation in *P. cocoes* and *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar (Appendix-IV: 7.19.1 to 7.19.14)

The accumulation of seven metals viz; Aluminum (Al), Iron (Fe), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Zinc (Zn) were estimated in thalli of *P. cocoes* and *B. incongruens* in all directions from the thermal power plant i.e. point source.

P. cocoes showed higher total metal (180.43 $\mu g g^{-1}$) concentration in south and lowest in north (116.17$\mu g g^{-1}$) direction of the study area (Table-7.19; Fig-7.19). Among seven metals Zn was accumulated in maximum concentration followed by the decreased accumulation sequence of Al > Cu > Fe > Pb > Cr > Cd. Both the lichen species collected around thermal power plant having mixed pollution source like automobile exhausts, coal burning and pesticide application generally influenced the concentration of Al in lichen thallus (Bajpai et al., 2011). Highest Zn accumulation of le102.5±0.36 $\mu g g^{-1}$ was recorded in east and minimum 59.71±0.14 $\mu g g^{-1}$ in north that indicates settling of this metal in the south direction.

P. cocoes accumulated Al in the range between 2.47±0.20 $\mu g g^{-1}$ in east to 25.47±0.03 $\mu g g^{-1}$ in south direction while Cu had maximum accumulation (25.16±1.24 $\mu g g^{-1}$) in south and minimum in east direction (7.45±0.08 $\mu g g^{-1}$). The distance near the thermal power exhibit higher concentration of Cu than the distant locality as Cu being a larger particle metal unable to disperse in long ranges. Accumulation of Fe ranged from 10.25±0.42 $\mu g g^{-1}$ in east to 17.56±0.13 $\mu g g^{-1}$ in south direction. Lichens have an affinity with Al and Fe metals and collected both metals in higher concentration. (Loppi et al., 1998a, b).

The site in north and south exhibited Pb accumulation ranged from 8.14±0.16 $\mu g g^{-1}$ in north direction to 16.77±0.12 $\mu g g^{-1}$ in a south direction respectively and shows close similarity. The maximum level of Cr was recorded in South (19.59±0.52 $\mu g g^{-1}$) and minimum in east direction (0.56±0.03$\mu g g^{-1}$). Cd was recorded in the lowest concentration in the range of 0.98±0.09 $\mu g g^{-1}$ in west to 2.85±0.07 $\mu g g^{-1}$ in south direction. Dispersion and distribution of metals depend on wind speed and direction as well as the density of the element under consideration (Garty, 2001).

In the present study, the directional accumulation of most of the metals may be due to directional deposition of pollutants from the source of pollution and exhibited a sequence of accumulation as south > west > east > north i.e. decreasing concentration with increasing distance from the centre of the study area. The south direction of the study area exhibited higher concentration of Zn and Al metals. The probable reason for higher concentration of metals Zn and Al around thermal power plant may be due to anthropogenic activities as well as natural origin. *P. cocoes* showed more or less similar selectivity sequence of metals as Zn> Al> Cu> Fe> Pb> Cr> Cd in all the four directions, while *B. incongruens* exhibited a different sequence (Table-7.19; Fig-7.20).

Out of the four directions, samples from east have a minimum concentration of Al, Cr, Cu and Zn while south direction has the maximum concentration of most of the metals. The total metal concentration in *B. incongruens* was recorded higher in north (488.39 $\mu g g^{-1}$) and lower in south direction (336.27 $\mu g g^{-1}$). Thalli of *B. incongruens* accumulated lower concentration of Cd (0.44±0.02 $\mu g g^{-1}$) and higher accumulation of metal Fe (293.46±0.42 $\mu g g^{-1}$) in east direction followed by west, north and south direction. *B. incongruens* also exhibit the metal selectivity sequence similar to *P. cocoes* except higher concentration of Fe than Zn (Table-7.19; Fig-7.20).

Accumulation of Zn and Fe in the thalli of *P. cocoes* and *B. incongruens* respectively showed significant difference in LSD analysis at $p < 0.01$ in all directions from the thermal power plant (Table-7.19). According to Loppi et al. (1998a) and Bajpai et al. (2010a), Al and Fe are the two important metals in the earth's crust are strongly correlated in lichens and environmental contamination besides that Al also has limited metabolic significance and contamination by wind-borne soil, rock dust. Both *P. cocoes* and *B. incongruens* showed higher accumulation of Al and Fe and lower accumulation of Pb, Cr and Cd in all directions (Table-7.19). Cr and Fe are normally coupled with fly ash, which tends to fall out close to the source (Fernandez et al., 1992).

Thalli of *P. cocoes* around Tanda Thermal Power Plant accumulated more concentration in comparison of *B. incongruens.* Higher concentration of Pb and Zn around the thermal power plant may be due to the high vehicular activity involved in the disposal of coal waste. Lead (Pb) released from engine exhaust whereas other elements and Zn may be emitted by automobile tires and brake pads (Berry and Wallace, 1981; Ward, 1989) and Cr enter the surrounding environment due to metallic parts of the vehicles.

The correlation coefficients were calculated (Table-7.20) for concentration in paired element and for the element content in the lichen in different directions. The correlations (all significant at $p<0.01$ level) of Cd and Cr in both the species, Cu and Pb only in *P. cocoes*. Zinc (in *P. cocoes*) and Pb (in *B. incongruens*) had negative correlations with other elements (Table-7.20).

The level of concentration of different metal present in the lichens helped in assessment of risk to the population living in the vicinity of the power plant together with long-term hazard due to metal accumulation. The study provided an understanding about the mechanisms adopted by different growth form of lichens for bioaccumulation of metals emitted by thermal power plant and indicates that the particulate bound adsorption is the major factor responsible for bioaccumulation in lichens irrespective of their growth form.

Table-7.19: Metal accumulation in the thalli of lichens in all directions around Tanda Thermal Power Plant, Ambedkar Nagar (Appendix-IV: 7.19.1 to 7.19.14)

Directions	*P. cocoes* (concentration in µgg^{-1} dry weight)							Total metal
	Al	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**	
East	2.47±0.20	10.25±0.42	0.98±0.13	0.56±0.03	7.45±0.08	BDL	102.5±0.36	**124.21**
West	21.26±0.24	12.44±0.26	0.98±0.09	0.96±0.05	9.46±0.47	BDL	85.06±0.11	**130.16**
North	19.33±0.08	11.28±0.24	1.06±0.07	1.02±0.09	15.63±0.09	8.14±0.16	59.71±0.14	**116.17**
South	25.47±0.03	17.56±0.13	2.85±0.07	19.59±0.52	25.16±1.24	16.77±0.12	73.03±1.75	**180.43**
Total metal	**68.53**	**51.53**	**5.87**	**22.13**	**57.70**	**24.91**	**320.3**	
CV%	0.944	2.188	6.189	4.795	4.599	1.589	1.120	
LSD(p< 0.05)	0.323**	0.563**	0.182**	0.530**	1.325**	0.198**	1.791**	
Directions	***B. incongruens*** **(concentration in µgg^{-1} dry weight)**							**Total metal**
	Al	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**	
East	16.56±0.49	215.34±2.70	0.44±0.02	0.87±0.09	16.5±0.09	10.61±0.34	94.94±0.08	**355.26**
West	14.17±0.30	229.20±0.81	0.42±0.03	1.07±0.12	28.05±0.09	12.74±0.24	147.73±0.03	**433.38**
North	15.7±0.43	293.46±0.42	0.39±0.01	0.97±0.08	30.86±0.34	9.44±0.10	137.57±0.28	**488.39**
South	12.59±0.23	137.96±0.12	2.05±0.06	12.76±0.43	41.83±0.13	10.58±0.08	118.5±0.35	**336.27**
Total metal	**59.02**	**875.96**	**3.3**	**15.67**	**117.24**	**43.37**	**498.74**	
CV%	2.567	0.650	3.974	5.867	1.876	2.021	0.181	
LSD(p<0.05)	0.757**	2.842**	0.065**	0.459**	0.388**	0.438**	0.450**	

Mean±S.D., n=3 in µgg^{-1} dry weight; S. D.= Standard Deviation

** Significance at the level of 0.01

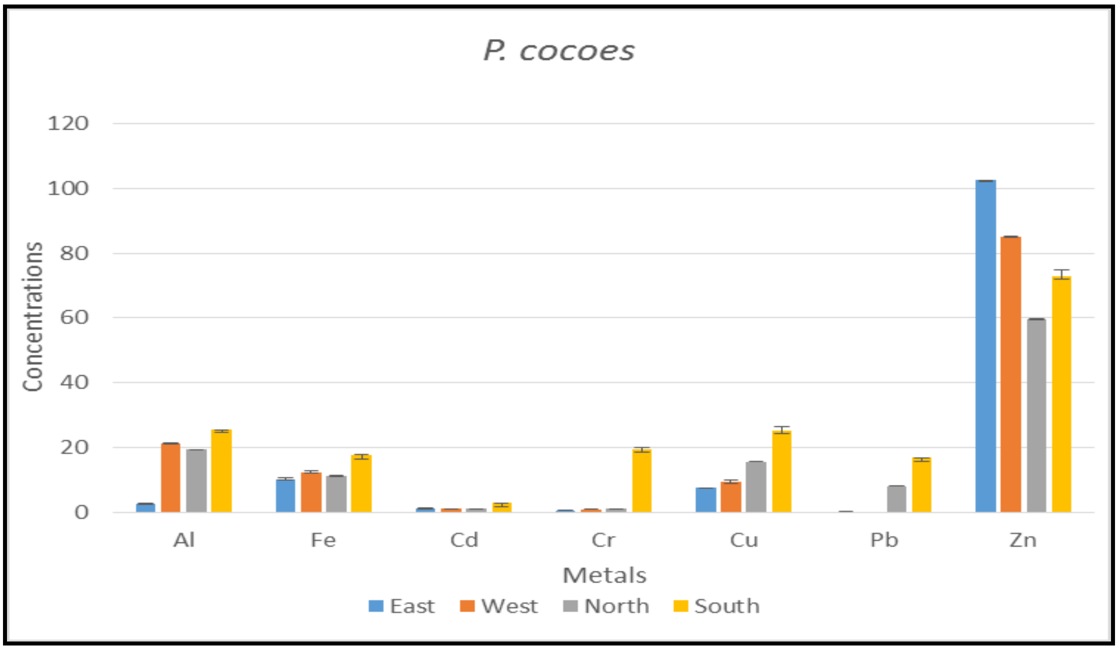


Fig-7.19: Graphical representation of metal accumulation in the thalli of *P. cocoes* in all directions around Tanda Thermal Power Plant, Ambedkar Nagar

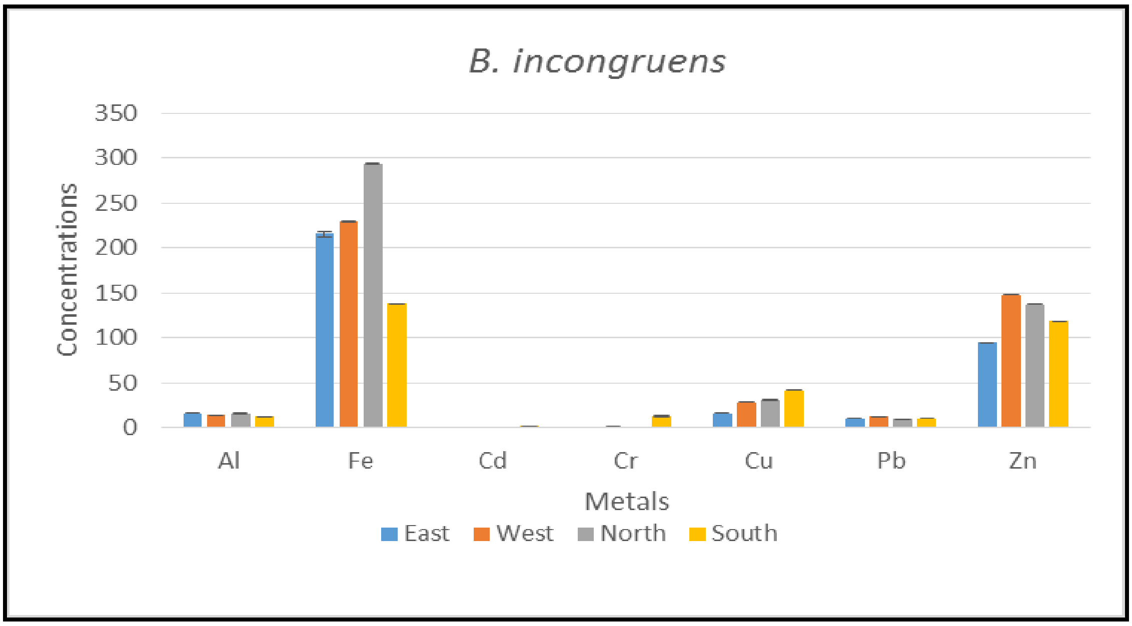


Fig-7.20: Graphical representation of metal accumulation in the thalli of *B. incongruens* in all directions around Tanda Thermal Power Plant, Ambedkar Nagar

Table-7.20: Values of correlation matrix between the elements around Tanda Thermal Power Plant, Ambedkar Nagar

P. cocoes	**Al**	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Al	1	0.735	0.564	0.568	0.721	0.65	-0.747
Fe		1	.960*	.966*	0.889	0.839	-0.348
Cd			1	.999**	0.916	0.897	-0.294
Cr				1	0.906	0.884	-0.277
Cu					1	.993**	-0.648
Pb						1	-0.65
Zn							1
B. incongruens	**Al**	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Al	1	0.696	-0.821	-0.833	-0.879	-0.316	-0.341
Fe		1	-0.859	-0.845	-0.434	-0.239	0.405
Cd			1	.999**	0.788	-0.116	-0.194
Cr				1	0.808	-0.118	-0.165
Cu					1	-0.113	0.406
Pb						1	0.356
Zn							1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

7.4 Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli had moderate lichen diversity in comparison to Panki and Tanda Thermal Power Plants. The study area showed occurrence of 18 epiphytic lichen species belonging to 12 genera and 10 families found growing at 80 monitoring sites upto a distance of 21 km in all directions of Feroze Gandhi Unchahar National Thermal Power Plant Corporation (Table-7.21 & 7.22; Fig-7.21; Plate-7.3 & 7.4). Several species of lichens i.e. *Anisomeridium nidulans* (Müll. Arg.) R.C. Harris; *Bacidia incongruens* (Stirton) Zahlbr.; *B. medialis* (Tuck. ex. Nyl.) Zahlbr.; *B. rubella* (Hoffm.) A. Massal.; *B. submedialis* (Nyl.) Zahlbr.; *Caloplaca bassiae* (Willd. ex. Ach.) Zahlbr.; *Dirinaria consimilis* (Stirton.) D. D. Awasthi; *Hyperphyscia adglutinata* var. adglutinata (Flörke) H. Mayrhofer & Poelt; *Lecanora achroa* Nyl. In J. M. Crombie; *L. tropica* Zahlbr.; *L. helva* Stizenb., *Opegrapha astraea* Tuck.; *Peltula corticola* Büdel & R. Sant; *Pertusaria quassiae* (Fée.) Nyl.; *Pyxine cocoes* (Sw.) Nyl.; *P. sorediata* (Ach.) Mont.; *Rinodina sophodes* (Ach.) A. Massal. and *Strigula elegans* (Fée) Müll. Arg. were recorded around the study area from all the directions (Table-7.23; Fig-7.21 & 7.22; Plate-7.3 & 7.4).

Among all the species, *Pyxine sorediata* (Ach.) Mont. species was new addition to lichen flora of Uttar Pradesh. The three lichen species i.e. *B. incongruens, P. cocoes* and *R. sophodes* showed their dominance over other species in the area surveyed. The bark of *Mangifera indica* (Mango), *Acacia nilotica* (babool) and *Azadirachta indica* (Neem) were the common substrate for growth and development of lichen species.

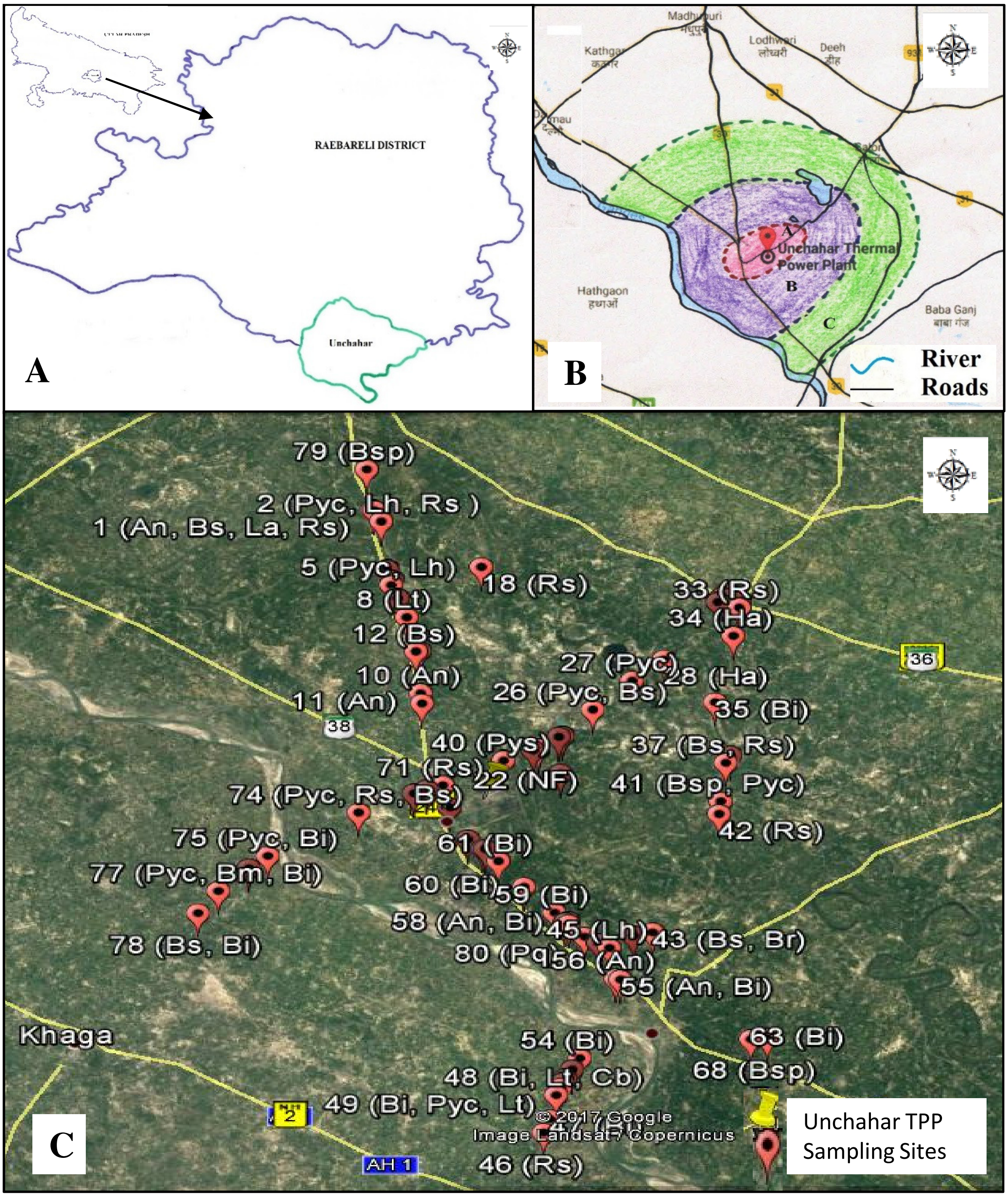


Plate-7.3: Feroze Gandhi Unchahar Thermal Power Plant Corporation (FGUTPPC), Raebareli: (A) Uttar Pradesh Region Showing Raebareli district; (B) Zone Map showing distribution pattern of lichen taxa around FGUTPPC, Raebareli: Zone A: Poor lichen growth- Polluted; Zone B: Moderate lichen growth- Moderate Pollution; Zone C: Normal lichen growth- More or less Pollution free area; (C) Lichen Distribution Map around FGUTPPC, Raebareli (refer Table- 7.21 & 7.22) (Source: Google Earth)

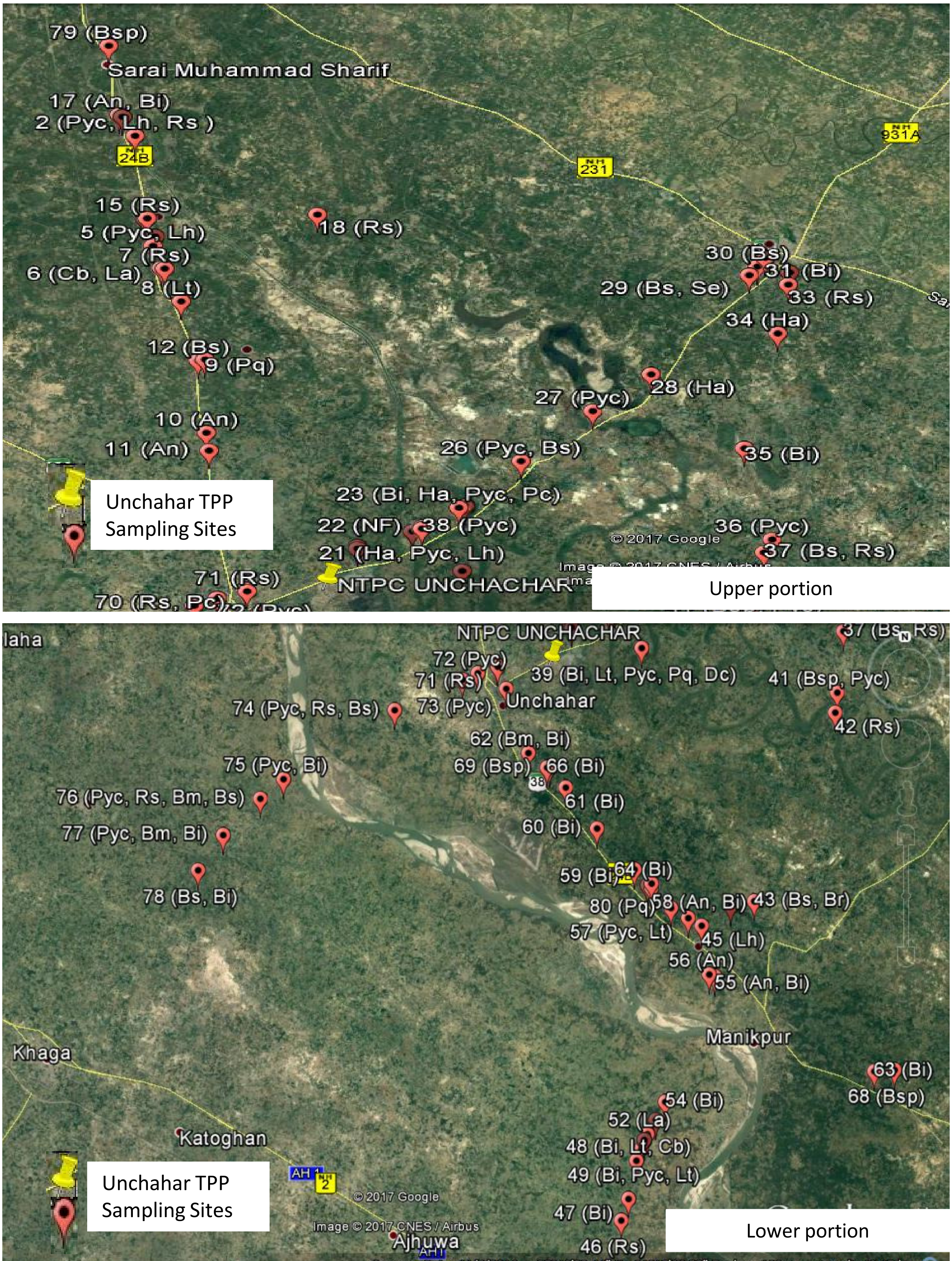


Plate-7.4: Lichen Distribution Map around Feroze Gandhi Unchahar Thermal Power Plant Corporation (FGUTPPC), Raebareli: (A) Upper Portion; (B) Lower Portion (refer Table- 7.21 & 7.22) (Source: Google Earth)

Table-7.21: Localities surveyed for collection of lichens around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli, Uttar Pradesh

Feroze Gandhi Unchahar Thermal Power Plant Corporations, Raebareli					
S. No.	**Localities**	**Latitude (N)**	**Longitude (E)**	**Altitude**	**Sp. Occ.**
1	near Nababganj, Sanhoo Kuwan	26°04'25.0"	81°16'08.3"	89 m	An, Bs, La, Rs
2	Bhikh, Jog magdipur	26°04'00.7"	81°16'20.1"	85 m	Pyc, Lh, Rs
3	Bairihat	26°01'54.6"	81°16'31.4"	92 m	Rs
4	Bairihat	26°01'53.8"	81°16'35.9"	84 m	Rs
5	Rojhaia Gokulpur	26°01'42.2"	81°16'33.3"	87 m	Pyc, Lh
6	Rojhaia Gokulpur	26°01'14.1"	81°16'40.9"	90 m	Cb, La
7	Rojhaia Gokulpur	26°01'13.2"	81°16'44.2"	95 m	Rs
8	Itaura buzurg	26°00'31.6"	81°16'59.4"	102 m	Lt
9	Itaura buzurg near chandrai	25°59'18.0"	81°17'20.9"	100 m	Pq
10	near bhagipur,sarain tula ram	25°57'46.3"	81°17'18.9"	97 m	An
11	Sarain tula ram near gopapur	25°57'23.8"	81°17'20.8"	98 m	An
12	Chandrai	25°59'17.0"	81°17'13.9"	111 m	Bs
13	Bhikh, Harjanpurwa village	26°04'27.7"	81°16'05.2"	75.8 m	La, Pc, Rs
14	Taghan near Ganganahar	26°02'16.1"	81°16'26.5"	97.4 m	Rs
15	Taghan near Ganganahar	26°02'16.8"	81°16'28.8"	99 m	Rs
16	Bairihat around 21 km	26°02.273'	81°16.453	105 m	Rs, Pc
17	Sanhoo kuwan, thana-bhadokhar, harjanpurwa	26°04'27.8"	81°16'04.9"	98.7 m	An, Bi
18	Harpur halla	26°02'16.2"	81°19'21.9"	97 m	Rs
19	Manirampur	25°55'19.3"	81°19'46.8"	94 m	Bi, Oa
20	Raghunathpur paterwa	25°55'36.5"	81°20'43.2"	99 m	An,Pyc,Rs,Pc
21	near raghunathpur paterwa	25°55'39.4"	81°20'53.1"	98 m	Ha, Pyc, Lh
22	near raghunathpur paterwa	25°55'41.2"	81°20'52.7"	94 m	NF
23	Umaran	25°56'04.5"	81°21'31.4"	100 m	Bi, Ha, Pyc, Pc
24	near umaran	25°56'05.7"	81°21'38.6"	100 m	Pyc, Rs
25	Umaran	25°56'06.7"	81°21'37.4"	92 m	Bi, Ha
26	Umaran near hanumant nagar	25°57'00.8"	81°22'36.6"	106 m	Pyc, Bs
27	Paksrawan near	25°58'01.3"	81°23'51.8"	103 m	Pyc

	usraina				
28	Samaspur khalsa	25°58'45.4"	81°24'52.7"	95 m	Ha
29	Salon near bhawanipur	26°00'46.5"	81°26'37.1"	92 m	Bs, Se
30	near salon bazar	26°00'57.1"	81°26'45.9"	96 m	Bs
31	Salon dehat near meta merauli	26°01'07.7"	81°26'54.2"	89 m	Bi
32	near Amarupur	26°00'48.5"	81°27'18.2"	92 m	Bi, Rs
33	Amarupur	26°00'33.4"	81°27'16.3"	95 m	Rs
34	Mohammabad	25°59'32.6"	81°27'03.1"	100 m	Ha
35	Autahiya	25°57'09.8"	81°26'23.6"	97 m	Bi
36	Lawana	25°55'14.7"	81°26'47.3"	91 m	Pyc
37	near Lawana	25°54'58.7"	81°26'38.4"	89 m	Bs, Rs
38	near raghunathpur paterwa	25°55.693'	81°20.894'	103m	Pyc
39	Umaran (5-10 km)	25°56.075'	81°21.527'	101m	Bi, Lt, Pyc, Pq, Dc
40	Manirampur (0-5 km)	25°55.273'	81°19.781'	111m	Pys
41	Chandapur	25°53'35.3"	81°26'25.7"	89 m	Bsp, Pyc
42	near chandapur	25°53'08.2"	81°26'21.5"	102 m	Rs
43	Lalaganj- kalakanpur road, rampur garauli near Barabigah	25°48'55.1"	81°24'08.5"	94 m	Bs, Br
44	Lalaganj- kalakanpur road, rampur garauli near ramnagar	25°48'49.6"	81°23'32.7"	114 m	Bs
45	Lalaganj- kalakanpur road, rampur garauli near	25°48'24.2"	81°22'47.6"	125 m	Lh
46	Ganga bridge road, sultanpur khwaja karak	25°41'47.2"	81°20'30.5"	88 m	Rs
47	Ganga bridge road, sultanpur khwaja karak	25°42'16.1"	81°20'42.7"	90 m	Bi
48	Bihamidpur, deviganj	25°43'07.7"	81°20'56.6"	86 m	Bi, Lt, Cb
49	Ganga bridge road, sounrai buzurg	25°43'24.0"	81°21'05.0"	89 m	Bi, Pyc, Lt
50	Ganga bridge road, girdharpur garhi	25°43'34.6"	81°21'09.4"	95 m	Lt, Pyc
51	Ganga bridge road, girdharpur garhi	25°43'35.5"	81°21'09.6"	94 m	An, Bi
52	Ganga bridge road, girdharpur garhi	25°43'43.2"	81°21'14.6"	90 m	La
53	Girdharpur garhi, ujiyari gaon	25°44'02.2"	81°21'28.1"	97 m	Pyc, La, Bm
54	Girdharpur garhi, bharpuwa	25°44'26.2"	81°21'43.4"	95 m	Bi

55	Manikpur near retahi	25°47'14.7"	81°23'04.9"	100 m	An, Bi
56	Manikpur near sangrampur	25°47'17.5"	81°22'56.5"	90 m	An
57	Allahabad Lucknow road, alapur	25°48'35.3"	81°22'27.8"	105 m	Pyc, Lt
58	Allahabad Lucknow road,ahmedganj	25°49'17.8"	81°21'33.8"	104 m	An, Bi
59	Allahabad Lucknow road, milikpur ahtimali	25°49'43.8"	81°21'09.0"	96 m	Bi
60	Allahabad Lucknow road, barauliya yakuvpur	25°50'41.4"	81°20'14.5"	97 m	Bi
61	Bramhauli	25°51'38.6"	81°19'29.3"	95 m	Bi
62	near arkha mustakil	25°52'27.4"	81°18'34.6"	105 m	Bm, Bi
63	Baharamaee	25°44'57.9"	81°27'01.1"	128 m	Bi
64	Ahmadganj	25°49'24.0"	81°21'34.1"	93 m	Bi
65	Ahmedganj, murrassapur vill., bariyawan	25°49'21.8"	81°21'27.8"	100 m	An
66	Allahabad - lucknow Rd, Arkha Mustakil	25°52'06.6"	81°19'02.2"	92 m	Bi
67	Arkha Mustakil, 0-5 km	25°52'06.1"	81°19'06.1"	97 m	Bi, Bsp
68	Matehullapur village	25°44'58.7"	81°27'31.8"	91 m	Bsp
69	Arkha Mustail (0-10)	25°52'06.5"	81°19'01.3"	95 m	Bsp
70	Ashok Nagar around 0-5 km	25°54'28.9"	81°17'51.0"	98m	Rs, Pc
71	near NTPC (0-2 km)	25°54'26.3"	81°17'52.7"	117 m	Rs
72	near NTPC (0-5 km)	25°54'18.4"	81°17'22.2"	200 m	Pyc
73	Unchahar dehat near Mustafabad	25°54'10.1"	81°16'58.4"		Pyc
74	Kand Rawan	25°53'31.9"	81°15'14.4"		Pyc, Rs, Bs
75	Baigaon	25°52'03.0"	81°12'22.7"		Pyc, Bi
76	Allipurbahera	25°51'37.4"	81°11'46.7"		Pyc, Rs, Bm, Bs
77	Gaidhemau	25°50'49.6"	81°10'48.7"		Pyc, Bm, Bi
78	Airayan sadat	25°50'02.8"	81°10'09.1"		Bs, Bi
79	Saray mohammad sarif	26°05'54.6"	81°15'57.4"		Bsp
80	Allahabad-lucknow road, Jagroop Nagar	25°48'49.8"	81°22'02.3"	104 m	Pq

An= *Anisomeridium nidulans;* Bi= *Bacidia incongruens;* Bm= *Bacidia medialis;* Br= *Bacidia rubella;* Bs= *Bacidia submedialis;* Bsp= *Bacidia* sp.; Cb= *Caloplaca bassiae;* Dc= *Dirinaria consimilis;* Ha= *Hyperphyscia adglutinata;* La= *Lecanora achroa;* Lh= *Lecanora helva;* Lt= *Lecanora tropica*; Oa= *Opegrapha astraea*; Pc= *Peltula corticola;* Pq= *Pertusaria quassiae;* Pyc= *Pyxine cocoes;* Pys= *Pyxine sorediata;* Rs= *Rinodina sophodes;* Se= *Strigula elegans;* NF= Not Found; Sp. Occ.= Species Occurred

Table-7.22: List of lichen taxa observed around Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

Name of Species	Family	Localities	Substrate	Field No.	Accession No.
		EAST DIRECTION			
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	manirampur	on *Mangifera indica* bark	016-031744	34725
Opegrapha astraea Tuck.	Opegraphaceae	manirampur	on *Mangifera indica* bark	016-029731	35492
Anisomeridium nidulans (Müll. Arg.) R. C. Harris	Monoblastiaceae	raghunathpur paterwa	on *Mangifera indica* bark	016-031746	34726
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	raghunathpur paterwa	on *Mangifera indica* bark	016-031747	34740
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	raghunathpur paterwa	on *Mangifera indica* bark	016-031745	34727
Hyperphyscia adglutinata var. adglutinata (Flörke) H. Mayrhofer & Poelt	Physciaceae	near raghunathpur paterwa	on *Mangifera indica* bark	016-031749	34741
Peltula corticola Büdel &R. Sant.	Peltulaceae	near raghunathpur paterwa	on *Mangifera indica* bark	016-031750	34728
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	near raghunathpur paterwa	on *Mangifera indica* bark	016-031751	34742
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near raghunathpur paterwa	on *Mangifera indica* bark	016-031748	34729
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	near raghunathpur paterwa	on *Mangifera indica* bark	016-031752	34730
Lecanora helva Stizenb.	Lecanoraceae	near raghunathpur paterwa	on *Mangifera indica* bark	016-029729	35489
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	umaran	on *Mangifera indica* bark	016-031753	34743

Hyperphyscia adglutinata var. adglutinata (Flörke) H. Mayrhofer & Poelt	Physciaceae	umaran	on *Mangifera indica* bark	016-031754	34744
Peltula corticola Büdel &R. Sant.	Peltulaceae	umaran	on *Mangifera indica* bark	016-031755	34745
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	umaran	on *Mangifera indica* bark	016-031756	34770
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	near umaran	on *Mangifera indica* bark	016-031757	34769
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near umaran	on *Mangifera indica* bark	016-031758	34746
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	umaran	on *Mangifera indica* bark	016-031759	34747
Hyperphyscia adglutinata var. adglutinata (Flörke) H. Mayrhofer & Poelt	Physciaceae	umaran	on *Mangifera indica* bark	016-031760	34748
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	umaran near hanumant nagar	on *Mangifera indica* bark	016-031762	34749
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	umaran near hanumant nagar	on *Mangifera indica* bark	016-029720	34907
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	paksrawan near usraina	on *Mangifera indica* bark	016-031761	34750
Hyperphyscia adglutinata var. adglutinata (Flörke) H. Mayrhofer & Poelt	Physciaceae	samaspur khalsa	on *Mangifera indica* bark	016-031763	34751
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	salon near bhawanipur	on *Mangifera indica* leaves	016-031764	34752
Strigula elegans (Fée) Müll. Arg.	Strigulaceae	salon near bhawanipur	on *Mangifera indica* leaves	016-031765	34753
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	near salon bazar	on *Mangifera indica* leaves	016-031766	34754
Bacidia incongruens	Ramalinaceae	Salon dehat near meta	on *Mangifera indica* bark	016-031768	34737

(Stirton) Zahlbr.		merauli			
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	near Amarupur	on *Mangifera indica* bark	016-031767	34731
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near Amarupur	on *Mangifera indica* bark	016-031769	34732
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Amarupur	on *Mangifera indica* bark	016-031770	34733
Hyperphyscia adglutinata var. adglutinata (Flörke) H. Mayrhofer & Poelt	Physciaceae	Mohammabad	on *Mangifera indica* bark	016-031771	34734
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Autahiya	on *Mangifera indica* bark	016-031772	34739
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Lawana	on *Mangifera indica* bark	016-031773	34738
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	near Lawana	on *Mangifera indica* bark	016-031774	34735
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near Lawana	on *Mangifera indica* bark	016-031775	34736
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	near raghunathpur paterwa	on bark	013-023712	11998
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	umaran (5-10kms)	on *Mangifera indica* bark	013-023713	11996
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	umaran (5-10kms)	on *Mangifera indica* bark	013-023710	12000
Lecanora tropica Zahlbr.	Lecanoraceae	umaran (5-10kms)	on *Mangifera indica* bark	013-023715	11993
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	umaran (5-10kms)	on *Mangifera indica* bark	013-023714	11995
Pyxine sorediata (Ach.) Mont.	Caliciaceae	manirampur (0-5Kms)	on *Mangifera indica* bark	013-023711	11999
Pertusaria quassiae (Fée.) Nyl.	Pertusariaceae	Umran (5-10 km)	on *Mangifera indica* bark	013-023716	11992

Pyxine cocoes (Sw.) Nyl.+ *Dirinaria consimilis* (Stirton.) D. D. Awasthi	Caliciaceae	Umran (5-10 km)	on *Mangifera indica* bark	013-023717	11997
WEST DIRECTION					
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	ashok nagar around 0-5 km	on *Acacia nilotica* bark (babool)	013-023707	11994
Rinodina sophodes (Ach.) A. Massal. + *Peltula corticola* Büdel & R. Sant.	Physciaceae + Peltulaceae	ashok nagar around 0-5 km	on *Acacia nilotica* bark (babool)	013-023708	12003
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	ashok nagar around 0-5 km	on *Azadirachta indica* bark	013-023709	12001
Peltula corticola Büdel & R. Sant.	Peltulaceae	ashok nagar around 0-5 km	on bark	013-023733	32848
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near ntpc (0-2kms)	on bark	013-023729	32611
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near ntpc (0-2kms)	on bark	013-023730	32610
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	near ntpc (0-5kms)	on *Mangifera indica* bark	016-029704	34806
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	unchahar dehat near Mustafabad	on *Mangifera indica* bark	016-029705	34807
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	kand rawan	on *Mangifera indica* bark	016-029706	34801
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	kand rawan	on *Mangifera indica* bark	016-029707	34812
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	kand rawan	on *Mangifera indica* bark	016-029708	34808
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Baigaon	on *Mangifera indica* bark	016-029709	34771
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Baigaon	on *Mangifera indica* bark	016-029710	34809
Bacidia submedialis (Nyl.)	Ramalinaceae	Allipurbahera	on *Mangifera indica* bark	016-029711	34802

Zahlbr.					
Bacidia medialis (Tuck. Ex Nyl.) Zahlbr.	Ramalinaceae	Allipurbahera	on *Mangifera indica* bark	016-029722	34905
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Allipurbahera	on *Mangifera indica* bark	016-029712	34810
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Allipurbahera	on bark	013-023735	32624
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Gaidhemau	on *Mangifera indica* bark	016-029713	34803
Bacidia medialis (Tuck. Ex Nyl.) Zahlbr.	Ramalinaceae	Gaidhemau	on *Mangifera indica* bark	016-029719	34908
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Gaidhemau	on *Mangifera indica* bark	016-029714	34811
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Airayan sadat	on *Mangifera indica* bark	016-029715	34804
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	Airayan sadat	on *Mangifera indica* bark	016-029716	34805
Bacidia medialis (Tuck. Ex Nyl.) Zahlbr. + *B. incongruens* (Stirton) Zahlbr.	Ramalinaceae	near arkha mustakil	on *Mangifera indica* bark	016-029703	12006
NORTH DIRECTION					
Anisomeridium nidulans (Müll. Arg.) R.C.Harris	Monoblastiaceae	near Nababganj, Sanhoo Kuwan	on *Mangifera indica* bark	016-031727	34708
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	near Nababganj, Sanhoo Kuwan	on *Mangifera indica* bark	016-031728	34710
Lecanora achroa Nyl. In J.M. Crombie	Leacanoraceae	near Nababganj, Sanhoo Kuwan	on *Mangifera indica* bark	016-031729	34711
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near Nababganj, Sanhoo Kuwan	on *Mangifera indica* bark	016-031730	34712
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Bhikh, Jog magdipur	on *Mangifera indica* bark	016-031731	34713
Lecanora helva Stizenb.	Leacanoraceae	Bhikh, Jog magdipur	on *Mangifera indica* bark	016-029724	35484

Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Bhikh, Jog magdipur	on *Mangifera indica* bark	016-031732	34714
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Bairihat	on *Mangifera indica* bark	016-031733	34715
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Bairihat	on *Mangifera indica* bark	016-031734	34716
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Rojhaia Gokulpur	on *Mangifera indica* bark	016-031735	34717
Lecanora helva Stizenb.	Leacanoraceae	Rojhaia Gokulpur	on *Mangifera indica* bark	016-029723	35485
Caloplaca bassiae (Willd.ex.Ach.) Zahlbr.	Teloschistaceae	Rojhaia Gokulpur	on *Mangifera indica* bark	016-031736	34718
Lecanora achroa Nyl. In J.M. Crombie	Leacanoraceae	Rojhaia Gokulpur	on *Mangifera indica* bark	016-031737	34719
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Rojhaia Gokulpur	on *Mangifera indica* bark	016-031738	34720
Lecanora tropica Zahlbr.	Leacanoraceae	itaura buzurg	on *Mangifera indica* bark	016-031739	34721
Pertusaria quassiae (Fée.) Nyl.	Pertusariaceae	itaura buzurg near chandrai	on *Mangifera indica* bark	016-031740	34722
Anisomeridium nidulans (Müll. Arg.) R.C.Harris	Monoblastiaceae	near bhagipur,sarain tula ram	on *Mangifera indica* bark	016-031741	34723
Anisomeridium nidulans (Müll. Arg.) R.C.Harris	Monoblastiaceae	sarain tula ram near gopapur	on *Mangifera indica* bark	016-031742	34724
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	chandrai	on *Mangifera indica* bark	016-031743	34709
Lecanora achroa Nyl. In J.M. Crombie	Leacanoraceae	Bhikh, Harjanpurwa village	on *Mangifera indica* bark	013-023702	12007
Peltula corticola Büdel & R. Sant.	Peltulaceae	Bhikh, Harjanpurwa village	on *Mangifera indica* bark	013-023732	32609
Peltula corticola Büdel & R. Sant.	Peltulaceae	Bhikh, Harjanpurwa village	on *Mangifera indica* bark	013-023734	32622

Rinodina sophodes (Ach.) A. Massal.	Physciaceae	Bhikh, Harjanpurwa village	on *Mangifera indica* bark	013-023727	32613
Rinodina sophodes (Ach.) A. Massal. + *Peltula corticola* Büdel & R. Sant.	Physciaceae + Peltulaceae	Bhikh, Harjanpurwa village	on *Mangifera indica* bark	013-023731	32608
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	taghan near ganganahar	on *Azadirachta indica* bark	013-023722	32623
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	taghan near ganganahar	on bark	013-023701	12008
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	bairihat around 21 kms	on bark	013-023706	12002
Rinodina sophodes (Ach.) A. Massal.+*Peltula corticola* Büdel & R. Sant	Physciaceae + Peltulaceae	bairihat around 21 kms	on bark	013-023705	12004
Rinodina sophodes(Ach.) A. Massal.	Physciaceae	bairihat around 21 kms	on *Azadirachta indica* (bark)	013-023704	12005
Anisomeridium nidulans (Müll. Arg.) R.C.Harris	Monoblastiaceae	sanhoo kuwan, thana-bhadokhar, harjanpurwa	on *Mangifera indica* bark	013-023725	32620
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	sanhoo kuwan, thana-bhadokhar, harjanpurwa	on *Mangifera indica* bark	016-029718	34773
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	harpur halla	on *Acacia nilotica* bark (babool)	013-023719	32616
SOUTH DIRECTION					
Bacidia sp.	Ramalinaceae	chandapur	on *Mangifera indica* bark	016-031776	34778
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	chandapur	on *Mangifera indica* bark	016-031777	34796
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	near chandapur	on *Mangifera indica* bark	016-031778	34772
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	lalaganj- kalakanpur road, rampur garauli	on *Artocarpous heterophyllus* bark	016-031779	34790

		near Barabigah			
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	lalaganj- kalakanpur road, rampur garauli near Barabigah	on *Mangifera indica* bark	016-031780	34791
Bacidia rubella (Hoffm.) A. Massal.	Ramalinaceae	lalaganj- kalakanpur road, rampur garauli near Barabigah	on *Mangifera indica* bark	016-029721	34906
Bacidia submedialis (Nyl.) Zahlbr.	Ramalinaceae	lalaganj- kalakanpur road, rampur garauli near ramnagar	on *Mangifera indica* bark	016-031781	34792
Lecanora helva Stizenb.	Leacanoraceae	lalaganj- kalakanpur road, pariyawan	on *Artocarpous heterophyllus* bark	016-029725	35486
Rinodina sophodes (Ach.) A. Massal.	Physciaceae	ganga bridge road, sultanpur khwaja karak	on *Mangifera indica* bark	016-031782	34800
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	ganga bridge road, sultanpur khwaja karak	on *Mangifera indica* bark	016-031783	34782
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	bihamidpur, deviganj	on *Mangifera indica* bark	016-031784	34783
Lecanora tropica Zahlbr.	Leacanoraceae	bihamidpur, deviganj	on *Mangifera indica* bark	016-029727	35490
Caloplaca bassiae (Willd. ex. Ach.) Zahlbr.	Teloschitaceae	bihamidpur, deviganj	on *Mangifera indica* bark	016-029730	35491
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	ganga bridge road, sounrai buzurg	on *Mangifera indica* bark	016-031786	34784
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	ganga bridge road, sounrai buzurg	on *Mangifera indica* bark	016-031785	34797
Lecanora tropica Zahlbr.	Leacanoraceae	ganga bridge road, sounrai buzurg	on *Mangifera indica* bark	016-029728	35487
Lecanora tropica Zahlbr.	Lecanoraceae	ganga bridge road, girdharpur garhi	on *Mangifera indica* bark	016-031787	34795

Pyxine cocoes (Sw.) Nyl.	Caliciaceae	ganga bridge road, girdharpur garhi	on *Mangifera indica* bark	016-031788	34798
Anisomeridium nidulans (Müll. Arg.) R. C. Harris	Monoblastiaceae	ganga bridge road, girdharpur garhi	on *Mangifera indica* bark	016-031789	34774
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	ganga bridge road, girdharpur garhi	on *Mangifera indica* bark	016-031790	34785
Lecanora achora Nyl.in J. M. Crombie	Lecanoraceae	ganga bridge road, girdharpur garhi	on *Mangifera indica* bark	016-031791	34794
Pyxine cocoes (Sw.) Nyl. + *Lecanora achroa* Nyl. In J. M. Crombie	Caliciaceae + Lecanoraceae	girdharpur garhi, ujiyari gaon	on *Mangifera indica* bark	016-031792	34793
Bacidia medialis (Tuck. Ex Nyl.) Zahlbr.	Ramalinaceae	girdharpur garhi, ujiyari gaon	on *Mangifera indica* bark	016-029717	34909
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	girdharpur garhi, bharpuwa	on *Mangifera indica* bark	016-031793	34786
Anisomeridium nidulans (Müll. Arg.) R. C. Harris	Monoblastiaceae	manikpur near retahi	on *Mangifera indica* bark	016-031794	34775
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	manikpur near retahi	on *Mangifera indica* bark	016-031795	34787
Anisomeridium nidulans (Müll. Arg.) R. C. Harris	Monoblastiaceae	manikpur near sangrampur	on *Mangifera indica* bark	016-031796	34776
Pyxine cocoes (Sw.) Nyl.	Caliciaceae	Allahabad Lucknow road, alapur	on *Mangifera indica* bark	016-031797	34799
Lecanora tropica Zahlbr.	Leacanoraceae	Allahabad Lucknow road, alapur	on *Mangifera indica* bark	016-029726	1. 35 488
Anisomeridium nidulans (Müll. Arg.) R. C. Harris	Monoblastiaceae	Allahabad Lucknow road,ahmedganj	on *Mangifera indica* bark	016-031798	34777
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Allahabad Lucknow road,ahmedganj	on *Mangifera indica* bark	016-031799	34788

Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Allahabad Lucknow road, milikpur ahtimali	on *Mangifera indica* bark	016-031800	34789
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Allahabad Lucknow road, barauliya yakuvpur	on *Mangifera indica* bark	016-029701	34779
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	bramhauli	on *Mangifera indica* bark	016-029702	34780
Bacidia medialis (Tuck. Ex Nyl.) Zahlbr. + *Bacidia incongruens* (Stirton) Zahlbr.	Ramalinaceae	near arkha mustakil	on *Mangifera indica* bark	016-029703	34781
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	baharamaee	on *Mangifera indica* bark	013-023736	32625
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	ahmadganj	on *Mangifera indica* bark	013-023718	32626
Anisomeridium nidulans (Müll. Arg.) R. C. Harris	Monoblastiaceae	ahmedganj, murrassapur vill., bariyawan	on *Mangifera indica* bark	013-023724	32619
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Allahabad - lucknow Rd, Arkha Mustakil	on *Mangifera indica* bark	013-023737	32621
Bacidia incongruens (Stirton) Zahlbr.	Ramalinaceae	Arkha Mustakil, 0-5kms	on *Mangifera indica* bark	013-023728	32612
Bacidia sp.	Ramalinaceae	matehullapur village	on *Mangifera indica* bark	013-023721	32617
Bacidia sp.	Ramalinaceae	matehullapur village	on *Mangifera indica* bark	013-023726	32614
Bacidia sp.	Ramalinaceae	Arkha Mustail (0-10)	on *Mangifera indica* bark	013-023720	32615
Bacidia sp.	Ramalinaceae	girdharpur garhi, ujiyari gaon	on *Mangifera indica* bark	013-023723	32618
Bacidia sp.	Ramalinaceae	Saray mohammad sarif	on bark	013-023703	12006
Pertusaria quassiae (Fée.) Nyl.	Pertusariaceae	Allahabad - lucknow Rd, Jagroop Nagar	on *Mangifera indica* bark	016-029732	35493

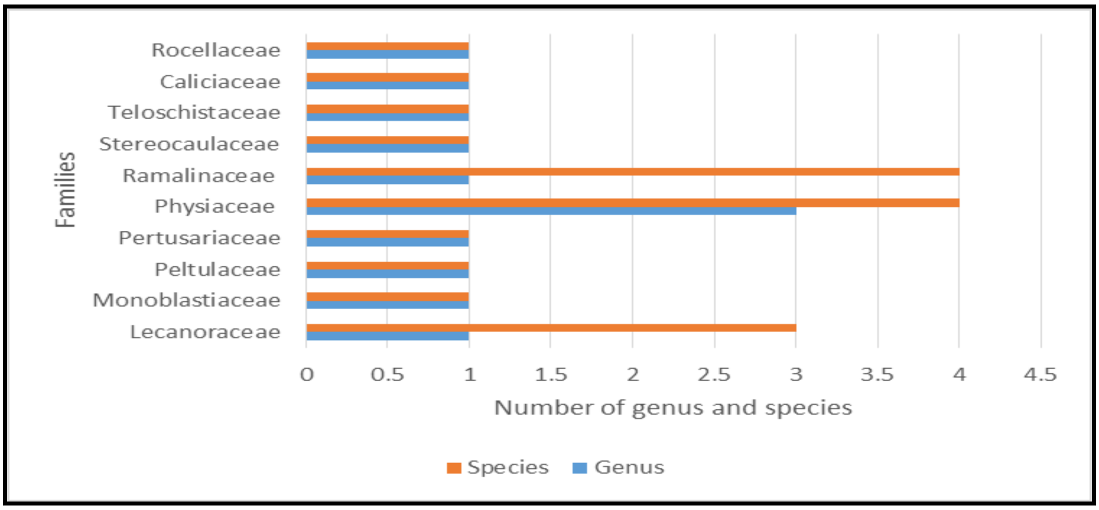


Fig-7.21: Representation of all the lichens recorded around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Table-7.23: Comprehensive list of all the lichens recorded around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

S. No.	Family	Genus	Species
1	Lecanoraceae	*Lecanora*	*Lecanora achroa* Nyl. In J. M. Crombie *Lecanora tropica* Zahlbr. *Lecanora helva* Stizenb.
2	Monoblastiaceae	*Anisomeridium*	*Anisomeridium nidulans* (Müll. Arg.) R.C.Harris
3	Peltulaceae	*Peltula*	*Peltula corticola* Büdel & R. Sant
4	Pertusariaceae	*Pertusaria*	*Pertusaria quassiae* (Fée.) Nyl.
5	Physiaceae	*Hyperphyscia*	*Hyperphyscia adglutinata* var. adglutinata (Flörke) H. Mayrhofer & Poelt
		Rinodina	*Rinodina sophodes* (Ach.) A. Massal.
6	Caliciaceae	*Pyxine*	*Pyxine cocoes* (Sw.) Nyl. ***Pyxine sorediata* (Ach.) Mont.**
		Dirinaria	*Dirinaria consimilis* (Stirton.) D. D. Awasthi
7	Ramalinaceae	*Bacidia*	*Bacidia incongruens* (Stirton) Zahlbr. *Bacidia medialis* (Tuck. ex Nyl.) Zahlbr. *Bacidia rubella* (Hoffm.) A. Massal. *Bacidia submedialis* (Nyl.) Zahlbr.
8	Strigulaceae	*Strigula*	*Strigula elegans* (Fée) Müll. Arg.
9	Teloschistaceae	*Caloplaca*	*Caloplaca bassiae* (Willd.ex.Ach.) Zahlbr.
10	Opegraphaceae	*Opegrapha*	*Opegrapha astraea* Tuck.

*New Addition to Uttar Pradesh

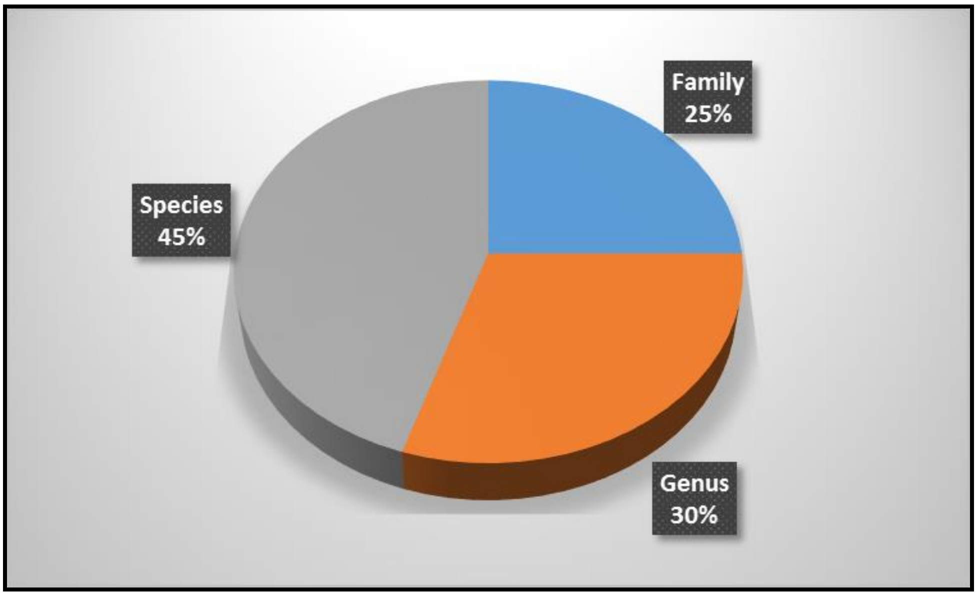


Fig-7.22: Share of family, genus and species of all the lichens reported from Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

7.4.1 Analysis of Lichens by Fourier- Transform Infrared Spectroscopy (FTIR) around Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

All the three common lichen species were examined by FTIR analysis to find specific spectroscopic biomarkers for rapid identification and discrimination between the two different growth forms of lichen species. Developing specific biomarkers by FTIR microscopy could be highly important for future rapid and reliable detection and identification.

FTIR analysis provides spectroscopic evidence of the role of chemicals in metal absorption as the variation in the frequency is affected by bond dissociation and bond formation which plays important role in metal chelation. Secondary metabolites plays important role in chelation. So, variation in the functional group bands in IR region shows the effect of pollutant on the functional group chemistry of the species. The wave numbers of prominent peaks obtained from the absorbance spectra given in Fig-7.23; showed the spectra of all three lichen species. It can be seen that, lichen species have good similarity in the spectra, in comparison between the obtained spectra of the lichen species, it is possible to point out on several spectral peaks.

7.4.1.1 FTIR spectra measurement of *B. incongruens* around Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

For lichen *B. incongruens* (Table-7.24; Fig-7.23A), the strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3415.9 cm^{-1} (north), 3408.3 cm^{-1} (east), 3415.2 cm^{-1} (south), 3416.5 cm^{-1} (west), showed the stretching of N-H/ O-H groups. The spectral band observed between 3000- 2800 cm^{-1} in all directions of the study area due to asymmetrical vibration of C-H showed the presence of protein and phospholipids (Ramrakhiani et al., 2011). The absorbance bands observed at 2035.7 cm^{-1} only in south direction of study area due to NH_3^+ torsional vibration (Mohan, 2005). The wave numbers observed at 1635.3 cm^{-1} (north), 1629.2 cm^{-1} (east), 1634.1 cm^{-1} (south), 1635.4 cm^{-1} (west), 1728.9 cm^{-1} due to C=O ester stretching showed the presence of carbonyl group (Sandt et al., 2003). The minor absorption bands observed at 1515.1 cm^{-1} in north direction only which showed presence of Amide-II, CN strectching, NH bending (Jilie and Shaoning, 2007). The C=O symmetric stretching –COO (Naumann, 2000) showed the presence of absorption infra-red bands in all four directions. The spectra observed at 1378.4 cm^{-1} in north direction showed stretching of C-H rocks as well as the presence of alkanes. The absorbance bands observed at 1262.4 cm^{-1} (north), 1267.4 cm^{-1} (east), 1256.1 cm^{-1} (south); showed components of α- helix (Adriana and Gabi, 2011).

The minor absorbance bands ranged between 1250- 1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters at 1229.6 cm^{-1} (west) (Naumann, 2000). The range of wave number 1080-1010 cm^{-1} showed SO_3 asymmetric stretching (Cirik et al., 2012); and C-O bonding due to polysaccharides (Das and Guha, 2007) in all directions. The range of wave number 900-600 cm^{-1} showed $O-CH_3$ stretching of methoxy groups at 775.5 cm^{-1} (south) and 776.4 cm^{-1} (west) (Movasaghi et al., 2008) and only at 690.8 cm^{-1} (west) showed the presence at absorbance band 770-620 cm^{-1} showed the presence of amines-V with out of plane NH bending (Jilie and Shaoning, 2007). The peaks ranged between 690-515 cm^{-1} and 530-400 cm^{-1} resulted absorbance values in all directions of the study area due the vibration modes of C- Br stretching coupled to alkyl halides and the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated) respectively (Tarte, 1962; 1964). These are useful for rapid detection and characterization of lichen *B. incongruens* at a different level around thermal power plant.

7.4.1.2 FTIR spectra measurement of *P. cocoes* around Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

For lichen *P. cocoes* spectra (Table-7.24; Fig-7.23B), the strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3420.8 cm^{-1} (north), 3423.6 cm^{-1} (east), 3425.9 cm^{-1} (south) and 3421.9 cm^{-1} (west) showed the stretching of bonded N-H/ O-H groups (Ramrakhiani et al., 2011). The major spectral band ranged between 3300- 2500 cm^{-1} due to symmetrical stretching of bonded O-H showed the presence of carboxylic acid. The absorbance bands observed at ranged between 2200-2000 cm^{-1} due to NH_3^+ torsional vibration at absorbance value 2038.9 cm^{-1} (west) (Mohan, 2005). The wave numbers observed at 1642.0 cm^{-1} (north), 1635.0 cm^{-1} (east), 1635.5 cm^{-1} (south) and 1639.4 cm^{-1} (west) ranged between absorbance bands 1680- 1640 cm^{-1} due to C=O showed the presence of primary amines (Jilie and Shaoning, 2007). The wave numbers observed 1560-1530 cm^{-1} due to stretch vibration of C-N at 1549.9 cm^{-1} (north) and 1566.1 cm^{-1} (south) respectively showed the presence of secondary amines. The bonded C=O symmetric stretching absorbed infra-red at all four directions of the study area (Naumann, 2000).

Table-7.24: Absorption frequencies of FTIR spectra of *B. incongruens*, *P. cocoes* and *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

S. No.	Range of wave number (cm^{-1})	*B. incongruens* Band Position (in cm^{-1})				*P. cocoes* Band Position (in cm^{-1})				*R. sophodes* Band Position (in cm^{-1})				Band Assignment
		North	East	South	West	North	East	South	West	North	East	South	West	
1	3500-3300	3415.9	3408.3	3415.2	3416.5	3420.8	3423.6	3425.9	3421.9	3422.8	3408.3	3423.3	3424.8	N-H stretching Amide- A, O-H stretching of hydroxyl groups (primary, secondary, amines and amides) (Ramrakhiani et al., 2011)
2	3300-2500					2943.5	2946.4	2943.6	-					O-H stretching (carboxylic acid)
						2913.9	2889.9	2899.2	2918.2					
3	3000-2800	2922.2	2923.4	2920.1	2921.7					2944.9	2939.0	2920.0	2942.9	Asymmetric vibration C-H of CH_2, protein and phospholipids (Ramrakhiani et al., 2011)
		2853.1	-	2849.9	-									
4	2200-2000	-	-	2035.7	-	-	-	-	2038.9	-	-	2036.1	2037.2	NH_3^+ torsional vibration (Mohan, 2005)
5	1760-1665	1635.3	1629.2	1634.1	1635.4									C=O ester stretching (Carbonyls group) (Sandt et al.,2003)
6	1680-1640					1642.0	1635.0	1635.5	1639.4	1630.9	1633.0	1630.8	1630.5	Amide- I, C=O stretching (Jilie and Shaoning, 2007)
7	1560-1530	1515.1	-	-	-	1549.9	-	1566.1	-	-	1513.9	1511.8	-	Amide- II, CN stretching, NH bending (Jilie and Shaoning, 2007)
8	1450-1400	1457.6	1426.1	1423.9	1426.0	1424.5	1429.2	1427.2	1427.3	1428.5	1424.2	1427.5	1427.6	C=O symmetric stretching $-COO^-$ (Naumann, 2000)
9	1370-1350	1378.4	-	-	-	1374.3	-	1374.2	1374.7					C-H rock (alkanes)
10	1360-1290	1262.4	1267.4	1256.1	-	-	1318.1	1317.8	1321.3	1320.8	1321.4	1320.3	1319.2	components of α- helix proteins (Adriana and Gabi, 2011)
										-	1267.0	1266.6	1270.7	
11	1250-1220	-	-	-	1229.6	1235.8	1230.5	1280.1	1248.6					P=O stretching (asym.) of PO_2^- phosphodiesters (Naumann, 2000)
12	1080-1010	1031.7	1034.4	1026.4	1030.2	1037.2	1035.5	1038.9	1035.3	1027.4	1028.6	1026.2	1028.1	SO_3 asymmtric (Cirik et al, 2012); C-O bonding due to polysaccharides (Das and Guha, 2007)
13	900-600	-	-	775.5	776.4					776.6	774.9	-	777.7	O-CH_3 stretching of methoxy groups (Movasaghi et al., 2008)
14	800-640					773.8	777.8	776.6	-					C-H out of plane bending vibrations (Jilie and Shaoning, 2007)
15	770-620	-	-	-	690.8	692.0	690.4	-	-					Amide- V, Out of plane NH bending (Jilie and Shaoning, 2007)
16	690-515	531.0	606.3	587.4	529.2	530.2	526.7	563.6	564.0	-	-	596.3	-	C-Br stretching (alkyl halides)
17	530-400	466.3	469.0	471.3	467.9	469.2	469.2	-	470.0	528.7	531.0	-	528.1	Al-O stretching (AlO_8 Octahedral, isolated) (Tarte, 1962; 1964)
										421.7	468.3	467.4	467.7	

The spectra observed at 1374.3 cm^{-1} (north), 1374.2 cm^{-1} (south) and 1374.7 cm^{-1} (west) showed stretching of C-H rocks. The absorbance bands ranged 1350-1300 cm^{-1} showed components of α- helix protein at 1318.1 cm^{-1} (east), 1317.8 cm^{-1} (south) and 1321.3 cm^{-1} (west) (Adriana and Gabi, 2011). The absorbance bands ranged between 1250- 1220 cm^{-1} and 1080-1010 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters (Naumann, 2000) and asymmetric stretching of SO_3 As well as C-O bonding due to polysaccharides in all directions respectively (Das and Guha, 2007).

The wave number 773.8 cm^{-1} (north) 777.8 cm^{-1} (east) and 776.6 cm^{-1} (south) showed C-H out of plane bending vibrations (Jilie and Shaoning, 2007). The bands range 770-620 cm^{-1} represents N-H bending with the presence of amine-V at absorbance value 692.0 cm^{-1} (north) and 690.4 cm^{-1} (east). The major peaks ranged between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides. The peaks observed at 469.2 cm^{-1} (north), 469.2 cm^{-1} (east) and 470.0 cm^{-1} (west) showed the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated) (Tarte, 1962; 1964).

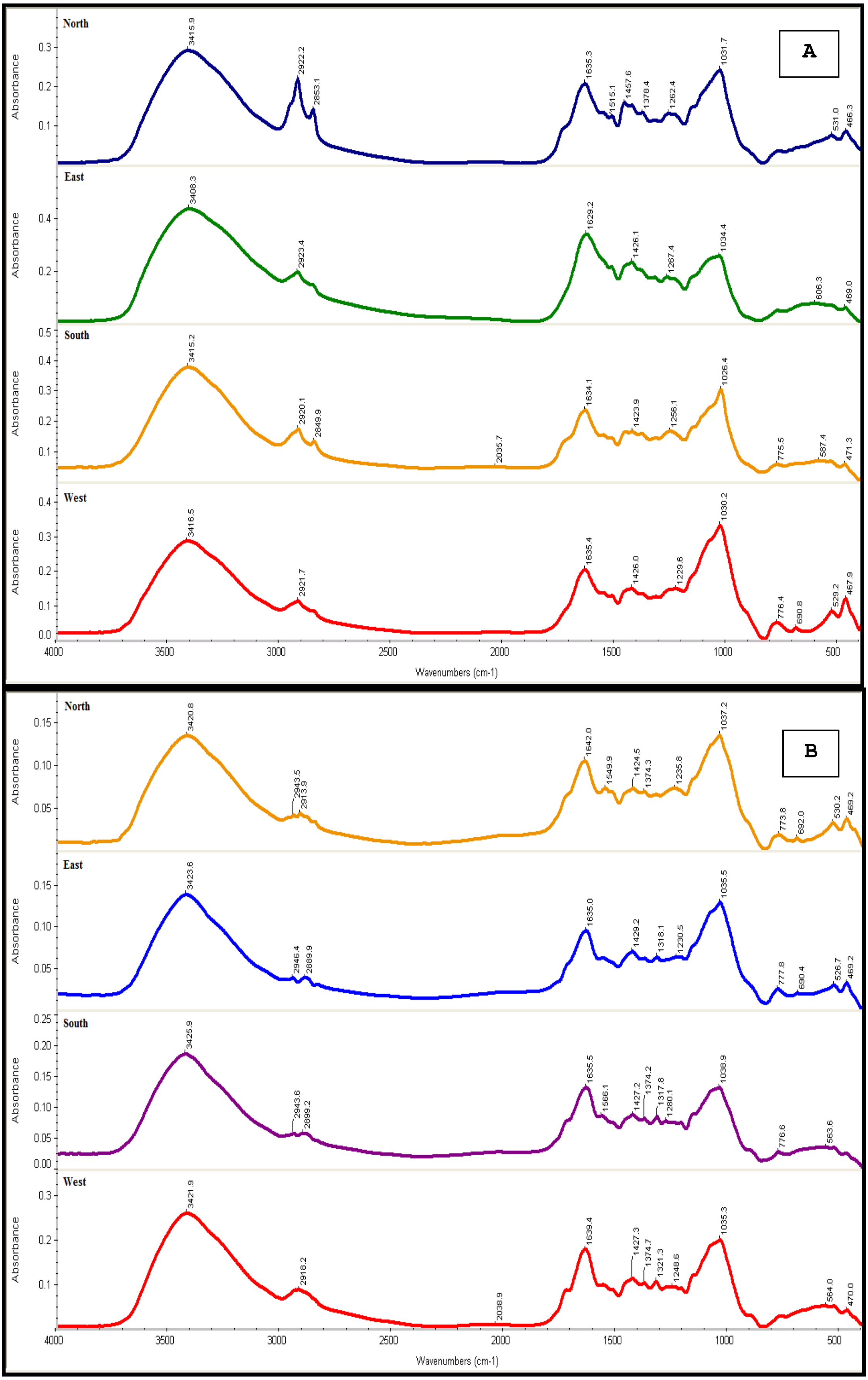
7.4.1.3 FTIR spectra measurement of *R. sophodes* around Feroze Gandhi Unchahar National Thermal Power Plant Corporation (FGUNTPC), Raebareli

For lichen *R. sophodes* (Table-7.24; Fig-7.23C), the major absorbance bands ranged between 3500- 3300 cm^{-1} and 3000- 2800 cm^{-1} in all directions of the study area (north, east, south, west) showed the stretching of N-H/ O-H groups and due to asymmetrical vibration of C-H showed the presence of protein and phospholipids (Ramrakhiani et al., 2011). The absorbance bands observed at 2036.1 cm^{-1} in south and 2037.2 cm^{-1} in west direction of study area due to NH_3^+ torsional vibration (Mohan, 2005). The wave numbers ranged between 1680-1640 cm^{-1}, 1450-1400 cm^{-1} and 1360-1290 cm^{-1} observed in all four directions of the study area.

The minor absorption bands observed at 1513.9 cm^{-1} in east and 1511.8 cm^{-1} in south direction which showed presence of Amide-II, CN stretching, NH bending (Jilie and Shaoning, 2007). The range of wave number 1080-1010 cm^{-1} showed SO_3 asymmetric stretching (Cirik et al., 2012); and C-O bonding due to polysaccharides (Das and Guha, 2007) in all directions of the area. The range of wave number 900-600 cm^{-1} showed O-CH_3 stretching of methoxy groups at 776.6 cm^{-1} (north), 774.9 cm^{-1} (east) and 777.7 cm^{-1} (west) (Movasaghi et al., 2008). The peaks ranged between 690-515 cm^{-1} only observed at 596.3 cm^{-1} in south direction due the vibration modes of C- Br stretching coupled to alkyl halides, whereas 530-400 cm^{-1} resulted absorbance values in all directions of the study area due to the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated) respectively (Tarte, 1962; 1964).

The biodeterioration of granite monuments by *Ochrolechia parella* (L.) Mass (Prieto et al., 1999) & *Lecidea fuscoatra* (L.) Ach., *Porpidia cinereoatra* (Ach.) Hertel & Knoph and *P. macrocarpa* (DC.) Hertel & Schwab (Prieto et al., 2000) are available using FT Raman Spectroscopic studies.

In *B. incongruens* and *P. cocoes*, the presence of secondary metabolites along with primary metabolites enhances the probability of detection of IR bands in the region 3500-2800 cm^{-1} due to the presence of COOH and OH groups. While in *R. sophodes* number of band detected is less than band observed in other species which may be due to absence of secondary metabolites in the species. Secondary metabolites plays important role in chelation. So, variation in the functional group bands in IR region shows the effect of pollutant on the functional group chemistry of the particular lichen species.


A
North
3415.9
2922.2
2853.1
1635.3
1515.1
1457.6
1378.4
1262.4
1031.7
531.0
466.3
East
3408.3
2923.4
1629.2
1426.1
1267.4
1034.4
606.3
469.0
South
3415.2
2920.1
2849.9
2035.7
1634.1
1423.9
1256.1
1026.4
775.5
587.4
471.3
West
3416.5
2921.7
1635.4
1426.0
1229.6
1030.2
776.4
690.8
529.2
467.9
Absorbance
Wavenumbers (cm-1)
4000
3500
3000
2500
2000
1500
1000
500
B
North
3420.8
2943.5
2913.9
1642.0
1549.9
1424.5
1374.3
1235.8
1037.2
773.8
692.0
530.2
469.2
East
3423.6
2946.4
2889.9
1635.0
1429.2
1318.1
1230.5
1035.5
777.8
690.4
526.7
469.2
South
3425.9
2943.6
2899.2
1635.5
1566.1
1427.2
1374.2
1317.8
1260.1
1038.9
776.6
563.6
West
3421.9
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1035.3
564.0
470.0

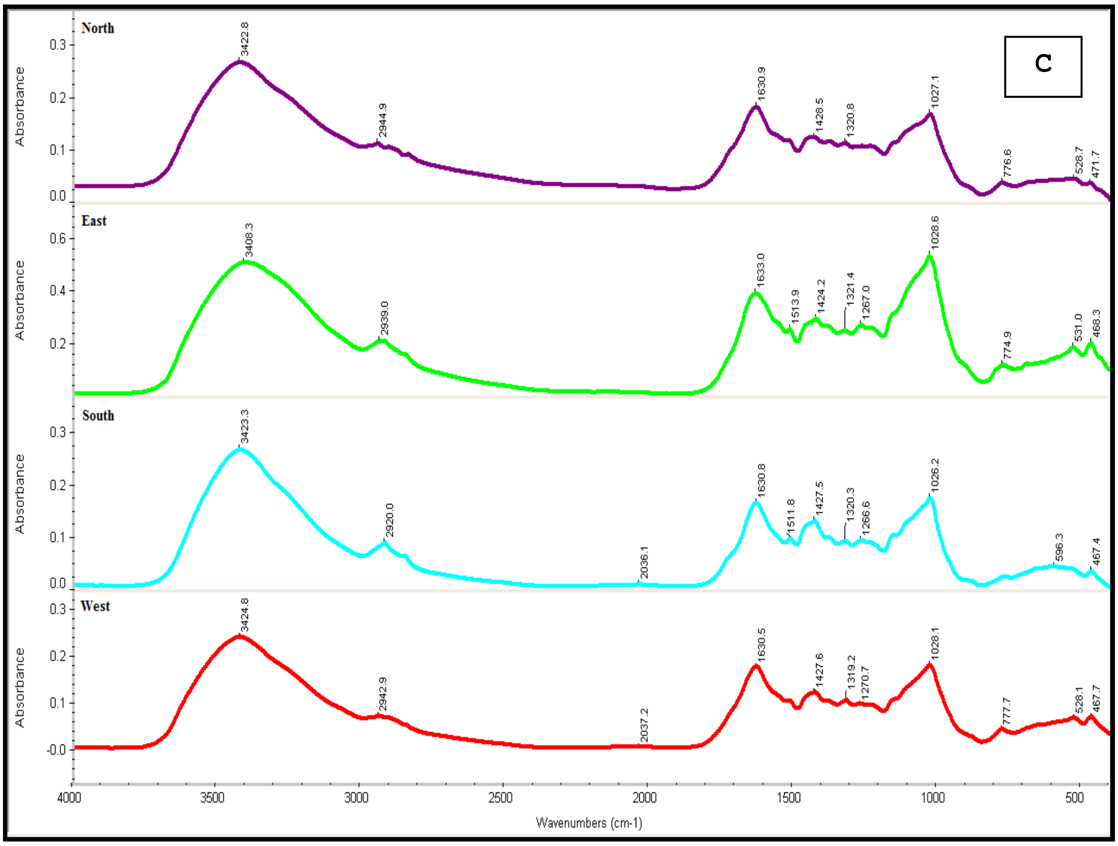

Fig-7.23: Direction-wise FTIR spectra of lichen species around Feroze Gandhi Unchahar thermal power corporation, Raebareli; (A) *B. incongruens;* (B) *P. cocoes* and (C) *R. sophodes*

7.4.2 Comparative physiological response of *B. incongruens*, *P. cocoes* and *R. sophodes* around Feroze Gandhi Unchahar thermal power corporation, Raebareli (Appendix-IV: 7.25.1 to 7.25.18)

The three commonly occurring lichen species viz; *B. incongruens*, *P. cocoes* and *R. sophodes* were selected for photosynthetic pigment analysis and metal concentration in all the directions around the study area. In *B. incongruens,* chlorophyll a showed minimum concentration (0.00±0.00 μgg^{-1}) in south direction whereas maximum concentration (0.04±0.01μgg^{-1}) in both east and north directions. Chlorophyll b content showed same concentration of 0.01±0.00 μgg^{-1} in all directions of the study area. The total chlorophyll (chlorophyll a + chlorophyll b) ranged from

0.01±0.00 μgg^{-1} in south to 0.05±0.01 μgg^{-1} in both east and north directions respectively.

Lowest concentration of carotenoid was detected in *B. incongruens* in west (0.01±0.00 μgg^{-1}), while highest concentration was detected in other three direction with concentration of 0.02±0.00 μgg^{-1}. The concentration of carotenoid and protein content of *B. incongruens* significantly decreased with the increasing distance from the study area. The concentration of chlorophyll degradation was highest in north decreased with increasing distance in east, west and south direction from source of pollution and it ranged from 0.61±0.03μgg^{-1} to 1.06±0.01μgg^{-1} in south and north directions respectively.

The increased level of protein content ranged from 0.63±0.06 μgg^{-1} in west to 0.78±0.10 μgg^{-1}in south direction which had more or less similarity with the findings for the *Ramalina ecklonii* (González et al., 1996). LSD analysis at $p< 0.01$ level showed significant difference in chl. a, chl. b, total chlorophyll, carotenoid and chlorophyll degradation while only protein content showed non-significant difference in *B. incongruens* (Table-7.25; Fig-7.24).

In *P. cocoes,* chlorophyll a showed minimum concentration of 0.04±0.01μgg^{-1} in south and west directions whereas maximum concentration of 0.06±0.02 μgg^{-1} in east direction. Chlorophyll b content ranged from 0.01±0.00 μgg^{-1} (south) to 0.04±0.01 μgg^{-1} (east), whereas total chlorophyll (chlorophyll a + chlorophyll b) ranged from 0.06±0.01 μgg^{-1} in both south and west directions to 0.09±0.04 μgg^{-1} in east direction respectively.

Highest concentration of carotenoid was detected in *P. cocoes* from in north and east directions (0.03±0.01 μgg^{-1}), while lowest concentration was detected in south direction with concentration of 0.02±0.00 μgg^{-1}. Chlorophyll degradation concentration was ranged from 0.69±0.55 μgg^{-1} to 1.05±0.04 μgg^{-1} in east and south directions respectively. Protein concentration ranged from 0.52±0.05 μgg^{-1} in south to

0.74±0.29 μgg^{-1} in west direction. The concentration of chlorophyll a and total chlorophyll showed same accumulation trend in particular lichen species with minimum concentration in south and west directions as well as maximum concentration in east direction (Table-7.25; Fig-7.25). Similar to this, chlorophyll b and carotenoid showed same pattern of concentration in *P. cocoes.* LSD analysis at p< 0.01 level showed significant difference only in chlorophyll b, while other physiological parameters showed non-significant difference in *P. cocoes* (Table-7.25; Fig-7.25).

In case of *R. sophodes,* chlorophyll a, total chlorophyll and chlorophyll degradation showed similar trend of lower concentration in south together with similar trend of higher concentration showed in chlorophyll a, chlorophyll b, total chlorophyll and carotenoid in west direction only. Chlorophyll a and total chlorophyll concentration in thalli of *R. sophodes* had same trend of accumulation i.e. maximum (0.04±0.00 μgg^{-1} and 0.06±0.00 μgg^{-1}) in west and minimum (0.01±0.02 μgg^{-1} and 0.02±0.03) in north and south directions respectively. While, both chlorophyll b and carotenoid showed minimum concentration of 0.01±0.00 μgg^{-1} in east and 0.02±0.00 μgg^{-1} but maximum in west direction with concentration of 0.02±0.00 μgg^{-1} and 0.04±0.01 μgg^{-1} respectively.

Chlorophyll degradation and protein concentration were dissimilar trend of accumulation of photosynthetic pigment. Chlorophyll degradation ranged from 0.84±0.09 μgg^{-1} in south to 1.03±0.02 μgg^{-1} in east direction. Whereas, Protein content in *R. sophodes* ranged from 1.11±0.20 μgg^{-1} in north to 1.46±0.34 μgg^{-1} in south direction (Fig-7.26). LSD studies showed that directions from sources of pollution (i.e. thermal power plant) play an important role in pigment concentration of lichen thalii and exhibited significant difference at p<0.01 level in only chlorophyll degradation, while chlorophyll a, b, total chlorophyll, carotenoid and protein content showed non- significant difference in *R. sophodes* (Table-7.25; Fig-7.26).

In *B. incongruens*, east and north direction showed higher pigment concentration in chlorophyll a, total chlorophyll, carotenoid and chlorophyll degradation whereas, south direction showed lower concentration in comparison to other directions.

Likewise, *P. cocoes* showed directionally opposite to the lichen *R. sophodes* because in this species chlorophyll a and total chlorophyll showed lower concentration in south as well as west directions and higher concentration in east direction. Same as chlorophyll a and carotenoid showed similar trend of concentration i.e. higher in east, but lower in south direction.

In *R. sophodes,* chlorophyll a and total chlorophyll showed similar trend of concentration (lower in north and south; higher in west direction); whereas, chlorophyll b and carotenoid showed similar pattern of concentration (lower in east and higher in west direction). So, it is common to say that the west direction showed maximum concentration in this species.

Correlations of various physiological parameters (Table-7.26) were calculated for physiological parameters of different lichen species. *B. incongruens* showed highly significant correlation of chlorophyll a with total chlorophyll and chlorophyll degradation; whereas total chlorophyll also showed significant correlation with chlorophyll degradation (0.998) at $p<0.01$ level. Protein content showed negative correlation with chlorophyll a (-0.853), total chlorophyll (-0.853) and chlorophyll degradation (-0.883) in *B. incongruens.* In *P. cocoes*, chlorophyll degradation as well as protein content showed negative correlation with chlorophyll a, b, total chlorophyll except protein with carotenoid (0.562) but total chlorophyll showed highly significant correlation with chlorophyll degradation (-0.999) at $p<0.01$ level.

In *R. sophodes,* chlorophyll a showed significant correlation with total chlorophyll (0.986) at $p<0.05$ level; whereas chlorophyll b with carotenoid showed highly significant correlation at $p<0.01$ level. Especially chlorophyll degradation

Table-7.25: Photosynthetic pigment and protein content analysis of lichens in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (Appendix-IV: 7.25.1 to 7.25.18)

Directions	*B. incongruens* (concentration in µgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
North	0.04±0.01	0.01±0.00	0.05±0.01	0.02±0.00	1.06±0.01	0.64±0.02
East	0.04±0.01	0.01±0.00	0.05±0.01	0.02±0.00	1.05±0.03	0.63±0.07
South	0.00±0.00	0.01±0.00	0.01±0.00	0.02±0.00	0.61±0.03	0.78±0.10
West	0.02±0.00	0.01±0.00	0.03±0.00	0.01±0.00	0.86±0.03	0.63±0.06
CV%	22.08	21.82	19.96	12.48	3.01	10.18
LSD (p<0.05)	0.010**	0.004**	0.012**	0.004**	0.045**	0.114^{NS}
Directions	*P. cocoes* (concentration in µgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
North	0.05±0.02	0.02±0.01	0.06±0.02	0.03±0.01	1.03±0.01	0.64±0.13
East	0.06±0.02	0.04±0.01	0.09±0.04	0.03±0.01	0.69±0.55	0.53±0.45
South	0.04±0.01	0.01±0.00	0.06±0.01	0.02±0.00	1.05±0.04	0.52±0.05
West	0.04±0.01	0.02±0.00	0.06±0.01	0.03±0.00	1.03±0.02	0.74±0.29
CV%	26.064	30.320	37.088	343.672	28.953	45.543
LSD (p<0.05)	0.021 ^{NS}	0.010*	0.040 ^{NS}	18.759 ^{NS}	0.457 ^{NS}	0.461 ^{NS}
Directions	*R. sophodes* (concentration in µgg^{-1} Fresh weight)					
	Chl. a	Chl. b	Total Chl.	Carotenoid	Chl. deg.	Protein
North	0.01±0.02	0.01±0.01	0.02±0.03	0.02±0.02	0.94±0.05	1.11±0.20
East	0.03±0.01	0.01±0.00	0.04±0.01	0.02±0.00	1.03±0.02	1.21±0.08
South	0.01±0.02	0.01±0.01	0.02±0.03	0.02±0.02	0. 84±0.09	1.46±0.34
West	0.04±0.00	0.02±0.00	0.06±0.00	0.04±0.01	0.92±0.02	1.33±0.09
CV%	73.129	66.873	64.191	61.192	5.640	16.115
LSD (p<0.05)	0.025 ^{NS}	0.014 ^{NS}	0.037 ^{NS}	0.023 ^{NS}	0.087*	0.343 ^{NS}

Mean±S.D., n=3 in µgg^{-1} Fresh weight; S.D.= Standard Deviation; NS= Not Significant
** Significance at the level of 0.01
*Significance at the level of 0.05

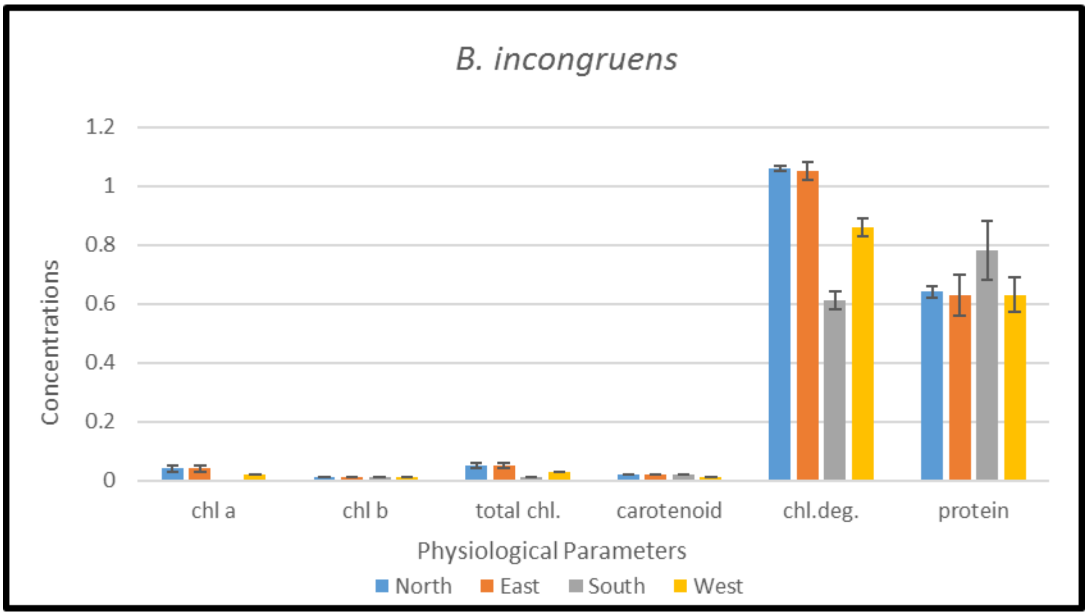

Fig-7.24: Graphical representation of photosynthetic pigments in the thalli of *B. incongruens* in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

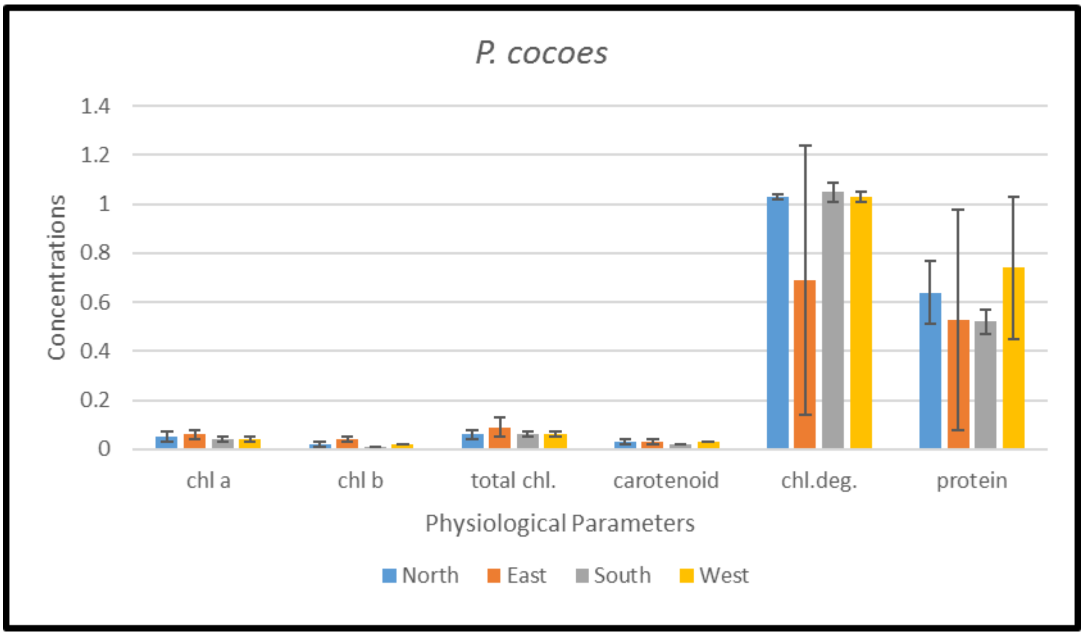

Fig-7.25: Graphical representation of photosynthetic pigments in the thalli of *P. cocoes* in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

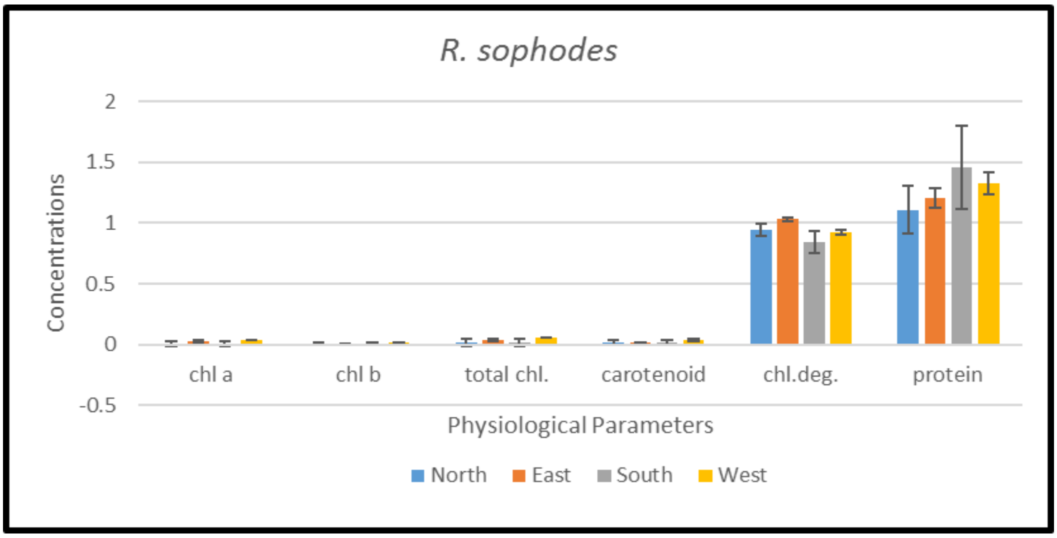

Fig-7.26: Graphical representation of photosynthetic pigments in the thalli of *R. sophodes* in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Table-7.26: Values of correlation matrix between the physiological parameters around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

B. incongruens	**Chl a**	**Chl b**	**Total chl.**	**Carotenoid**	**Chl.deg.**	**Protein**
Chl a	1	.a	1.000**	0.174	.998**	-0.853
Chl b		.a	.a	.a	.a	.a
Total chl.			1	0.174	.998**	-0.853
Carotenoid				1	0.111	0.363
Chl.deg.					1	-0.883
Protein						1
P. cocoes	**Chl a**	**Chl b**	**Total chl.**	**Carotenoid**	**Chl.deg.**	**Protein**
Chl a	1	0.899	0.87	0.522	-0.882	-0.411
Chl b		1	0.927	0.662	-0.946	-0.172
Total chl.			1	0.333	-.999**	-0.498
Carotenoid				1	-0.384	0.562
Chl.deg.					1	0.455
Protein						1
R. sophodes	**Chl a**	**Chl b**	**Total chl.**	**Carotenoid**	**Chl.deg.**	**Protein**
Chl a	1	0.778	.986*	0.778	0.448	0.033
Chl b		1	0.87	1.000**	-0.107	0.231
Total chl.			1	0.87	0.323	0.086
Carotenoid				1	-0.107	0.231
Chl.deg.					1	-0.716
Protein						1

a.Cannot be computed because at least one of the variables is constant.
*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

showed negative correlation with chlorophyll b, carotenoid (-0.107 each) and protein content (-0.716). According to Neumann et al. (1994), increase in protein due to stressed condition has been reported in higher plants.

Overall pattern showed more or less concentration in species *B. incongruens* and *P. cocoes,* while *R. sophodes* showed opposite trend in photosynthetic pigment analysis of the study area. The dissimilar pattern of concentration varied with the direction as well as species and it showed increasing trend with the increasing distance from the thermal power plant.

7.4.3 Comparative response of metal accumulation in *B. incongruens, P. cocoes* and *R. sophodes* at different directions of Feroze Gandhi Unchahar thermal power corporation, Raebareli (Appendix-IV: 7.27.1 to 7.27.27)

Accumulation of nine metals viz; Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As) and Selenium (Se) were estimated in commonly occurring lichen thalli of *B. incongruens, P. cocoes* and *R. sophodes* in all directions from the thermal power plant to compare the bioaccumulation of metals (Fig-7.27, 7.28 & 7.29).

Enhanced level of Fe accumulation in lichen thallus is from vehicular activity, crusher, coal and fossil fuels. Baptista et al. (2008) described that the Fe content in lichens is evidently affected by Fe-originating sources i.e. from fuel and soil dust. *B. incongruens* exhibited a dissimilar sequence of concentration in case of Zn and Fe only as compared to *P. cocoes.* The study area showed higher accumulation of Fe, Mn, Zn, Cr, Ni metals, while Cu, Co, As, Se accumulated in lower concentration in all the three lichen species.

Total metal concentration in *B. incongruens* was recorded higher from west (52730.61 $\mu g g^{-1}$) and lower in south direction (26452.19 $\mu g g^{-1}$) (Fig-7.27). Thalli of *B. incongruens* around study area showed lower accumulation of metals: Se

(1.62±0.05 μgg^{-1}) in north; As (8.38±0.27 μgg^{-1}) in south; Co (10.72±0.17 μgg^{-1}) in north; Cu (12.49±0.13 μgg^{-1}) in east; Ni (34.48±0.33 μgg^{-1}) in south; Cr (51.79±0.37 μgg^{-1}) in north; Zn (24.98±0.40 μgg^{-1}) in north; Mn (372.74±0.53 μgg^{-1}) in north and Fe (25523.04±0.86 μgg^{-1}) in south, while higher metals accumulation were showed in only west direction in all metals i.e. Se (6.6±0.33 μgg^{-1}); As (16.37±0.07 μgg^{-1}); Co (23.95±0.33 μgg^{-1}); Cu (64.13±0.10 μgg^{-1}); Ni (69.82±0.79 μgg^{-1}); Cr (69.49±0.41 μgg^{-1}); Zn (299.18±0.08 μgg^{-1}); Mn (1798.03±0.17 μgg^{-1}) and Fe (50383.04±1.24 μgg^{-1}). *B. incongruens* had metal selectivity sequence as Fe> Mn> Zn> Cr> Ni> Cu> Co> As> Se (Table-7.27). Higher accumulation of Zn was associated with automobile tire and also incomplete combustion of fossil fuels (Ward and Sampson, 1989). According to Harte et al. (1991), Zn level may be elevated near motorways due to tire wear, but the maximum concentration of Zn was recorded in the thalli of *B. incongruens* from the study area. According to Garty (2001), wind speed, direction as well as the density of the element is the major cause of dispersion and distribution of metals in lichen thalli.

In *P. cocoes*, total metal concentration was highest in east (23628.32 μgg^{-1}) and lowest in west (18637.68 μgg^{-1}) direction of the study area (Table-7.27; Fig-7.28). The metal selectivity sequence of nine metals in *P. cocoes*: Fe> Mn> Zn> Cr> Ni> Cu> As> Co> Se. Highest Fe concentration of 23153.05±0.04 μgg^{-1} was recorded in east and lowest concentration of 18223.04±0.39 μgg^{-1} in west that indicates settling of this metal in the east direction. Manganese (Mn) ranged between 267.44±0.30 μgg^{-1} to 354.24±0.30 μgg^{-1} in north and south directions respectively. Zinc (Zn) had maximum accumulation of 145.48±0.20 μgg^{-1} in south and minimum accumulation of 42.98±0.13 μgg^{-1} in east direction. Chromium (Cr) ranged between 31.93±0.29 μgg^{-1} to 62.45±0.14 μgg^{-1}; Ni ranged between 23.32±0.63 μgg^{-1} to

35.89±0.79 μgg^{-1} showed similar trend of accumulation in west and north directions respectively. Because of large particle metals Cu is incapable of long-range dispersion and ranged from (11.75±0.21 μgg^{-1} to 34.19±0.06 μgg^{-1}).

Menard et al. (1987) reported that As in air is found in particulate forms as inorganic As and contained by dust of industrial periphery. In earlier study, Bajpai et al. (2009) concluded that maximum concentration of 51.9±0.21 μgg^{-1} of As in thallus of *Phaeophyscia hispidula* from a site having past mining activities. Accumulation of pollutants is a continuous process for higher as well as lower group of plants especially for lichens, they accumulate pollutants cumulatively over the year with least possibilities of leaching out from the thallus. However, pollutants deposited on substratum can be washed out with rain water or blown off by wind (Bajpai et al., 2010c). In the present study, As ranged from 6.27±0.06 μgg^{-1} in west to 14.94±0.17 μgg^{-1} in north direction (similar accumulation pattern as in Cr and Ni), which is obviously due to gases from industrial emission and heavy traffic activities involved in transportation of coal for thermal power plant production. Accumulation of Co ranged from 6.67±0.39 μgg^{-1} to 9.66±0.21 μgg^{-1} in west and east directions respectively. Selenium (Se) was recorded as the lowest concentrated metal which ranged from 0.69±0.12 μgg^{-1} in north to 2.12±0.12 μgg^{-1} in west direction from the study area.

Thalli of *R. sophodes* (Table-7.27; Fig-7.29) around Feroze Gandhi Unchahar Thermal power plant showed ranged of accumulation of metals as Se (1.61±0.24 μgg^{-1} in south to 8.99±0.13 μgg^{-1} in east); Co (8.74±0.34 μgg^{-1} in west to 11.68±0.11 μgg^{-1} in east); As (6.28±0.33 μgg^{-1} in south to 36.86±0.46 μgg^{-1} in east); Cu (6.59±0.27 μgg^{-1} in north to 60.73±0.27 μgg^{-1} in south); Ni (18.54±0.11 μgg^{-1} in west to 69.65±0.39 μgg^{-1} in north); Cr (33.43±0.44 μgg^{-1} in west to 57.91±0.71 μgg^{-1}

in east); Zn (45.38±0.33 $\mu g g^{-1}$ in east to 113.38±0.16 $\mu g g^{-1}$ in north); Mn (213.04±0.20 $\mu g g^{-1}$ in west to 788.04±0.57 $\mu g g^{-1}$ in south) and Fe (15053.04±0.90 $\mu g g^{-1}$ in north to 20973.04±0.58 $\mu g g^{-1}$ in east direction. *R. sophodes* had metal selectivity sequence as Fe> Mn> Zn> Cr> Ni> Cu> As> Co> Se.

In the present study, accumulation of most of the metals at different directions exhibited dissimilar sequence of accumulation as west> east> north> south (*B. incongruens*); east> south> north> west (*P. cocoes*); east> west> south> north (*R. sophodes*). East direction had settling of metal accumulation in *P. cocoes* and *R. sophodes* with rich and diverse lichen metal profile area. At all the zones all the species showed more or less similar selectivity sequence of metals (Table-7.27). The probable reason of higher metal concentration of Fe, Mn, Zn, Cr and Ni around thermal power plant may be due to presence of dense tuft of rhizinae on the lower side of thallus which act as metal reservoir (Goyal and Seaward, 1982), anthropogenic activity including vehicular activity along with wind pattern as well as natural origin.

The correlation coefficients were calculated (Table-7.28) for concentration in paired element and for the element content in the lichen in different directions. The possible source of element may be indicated by significant correlation between elements in the lichen thallus. In this species, all the metals showed positive correlation in between paired elements. The correlations (all significant at $p<0.01$ level) of Cr and Fe (0.999), Mn and Co (0.993), Zn and Se (0.994) whereas the correlations of Cr with Mn (0.953) and Co (0.980) as well as Co with Fe (0.973) at $p<0.05$ level in *B. incongruens.*

In *P. cocoes*, Cr showed significant correlation with Ni (0.975), As (0.974) and negatively significantly correlated with Se (-0.981), Co and Fe (0.964) at $p<0.05$ level. But highly significant correlation recorded in the paired element as Ni and As

(0.997), Ni and Se (-0.998), As and Se (-0.999) at $p<0.01$ level. While *R. sophodes* showed significant correlation with Mn and Cu (0.969), Co and As (0.967), As and Se (0.972) at $p<0.05$ level. Cobalt with Se (0.998) only represents the highly significant correlation at $p<0.01$ level.

The present study illustrates the pattern of lichen diversity and metal accumulation through emission of coal-based thermal power plant in all three lichen species i.e. *B. incongruens, P. cocoes* and *R. sophodes* in different directions. The study also indicates that the concentration of metal increases with decreasing distance from thermal power plant and provide direct evidence about the air quality status. The utility of lichen species as an environmental sensor is clearly displayed as species exhibit more or less similar metal accumulation in between the species. Higher concentration of Fe, Mn, Zn, Cr and Ni around the thermal power plant may be due to the high vehicular activity and other source of pollution involved in the disposal of coal waste. Vehicular activity along with wind pattern also may be a cause for the dumping of all metal from outside the source.

The information available on metal pollution around thermal power plant will not only help to assess the long term hazards to the human beings living there but also help for preparation of management strategies to reduce the air pollution in the area.

Table-7.27: Metal accumulation in the thalli of lichens in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (Appendix-IV: 7.27.1 to 7.27.27)

Directions	*B. incongruens* (concentration in μgg^{-1} Dry weight)									Total metal
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	
East	54.92±0.07	416.74±0.28	30123.04±0.06	12.2±0.14	48.48±0.33	12.49±0.13	140.58±0.14	12.21±0.34	3.79±0.33	**30824.45**
West	69.49±0.41	1798.03±0.17	50383.04±1.24	23.95±0.33	69.82±0.79	64.13±0.10	299.18±0.08	16.37±0.07	6.6±0.33	**52730.61**
North	51.79±0.37	372.74±0.53	26803.04±0.10	10.72±0.17	48.21±0.40	31.81±0.22	24.98±0.40	15.48±0.14	1.62±0.05	**27360.39**
South	51.94±0.57	681.34±0.39	25523.04±0.86	12.91±0.37	34.48±0.33	29.21±0.17	107.28±0.27	8.38±0.27	3.61±0.14	**26452.19**
Total metal	**228.14**	**3268.85**	**132832.16**	**59.78**	**200.99**	**137.64**	**572.02**	**52.44**	**15.62**	
CV%	0.698	0.044	0.002	1.810	0.992	0.470	0.176	1.756	6.294	
LSD(p< 0.05)	0.664**	0.612**	1.266**	0.451**	0.831**	0.270**	0.421**	0.383**	0.409**	
Directions	*P. cocoes* (concentration in μgg^{-1} Dry weight)									**Total metal**
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	
East	39.26±0.31	314.64±0.61	23153.05±0.04	9.66±0.21	24.8±0.38	34.19±0.06	42.98±0.13	7.89±0.08	1.85±0.06	**23628.32**
West	31.93±0.29	272.74±0.32	18223.04±0.39	6.67±0.39	23.32±0.63	13.01±0.09	58.58±0.38	6.27±0.06	2.12±0.12	**18637.68**
North	62.45±0.14	267.44±0.30	19743.04±0.90	8.29±0.66	35.89±0.79	31.34±0.11	76.78±0.29	14.94±0.17	0.69±0.12	**20240.86**
South	37.03±1.89	354.24±0.30	19723.04±0.45	7.65±0.27	26.97±0.47	11.75±0.21	145.48±0.20	9.24±0.12	1.67±0.19	**20317.07**
Total metal	**170.67**	**1209.06**	**80842.17**	**32.27**	**110.98**	**90.29**	**323.82**	**38.34**	**6.33**	
CV%	2.275	20.134	0.008	5.174	2.115	0.582	0.329	1.206	8.293	
LSD(p< 0.05)	1.618**	0.675**	2.715**	0.696**	0.978**	0.219**	0.444**	0.193**	0.219**	
Directions	*R. sophodes* (concentration in μgg^{-1} Dry weight)									**Total metal**
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	
East	57.91±0.71	499.34±0.78	20973.04±0.58	11.68±0.11	41.78±0.29	16.41±0.16	45.38±0.33	36.86±0.46	8.99±0.13	**21691.39**
West	33.43±0.44	213.04±0.20	19313.04±0.64	8.74±0.34	18.54±0.11	BDL	BDL	7.03±0.01	BDL	**19593.82**
North	46.63±0.24	350.74±0.19	15053.04±0.90	9.35±0.17	69.65±0.39	6.59±0.27	113.38±0.16	6.29±0.23	1.93±0.14	**15657.6**
South	35.3±1.10	788.04±0.57	18153.04±0.39	9.41±0.28	28.14±0.29	60.73±0.27	108.78±0.22	6.28±0.33	1.61±0.24	**19191.33**
Total metal	**173.27**	**1851.16**	**73492.16**	**39.18**	**158.11**	**83.73**	**267.54**	**56.46**	**12.53**	
CV%	1.616	0.109	0.003	2.467	0.729	0.990	0.317	2.143	4.865	
LSD(p< 0.05)	1.167**	0.842**	1.087**	0.403**	0.480**	0.345**	0.353**	0.504**	0.254**	

Mean±S.D., n=3 in μgg^{-1} dry weight, S.D.= Standard Deviation; BDL= Below Detection Limit; ** Significance at the level of 0.01

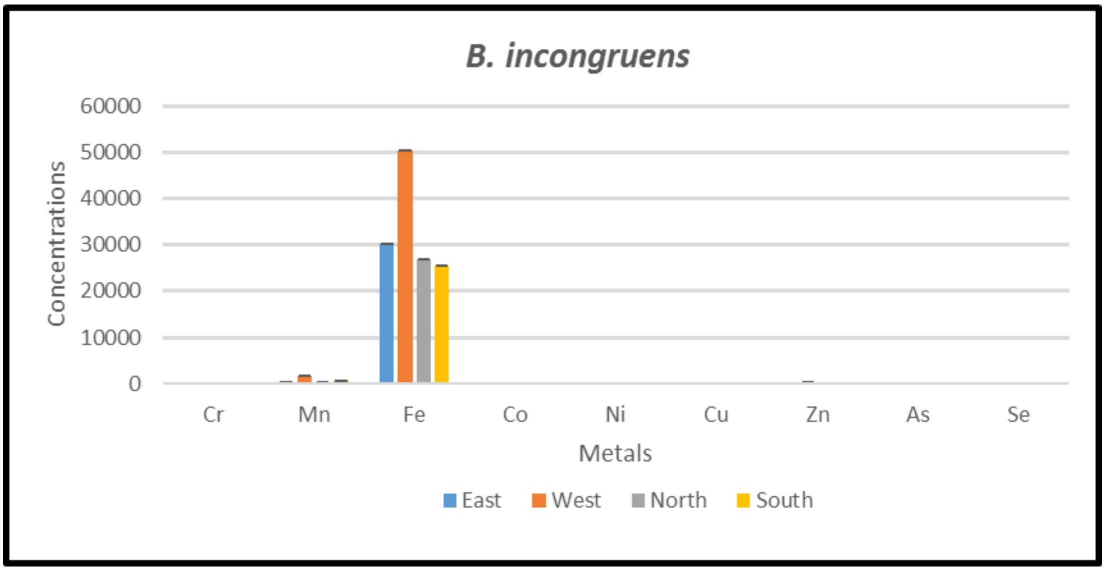

Fig-7.27: Graphical representation of metal accumulation in the thalli of *B. incongruens* in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

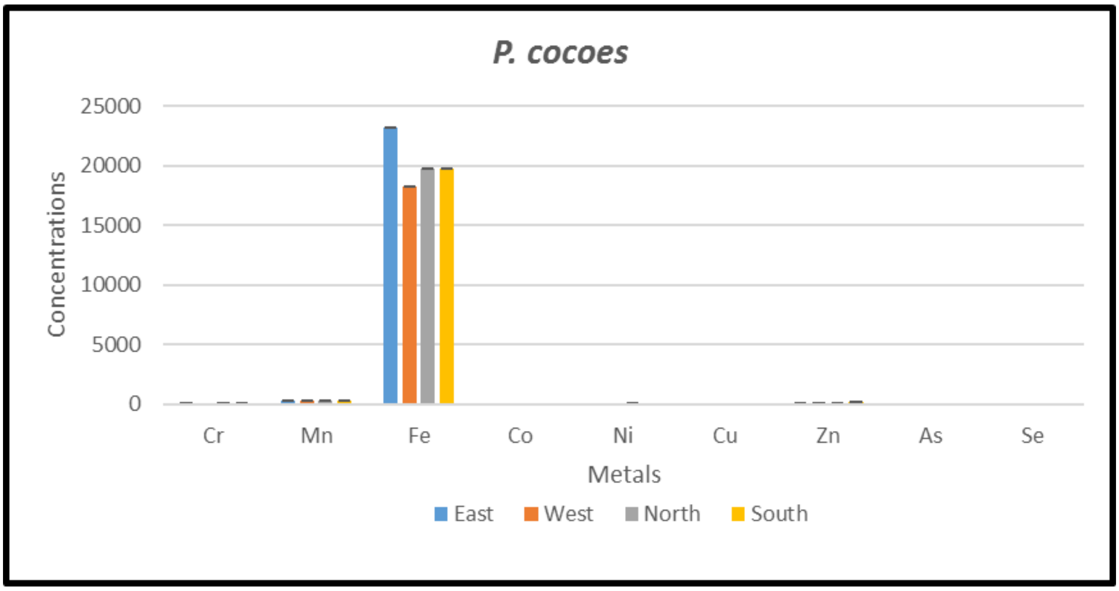

Fig-7.28: Graphical representation of metal accumulation in the thalli of *P. cocoes* in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

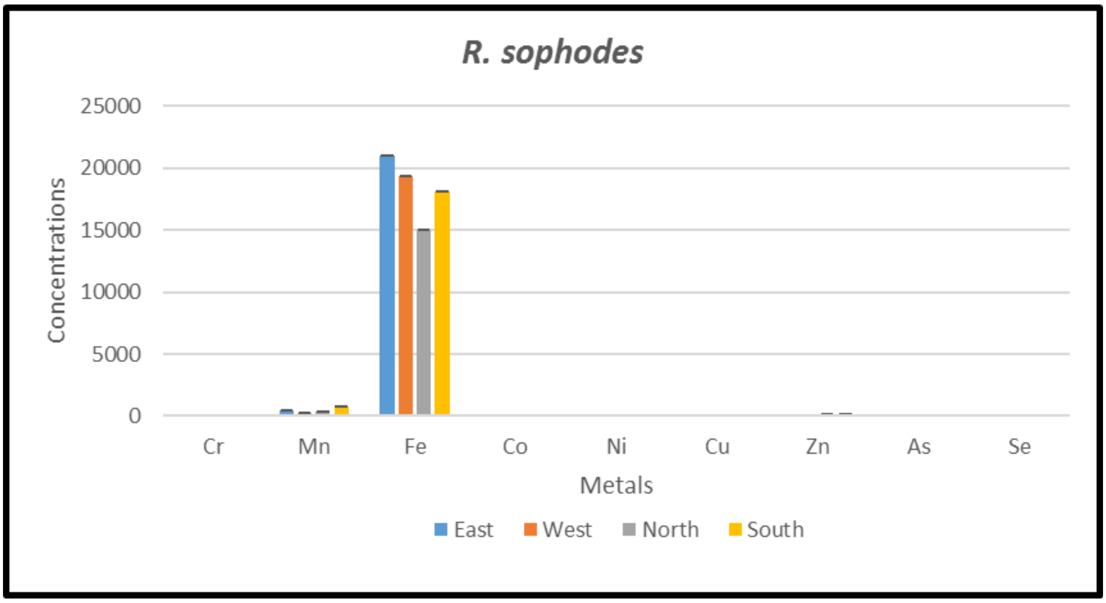

Fig-7.29: Graphical representation of metal accumulation in the thalli of *R. sophodes* in all directions around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Table-7.28: Values of correlation matrix between the elements around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

B. incongruens	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**
Cr	1	.953*	.999**	.980*	0.917	0.837	0.947	0.591	0.913
Mn		1	0.944	.993**	0.785	0.92	0.919	0.433	0.913
Fe			1	.973*	0.936	0.844	0.929	0.633	0.891
Co				1	0.834	0.889	0.948	0.476	0.934
Ni					1	0.749	0.768	0.851	0.694
Cu						1	0.697	0.575	0.679
Zn							1	0.321	.994**
As								1	0.219
Se								0.219	1
P. cocoes	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**
Cr	1	-0.429	0.057	0.321	.975*	0.619	-0.042	.974*	-.981*
Mn		1	0.339	0.207	-0.335	-0.307	0.671	-0.278	0.304
Fe			1	.964*	-0.094	0.734	-0.342	-0.031	0.024
Co				1	0.171	0.861	-0.336	0.231	-0.239
Ni					1	0.439	0.166	.997**	-.998**
Cu						1	-0.6	0.468	-0.488
Zn							1	0.184	-0.152
As								1	-.999**
Se									1
R. sophodes	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**
Cr	1	0.003	0.228	0.899	0.57	-0.242	0.09	0.85	0.917
Mn		1	0.087	0.269	-0.107	.969*	0.606	0.083	0.215
Fe			1	0.565	-0.669	0.036	-0.694	0.706	0.555
Co				1	0.201	0.044	-0.032	.967*	.998**
Ni					1	-0.25	0.629	0.053	0.225
Cu						1	0.56	-0.124	-0.013
Zn							1	-0.286	-0.056
As								1	.972*
Se									1

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Chapter- 8
Summary

"Discovery consist of looking at the same thing as everyone else and thinking something different".

The research work initiated with survey and collection of lichens from localities around all the three thermal power plants of Uttar Pradesh during the year **2013-2017**. A total of more than 500 lichen samples were collected and were dried and labelled with locality, date of collection and other ecological notes. The specimens were identified based on the morphological characters, anatomy and chemistry.

Morphological characters were studied under LABOMED dissecting microscope while LEICA ATC 2000 compound microscope was used for microscopic anatomical details. The chemical compounds present were identified by using colour spot tests and Thin Layer Chromatography (TLC) techniques. Complete identification of the all the samples revealed the occurrence of 21 species belonging to 14 genera and 11 families with maximum representation of lichen family Ramalinaceae followed by Physciaceae, Caliciaceae and Lecanoraceae from all the sites explored around selected thermal power plants of Uttar Pradesh. One specimen of each species was deposited in the National Repository CSIR-National Botanical Research Institute, Herbarium (LWG). Among of all the thermal power plants, Unchahar thermal power plant has the highest representation of 18 species of lichens, followed by Tanda thermal power plant and Panki Thermal Power plant with 11 and 8 species of lichens respectively.

Out of the 21 species recorded, only *Pyxine sorediata* reported as new addition to the lichen flora of Uttar Pradesh. Lichen genus, *Bacidia* emerges as the dominant genus with 4 species. The crust forming lichens exhibit their dominance with 14 species followed by foliose and squamulose represented by 4 and 2 species respectively. A follicolous lichen, *Strigula elegans* is the only lichen taxa reported from the single locality on the leaves of *Mangifera indica* at Salon near Bhawanipur, Unchahar thermal power plant. *Mangifera indica* trees cultivated in orchards in all the sites bears the maximum growth of lichen species on their bark, twig, trunks and branches followed by *Artocarpous heterophyllus, Azadirachta indica, Litchi chinensis* and *Pongamia pinnata* respectively. Among, all 21 lichen species, only 3 species are commonly reported from selected thermal power plant of Uttar Pradesh i.e. *Bacidia incongruens, Pyxine cocoes* and *Rinodina sophodes.*

On comparison of lichen data for all the three selected thermal power plant (156 sampling sites or localities), *Pyxine cocoes* is widely distributed around all the selected thermal power plants while other species of lichens have narrow range of distribution.

In the present study, maximum evenness are recorded for crustose and foliose growth forms whereas minimum evenness is recorded for squamulose and follicolous lichen. Distribution of lichens has also been observed to be affected by abiotic, biotic and other environmental factors. Field observation have revealed that rapid expansion of agriculture land, destruction of forest, execution of developmental activities such as construction of paths through breaking of rocks and other anthropogenic factors have resulted in deteriorating the lichen habitat thus posing serious threat to diversity of lichens around thermal power plants.

It is clear from the observation that lichen diversity and dominance of lichens exhibit increasing trend as the distance increases towards the outskirts from the source of pollution i.e. thermal power plant. The localities Rajesultanpur road, Mubarakpur has the highest number of species followed by Rajesultanpur road, Rampur benepur; Faizabad-Tanda road, Mehbubganj, Bhitaura from Tanda thermal power plant; whereas Umaran area of Unchahar thermal power plant has the maximum number of species followed by area Nababganj, Sanhoo kuwan;

Raghunathpur Paterwa; Allipurbahera. The Panki thermal power plant has poor diversity of lichens as only 8 species are recorded from the area, but the area Airport road, Kataraghan Shyam near Sachendi; Aligarh- Kanpur road, bagdudi bazar, Amiliha near Choubeypur Kalan near Tatiyaganj of the thermal power plant have more diversity of lichens can be termed as **"Lichen Rich Areas"**. It is clear from the study that air pollution is not equally spread around the thermal power plant. The areas near thermal power plant have higher vehicular activity, urbanization, industrial activity and lack of vegetation leads to more pollution than the outskirts areas of the thermal power plants. The east direction of Panki thermal power plant can be termed as **"Lichen Desert Area"** as it showed complete absence of lichen species.

Epiphytic lichens are more sensitive than rock and soil inhabiting lichens, therefore they are generally considered as good indicators of air quality. The majority of air pollution sites have open dry spaces with heavy anthropogenic activities resulted into complete absence of sensitive lichens. The distribution data of lichen collected from all the study area provides an idea about the overall picture of the lichen distribution around thermal power plants.

Out of all the lichen species encountered in the study area, the species can be categorized into tolerant (2 species), moderate sensitive (2 species) and sensitive species (17 species) with reference to air pollution. The species mostly found growing in polluted areas *Pyxine cocoes* and *Rinodina sophodes* are well known toxitolerant taxa of lichens. The genus *Anisomeridium, Arthothelium, Caloplaca, Dirinaria, Lecanora, Peltula* and *Strigula* collected from more or less pollution free or moderately polluted areas are the pollution sensitive species of lichens recorded from the study area.

Lichen species differs in morphology and anatomy but bioaccumulates more or less similar concentration of metal through adsorption and absorption, as validated by SEM and FTIR respectively. FTIR spectra showed structural peculiarities of metabolites in the lichens as well as variation in the functional groups which indicating the role of metabolites in sequestration of metals (absorption phenomenon), while SEM analysis showed adsorption of particulate bonded matter on the surface of lichen thallus which is responsible for bioaccumulation. The variation in the functional group bands in IR region shows the effect of pollutant on the functional group chemistry of the particular lichen species. This phenomenon is principally involved in metal absorption by formation of chelates or bond dissociation due to the presence of phytotoxic gases mainly SO_2.

Changes both in Chlorophyll and carotenoid content may be used as a tool to monitor changes in area due to air pollution. Carotenoids are considered to be relatively more tolerant to metal toxicity than the chlorophyll. The lichens in polluted area exhibit decrease in chlorophyll content but when the pollution increases some lichen species can adapt to that increasing level of pollution.

The level of concentration of different metal present in the lichens helped in assessment of risk to the population living in the vicinity of the power plant together with long-term hazard due to metal accumulation. The study provided an understanding about the mechanisms adopted by different growth form of lichens for bioaccumulation of metals emitted by thermal power plant and indicates that the particulate bound adsorption is the major factor responsible for bioaccumulation in lichens irrespective of their growth form.

Out of the three sites, the species showed more or less similar sequence of metal accumulation around thermal power plants. *P. cocoes* had metal selectivity sequence as Fe> Mn> Zn> Pb> Cr> Cu> Ni> As> Co> Se> Cd while *R. sophodes* had metal selectivity sequence as Fe> Mn> Pb> Zn> Cr> Cu> Ni> As> Co> Se> Cd around Panki thermal power plant. Accumulation of most of the metals at different directions exhibited least similar sequence of accumulation. The east direction had complete absence of lichens because of construction of roads, buildings and residential area. Among the different metals, Fe showed higher accumulation while Cd accumulated in lower concentration in both the species. Since the area is close to Panki thermal power plant, therefore, the probable source of metals in species may be attributed to the emission of thermal power plant. Total metal concentration in *Pyxine cocoes* was recorded higher in west direction (33681.28 μgg^{-1}) while *Rinodina sophodes* exhibit higher accumulation of metals (36850.07 μgg^{-1}) in north direction from Panki thermal power plant.

In samples from Tanda thermal power plant, *P. cocoes* showed more or less similar selectivity sequence of metals as Zn> Al> Cu> Fe> Pb> Cr> Cd in all the four directions, while *B. incongruens* exhibited a different sequence of metals as Fe> Zn> Cu> Al> Pb> Cr> Cd. Out of the four directions, *P. cocoes* showed minimum concentration of 116.17 μgg^{-1} were recorded from north direction whereas maximum accumulation was recorded from south direction (1810.43μgg^{-1}), while total metal concentration in *B. incongruens* was recorded higher from north (488.39 μgg^{-1}) and lower in south direction (336.27 μgg^{-1}). Both *P. cocoes* and *B. incongruens* showed higher accumulation of Zn, Al, Fe, Cu and lower accumulation of Pb, Cr and Cd in all directions around Tanda thermal power plant. The total metal bioaccumulation are having different source as evident from the Pb in *B. incongruens* showed negative correlation with almost all metal while in *P. cocoes* it is positively correlated.

All the three lichen species such as *B. incongruens, P. cocoes* and *R. sophodes* exhibit similar type of metal selectivity sequence of Fe> Mn> Zn> Cr> Ni> Cu> Co> As> Se around Feroze Gandhi Unchahar Thermal Power Plant. In *P. cocoes,* the total metal concentration was highest in east (23628.32 $\mu g g^{-1}$) and lowest in west (18637.68 $\mu g g^{-1}$) direction of the study area. Among nine metals, Fe> Mn> Zn> Cr> Ni was accumulated in maximum concentration followed by Cu> Co> As> Se. Among the nine metals accumulated, Fe showed higher accumulation while Se accumulated in lower concentration in all the three species. Highest Fe accumulation of 50383.04±1.24 $\mu g g^{-1}$ was recorded in west (in *B. incongruens*) and minimum accumulation of 15053.04±0.90 $\mu g g^{-1}$ in north direction (in *R. sophodes*); while Se was recorded higher accumulation of 8.99±0.13 $\mu g g^{-1}$ in east (in *R. sophodes*) and lower accumulation of 0.69±0.12 $\mu g g^{-1}$ in north direction (in *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant.

The present study illustrates the pattern of lichen diversity and metal accumulation may influence of prolonged exposure to emission of coal-based thermal power plant in all three lichen species i.e. *B. incongruens, P. cocoes* and *R. sophodes* in different directions. The study also indicates that the concentration of metal increases with decreasing distance from thermal power plant and provide direct evidence about the air quality status. The utility of lichen species as an environmental sensor is clearly displayed as metal accumulation in between the species exhibit more or less similar concentration of metal. Assessment of immediate risk to the population living in the vicinity of the power plant, long-term hazard due to metal accumulation should be seriously considered around thermal power plant. Higher concentration of Fe, Mn, Zn, Cr and Ni around the thermal power plant may be due to the high vehicular activity and other source of pollution involved in the disposal of coal waste.

Vehicular activity along with wind pattern also may be a cause for the dumping of all metal from outside the source.

Present study provides useful information to some selected thermal power plants in the state of Uttar Pradesh for the use of lichen as biomonitors of environmental pollution. The available account of lichens from the study area not only contributes a clear picture of lichen diversity around thermal power plants of Uttar Pradesh, but also provides a platform for studying lichens as biomonitors which are well known from their unique secondary metabolites or developments of green biomolecules for treatment of various disease of mankind. Thus, the result showed that the vehicular and anthropogenic activities are the major cause of metal load in the study area.

The sufficient past distribution data of the lichen taxa from the study area were not available; therefore it was not possible to draw any conclusion about the changes in the distribution pattern of lichen communities at present. However, the present available distribution pattern can be used as a record for carrying out future biomonitoring studies in the area.

Chapter-9

Conclusion

The study revealed the occurrence of 21 species of lichens belonging to 14 genera and 11 families with maximum representation of lichen family Ramalinaceae followed by Physciaceae, Caliciaceae and Lecanoraceae from all the sites explored around selected thermal power plants of Uttar Pradesh. Lichen genus, *Bacidia* emerges as the dominant genus with 4 species.

The crust forming lichens with 14 species which are considered as most pollution tolerant than foliose and fruticose lichen growth forms, dominates all the sites around power plants. Follicolous lichens growing on perennial leaves are well known sensitive lichen taxa exclusively occur in Feroze Gandhi Unchahar thermal power plant in the pollution free sites and indicate high ecologically sensitive nature of lichens.

The Feroze Gandhi Unchahar thermal power plant exhibit the rich diversity of 18 lichens followed by Tanda and Panki Thermal Power plant represented by 11, 8 species respectively. The localities around Panki Thermal Power plant exhibit complete absence of lichens in east direction having higher vehicular activity, urbanization, industrial activity and scarce occurrence of tree vegetation. The occurrence of lichens showed a negative correlation with levels of air pollution.

It is well evident from the study that the lichen family Ramalinaceae with 4 species; Physiaceae, Caliciaceae and Lecanoraceae with 3 species each have the potential of bioaccumulation and can be utilized for assessing the ambient air quality status at different regions in the state as well as country.

On the basis of observation, it is clear that the lichen diversity exhibit increasing trend in the number of species as the distance from the thermal power plants increased towards the outskirts. Air pollution sites have open dry spaces with heavy anthropogenic activities resulted into complete absence of sensitive lichens.

Distributional data of lichens collected from all the sites of the study area clearly exhibit that *Pyxine, Bacidia* and *Rinodina* are found to be most tolerant species and shows their luxuriant growth around thermal power plants.

The lichen genus such as *Anisomeridium, Arthothelium, Caloplaca, Dirinaria, Lecanora*, *Peltula* and *Strigula* found growing in the pollution free areas are sensitive to the pollution thus belongs to the pollution sensitive lichens of the area. The sufficient past distribution data of the lichen taxa from the study area were not available; therefore it was not possible to draw any conclusion about the changes in the distribution pattern of lichen communities at present.

It is clear from the above observations that not only lichens can be used as a tool to monitor the distribution of air pollution around thermal power plants but also been utilized to examine the amount of particulate matter measured through SEM and deposition pattern by FTIR technique around the source of pollution. The study provided an understanding about the mechanisms adopted by different growth form of lichens for bioaccumulation of metals emitted by thermal power plant and indicates that the particulate bound adsorption is the major factor responsible for bioaccumulation in lichens irrespective of their growth form.

The present study also illustrates the influence of prolonged exposure of coal-based thermal power plant pollutants on diversity of lichens. *Pyxine cocoes* which is common epiphytic lichen species was found to be an excellent accumulator of air pollution. The function of lichen species as an environmental sensor is clearly displayed by studying the physiological damage. Assessment of immediate risk to the population living in the vicinity of the power plant, long-term hazard due to metal accumulation should be seriously considered around thermal power plant. Lichens respond differently to different pollutants/abiotic/biotic stress depending on the type of nature of pollution and the lichen species involved, therefore, it is important to clarify and classify the causes of differential sensitivity to different lichen species towards various pollutants.

Though air pollution monitoring in an area may be measured by involving different equipment, however, the monitoring through equipment may be restricted only upto one or two sites. One cannot operate equipment in a large number of sites while utilizing lichens one can monitor wide geographical area with too many sites. Thus, the monitoring air pollution with lichens is economic and easy as compared to equipments. Further, monitoring through lichens also provide important information on damage caused to the biological element, which is not possible through simple equipments.

The available diversity, distribution of lichens, concentration of metals and pigments together with process of adsorption and absorption data will provide baseline data on lichens at different sites around the thermal power plant which will be helpful for carrying out future biomonitoring studies.

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"When you achieve the goal, let's remember the former's role".

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<u>**RESEARCH PAPERS**</u>

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2. **Gupta, N.,** Gupta, V. & Dwivedi, S. K. (2016). New addition to lichen flora of Uttar Pradesh, India. *Journal of Tropical Plant Research,* 3(1), 153-156. [ISSN (Print): 2349-9265; (Online): 2349-1183].

3. **Gupta, N.,** Dwivedi, S. K., & Upreti, D. K. (2017a). Physiological variation and accumulation of metals in two growth forms of lichens growing around Panki Thermal Power Plant of Uttar Pradesh, India. *International Journal of Advanced Research,* 5(7), 1554-1164. [ISSN: 2320-5407]

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Abstracts Published in Conferences/ Seminars

❖ **National**

1. **Gupta, N.,** Dwivedi, S. K., & Upreti D. K. (2017). Estimation of Metal pollutants using two lichen species around Panki Thermal Power Plant, Kanpur, Uttar Pradesh, India in XXXX All India Botanical Conference of the Indian Botanical Society (IBS-2017) at Punjab University, Patiala on 15th -17th, Sep., 2017. **(Communicated)**
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3. Dwivedi, S. K., & **Gupta, N.** (2016). भूमंडलीय ऊष्मीकरण : कारण, प्रभाव एवं समाधान in a National Seminar on New Dimensions of Social Work organized by Uttar Pradesh Rajshri Tondon Open University, Allahabad, U.P., India during 8th-9th March, 2016.
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5. **Gupta, N.,** Dwivedi, S. K., & Upreti D. K. (2015). Environmental Impact Assessment in relation to coal based thermal power plants with lichens in 3rd Lucknow Science Congress (LUSCON-2015) and National Conference on Science for Society an Interdisciplinary Approach organized by Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 31st Oct.- 2nd Nov., 2015. p. 187-188.

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9. **Gupta, N.** (2014). Attended a two days conference on 2nd Lucknow Science Congress (LUSCON-2013) organized by Department of Biotechnology at Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 27th -28th March.
10. **Gupta, N.,** & Upreti, D. K. (2013). Air Pollution Monitoring with Lichens in and around Panki Thermal Power Station, Kanpur, Uttar Pradesh, India in an UGC-Sponsored National Conference on Resource management & its sustainable use organized by Pt. L. M. S. Government Post Graduate College, Rishikesh, Uttrakhand on March, 22nd -23rd, 2013, p.51.
11. **Gupta, N.,** & Upreti, D. K. (2013). Need for monitoring air quality with lichens in and around thermal power plant of Uttar Pradesh, India in National Seminar on Environmental issues and challenges in the 21st century organized by Department of Environmental Sciences, Bareilly College, Bareilly, U.P. on 3rd - 5th Feb., 2013. p. 20.
12. **Gupta, N.** (2011). Conserving biodiversity under climate change in National seminar on Climate Change & its impact on the biological communities (CCIBC-2011) organized by Department of Environmental Sciences, Dr. R.M.L. Avadh University- Faizabad on 12th -13th Feb. 2011, p.72.

- **International**

1. Dwivedi, S. K., Upreti, D. K., & **Gupta, N.** (2016). Suitability of lichens in monitoring air pollutants in Uttar Pradesh, India in Two days International Seminar on “Recent Trends and Experimental Approaches in Science, Technology and Nature” organized by Society for Science and Nature and co-organized by Oura Prakashan, Lucknow on 23rd-24th Dec., 2016. p. 52.
2. Dwivedi, S. K., & **Gupta, N.** (2016). Role of E-technology in the society in Two days International Seminar on “Globalization, Environment and Social Justice: Perspectives, Issues and Concerns” organized by Department of Sociology, Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow and sponsored by ICSSR, New Delhi and ICPR, New Delhi in collaboration with ASEDS, Lucknow on 15th – 16th February, 2016. p. 102.
3. **Gupta, N.**, Ram Gopal, & Dwivedi, S. K. (2015). The Emerging Role of Social Media in Research Studies in an International Conference on Issues and Challenges in Doctoral Research organized under the Aegis of Global Network of Doctorates by Banaras Hindu University, Varanasi on 25th August, 2015. p.11.
4. Gupta, V., **Gupta N.**, Upreti, D. K., & Singh, J. (2015). Air Pollution Monitoring in and around Faizabad city utilizing lichen distribution pattern in Fifth International Conference on Plants & Environmental Pollution (ICPEP-5) organized by CSIR- National Botanical Research Institute, Lucknow, India on 24th - 27th Feb., 2015, p. 159.
5. Dwivedi, S. K., **Gupta, N.,** & Upreti, D. K. (2014). Lichen diversity changes with reference to Environmental Pollution Monitoring and Climate Change in an International Conference on Biodiversity: Status, Utilization and Impact of Challenging Climatic Conditions organized by Department of Applied Animal Science, Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow in Collaboration with Indian Academy of Environmental Sciences, Haridwar on 30th -31st , Oct., 2014, p. 252.
6. Dwivedi, S. K., **Gupta, N.,** & Upreti, D. K. (2014). Air quality assessment by lichens in and around Panki Thermal Power Plant, Kanpur (U.P.) in an International Conference on Environmental Technology and Sustainable Developments: Challenges and Remedies organized by Department of Environmental Science, School for Environmental Sciences at Babasaheb

Bhimrao Ambedkar (A Central) University, Lucknow on 21st -23rd, Feb., 2014, p. 3.

7. **Gupta, N.,** & Gupta, V. (2012). Radiation in everyday life in an International Conference on Radiation Environment- Assessment, Measurement & its Impact (RADENVIRON- 2012) organized by Department of Applied Physics, School for Physical Sciences at Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 12th -14th April, 2012, p. 59.

<u>TRAINING PROGRAMS</u>

1. Participated in **Training Course on "Classical and Modern Methods in Plant Taxonomy & Biosystematics"** organized by CSIR-NBRI, Lucknow (U.P.) on 3rd-10th November, 2016.
2. Participated in **Hands-on-Training on SEM, FTIR, FPLC and Ion Chromatography** organized by University Science Instrumentation Centre, Babasaheb Bhimrao Ambedkar Ambedkar (A Central) University, Lucknow on 18th-20th February, 2015.
3. Participated in a National Workshop on **Data Analysis and Project Designing** organized by School for Home Science, Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 9th -13th February, 2015.
4. Attended a Two days International Workshop on **Bridging Development Divide for Inclusive Growth through Science, Technology and Innovation (BRIDGES- 2015)** organized by DST- Centre for Policy Research & Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 16th -17th January, 2015.
5. Poster presentation on **Lichens as an indicator of pollution level in and around Panki thermal power station, Kanpur (U.P.): Physiological and distributional variable** in the Department of Environmental Science, Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 27th -28th March, 2014.
6. Dwivedi, S. K., **Gupta N.** and Upreti, D. K. (2014). **Sensitivity of lichens a tool to biomonitors air quality in the vicinity of a coal-based thermal power plant of Uttar Pradesh, India** in Two days workshop on **Innovation and Technology transfer to Industries: Role of Universities** organized by Centre for Industry Institute Partnership Program at Babasaheb Bhimrao Ambedkar (A Central) University, Lucknow on 10th -11th March, 2014, p. 49.

7. Participated in a One day Workshop on **Mainstreaming Climate Change Adaptation & Disaster Risk Reduction** at Department of Environmental Sciences, Babasaheb Bhimrao Ambedkar (A Central) University- Lucknow on March 07th, 2014.
8. Participated in a Three days Workshop on **Water Treatment by Adsorption** at Department of Environmental Sciences, Dr. R.M.L. Avadh University, Faizabad on July, 27th -29th, 2013.

6.4.1 Ecological parameters estimated for lichen taxa around Panki Thermal Power Plant, Kanpur (I Sampling sites=17)

S. No.	Lichen Taxa	Panki Thermal Power Plant, Kanpur																	Ecological Parameters							
		Number of Quadrates																	No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17								
1	***Anisomeridium nidulans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
2	***Arthothelium chiodectoides***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	***Bacidia incongruens****	-	-	-	-	1	-	-	1	-	-	-	-	-	-	-	-	-	2	2	11.76	0.12	0.117	15.38	15.48	30.86
4	***Bacidia medialis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
5	***Bacidia rubella***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	***Bacidia submedialis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
7	***Caloplaca bassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
8	***Dirinaria consimilis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	***Hyperphyscia adglutinata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
10	***Lecanora achroa***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
11	***Lecanora tropica***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
12	***Lecanora helva***	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.88	0.06	0.059	7.69	7.74	15.43
13	***Opegrapha astraea***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	***Peltula corticola***	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.88	0.06	0.059	7.69	7.74	15.43
15	***Pertusaria quassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
16	***Phyllopeltula steppae***	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.88	0.06	0.059	7.69	7.74	15.43
17	***Pyxine cocoes***	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	3	4	17.65	0.18	0.235	23.08	23.22	46.30
18	***Pyxine sorediata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
19	***Rinodina exigua***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	***Rinodina sophodes***	-	-	-	4	1	1	-	-	-	-	-	-	-	-	-	-	-	5	10	29.41	0.29	0.589	38.46	38.70	77.16
21	***Strigula elegans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	**0**	**0**	**0**	**6**	**5**	**2**	**0**	**3**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13**	**19**	**76.47**	**0.76**	**1.12**	**100.00**	**100.62**	**200.62**
	Average																		**0.619**	**0.904**	**3.641**	**0.036**	**0.053**	**4.762**	**4.791**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index; **Bacidia* sp. (sterile form) merged with this species

6.4.2 Ecological parameters estimated for lichen taxa around Panki Thermal Power Plant, Kanpur (II Sampling sites=17)

S. No.	Lichen Taxa	Panki Thermal Power Plant, Kanpur																	Ecological Parameters							
		Number of Quadrate																								
		18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
1	***Anisomeridium nidulans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.88	0.06	0.059	16.67	16.81	33.48
2	***Arthothelium chiodectoides***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	***Bacidia incongruens****	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1		2	2	11.76	0.12	0.117	33.34	33.61	66.95
4	***Bacidia medialis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
5	***Bacidia rubella***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	***Bacidia submedialis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
7	***Caloplaca bassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
8	***Dirinaria consimilis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	***Hyperphyscia adglutinata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
10	***Lecanora achroa***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
11	***Lecanora tropica***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
12	***Lecanora helva***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
13	***Opegrapha astraea***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	***Peltula corticola***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
15	***Pertusaria quassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.88	0.06	0.059	16.67	16.81	33.48
16	***Phyllopeltula steppae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	***Pyxine cocoes***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.88	0.06	0.059	16.67	16.81	33.48
18	***Pyxine sorediata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
19	***Rinodina exigua***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	***Rinodina sophodes***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	1	2	5.88	0.06	0.117	16.67	16.81	33.48
21	***Strigula elegans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	6	0	6	7	35.29	0.35	0.41	100.01	100.84	200.85
	Average																		**0.286**	**0.333**	**1.681**	**0.017**	**0.019**	**4.762**	**4.802**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index; **Bacidia* sp. (sterile form) merged with this species

6.5.1 Ecological parameters estimated for lichen taxa around Tanda Thermal Power Plant, Ambedkar Nagar (I Sampling sites=21)

S. No.	Lichen Taxa	Tanda Thermal Power Plant, Ambedkar Nagar																					Ecological Parameters							
		Number of Quadrates																					No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21								
1	***Anisomeridium nidulans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
2	***Arthothelium chiodectoides***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	2	4.76	0.05	0.095	2.44	2.44	4.88
3	***Bacidia incongruens***	1	2	2	1	-	-	-	-	-	-	-	1	1	1	-	-	1	-	-	2	-	9	12	42.86	0.43	0.571	21.95	21.98	43.93
4	***Bacidia medialis***	-	2		1	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	3	4	14.29	0.14	0.190	7.32	7.33	14.64
5	***Bacidia rubella***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	***Bacidia submedialis***	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1	-	-	-	3	5	14.29	0.14	0.238	7.32	7.33	14.64
7	***Caloplaca bassiae***	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	1	-	-	2	3	5	14.29	0.14	0.238	7.32	7.33	14.64
8	***Dirinaria consimilis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	***Hyperphyscia adglutinata***	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4.76	0.05	0.047	2.44	2.44	4.88
10	***Lecanora achroa***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
11	***Lecanora tropica***	1	3		1	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	4	6	19.05	0.19	0.285	9.76	9.77	19.52
12	***Lecanora helva***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
13	***Opegrapha astraea***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	***Peltula corticola***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
15	***Pertusaria quassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
16	***Phyllopeltula steppae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	***Pyxine cocoes***	1	1	-	1	1		3		1	1	-	1	1	1	-	-	-	-	2		3	12	17	57.14	0.57	0.809	29.27	29.30	58.57
18	***Pyxine sorediata***	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4.76	0.05	0.047	2.44	2.44	4.88
19	***Rinodina exigua***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	***Rinodina sophodes***	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	3	3	14.29	0.14	0.143	7.32	7.33	14.64
21	***Strigula elegans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	**3**	**12**	**2**	**4**	**2**	**1**	**3**	**0**	**1**	**3**	**0**	**2**	**3**	**2**	**0**	**0**	**4**	**2**	**3**	**2**	**7**	**40**	**56**	**190.48**	**1.90**	**2.67**	**97.59**	**97.68**	**195.24**
	Average																						**1.905**	**2.667**	**9.070**	**0.091**	**0.127**	**4.646**	**4.651**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index

6.5.2 Ecological parameters estimated for lichen taxa around Tanda Thermal Power Plant, Ambedkar Nagar (II Sampling sites=21)

S. No.	Lichen Taxa	Tanda Thermal Power Plant, Ambedkar Nagar																					Ecological Parameters							
		Number of Quadrates																					No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
		22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42								
1	***Anisomeridium nidulans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
2	***Arthothelium chiodectoides***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	***Bacidia incongruens***	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	-	3	3	14.29	0.14	0.143	12.50	12.53	25.03
4	***Bacidia medialis***	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	2	9.52	0.10	0.095	8.33	8.35	16.69
5	***Bacidia rubella***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	***Bacidia submedialis***	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4	4	19.05	0.19	0.190	16.67	16.71	33.37
7	***Caloplaca bassiae***	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4.76	0.05	0.047	4.17	4.18	8.34
8	***Dirinaria consimilis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	***Hyperphyscia adglutinata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
10	***Lecanora achroa***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
11	***Lecanora tropica***	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	2	2	9.52	0.10	0.095	8.33	8.35	16.69
12	***Lecanora helva***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
13	***Opegrapha astraea***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	***Peltula corticola***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
15	***Pertusaria quassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
16	***Phyllopeltula steppae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	***Pyxine cocoes***	-	1	1	-	-	-	-	-	-	-	-	-	1	1	1	1	1	1	1	1	2	11	12	52.38	0.52	0.571	45.83	45.95	91.78
18	***Pyxine sorediata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
19	***Rinodina exigua***	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	4.76	0.05	0.047	4.17	4.18	8.34
20	***Rinodina sophodes***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
21	***Strigula elegans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	**1**	**5**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**1**	**2**	**1**	**1**	**2**	**3**	**4**	**24**	**25**	**114.29**	**1.14**	**1.19**	**100.00**	**100.25**	**200.25**
	Average																						**1.143**	**1.190**	**5.442**	**0.054**	**0.056**	**4.761**	**4.773**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index

6.6.1 Ecological parameters estimated for lichen taxa around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (I Sampling sites=20)

S. No.	Lichen Taxa	Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli																				Ecological Parameters							
		Number of Quadrates																											
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	qua drat e	ple s	F	D	A	Rf	Rd	IVI
1	***Anisomeridium nidulans***	1	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	-	-	1	5	5	25.00	0.25	0.25	14.29	14.29	28.57
2	***Arthothelium chiodectoides***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	***Bacidia incongruens****	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	2	2	10.00	0.10	0.1	5.71	5.71	11.43
4	***Bacidia medialis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
5	***Bacidia rubella***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	***Bacidia submedialis***	1	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	2	2	10.00	0.10	0.1	5.71	5.71	11.43
7	***Caloplaca bassiae***	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	2.86	2.86	5.71
8	***Dirinaria consimilis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	***Hyperphyscia adglutinata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
10	***Lecanora achroa***	1	-	-	-	-	1	-	1	-	-	-	-	1	-	-	-	-	-	-	-	4	4	20.00	0.20	0.2	11.43	11.43	22.86
11	***Lecanora tropica***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
12	***Lecanora helva***	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	10.00	0.10	0.1	5.71	5.71	11.43
13	***Opegrapha astraea***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.00	0.05	0.05	2.86	2.86	5.71
14	***Peltula corticola***	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	1	-	-	-	1	3	5	15.00	0.15	0.25	8.57	8.57	17.14
15	***Pertusaria quassiae***	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	2.86	2.86	5.71
16	***Phyllopeltula steppae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	***Pyxine cocoes***	-	1	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	4	15.00	0.15	0.2	8.57	8.57	17.14
18	***Pyxine sorediata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
19	***Rinodina exigua***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	***Rinodina sophodes***	1	1	1	1	-	-	1	-	-	-	-	-	2	1	1	3	-	1	-	2	11	15	55.00	0.55	0.75	31.43	31.43	62.86
21	***Strigula elegans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	**4**	**3**	**1**	**1**	**2**	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**6**	**1**	**1**	**4**	**2**	**1**	**2**	**6**	**35**	**42**	**175.00**	**1.75**	**2.10**	**100.0 0**	**100.00**	**200.00**
	Average																					**1.666**	**2**	**8.333**	**0.083**	**0.1**	**4.762**	**4.762**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index; **Bacidia* sp. (sterile form) merged with this species

6.6.2 Ecological parameters estimated for lichen taxa around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (II Sampling sites=20)

S. No.	Lichen Taxa	Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli																				Ecological Parameters							
		Number of Quadrates																				No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
		21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40								
1	*Anisomeridium nidulans*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
2	*Arthothelium chiodectoides*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	*Bacidia incongruens**	-	-	1	-	1	-	-	-	-	-	1	1	-	-	1	-	-	-	2		6	7	30.00	0.30	0.35	17.65	17.65	35.29
4	*Bacidia medialis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
5	*Bacidia rubella*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	*Bacidia submedialis*	-	-	-	-	-	1	-	-	1	1	-	-	-	-	-	-	1	-	-	-	4	4	20.00	0.20	0.2	11.76	11.76	23.53
7	*Caloplaca bassiae*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
8	*Dirinaria consimilis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.00	0.05	0.05	2.94	2.94	5.88
9	*Hyperphyscia adglutinata*	1	-	1	-	1	-	-	1	-	-	-	-	-	1	-	-	-	-	-	-	5	5	25.00	0.25	0.25	14.71	14.71	29.41
10	*Lecanora achroa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
11	*Lecanora tropica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.00	0.05	0.05	2.94	2.94	5.88
12	*Lecanora helva*	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	2.94	2.94	5.88
13	*Opegrapha astraea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	*Peltula corticola*	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	2.94	2.94	5.88
15	*Pertusaria quassiae*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	1	5.00	0.05	0.05	2.94	2.94	5.88
16	*Phyllopeltula steppae*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	*Pyxine cocoes*	1	-	1	1	-	1	1	-	-	-	-	-	-	-	-	1		1	2	-	8	9	40.00	0.40	0.45	23.53	23.53	47.06
18	*Pyxine sorediata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	5.00	0.05	0.05	2.94	2.94	5.88
19	*Rinodina exigua*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	*Rinodina sophodes*	-	-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	1	-	-	-	4	4	20.00	0.20	0.2	11.76	11.76	23.53
21	*Strigula elegans*	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	2.94	2.94	5.88
	Total	**3**	**0**	**4**	**2**	**2**	**2**	**1**	**1**	**2**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**2**	**1**	**7**	**1**	**34**	**36**	**170.00**	**1.70**	**1.80**	**100.00**	**100.00**	**200.00**
	Average																					**1.619**	**1.714**	**8.095**	**0.081**	**0.086**	**4.762**	**4.762**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index; **Bacidia* sp. (sterile form) merged with this species

6.6.3 Ecological parameters estimated for lichen taxa around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (III Sampling sites=20)

S. No	Lichen Taxa	Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli																				Ecological Parameters							
		Number of Quadrates																				No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
		41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60								
1	***Anisomeridium nidulans***	-	-	-	-	-	-	-	-	-	-	1	-	-	-	1	1	-	1	-	-	4	4	20.00	0.20	0.2	12.12	12.12	24.24
2	***Arthothelium chiodectoides***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	***Bacidia incongruens****	1	-	-	-	-	-	1	1	1	-	1	-	-	1	1	-	-	1	1	1	10	10	50.00	0.50	0.5	30.30	30.30	60.61
4	***Bacidia medialis***	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	3.03	3.03	6.06
5	***Bacidia rubella***	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	3.03	3.03	6.06
6	***Bacidia submedialis***	-	-	2	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	3	10.00	0.10	0.15	6.06	6.06	12.12
7	***Caloplaca bassiae***	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	3.03	3.03	6.06
8	***Dirinaria consimilis***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	***Hyperphyscia adglutinata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
10	***Lecanora achroa***	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	-	-	-	-	2	2	10.00	0.10	0.1	6.06	6.06	12.12
11	***Lecanora tropica***	-	-	-	-	-	-	-	1	1	1	-	-	-	-	-	-	1	-	-	-	4	4	20.00	0.20	0.2	12.12	12.12	24.24
12	***Lecanora helva***	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	3.03	3.03	6.06
13	***Opegrapha astraea***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	***Peltula corticola***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
15	***Pertusaria quassiae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
16	***Phyllopeltula steppae***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	***Pyxine cocoes***	1	-	-	-	-	-	-	-	1	1	-	-	1	-	-	-	1	-	-	-	5	5	25.00	0.25	0.25	15.15	15.15	30.30
18	***Pyxine sorediata***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
19	***Rinodina exigua***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	***Rinodina sophodes***	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	2	10.00	0.10	0.1	6.06	6.06	12.12
21	***Strigula elegans***	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	**2**	**1**	**3**	**1**	**1**	**1**	**1**	**3**	**3**	**2**	**2**	**1**	**3**	**1**	**2**	**1**	**2**	**2**	**1**	**1**	**33**	**34**	**165.00**	**1.65**	**1.70**	**100.00**	**100.00**	**200.00**
	Average																					**1.571**	**1.619**	**7.857**	**0.078**	**0.081**	**4.762**	**4.762**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index; **Bacidia* sp. (sterile form) merged with this species

6.6.4 Ecological parameters estimated for lichen taxa around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli (IV Sampling sites=20)

S. No	Lichen Taxa	Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli																				Ecological Parameters							
		Number of Quadrates																				No. of species occurred in quadrate	Total Samples	F	D	A	Rf	Rd	IVI
		61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80								
1	*Anisomeridium nidulans*	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	5.00	0.05	0.05	3.23	3.23	6.45
2	*Arthothelium chiodectoides*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
3	*Bacidia incongruens**	1	2	1	1	-	1	2	2	1	-	-	-	-	-	1	-	1	1	1	-	12	15	60.00	0.60	0.75	38.71	38.71	77.42
4	*Bacidia medialis*	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	-	-	-	3	4	15.00	0.15	0.2	9.68	9.68	19.35
5	*Bacidia rubella*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
6	*Bacidia submedialis*	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	1	-	-	3	3	15.00	0.15	0.15	9.68	9.68	19.35
7	*Caloplaca bassiae*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
8	*Dirinaria consimilis*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
9	*Hyperphyscia adglutinata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
10	*Lecanora achroa*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
11	*Lecanora tropica*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
12	*Lecanora helva*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
13	*Opegrapha astraea*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
14	*Peltula corticola*	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	1	2	5.00	0.05	0.1	3.23	3.23	6.45
15	*Pertusaria quassiae*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1	5.00	0.05	0.05	3.23	3.23	6.45
16	*Phyllopeltula steppae*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
17	*Pyxine cocoes*	-	-	-	-	-	-	-	-	-	-	-	1	1	1	1	1	1	-	-	-	6	6	30.00	0.30	0.3	19.35	19.35	38.71
18	*Pyxine sorediata*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
19	*Rinodina exigua*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
20	*Rinodina sophodes*	-	-	-	-	-	-	-	-	-	3	2	-	-	1	-	1	-	-	-	-	4	7	20.00	0.20	0.35	12.90	12.90	25.81
21	*Strigula elegans*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	0.00	0.00	0	0.00	0.00	0.00
	Total	**1**	**4**	**1**	**1**	**1**	**1**	**2**	**2**	**1**	**5**	**2**	**1**	**1**	**3**	**2**	**4**	**3**	**2**	**1**	**1**	**31**	**39**	**155.00**	**1.55**	**1.95**	**100.00**	**100.00**	**200.00**
	Average																					**1.476**	**1.857**	**7.381**	**0.074**	**0.093**	**4.762**	**4.762**	

Abbreviation: F=Frequency; D=Density; A=Abundance; Rf= Relative frequency; Rd= Relative density; IVI= Important Value Index; **Bacidia* sp. (sterile form) merged with this species

7.7.1 Chlorophyll a analysis of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	6.07E-05	2	3.03E-05	4.014706 NS	0.078223	5.143253
Within Groups	4.53E-05	6	7.56E-06			
Total	0.000106	8				

LSD 0.05%= 0.00489 and LSD 0.01%= 0.00686; NS = Non-Significant

7.7.2 Chlorophyll b analysis of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1.27E-05	2	6.33E-06	4.071429 NS	0.076356	5.143253
Within Groups	9.33E-06	6	1.56E-06			
Total	0.000022	8				

LSD 0.05%= 0.00222 and LSD 0.01%= 0.00311; NS = Non-Significant

7.7.3 Total Chlorophyll analysis of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000123	2	6.14E-05	5.216981*	0.048666	5.143253
Within Groups	7.07E-05	6	1.18E-05			
Total	0.000194	8				

LSD 0.05%= 0.00611 and LSD 0.01%= 0.00856; *=Significant at 0.05% level.

7.7.4 Carotenoid analysis of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	3.49E-05	2	1.74E-05	7.85*	0.021139	5.143253
Within Groups	1.33E-05	6	2.22E-06			
Total	4.82E-05	8				

LSD 0.05%= 0.00265 and LSD 0.01%= 0.00372; *=Significant at 0.05% level.

7.7.5 Chlorophyll Degradation analysis of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.094682	2	0.047341	240.7169**	1.87E-06	5.143253
Within Groups	0.00118	6	0.000197			
Total	0.095862	8				

LSD 0.05%= 0.02495 and LSD 0.01%= 0.03498; **= Significant at 0.01% level.

7.7.6 Protein Content Analysis of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.089425	2	0.044712	1.953418 NS	0.222151	5.143253
Within Groups	0.137336	6	0.022889			
Total	0.226761	8				

LSD 0.05%= 0.26917 and LSD 0.01%= 0.37738; NS = Non-Significant

7.7.7 Chlorophyll a analysis of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.153273	2	0.076636	14.40924**	0.005117	5.143253
Within Groups	0.031911	6	0.005319			
Total	0.185184	8				

LSD 0.05%= 0.145709 and LSD 0.01%= 0.220736; **= Significant at 0.01% level.

7.7.8 Chlorophyll b analysis of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.125171	2	0.062585	10.35457*	0.011336	5.143253
Within Groups	0.036265	6	0.006044			
Total	0.161436	8				

LSD 0.05%= 0.155331 and LSD 0.01%= 0.235314; *=Significant at 0.05% level.

7.7.9 Total Chlorophyll analysis of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.553544	2	0.276772	13.34263**	0.006186	5.143253
Within Groups	0.124461	6	0.020743			
Total	0.678005	8				

LSD 0.05%= 0.287759 and LSD 0.01%= 0.435931; **= Significant at 0.01% level.

7.7.10 Carotenoid analysis of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.145275	2	0.072637	11.82094**	0.008293	5.143253
Within Groups	0.036869	6	0.006145			
Total	0.182144	8				

LSD 0.05%= 0.156618 and LSD 0.01%= 0.237264; **= Significant at 0.01% level.

7.7.11 Chlorophyll Degradation analysis of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.21744	2	0.10872	960.2365**	3.02E-08	5.143253
Within Groups	0.000679	6	0.000113			
Total	0.21812	8				

LSD 0.05%= 0.02126 and LSD 0.01%= 0.032206; **= Significant at 0.01% level.

7.7.12 Protein Content Analysis of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	64.40748	2	32.20374	1653.148**	5.94E-09	5.143253
Within Groups	0.116882	6	0.01948			
Total	64.52436	8				

LSD 0.05%= 0.27886 and LSD 0.01%= 0.422449; **= Significant at 0.01% level.

7.9.1 Cr Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	6186.032	2	3093.0159	10060.76949**	2.65E-11	5.143253
Within Groups	1.8446	6	0.3074333			
Total	6187.876	8				

LSD 0.05%= 0.924455 and LSD 0.01%= 1.24498; **= Significant at 0.01% level.

7.9.2 Mn Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	446556.2	2	223278.098	2398261**	1.96E-18	5.143253
Within Groups	0.5586	6	0.0931			
Total	446556.8	8				

LSD 0.05%= 0.508727 and LSD 0.01%= 0.685113; **= Significant at 0.01% level.

7.9.3 Fe Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1.79E+09	2	895655222	3.24E+09**	7.9E-28	5.143253
Within Groups	1.6562	6	0.276033333			
Total	1.79E+09	8				

LSD 0.05%= 0.875973 and LSD 0.01%= 1.17969; **= Significant at 0.01% level.

7.9.4 Co Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	295.5662	2	147.7831	980.86128**	2.84E-08	5.143253
Within Groups	0.904	6	0.150667			
Total	296.4702	8				

LSD 0.05%= 0.64717 and LSD 0.01%= 0.871557; **= Significant at 0.01% level.

7.9.5 Ni Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	3694.38	2	1847.19	109301.189**	2.07E-14	5.143253
Within Groups	0.1014	6	0.0169			
Total	3694.482	8				

LSD 0.05%= 0.216747 and LSD 0.01%= 0.291898; **= Significant at 0.01% level.

7.9.6 Cu Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	4257.484	2	2128.7419	103170.0436**	2.46E-14	5.143253
Within Groups	0.1238	6	0.020633333			
Total	4257.608	8				

LSD 0.05%= 0.239494 and LSD 0.01%= 0.322531; **= Significant at 0.01% level.

7.9.7 Zn Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	72360.64	2	36180.3208	510941.2955**	2.02415 E-16	5.143253
Within Groups	0.424867	6	0.07081111			
Total	72361.07	8				

LSD 0.05%= 0.443671 and LSD 0.01%= 0.5975; **= Significant at 0.01% level.

7.9.8 As Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	609.5072	2	304.7536	5390.688679**	1.7207E-10	5.143253
Within Groups	0.3392	6	0.0565333			
Total	609.8464	8				

LSD 0.05%= 0.396426 and LSD 0.01%= 0.533875; **= Significant at 0.01% level.

7.9.9 Se Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	54.3678	2	27.1839	378.9577**	4.84527E-07	5.143253
Within Groups	0.4304	6	0.071733			
Total	54.7982	8				

LSD 0.05%= 0.446551 and LSD 0.01%= 0.601378; **= Significant at 0.01% level.

7.9.10 Cd Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	22.0448	2	11.0224	604.5192**	1.2E-07	5.143253
Within Groups	0.1094	6	0.018233			
Total	22.1542	8				

LSD 0.05%= 0.225135 and LSD 0.01%= 0.303194; **= Significant at 0.01% level.

7.9.11 Pb Accumulation in the thalli of *P. cocoes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	94256.14	2	47128.07	585199.5**	1.35E-16	5.143253
Within Groups	0.4832	6	0.080533			
Total	94256.62	8				

LSD 0.05%= 0.473149 and LSD 0.01%= 0.637199; **= Significant at 0.01% level.

7.9.12 Cr Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	13877.2664	2	6938.6332	47874.65409**	2.46017E-13	5.14325285
Within Groups	0.8696	6	0.1449333			
Total	13878.136	8				

LSD 0.05%= 0.63474 and LSD 0.01%= 0.85481; **= Significant at 0.01% level.

7.9.13 Mn Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	2436898.641	2	1218449.32	4577004**	2.81591E-19	5.143253
Within Groups	1.597266667	6	0.266211111			
Total	2436900.238	8				

LSD 0.05%= 0.86025 and LSD 0.01%= 1.15851; **= Significant at 0.01% level.

7.9.14 Fe Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	2340862885	2	1170431442	39477540.69**	4.38847E-22	5.143253
Within Groups	177.8882	6	29.64803333			
Total	2340863062	8				

LSD 0.05%= 9.07837 and LSD 0.01%= 12.226; **= Significant at 0.01% level.

7.9.15 Co Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	789.3662	2	394.6831	9382.324**	3.266E-11	5.143253
Within Groups	0.2524	6	0.0420667			
Total	789.6186	8				

LSD 0.05%= 0.34196 and LSD 0.01%=0.46053; **= Significant at 0.01% level.

7.9.16 Ni Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	6171.2858	2	3085.6429	55597.16937**	1.57085E-13	5.143253
Within Groups	0.333	6	0.0555			
Total	6171.6188	8				

LSD 0.05%= 0.39279 and LSD 0.01%= 0.52897; **= Significant at 0.01% level.

7.9.17 Cu Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1893.8552	2	946.9276	85308.79279**	4.34847E-14	5.143253
Within Groups	0.0666	6	0.0111			
Total	1893.9218	8				

LSD 0.05%= 0.17566 and LSD 0.01%= 0.23656; **= Significant at 0.01% level.

7.9.18 Zn Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	14279.22	2	7139.61	276729.0698**	1.27405E-15	5.143253
Within Groups	0.1548	6	0.0258			
Total	14279.3748	8				

LSD 0.05%= 0.26781 and LSD 0.01%= 0.36066; **= Significant at 0.01% level.

7.9.19 As Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1941.6098	2	970.8049	29418.3303**	1.06017E-12	5.143253
Within Groups	0.198	6	0.033			
Total	1941.8078	8				

LSD 0.05%= 0.30288 and LSD 0.01%= 0.40789; **= Significant at 0.01% level.

7.9.20 Se Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	34.4582	2	17.2291	950.1341912**	3.11818E-08	5.143253
Within Groups	0.1088	6	0.018133			
Total	34.567	8				

LSD 0.05%= 0.22452 and LSD 0.01%= 0.30236; **= Significant at 0.01% level.

7.9.21 Cd Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1.2806	2	0.6403	15.25735**	0.004437	5.143253
Within Groups	0.2518	6	0.041967			
Total	1.5324	8				

LSD 0.05%= 0.22452 and LSD 0.01%= 0.30236; **= Significant at 0.01% level.

7.9.22 Pb Accumulation in the thalli of *R. sophodes* around Panki Thermal Power Plant, Kanpur

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	297385.28	2	148692.64	2121150.357**	2.8291E-18	5.143253
Within Groups	0.4206	6	0.0701			
Total	297385.7006	8				

LSD 0.05%= 0.44144 and LSD 0.01%= 0.59449; **= Significant at 0.01% level.

7.17.1 Chlorophyll a analysis of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.303666667	3	0.101222222	40.8978676**	3.36926E-05	4.066181
Within Groups	0.0198	8	0.002475			
Total	0.323466667	11				

LSD 0.05%= 0.0994 and LSD 0.01%= 0.1506; **= Significant at 0.01% level.

7.17.2 Chlorophyll b analysis of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.103891667	3	0.034631	6.9960718*	0.0125959	4.066181
Within Groups	0.0396	8	0.00495			
Total	0.143491667	11				

LSD 0.05%= 00.1406 and LSD 0.01%= 0.2130; *=Significant at 0.05% level.

7.17.3 Total Chlorophyll analysis of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.742825	3	0.247608	17.675788**	0.0006875	4.066181
Within Groups	0.112067	8	0.014008			
Total	0.854892	11				

LSD 0.05%= 0.2365 and LSD 0.01%= 0.3582; **= Significant at 0.01% level.

7.17.4 Carotenoid analysis of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.230867	3	0.076956	7.954063**	0.00874	4.066181
Within Groups	0.0774	8	0.009675			
Total	0.308267	11				

LSD 0.05%= 0.1965 and LSD 0.01%= 0.2977; **= Significant at 0.01% level.

7.17.5 Chlorophyll Degradation analysis of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.296092	3	0.098697	151.8419**	2.17E-07	4.066181
Within Groups	0.0052	8	0.00065			
Total	0.301292	11				

LSD 0.05%= 0.0509 and LSD 0.01%= 0.0772; **= Significant at 0.01% level.

7.17.6 Protein Content Analysis of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.236567	3	0.078856	4.291459*	0.044165	4.066181
Within Groups	0.147	8	0.018375			
Total	0.383567	11				

LSD 0.05%= 0.2708 and LSD 0.01%= 0.4103; *= Significant at 0.05% level.

7.17.7 Chlorophyll a analysis of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.3383	3	0.11276667	4.202484*	0.046363	4.066181
Within Groups	0.214666667	8	0.02683333			
Total	0.552966667	11				

LSD 0.05%= 0.3273 and LSD 0.01%= 0.4958; *= Significant at 0.05% level.

7.17.8 Chlorophyll b analysis of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.003767	3	0.001256	0.182626 NS	0.905243	4.066181
Within Groups	0.055	8	0.006875			
Total	0.058767	11				

LSD 0.05%= 0.1657 and LSD 0.01%= 0.2510; NS= Non-Significant

7.17.9 Total Chlorophyll analysis of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.413225	3	0.137742	2.3053**	0.153444	4.066181
Within Groups	0.478	8	0.05975			
Total	0.891225	11				

LSD 0.05%= 0.4884 and LSD 0.01%= 0.7399; **= Significant at 0.01% level.

7.17.10 Carotenoid analysis of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.018967	3	0.006322	1.573997 NS	0.269917	4.066181
Within Groups	0.032133	8	0.004017			
Total	0.0511	11				

LSD 0.05%= 0.1266 and LSD 0.01%= 0.1918; NS= Non-Significant

7.17.11 Chlorophyll Degradation analysis of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.658492	3	0.219497	77.01657**	3.05E-06	4.066181
Within Groups	0.0228	8	0.00285			
Total	0.681292	11				

LSD 0.05%= 0.1067 and LSD 0.01%= 0.1616; **= Significant at 0.01% level.

7.17.12 Protein Content Analysis of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1.0833	3	0.3611	3.514355 NS	0.068898	4.066181
Within Groups	0.822	8	0.10275			
Total	1.9053	11				

LSD 0.05%= 0.6404 and LSD 0.01%= 0.9702; NS= Non-Significant

7.19.1 Al Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	919.1042	3	306.368075	11704.61**	6.62E-15	4.066181
Within Groups	0.2094	8	0.026175			
Total	919.3136	11				

LSD 0.05%= 0.3232 and LSD 0.01%= 0.4896; **= Significant at 0.01% level.

7.19.2 Fe Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	94.59309167	3	31.53103	396.7831**	4.87E-09	4.066181
Within Groups	0.635733333	8	0.079467			
Total	95.228825	11				

LSD 0.05%= 0.5632 and LSD 0.01%= 0.8532; **= Significant at 0.01% level.

7.19.3 Cd Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	7.658025	3	2.552675	309.4152**	1.31E-08	4.066181
Within Groups	0.066	8	0.00825			
Total	7.724025	11				

LSD 0.05%= 0.1814 and LSD 0.01%= 0.2749; **= Significant at 0.01% level.

7.19.4 Cr Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	790.8284	3	263.6095	3745.783**	6.3E-13	4.066181
Within Groups	0.563	8	0.070375			
Total	791.3914	11				

LSD 0.05%= 0.5300 and LSD 0.01%= 0.8029; **= Significant at 0.01% level.

7.19.5 Cu Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	570.197	3	190.0657	431.6895**	3.49E-09	4.066181
Within Groups	3.522267	8	0.440283			
Total	573.7193	11				

LSD 0.05%= 1.3257 and LSD 0.01%= 2.0083; **= Significant at 0.01% level.

7.19.6 Pb Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	577.0964	3	192.3655	19629.13**	8.37745E-16	4.066181
Within Groups	0.0784	8	0.0098			
Total	577.1748	11				

LSD 0.05%= 0.1978 and LSD 0.01%= 0.2996; **= Significant at 0.01% level.

7.19.7 Zn Accumulation in the thalli of *P. cocoes* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	2976.147	3	992.0491	1234.225**	5.3122E-11	4.066181
Within Groups	6.430267	8	0.803783			
Total	2982.578	11				

LSD 0.05%= 1.7913 and LSD 0.01%= 2.7136; **= Significant at 0.01% level.

7.19.8 Al Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	27.5415	3	9.1805	63.95333**	6.216E-06	4.066180551
Within Groups	1.1484	8	0.14355			
Total	28.6899	11				

LSD 0.05%= 0.7569 and LSD 0.01%= 1.1467; **= Significant at 0.01% level.

7.19.9 Fe Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	36687.8	3	12229.28	6030.34**	9.39212E-14	4.066181
Within Groups	16.2237	8	2.027958			
Total	36704.1	11				

LSD 0.05%= 2.8452 and LSD 0.01%= 4.3102; **= Significant at 0.01% level.

7.19.10 Cd Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	6.0063	3	2.0021	1862.419**	1.02786E-11	4.066181
Within Groups	0.0086	8	0.00108			
Total	6.0149	11				

LSD 0.05%= 0.0655 and LSD 0.01%= 0.0992; **= Significant at 0.01% level.

7.19.11 Cr Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	312.8192	3	104.2731	1973.934**	8.14826E-12	4.066181
Within Groups	0.4226	8	0.052825			
Total	313.2418	11				

LSD 0.05%= 0.4592 and LSD 0.01%= 0.6956; **= Significant at 0.01% level.

7.19.12 Cu Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	974.51	3	324.837	8587.88**	2.3E-14	4.06618
Within Groups	0.3026	8	0.03783			
Total	974.812	11				

LSD 0.05%= 0.3886 and LSD 0.01%= 0.5886; **= Significant at 0.01% level.

7.19.13 Pb Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	17.0714	3	5.69048	118.49**	5.7E-07	4.066181
Within Groups	0.3842	8	0.04803			
Total	17.4556	11				

LSD 0.05%= 0.4378 and LSD 0.01%= 0.6633; **= Significant at 0.01% level.

7.19.14 Zn Accumulation in the thalli of *B. incongruens* around Tanda Thermal Power Plant, Ambedkar Nagar

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	4859.88	3	1619.96	31915.2**	1.2E-16	4.066181
Within Groups	0.40607	8	0.05076			
Total	4860.29	11				

LSD 0.05%= 0.4501 and LSD 0.01%= 0.6819; **= Significant at 0.01% level.

7.25.1 Chlorophyll a analysis of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.002439	3	0.000813	24.82358**	0.000209	4.066181
Within Groups	0.000262	8	3.28E-05			
Total	0.002701	11				

LSD 0.05%= 0.0095 and LSD 0.01%= 0.0129; **= Significant at 0.01% level.

7.25.2 Chlorophyll b analysis of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000155	3	5.17E-05	9.84127**	0.004629	4.066181
Within Groups	0.000042	8	5.25E-06			
Total	0.000197	11				

LSD 0.05%= 0.0038 and LSD 0.01%= 0.00515; **= Significant at 0.01% level.

7.25.3 Total Chlorophyll analysis of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.003918	3	0.001306	24.60492**	0.000216	4.066181
Within Groups	0.000425	8	5.31E-05			
Total	0.004343	11				

LSD 0.05%= 0.0121 and LSD 0.01%= 0.0164; **= Significant at 0.01% level.

7.25.4 Carotenoid analysis of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000212	3	7.05E-05	11.59361**	0.002775	4.066181
Within Groups	4.87E-05	8	6.08E-06			
Total	0.00026	11				

LSD 0.05%= 0.0041 and LSD 0.01%= 0.0055; **= Significant at 0.01% level.

7.25.5 Chlorophyll degradation analysis of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.400078	3	0.133359	184.2405**	1.01E-07	4.066181
Within Groups	0.005791	8	0.000724			
Total	0.405869	11				

LSD 0.05%= 0.0449 and LSD 0.01%= 0.0604; **= Significant at 0.01% level.

7.25.6 Protein analysis of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.045248	3	0.015083	3.229602 NS	0.08212	4.066181
Within Groups	0.037361	8	0.00467			
Total	0.08261	11				

LSD 0.05%= 0.1139 and LSD 0.01%= 0.1534; NS= Non-Significant

7.25.7 Chlorophyll a analysis of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000879	3	0.000293	1.8397 ^{NS}	0.218121	4.066181
Within Groups	0.001274	8	0.000159			
Total	0.002153	11				

LSD 0.05%= 0.0210 and LSD 0.01%= 0.02834; NS= Non-Significant

7.25.8 Chlorophyll b analysis of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000862	3	0.000287	7.255439*	0.011372	4.066181
Within Groups	0.000317	8	3.96E-05			
Total	0.001178	11				

LSD 0.05%= 0.0105 and LSD 0.01%= 0.0141; *= Significant at 0.05% level.

7.25.9 Total Chlorophyll analysis of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.001582	3	0.000527	0.882088 ^{NS}	0.490171	4.066181
Within Groups	0.004781	8	0.000598			
Total	0.006363	11				

LSD 0.05%= 0.0408 and LSD 0.01%= 0.0549; NS= Non-Significant

7.25.10 Carotenoid analysis of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	379.6068	3	126.5356	0.999513 ^{NS}	0.44129	4.066181
Within Groups	1012.778	8	126.5973			
Total	1392.385	11				

LSD 0.05%= 18.7595 and LSD 0.01%= 25.2638; NS= Non-Significant

7.25.11 Chlorophyll degradation analysis of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.273135	3	0.091045	1.208503 ^{NS}	0.367309	4.066181
Within Groups	0.602695	8	0.075337			
Total	0.87583	11				

LSD 0.05%= 0.4576 and LSD 0.01%= 0.6163; NS= Non-Significant

7.25.12 Protein analysis of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.094643	3	0.031548	0.410877 ^{NS}	0.749717	4.066181
Within Groups	0.61425	8	0.076781			
Total	0.708893	11				

LSD 0.05%= 0.4620 and LSD 0.01%= 0.6222; NS= Non-Significant

7.25.13 Chlorophyll a analysis of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000875	3	0.000292	1.277393 NS	0.346137	4.066181
Within Groups	0.001827	8	0.000228			
Total	0.002703	11				

LSD 0.05%= 0.0252 and LSD 0.01%= 0.0339; NS= Non-Significant

7.25.14 Chlorophyll b analysis of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.000451	3	0.00015	1.86715 NS	0.213483	4.066181
Within Groups	0.000644	8	8.05E-05			
Total	0.001095	11				

LSD 0.05%= 0.0149 and LSD 0.01%= 0.0201; NS= Non-Significant

7.25.15 Total Chlorophyll analysis of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.002903	3	0.000968	1.898937 NS	0.208262	4.066181
Within Groups	0.004077	8	0.00051			
Total	0.00698	11				

LSD 0.05%= 0.0376 and LSD 0.01%= 0.0507; NS= Non-Significant

7.25.16 Carotenoid analysis of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.001011	3	0.000337	1.664745 NS	0.250713	4.066181
Within Groups	0.001619	8	0.000202			
Total	0.00263	11				

LSD 0.05%= 0.0237 and LSD 0.01%= 0.0319; NS= Non-Significant

7.25.17 Chlorophyll degradation analysis of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.054914	3	0.018305	6.632276*	0.014603	4.066181
Within Groups	0.022079	8	0.00276			
Total	0.076993	11				

LSD 0.05%= 0.0876 and LSD 0.01%= 0.1179; *= Significant at 0.05% level.

7.25.18 Protein analysis of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	0.205706	3	0.068569	1.616822 NS	0.260642	4.066181
Within Groups	0.339277	8	0.04241			
Total	0.544983	11				

LSD 0.05%= 0.3434 and LSD 0.01%= 0.4624; NS= Non-Significant

7.27.1 Cr Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	639.2079	3	213.0693	1340.691**	3.82E-11	4.066181
Within Groups	1.2714	8	0.158925			
Total	640.4793	11				

LSD 0.05%= 0.6647 and LSD 0.01%= 0.8951; **= Significant at 0.01% level.

7.27.2 Mn Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	4015234	3	1338411	9904376.5**	1.29E-26	4.066181
Within Groups	1.081067	8	0.135133			
Total	4015235	11				

LSD 0.05%= 0.6129 and LSD 0.01%= 0.8254; **= Significant at 0.01% level.

7.27.3 Fe Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1.21E+09	3	4.05E+08	701636418.8**	5.13E-34	4.066181
Within Groups	4.613	8	0.576625			
Total	1.21E+09	11				

LSD 0.05%= 1.2661 and LSD 0.01%= 1.7050; **= Significant at 0.01% level.

7.27.4 Co Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	331.8507	3	110.6169	1510.128**	2.37E-11	4.066181
Within Groups	0.586	8	0.07325			
Total	332.4367	11				

LSD 0.05%= 0.4512 and LSD 0.01%= 0.6077; **= Significant at 0.01% level.

7.27.5 Ni Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1916.917	3	638.9723	2569.766**	2.84E-12	4.066181
Within Groups	1.9892	8	0.24865			
Total	1918.906	11				

LSD 0.05%= 0.8314 and LSD 0.01%= 1.1196; **= Significant at 0.01% level.

7.27.6 Cu Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	4192.694	3	1397.565	53291.32**	1.54E-17	4.066181
Within Groups	0.2098	8	0.026225			
Total	4192.904	11				

LSD 0.05%= 0.2700 and LSD 0.01%= 0.3636; **= Significant at 0.01% level.

7.27.7 Zn Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	118808.1	3	39602.69	619760.4**	8.43E-22	4.066181
Within Groups	0.5112	8	0.0639			
Total	118808.6	11				

LSD 0.05%= 0.4215 and LSD 0.01%= 0.5676; **= Significant at 0.01% level.

7.27.8 As Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	118.2822	3	39.4274	743.9132**	4E-10	4.066181
Within Groups	0.424	8	0.053			
Total	118.7062	11				

LSD 0.05%= 0.3838 and LSD 0.01%= 0.5169; **= Significant at 0.01% level.

7.27.9 Se Accumulation in the thalli of *B. incongruens* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	37.7535	3	12.5845	208.2664**	6.25E-08	4.066181
Within Groups	0.4834	8	0.060425			
Total	38.2369	11				

LSD 0.05%= 0 0.4098 and LSD 0.01%= 0.5519; **= Significant at 0.01% level.

7.27.10 Cr Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1650.101	3	550.0337	583.3425**	1.05333E-09	4.066181
Within Groups	7.5432	8	0.9429			
Total	1657.644	11				

LSD 0.05%= 1.6189 and LSD 0.01%= 2.1803; **= Significant at 0.01% level.

7.27.11 Mn Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	14817.14	3	4939.048	30129.92**	1.50943E-16	4.066181
Within Groups	1.3114	8	0.163925			
Total	14818.45	11				

LSD 0.05%= 0.6750 and LSD 0.01%= 0.9091; **= Significant at 0.01% level.

7.27.12 Fe Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	39194319.25	3	13064773.08	39395234.95**	5.16655E-29	4.066181
Within Groups	2.653066667	8	0.331633333			
Total	39194321.9	11				

LSD 0.05%= 2.7157 and LSD 0.01%= 3.6573; **= Significant at 0.01% level.

7.27.13 Co Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	14.13863	3	4.712875	27.0427485**	0.000154	4.066181
Within Groups	1.3942	8	0.174275			
Total	15.53283	11				

LSD 0.05%= 0.6960 and LSD 0.01%= 0.9374; **= Significant at 0.01% level.

7.27.14 Ni Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	285.5859	3	95.1953	276.4493**	2.04E-08	4.066181
Within Groups	2.7548	8	0.34435			
Total	288.3407	11				

LSD 0.05%= 0.9784 and LSD 0.01%= 1.3176; **= Significant at 0.01% level.

7.27.15 Cu Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1261.21	3	420.4033	24300.767**	3.57E-16	4.066181
Within Groups	0.1384	8	0.0173			
Total	1261.348	11				

LSD 0.05%= 0.2193 and LSD 0.01%= 0.2953; **= Significant at 0.01% level.

7.27.16 Zn Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	18370.94	3	6123.648	86187.86**	2.25E-18	4.066181
Within Groups	0.5684	8	0.07105			
Total	18371.51	11				

LSD 0.05%= 0.4445 and LSD 0.01%= 0.5985; **= Significant at 0.01% level.

7.27.17 As Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	127.9719	3	42.6573	3189.331**	1.2E-12	4.066181
Within Groups	0.107	8	0.013375			
Total	128.0789	11				

LSD 0.05%= 0.1928 and LSD 0.01%= 0.2597; **= Significant at 0.01% level.

7.27.18 Se Accumulation in the thalli of *P. cocoes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	3.494025	3	1.164675	67.61538**	5.02E-06	4.066181
Within Groups	0.1378	8	0.017225			
Total	3.631825	11				

LSD 0.05%= 0.2188 and LSD 0.01%= 0.2947; **= Significant at 0.01% level.

7.27.19 Cr Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	1157.87	3	385.9567	787.3855**	3.19E-10	4.066181
Within Groups	3.9214	8	0.490175			
Total	1161.791	11				

LSD 0.05%= 1.1673 and LSD 0.01%= 1.572; **= Significant at 0.01% level.

7.27.20 Mn Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	546161.2	3	182053.7	713376.685**	4.80499E-22	4.066181
Within Groups	2.0416	8	0.2552			
Total	546163.2	11				

LSD 0.05%= 0.8423 and LSD 0.01%= 1.1343; **= Significant at 0.01% level.

7.27.21 Fe Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	56143200	3	18714400	43951150.78**	3.33499E-29	4.066181
Within Groups	3.4064	8	0.4258			
Total	56143203.41	11				

LSD 0.05%= 1.0879 and LSD 0.01%= 1.4652; **= Significant at 0.01% level.

7.27.22 Co Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	15.0375	3	5.0125	85.79375**	2.01E-06	4.066181
Within Groups	0.4674	8	0.058425			
Total	15.5049	11				

LSD 0.05%= 0.4030 and LSD 0.01%= 0.5427; **= Significant at 0.01% level.

7.27.23 Ni Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	4447.767	3	1482.589	17830.296**	1.23E-15	4.066181
Within Groups	0.6652	8	0.08315			
Total	4448.432	11				

LSD 0.05%= 0.4808 and LSD 0.01%= 0.6475; **= Significant at 0.01% level.

7.27.24 Cu Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	6744.513	3	2248.171	52252.6641**	1.67E-17	4.066181
Within Groups	0.3442	8	0.043025			
Total	6744.857	11				

LSD 0.05%= 0.3458 and LSD 0.01%= 0.4657; **= Significant at 0.01% level.

7.27.25 Zn Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	26559.13	3	8853.044	196734.3178**	8.31E-20	4.066181
Within Groups	0.36	8	0.045			
Total	26559.49	11				

LSD 0.05%= 0.3537 and LSD 0.01%= 0.4763; **= Significant at 0.01% level.

7.27.26 As Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	2070.45	3	690.1501	7542.624**	3.84E-14	4.066181
Within Groups	0.732	8	0.0915			
Total	2071.182	11				

LSD 0.05%= 0.50434 and LSD 0.01%= 0.6792; **= Significant at 0.01% level.

7.27.27 Se Accumulation in the thalli of *R. sophodes* around Feroze Gandhi Unchahar Thermal Power Plant Corporation, Raebareli

Source of Variation	*Sum of Squares*	*Degree of freedom*	*Mean Square*	*Computed F*	*P-value*	*Tabular F (crit) (5%)*
Between Groups	143.6606	3	47.88688	2061.868**	6.85E-12	4.066181
Within Groups	0.1858	8	0.023225			
Total	143.8464	11				

LSD 0.05%= 0.2541 and LSD 0.01%= 0.3422; **= Significant at 0.01% level.

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Comparative bioaccumulation potential of *Pyxine cocoes* and *Bacidia submedialis* in and around Faizabad city, Uttar Pradesh, India

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ABSTRACT

Spatial trend in lichens diversity pattern with respect to pollution source provides vital information regarding environmental condition of the study area. In order to assess lichen diversity changes in one of the cultural centre of Uttar Pradesh, Faizabad city, lichen zone mapping technique was employed to observe spatial trends of lichen diversity in a grid of 1x1 km within 0-5,6-12 and 13-20 km distance from city centre in all the four directions. Overall 15 species were recorded from different directions. Among the different lichen species, *Pyxine cocoes* and *Bacidia submedialis* were common in most of the grids. Changes in physiological parameters and metal profile with respect to distance from city centre to the outskirts of the city in both *P. cocoes* and *B. submedialis* were analyzed.

It was observed that the physiological parameters varied from site to site and in different directions, but the metal profile clearly indicates a decreasing trend of metal concentration with increasing distance from the city centre. The present study provides baseline data for future biomonitoring studies and further confirms the lichen biomonitoring study as an effective tool to monitor changes in environmental condition.

1) INTRODUCTION

Increasing population, anthropogenic activities including construction, unplanned developmental processes along with vehicular emission and rapid growth of industrialization results in higher pollution level which ultimately has deleterious impact on the biodiversity and human health. Atmospheric pollutant causes irreversible damage to living organisms. Damage can occur at all levels of biological organization, from the components of individual cells to ecosystems [1]. The places which are exposed to heavy tourist and vehicular activities are more susceptible to the increased metallic pollutant as vehicular and anthropogenic activity result in emission of pollutant in the atmosphere [2].

Lichens are being used as an ideal biomonitors of air pollution. Several lichen species have been effectively employed worldwide for monitoring of air quality [3, 4, 5, 6 and 7]. A large number of studies with reference to the pollution monitoring with plants are available in India however few cities in different geographical regions of the country have been systematically mapped utilizing lichens for their pollutant load [2].

Lichens can be utilized as the monitor of pollution by three different ways: (a) by identifying and mapping of lichen species present in the area; (b) by transplant the healthy lichen from non- polluted area to the polluted area and measuring the decrement in the structure of thallus; and (c) sampling of an individual species and measuring contaminants collected in the thallus [8]. Thus, the monitoring alteration in the distribution of lichens could be a serviceable tool to examine bioclimatic feature of an area.

In the last two-three decades, few studies utilizing lichens for monitoring in Indian cities are available. The city of Bangalore, Pune and Kolkata and some major towns in Himalaya are studied through lichen biomonitoring and metal load of lichens in the area are available [2]. Earlier, the accumulation of lead (Pb) in lichens at different sites in and around Faizabad city of Uttar Pradesh was studied and it was recorded that concentration of lead (Pb) in lichens decreased with distance from the source of pollution [9]. No records of lichen diversity in relation with air pollution and monitoring were available from the area, thus the present study is carried out with an aim to provide a detail distributional account of lichens in and around the Faizabad city followed by changes in physiological parameters and metal profile in *P. cocoes* and *B. submedialis* the two most common lichen species of the area.

2) MATERIALS AND METHODS

2.1 Study area: The city of Faizabad is situated in East of the state of Uttar Pradesh, spread over an area of 2,764 km² at an altitude of 26.90 m above sea level. Faizabad is placed at the

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latitude 26°47' N and longitude 82º 12' E. The district had a population of 2,468,371 based on Census of the year 2011.

2.2 Survey and Sample collection: Lichen species were collected, during March, 2014, in four directions North, West, South and East from 54 localities in and around Faizabad district **(Fig- 1)**. Mostly crustose and foliose lichens were collected on the bark of *Mangifera indica (Mango), Madhuca longifilia (Mahua), Pongamia pinnata (Karanj), Artocarpus heterophyllus (Kathal), Pithecellobium dulce (Jungle Jalebi), Ficus racemosa (Gular), Litchi chinesis (Litchi)* and *Azadirachta indica (Neem)* and cultivated Palm trees. The centre of the city is considered as '0' km. From city centre (0 km) the collection was performed towards each side of the district. Each side was further divided into 1x1 km^2 grid. The distribution of lichen taxa in all direction of area and within the grid was plotted. Approximately 0.2 g of the thallus of similar sizes was taken from sites from all directions in triplicate for further physiological and metal analysis.

The collected samples were kept at low temperature and wrapped in aluminum foil for the analysis. The collected specimens were identified by their morphological, anatomical and chemical characters [10, 11] and voucher specimens were preserved in the Lichen Herbarium of National Botanical Research Institute, Lucknow (LWG), India.

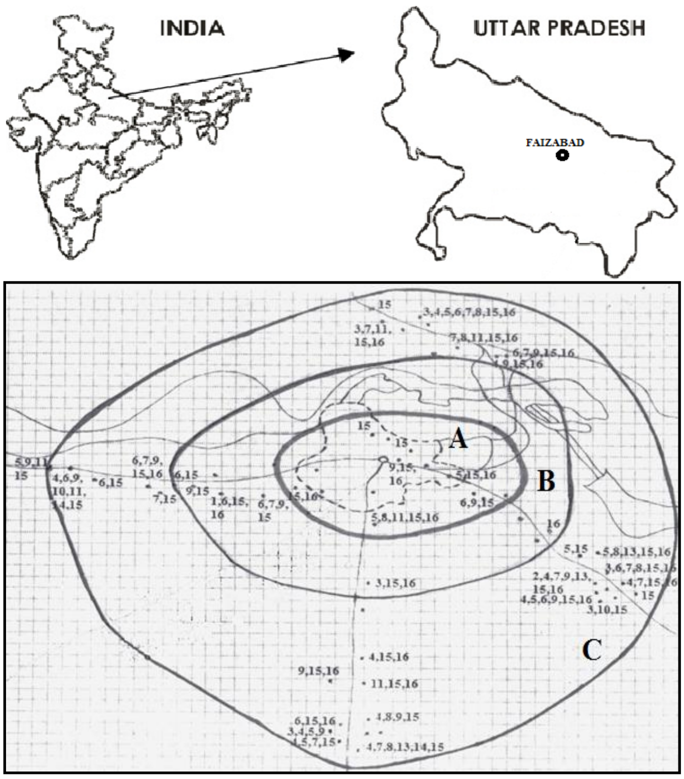

Fig- 1: Map showing collection sites in and around Faizabad City, Uttar Pradesh, India

2.3. Pigment analysis: Photosynthetic pigments (chlorophyll a, chlorophyll b, Total chlorophyll, Carotenoid) were extracted in 80% acetone (Merck, Analytical grade) and their concentrations determined using standard spectrophotometric procedures. 0.2 g of the sample was grinded with acid washed sand 10 mg calcium carbonate and 5 ml acetone (80%) on ice in dim light. The slurry was transferred to a 10 ml centrifuge tube, vigorously shaken and centrifuged at 10,000 rpm for 10 min. The supernatant was then decanted, kept in the cold and pellet re-suspended in 0.5 ml chilled acetone (80%) and centrifuged. The supernatant were then combined, made to known volume and analyzed using Genesys 10 UV scanning Spectrophotometer.

The chlorophyll content was calculated from absorbance values at 663 and 645 nm [12] and total carotenoid content was calculated [13] from absorbance values at 480 and 510 nm.

2.4. Chlorophyll degradation: Chlorophyll content and its degradation are often used as one of the most accurate methods of biomonitoring. The method was used to measure intensity of the photobiont chlorophyll [14]. The chlorophyll was extracted overnight in the dark in 5.0 ml Dimethyl sulfoxide (DMSO, Merck, analytical grade). The ratio of chlorophyll a to phaeophytin a (OD 435/415 nm ratio) was determined.

2.5. Protein estimation: The protein content was measured using Folin phenol as reagents with bovine serum albumin (BSA) as standard and calculations were made from absorbance values at 700 nm [15].

2.6. Metal analysis: The lichen thalli (0.2g) were removed from the bark with sharp knife. The samples were oven dried for 12 h at 90°C. The dried lichen samples (triplicates) were grinded to powder (0.5 g) and digested in mixture of concentrated HNO_3 and $HClO_4$ (v/v, 9:1) for 1 h. Residues were filtered through Whatmann filter paper no. 42 and diluted to 20 ml with double distilled water. Analysis was done with Flame Atomic Absorption Spectrophotometer (Perkin Elmer, model A Analyst 300). Stock standard were from Merck India and traceable to NIST (National Institute of Standards Technology). Working standards were prepared from the stock using deionized water.

2.7. Statistical analysis: Differences in chlorophyll response to air pollution and elemental content were compared using one-way analysis of variance (ANOVA) and least significant difference (LSD) was calculated with significance correlated at $p < 0.05$%.

3) RESULTS AND DISCUSSION

The identification of more than 250 specimens collected from 54 localities of Faizabad city revealed the occurrence of 15 species belonging to 11 genera from the area. The area showed dominance of crustose lichen represented by 12 species followed by 2 species of foliose lichen and single species of squamulose lichen. The *Mangifera indica* tree bears the maximum growth of 15 species on their trunks and branches followed by 3, 4 and 3 species on *Artocarpous heterophyllus*, *Azadirachta indica* and cultivated Palm trees respectively.

The total number of epiphytic lichen species increased with increasing distance from the centre of the city. The localities situated on outskirts of the city exhibited normal growth of most of the lichen species. Few sites within the city center with dense patches of trees also provides favourable habitat for normal growth of lichens. The *Azadirachta indica* (Neem) tree in such sites bear *P. cocoes*, *B.submedialis* and *Rinodina sophodes* on the trunk near the base. The *Mangifera indica* trees planted on the outskirts of the city exhibited good growth of differentlichen species.

The sites within the range of 0-5 km in the study area all around the centre of the city had scarce growth of epiphytic lichen growth with only occurrence of few toxitolerant species. It is interesting to note that, out of 54 sites, *P. cocoes* and *B. submedialis* exhibited their presence within localities of all the three zones.

The localities situated between the distances of 6-12 km from the city centre exhibit increasing number of species indicate a more or less moderate pollution. The localities between distances of 13-20 km around of the city have luxuriant and normal growth of lichens. The normal and rich lichen diversity of both sensitive and tolerant species in the outskirts of the city clearly indicates a more or less pollution free zone of the city. The probable reason for luxuriant growth of lichen in the outskirts of the city may be attributed due to the large number of orchards with dense canopy having moist and shady condition which supports good growth of varied lichen taxa.

Urbanization and human activities seems to affect the lichen diversity of an area upto a greater extends. Similar, to most of the Indian cities, the city of Faizabad too has undergone fast pace of urbanization resulting in loss of substratum and suitable microclimatic condition which ultimately leads to decline in epiphytic lichens of the area. Faizabad district is devoid of major factories and industries thus indicated that vehicular activity is the major source of air pollution of the study area. Vehicular activity together with machines operated for generating electricity and growth of urban areas are the main sources of pollution and responsible for the loss of substratum for lichen colonization in the area.

It is clear from the study that air pollution is not equally spread throughout the district. Distribution data of lichen taxa collected from five major areas of the city indicates the separation of the city area into three distinct zones. Zone A (0-5 km) having poor lichen growth indicates a more polluted zone. Zone B (6-12 km) is characterized by moderate growth of fewcrustose lichens on some scattered trees of mango and it is transitional zone of the city and corresponding to the area of the moderate pollution. Zone C (13-20 km) of the city exhibits normal growth of different epiphytic lichen taxa, situated on the boundary of the district and experiences almost no air pollution **(Fig- 1**).

The zone mapping technique provided circumstantial evidence about the prevalent lichen diversity of the area, but physiological parameters and pollutant (metal) profile provide direct evidence about the deteriorated air quality in the area.

3.1 Comparative physiological response of *Pyxine cocoes* and *Bacidia submedialis:* *P. cocoes* (foliose) and *B. submedialis* (crustose) lichen commonly occurring within the polluted and non-polluted area were selected for estimation of their pigment and accumulated metal concentration.

The concentration values for chlorophyll a in *P. cocoes* were similar in north and west directions, but showed dissimilar pattern in south and east directions and ranges from 0.19±0.01 μgg^{-1} at 13-20 km to 0.63±0.03 μgg^{-1} at 13-20 km west and east respectively. Chlorophyll b content also varied in different sites from different directions and it ranges from 0.08±0.02 μgg^{-1} to 0.41±0.31 μgg^{-1} at 0-5 km in south and east directions respectively.

The total chlorophyll (chlorophyll a + chlorophyll b) ranges from 0.27±0.01 μgg^{-1} at 13-20 km in west to 1.00±0.33 μgg^{-1} at 0-5 km in east direction. The concentration of chlorophyll a is known to get affected in stress condition [16]. Concentration of total chlorophyll is governed by the ambient environment, anthropogenic sources, vehicular traffic pollution and urban emission [17]. Photosynthetic parameters (chl. a, chl. b and total chlorophyll) showed similar pattern of variation in concentration in north, west and south directions, but different in east direction in the study area which may be due to pollution load in different directions and effect of wind direction.

The highest values of carotenoid were detected in samples of *P. cocoes* in east (0.35±0.04 μgg^{-1}) while lowest detected in the west (0.14±0.01 μgg^{-1}) at 13-20 km also affirms that east direction has suitable condition for lichen growth. The concentration of chlorophyll degradation was highest at 6-12 km and it decreased with increasing distance in north, east and west direction from city centre and it ranges from 0.99±0.00 μgg^{-1} at 13-20 km in west to 1.10±0.02 μgg^{-1} to 0-5 km in south direction.

Protein concentration ranged from 0.04±0.03 μgg^{-1} at 13-20 km in west to 0.24±0.09 μgg^{-1} at 6-12 km in north direction. The values of chlorophyll degradation and protein content were maximum at 13-20 km in west and minimum at 6-12 km in north (**Table- 1**). The increased level of protein in present study, at most polluted sites corresponds with the findings for the *Ramalina ecklonii* [18]. LSD analysis at p< 0.01% level showed significant difference in chl. a, total chlorophyll and carotenoid at different direction, while chl. b and protein may vary significantly at the level 0.05%. But there is no significant difference recorded in case of chl. degradation (**Table- 1**).

In *B. submedialis,* chlorophyll a concentration ranges from 0.16±0.05 μgg^{-1}in east to 0.54±0.02 μgg^{-1} in west at 6-12 km. The similar pattern of chlorophyll a content was recorded in north as well as west direction and decreasing trend with increasing distance was observed in south direction. The value of chlorophyll b ranges from 0.07±0.01 μgg^{-1} at 13-20 km in south to 0.23±0.02 μgg^{-1} at 6-12 km in west direction. The total chlorophyll ranged from 0.25±0.01 μgg^{-1} at 13-20 km in south to 0.77±0.05 μgg^{-1} at 6-12 km in west direction. Total chlorophyll showed similar variation in concentration in north and west direction.

Carotenoid content of *B. submedialis* was maximum (0.58±0.02 μgg^{-1}) at 6-12 km and minimum (0.13±0.03 μgg^{-1}) at 13-20 km in west. Carotenoid content analyzed from the east and south direction of the study area decreased with increasing distance from the city centre while samples from west as well as north direction have same carotenoid concentration. Chlorophyll degradation content ranged from 0.67±0.01 μgg^{-1} at 13-20 km in north to 1.10±0.01 μgg^{-1} at 6-12 km in west.

Protein content of *B. submedialis* ranged from 0.13±0.06 μgg^{-1} at 13-20 km in east to 0.53±0.13 μgg^{-1} at 6-12 km in west direction. The trend of protein was similar for north and south as well as for east and west.

The west part of the study area at distance of 6-12 km showed maximum level of concentration in each parameter, but the trend of chlorophyll degradation was different from other photosynthetic pigment analysis. Overall pattern for south showed decreased level of physiological parameters with increasing distance with respect to chl. a, chl. b, total chlorophyll and carotenoid. The north area of the Faizabad city have similar trend for chl. a, total chlorophyll, carotenoid and chlorophyll degradation. Particularly in east direction carotenoid decreases with increasing distance from the city centre but the level of chl. degradation in the present study increases with increasing distance. The east direction at 0-5 km showed maximum value for chlorophyll a, chl.b, total chl.

and carotenoid (**Table- 2**). Statistical correlation carried out using LSD analysisshowed that directions and distance from the Faizabad city play an important role in pigment content of lichens and mostly exhibited significant differences at 0.01% level. LSD analysis at p< 0.01% level showed significant difference in chl. a, chl. b, total chlorophyll, carotenoid and chl. degradation at different direction, while only non-significant difference was recorded in case of protein (Table-2).

It is clear from the observation that *P. cocoes* and *B. submedialis* showed similar trend of physiological parameters, but the variation in values may be attributed to the difference in morphology of the two species. The overall physiological attributes are able to represent the negative effect of air pollution on physiological status of both the lichen species.

3.2 Metal accumulation in *P. cocoes* and *B. submedialis* at different sites of Faizabad city: Total metal concentration was reported higher at 0-5 km north (3082.25 μgg^{-1}) and lower at 13-20 km west (750.31 μgg^{-1}). Accumulation of seven heavy metals Aluminium (Al), Iron (Fe), Cadmium (Cd), Chromium (Cr), Manganese (Mn), Lead (Pb) and Zinc (Zn) were estimated in thalli of *P. cocoes* in all directions at distance of 0-5, 6-12 and 13-20 km from the city centre (Table- 3). Among seven metals, Al was accumulated in maximum concentration followed by the sequence of Fe > Zn >Mn> Cr >Pb> Cd. Highest Al accumulation of 1609.3±0.87 $\mu gg^{-1}$was observed at 0-5 km south and minimum 551.95±0.80 μgg^{-1} at 13-20 km west, that indicates settling of this metal in the south direction. Accumulation of Al in the thalli of *P. cocoes* at all the sides is significantly different from each site based on LSD analysis at level 0.01% (Table-3). Accumulation of Fe ranged from 181.78±0.85 μgg^{-1} at 13-20 km west to 1403.0±0.12 μgg^{-1} at 0-5 west. The two most important metals i.e. Al and Fe in the earth's crust are strongly correlated in lichens and environmental contamination [20].

Among all the metals, Cd was reported as the lowest concentrated heavy metal in the present study area which ranged from 0.36±0.07 μgg^{-1} at 13-20 km south to 1.96±0.17 μgg^{-1} at 0-5 km north. The maximum level of Cr was recorded at 0-5 km west (12.38±0.53 μgg^{-1}) and minimum of 1.39±0.38 μgg^{-1} at 13-20 km west. The site at 0-5 km south and at 13-20 km north exhibited Mn accumulation ranged from 52.63±0.45 μgg^{-1} to 1.29±0.21 μgg^{-1} respectively. Thalli of *P. cocoes* in and around Faizabad city accumulated Pb in the ranges of 0.95±0.12 μgg^{-1} at 13-20 km east to 9.45±0.20 μgg^{-1} at 0-5 km north. Zn had maximum accumulation (60.23±0.73 μgg^{-1}) at 0-5 km west and minimum at 13-20 km north (11.05±0.22 μgg^{-1}). Dispersion and distribution of metals depends on wind speed and direction as well as density of the element under consideration [16].

In the present study, accumulation of all heavy metals at different sites exhibited sequence of accumulation as 0-5 km> 6-12 km> 13-20 km i.e. decreasing concentration with increasing distance from the city centre of the study area. The reason for higher concentration of Al and Fe around Faizabad city may be due to air pollution as well as natural origin.

At all the zones *P. cocoes* showed more or less similar selectivity sequence of metals such as Al> Fe>Mn> Zn> Cr> Pb> Cd (0-5 km); Al> Fe> Zn> Mn> Cr> Pb> Cd (6-12 km) and Al > Fe > Zn> Mn> Cr> Pb> Cd (13-20 km) (**Table- 3**).

B. submedialis also exhibited similar sequence of concentration of heavy metal (**Table- 4**). Samples from 0-5 km south has maximum concentration of both Al and Fe as 1337.4±0.52 μgg^{-1} and 1506.4±0.22 μgg^{-1}respectively and minimum accumulation was recorded at 13-20 km west as 108.62±0.28 $\mu gg^{-1}$and 55.45±0.11 μgg^{-1} respectively.

Thalli of *B. submedialis* in and around Faizabad city concentrated higher accumulation of metals, Cd (1.85±0.75 μgg^{-1}), Cr (12.04±0.25 μgg^{-1}), Mn (49.61±0.21 μgg^{-1}), Pb (8.31±0.38 μgg^{-1}) and Zn (59.62±0.30 μgg^{-1}) at 6-12 km south sites, while lower amount of Cd (0.14±0.08 μgg^{-1}), Cr (0.55±0.19 μgg^{-1}), Mn (0.67±0.11 μgg^{-1}), Pb (0.94±0.07 μgg^{-1}) and Zn (4.55±0.38 μgg^{-1}) at 13-20 km west.

The accumulation of Cr, Pb, and Cd on lichens in localities situated at outskirts of the city clearly indicates wide dispersion of the metals. *B. submedialis* also exhibited concentration of the most of the metals with increasing distance from the city centre of the study area (0-5 km> 6-12 km> 13-20 km). Total metal concentration in the species was recorded higher at 0-5 km south (2970.93 μgg^{-1}) and lower at 13-20 km west (170.92 μgg^{-1}).

B. submedialis also have the similar concentration of metal sequence to *P. cocoes* as Al> Fe> Zn> Mn> Cr> Pb> Cd (0-5 km); Al> Fe> Zn> Mn> Cr> Pb> Cd (6-12 km) and Al> Fe> Zn> Cr> Mn> Pb> Cd (13-20 km). Accumulation of Fe in the thalli of *P. cocoes* and *B. submedialis* are significantly different (LSD analysis at p< 0.01%; ref. Table 4) in all directions.

It is clear from the observation of the metal content that both *P. cocoes* and *B. submedialis* showed higher accumulation of Al and Fe and lower accumulation of Pb and Cd in all directions. Thus, the result showed that the vehicular and anthropogenic activities are the major cause of metal load in the study area.

4) CONCLUSION

The present study establishes the role of lichen biomonitoring studies in correlating the loss of lichen diversity with deterioration in air quality. Lichen zone mapping is a standardized technique to observe the impact of microclimatic changes on lichen diversity. Further assessment of physiological response and accumulation of metals in samples provides direct evidence about the air quality status. Lichen biomonitoring studies not only helps to know the status of pollutants in the environment but also provides an account the damage caused to the biological elements. In India, the use of lichen biomonitoring data has been so far not incorporated in air regulatory practices.

The present study provides the lichen diversity along with species distribution within each zone. The metal variation observed in the two toxitolerant species in Faizabad district will act as a baseline record for carrying out future biomonitoring studies in the area. Any further increase in metal load of the area in future may be better monitored observing changes in the lichen community composition and metal content comparing with the baseline data.

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Table-1: Photosynthetic pigment analysis and protein content of *Pyxine cocoes* in all directions in and around Faizabad city

Localities	*Pyxine cocoes* (concentration in μgg^{-1})					
	Chl. a	**Chl. b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
0-5 kms north	0.57±0.07	0.33±0.08	0.90±0.15	0.31±0.06	1.06±0.01	0.16±0.06
6- 12 kms north	0.56±0.09	0.25±0.09	0.80±0.18	0.30±0.05	1.07±0.05	0.24±0.09
13-20 kms north	0.47±0.08	0.17±0.05	0.63±0.13	0.28±0.09	1.03±0.04	0.22±0.07
0- 5 kms east	0.58±0.02	0.41±0.31	1.00±0.33	0.33±0.05	1.03±0.04	0.19±0.11
6- 12 kms east	0.38±0.10	0.19±0.06	0.57±0.10	0.20±0.04	1.06±0.03	0.08±0.10
13-20 kms east	0.63±0.03	0.31±0.06	0.94±0.09	0.35±0.04	1.00±0.00	0.18±0.07
0- 5 kms south	0.24±0.07	0.08±0.02	0.32±0.09	0.15±0.04	1.10±0.02	0.08±0.02
6- 12 kms south	0.40±0.09	0.15±0.03	0.55±0.12	0.31±0.01	1.00±0.01	0.18±0.12
13-20 kms south	0.50±0.14	0.20±0.06	0.70±0.20	0.31±0.03	1.02±0.01	0.13±0.03
0- 5 kms west	0.47±0.10	0.18±0.04	0.65±0.14	0.31±0.04	1.02±0.09	0.08±0.08
6- 12 kms west	0.45±0.14	0.18±0.08	0.63±0.22	0.28±0.09	1.04±0.09	0.10±0.01
13- 20 kms west	0.19±0.01	0.09±0.00	0.27±0.01	0.14±0.01	0.99±0.00	0.04±0.03
F	7.19**	2.49*	5.51**	5.22**	1.60 ^{NS}	2.33*
CV%	19.34	50.77	25.05	19.54	4.25	52.54
LSD (p< 0.05%)	0.148	0.180	0.280	0.090	0.074	0.123

(at p < 0.05% level by least significant difference (LSD) analysis) NS= Non- Significant
Mean±S.D., n=3 in μgg^{-1}
** Significance at the level of 0.01%.
* Significance at the level of 0.05%.

Table-2: Photosynthetic pigment analysis and protein content of *Bacidia submedialis* in all directions in and around Faizabad city

Localities	*Bacidia submedialis* (concentration in μgg^{-1})					
	Chl. a	**Chl. b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
0-5 kms north	0.38±0.03	0.20±0.02	0.58±0.05	0.34±0.04	0.82±0.08	0.23±0.06
6- 12 kms north	0.44±0.12	0.22±0.05	0.66±0.17	0.44±0.04	0.98±0.03	0.20±0.06
13-20 kms north	0.18±0.02	0.11±0.01	0.28±0.03	0.23±0.02	0.67±0.01	0.21±0.05
0- 5 kms east	0.25±0.08	0.18±0.06	0.43±0.14	0.44±0.13	0.76±0.10	0.30±0.08
6- 12 kms east	0.16±0.05	0.10±0.03	0.27±0.08	0.34±0.08	0.84±0.07	0.37±0.14
13-20 kms east	0.18±0.18	0.11±0.09	0.29±0.27	0.33±0.04	0.90±0.13	0.13±0.06
0- 5 kms south	0.28±0.10	0.15±0.05	0.42±0.16	0.44±0.16	0.92±0.03	0.46±0.23
6- 12 kms south	0.24±0.05	0.11±0.02	0.35±0.07	0.26±0.07	1.08±0.01	0.21±0.14
13-20 kms south	0.18±0.00	0.07±0.01	0.25±0.01	0.24±0.03	0.91±0.03	0.32±0.15
0- 5 kms west	0.46±0.06	0.19±0.03	0.65±0.09	0.40±0.03	1.01±0.03	0.41±0.09
6- 12 kms west	0.54±0.02	0.23±0.02	0.77±0.05	0.58±0.02	1.10±0.01	0.53±0.13
13- 20 kms west	0.20±0.06	0.11±0.02	0.30±0.08	0.13±0.03	1.08±0.01	0.38±0.56
F	7.91**	5.12**	6.79**	8.37**	15.03**	1.11 ^{NS}
CV%	27.90	27.68	27.56	20.69	6.54	63.34
LSD (p< 0.05%)	0.136	0.069	0.204	0.122	0.102	0.333

(at p < 0.05% level by least significant difference (LSD) analysis) NS= Non- Significant; Mean±S.D., n=3 in μgg^{-1}
** Significance at the level of 0.01%.
* Significance at the level of 0.05%.

Table-3: Heavy metal content of *P. cocoes* at 12 sites around Faizabad city

Localities	*P. cocoes* (Concentration in μgg^{-1})						
	Al	**Fe**	**Cd**	**Cr**	**Mn**	**Pb**	**Zn**
0-5 km north	1565.7±0.98	1395.8±0.82	1.96±0.17	10.71±0.56	51.47±5.55	9.45±0.20	47.16±0.81
6- 12 km north	946.27±0.10	278.56±0.49	0.85±0.38	7.107±0.21	20.19±0.65	3.09±0.11	21.28±0.61
13-20 km north	586.56±0.57	196.32±0.66	0.44±0.23	1.63±0.40	1.29±0.21	1.59±0.34	11.05±0.22
0- 5 km east	1456.7±1.06	1340.7±0.50	1.95±0.57	10.92±0.14	50.23±0.66	9.31±0.49	46.79±0.43
6- 12 km east	928.55±0.72	339.98±0.69	0.79±0.22	6.017±0.15	26.51±0.31	2.28±0.48	28.89±0.71
13-20 km east	569.45±0.52	201.52±0.20	0.39±0.17	1.84±0.12	2.54±0.22	0.95±0.12	12.78±0.23
0- 5 km south	1609.3±0.87	1340.7±0.35	1.87±0.47	10.8±0.74	52.63±0.45	9.32±0.25	46.97±0.14
6- 12 km south	952.12±0.23	357.71±0.76	0.76±0.31	7.59±0.71	22.08±0.84	3.33±0.08	21.15±0.38
13-20 km south	601.63±0.23	195.41±0.66	0.36±0.07	1.95±0.22	2.86±0.08	1.08±0.19	12.95±0.27
0- 5 km west	1378.6±0.50	1403±0.12	1.39±0.28	12.38±0.53	46.85±0.59	8.05±0.36	60.23±0.73
6- 12 km west	937.66±0.92	285.4±0.79	0.95±0.19	7.95±0.10	23.48±0.43	5.61±0.26	32.92±0.58
13- 20 km west	551.95±0.80	181.78±0.85	0.47±0.20	1.39±0.38	1.56±0.47	1.78±0.41	11.38±0.38
F	996755.02**	2094332.43**	12.572**	291.127**	4776.19**	391.52**	3440.717**
CV %	0.069	0.101	29.856	6.239	2.065	6.537	1.717
LSD(p< 0.05%)	1.239	1.126	0.511	0.704	0.924	0.513	0.853

(at p < 0.05% level by least significant difference (LSD) analysis)
Mean±S.D., n=3 in μgg^{-1}
** Significance at the level of 0.01%.
* Significance at the level of 0.05%.

Table-4: Heavy metal analysis of *B. submedialis* at 12 sites around Faizabad city

Localities	*B. submedialis* (Concentration in μgg^{-1})						
	Al	**Fe**	**Cd**	**Cr**	**Mn**	**Pb**	**Zn**
0-5 km north	1120.2±0.30	216.45±0.43	0.79±0.14	7.89±0.31	23.12±0.36	5.42±0.49	32.82±0.17
6- 12 km north	910.83±0.07	356.25±0.11	0.89±0.16	6.36±0.11	24.63±0.19	2.31±0.12	28.95±0.22
13-20 km north	125.12±0.29	88.25±0.49	0.42±0.10	1.06±0.04	1.12±0.04	1.45±0.16	9.17±0.19
0- 5 km east	1007.9±0.60	247.6±0.22	0.84±0.05	7.79±0.12	24.07±0.36	5.81±0.14	32.81±0.14
6- 12 km east	894.45±0.20	299.67±0.23	0.86±0.12	6.58±0.35	25.07±0.03	2.27±0.13	27.79±0.36
13-20 km east	119.78±0.23	79.64±0.22	0.21±0.08	0.98±0.16	0.76±0.13	1.08±0.18	6.18±0.33
0- 5 km south	1337.4±0.52	1506.4±0.22	1.26±0.13	12.02±0.27	46.57±0.39	8.1±0.08	59.18±0.07
6- 12 km south	1408±0.13	1421.3±0.19	1.85±0.75	12.04±0.25	49.61±0.21	8.31±0.38	59.62±0.30
13-20 km south	206.23±0.29	98.2±0.24	0.48±0.11	1.35±0.22	1.37±0.15	1.65±0.22	11.21±0.07
0- 5 km west	985.65±0.34	370.55±0.24	0.94±0.09	6.24±0.07	21.51±0.30	3.21±0.11	21.41±0.11
6- 12 km west	619.6±0.27	184.6±0.27	0.45±0.10	1.8±0.28	3.05±0.20	1.21±0.04	12.41±0.04
13- 20 km west	108.62±0.28	55.45±0.11	0.14±0.08	0.55±0.19	0.67±0.11	0.94±0.07	4.55±0.38
F	6658164.52**	10482277.34**	11.786**	1102.656**	16177.24**	472.865**	20717.49**
CV %	0.044	0.065	31.496	4.447	1.186	6.234	0.887
LSD (p< 0.05%)	0.549	0.454	0.403	0.403	0.369	0.365	0.381

(at p < 0.05% level by least significant difference (LSD) analysis)
Mean±S.D., n=3 in μgg^{-1}
** Significance at the level of 0.01%.
* Significance at the level of 0.05%.

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Short communication

New addition to lichen flora of Uttar Pradesh, India

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The lichen taxa collected from Uttar Pradesh are documented in different checklist, floristic, monographic and revisionary studies (Awasthi, 1980, 1988, 1991, 2000, 2007, Srivastava, 2004, Dubey *et al.* 2007, Singh & Sinha 2010, Karakoti *et al.* 2014, Gupta *et al.* 2015). Recently Nayaka & Upreti (2013) analyzed the status of lichen diversity in Uttar Pradesh which revealed the occurrence of 135 species belonging to 46 genera and 25 families.

This state represented three distinct phytogeographical regions. The transitional belt running along the entire length of the state of Uttarakhand and country of Nepal is called the "Terai' and 'Bhabhar' area and have thick forest cover, swamps and marshes. The Gangetic plain elongates the area from east to west is the most fertile as well as agricultural land. The southern fringe of the Gangetic Plains is demarcated by the Vindhya Hills and Plateau exhibit strong ground and low hills. Most of the central region of the state of Uttar Pradesh is most fertile and utilized for agriculture from the ancient time. The region is devoid of forest, however, mango orchards are quite common and provide suitable habitat for many lichen taxa to colonize.

The present investigation is carried out with an aim to document the lichen diversity pattern in mango orchards of Gangetic plain. Three districts of this phytogeographical zone *viz*. Faizabad, Ambedkar Nagar and Raebareli have been selected to conduct the present study. The identification of the lichen samples collected revealed occurrence of five species as new addition to the lichen flora of the state.

The mango orchards in and around Tanda Thermal Power plant, Ambedkar Nagar (lies between coordinates 26°33'00" N and 82°39'00" E); Feroz Gandhi Unchahar National Thermal Power Plant Corporation, Raebareli (between coordinates 25º49' to 26º36' N and 100º41' to 81º34' E and Faizabad district (situated at the latitude 26°47'N and longitude 82º12' E) was surveyed for collection of lichens.

The collected specimens were identified by their morphological, anatomical and chemical characters and specimens were preserved in the herbarium of CSIR-National Botanical Research Institute, Lucknow (LWG). The LABOMED dissecting microscope was used for external morphology study while LEICA ATC 2000 compound microscope was used for microscopic anatomical details. The samples were mounted in water, 10% KOH and Lugol's solution. Measurements of asci and ascospores were made on material examined in KOH. The colour test and Thin layer chromatography (TLC) of acetone extracts was performed using solvent system A and C, followed by Orange et al. (2001), Culberson (1972) and Walker and James (1980). The microscopic measurements were based on mature ascomata and are recorded for their minimum and maximum values.

Species description

1. *Anisomeridium subnexum* (Nyl.) R.C. Harris, *More Florida Lich*. (New York):150. 1995. **(Fig. 1A)**

≡ ***Arthopyrenia subnexa*** (Nyl.) Müll. Arg. *Hedwigia*. 30: 188. 1891. (Monoblastiaceae)

Thallus corticolous, crustose, yellow-grey, smooth, shining sometimes powdery, endophloeodal. Ascomata solitary, 0.25–0.45 (0.50) mm diam., (0.10–) 0.15–0.20 mm high, convex- hemispherical, globose completely covered with thallus or naked around ostiole and black; ostiole indistinct, plane or sometimes slightly depressed; centrum I-; pseudoparaphyses branched, anastomosed; asci cylindrical clavate,8-spored (90–) 100–16×15–22 µm, uniseriate or rarely biseriate; ascospore colourless, 1-septate, 23–27×(7–) 9–11 µm, oblong-ellipsoid,both cells equal in size, slightly constricted at septum, epispore to 1 µm thick. Pycnidia not seen. Thallus K-, C-, KC-, P-, no lichen substance upon TLC.

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Remarks: Hue (1892) reported this species from Andaman and Nicobar Islands and later recorded from Madhya Pradesh and Karnataka (Upreti and Pant, 1993). The species is rare in the area, as it is known from a single locality from the outskirts of the district Faizabad.

Specimen Examined: Faizabad district: Azamgarh road, Purabazar, Barauli, on tree trunk of *Mangifera indica*, 19th March, 2014, V. Gupta. 014-022614 (LWG).

2. *Arthothelium chiodectoides* (Nyl.) Zahlbr., *Cat. Lich. Univ*. 2: 122. 1922. **(Fig. 1B)**

≡ ***Arthonia chiodectoides*** Nyl. Flora 52: 72. 1869. (Arthoniaceae)

Thallus corticolous, crustose, most of the part endophloeodal, 88-166 µm thick; ascomata yellowish brown to dark blackish-brown, K-, punctuate, aggregated, covered with effuse thalline layer or naked; epithecium dark blackish-brown; hymenium pale brown 100–185 µm tall, I+ blue; hypothecium dark blackish-brown; asci butinicate, obovate to pyriform; paraphysoids profusely branched and anatomosed, strongly coherent; ascospore 8/ascus, hyaline, muriform, ovate to oblong, transversely 7 to 9-septate, vertically 1 to 3-septate, upper most cell larger, undivided, 28–36×3–5 µm.

Chemistry: No chemical tested. Triterpenes detected upon TLC.

Remarks: This species is reported from Arunachal Pradesh, Goa, Himachal Pradesh, Karnataka, Maharashtra, Sikkim and West Bengal. This species colonize on the bark of *Mangifera indica, Azadirachta indica* and *Litchi chinensis*. Now, for the first time it is reported from Uttar Pradesh.

Specimens Examined: Faizabad district: Azamgarh road: Rajepur, on tree trunk of *Mangifera indica*, 19th March, 2014, V. Gupta. 014-022610 (LWG); Purabazar, Jillu ka Purwa, on tree trunk of *Mangifera indica*, 19th March, 2014, V. Gupta. 014-022615 (LWG). **Sultanpur road:** Khanpur, 6 km. away from the city, on bark of *Litchi chinensis*, 20th March, 2014, V. Gupta. 014-022656 (LWG); Bikapur, Sugan rai ka purwa, on bark of *Mangifera indica*, 20th March, 2014, V. Gupta. 014-022659 (LWG). **Gonda road:** Nawabganj, Ghuse ka purwa, on tree trunk of *Mangifera indica*, 21st March, 2014, V. Gupta. 014-022707 (LWG); Birapur, on bark of *Azadirachta indica*, 21st March, 2014, V. Gupta. 014-022708 (LWG). **Raebareli road:** Ranibazar, Roadside, on tree trunk of *Mangifera indica*, 22nd March, 2014, V. Gupta. 014-022731 (LWG); Barun bazaar, Mahaveer Mishra ka purwa, on tree trunk of *Mangifera indica*, 22nd March, 2014, V. Gupta. 014-022740 (LWG).

3. *Bacidia medialis* (Tuck. ex Nyl.) Zahlbr., *Denskchr. Kaiserl. Akad. Wiss*., Wien, Math.- Naturwiss. Kl. 83: 127. 1909. **(Fig. 1C)**

≡ ***Lecidea medialis Tuck.*** Zahlbruckner's Cat. Lich. Univ. 4: 221. (Ramalinaceae)

Thallus corticolous, crustose effuse, rough, cracked, granuolose-furfaraceous, greyish brown to grey, 50–70 µm thick, Apothecia constricted at base, 0.2–0.5 mm in diam., over mature apothecia sometimes split up into lobes, sometime glomerulose aggregation of 3–4 apothecia, disc yellow brown, brown to red brown, plane to convex, epruinose, margin entire, distinct, pale yellow to pale brown and later excluded exciple colourless to pale, 36–70 µm thick at margin, K- epithecium colourless to pale brown, 10–12 µm thick, K-; hymenium 40–70 µm thick, I+ blue than vinose red; hypothecium colourless to pale yellow, 16-30 µm thick, K; spores rod shaped with both end rounded, rarely one ends narrower than the other, transversely (1-)3–5 septate, 16–32×2.4–3.2 µm; paraphyses simple to branched, thickened at apices. Thallus K-, C-, KC-, P-, no lichen substance upon TLC.

Remarks: This species is also known from Himanchal Pradesh, Kerala, Lakshadweep, Orissa, Tamil Nadu and West Bengal plains. The lichen species grows on the bark of *Mangifera indica* and *Artocarpus heterophyllus.*

Specimens Examined: Faizabad district: Azamgarh road: Bhikhapur, Shankargarh bazaar, on bark of *Mangifera indica*, 19th March, 2014, V. Gupta. 014-022604 (LWG); Darshan nagar, Sirsanda, on tree trunk of *Mangifera indica*, 19th March, 2014, V. Gupta. 014-022611 (LWG); Purabazar, Madna, on bark of *Artocarpus heterophyllus*, 19th March, 2014, V. Gupta. 014-022631 (LWG); Sarai Rasi, on bark of *Artocarpus heterophyllus*, 19th March, 2014, V. Gupta. 014-022632 (LWG). **Sultanpur road:** Near J.N.V., Dhabha Semar, on bark of *Mangifera indica*, 20th March, 2014, V. Gupta. 014-022651 (LWG); Bikapur, Burma, on bark of *Ficus racemosa*, 20th March, 2014, V. Gupta. 014-022665 (LWG); Bikapur, Sugan rai ka purwa, on bark of *Artocarpus heterophyllus*, 20th March, 2014, V. Gupta. 014-022666 (LWG). **Gonda road:** Birapur, on bark of *Mangifera indica*, 21st March, 2014, V. Gupta. 014-022710 (LWG). **Raebareli road:** Usroo, on bark of *Mangifera indica*, 22nd March, 2014, V. Gupta. 014-022728 (LWG); Barun, Vill- Khiharan, on tree trunk of *Mangifera indica*, 22nd March, 2014, V. Gupta. 014-022744 (LWG); Barun, Roadside, on bark of *Madhuca longifolia*, 21st March, 2014, V. Gupta. 014-022745 (LWG). **Lucknow road:** Near Sohawal, Masoomganj, on bark of *Mangifera indica*, 23rd March, 2014, V. Gupta. 014-022790 (LWG); Raunahi, on tree trunk of *Mangifera indica*, 23rd March, 2014, V. Gupta. 014-022791 (LWG).

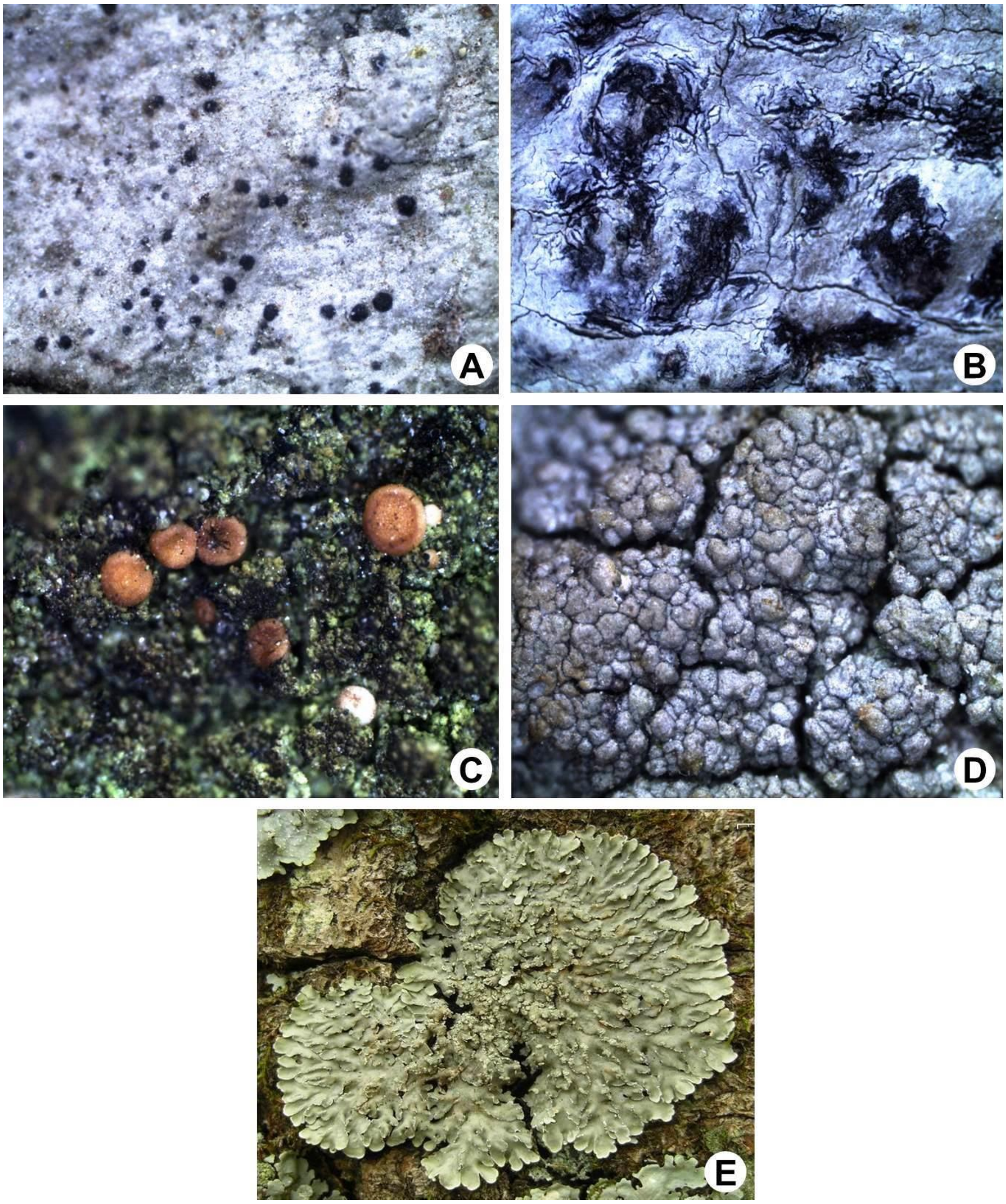

Figure 1. Lichen thallus of different species: **A,** *Anisomeridium subnexum* (Nyl.) Zahlbr.; **B,** *Arthothelium chiodectoides* (Nyl.) Zahlbr.; **C,** *Bacidia medialis* (Tuck.) Zahlbr.; **D,** *Pertusaria granulata* (Ach.) Müll. Arg.; **E,** *Pyxine sorediata* (Ach.) Mont.

4. ***Pertusaria granulata*** (Ach.) Müll. Arg., *Flora, Regensburg.* 68 (12): 259. 1885. **(Fig. 1D)**

≡ ***Porina granulata*** Ach., Syn. Meth. Lich.: 112. 1814. (Pertusariaceae)

Thallus corticolous, verrucose whitish grey to greenish grey, fertile verrucae with perithiceiod apothecia, fertile verrucae; constricted at base; verrucose on surface, asci and spores not seen as the ascomata are immature. Thallus K+ yellow, C-, KC-, P-; Atranorin and Perlatolic acid detected upon TLC.

Remarks: The species was previously reported from Karnataka, Kerela and Tamil Nadu. It is rare in the area, as it is collected from a single locality in the outskirts of the district growing on *Mangifera indica*.

Specimens Examined: Faizabad district: Raebareli road: Masodha, Kadipur.on bark of *Mangifera indica*, 22nd March, 2014, V. Gupta. 014-022756 (LWG).

5. ***Pyxine sorediata*** (Ach.) Mont. in Sagra, *Hist. Phys. Cuba*, Bot. Pl. Cell. 2: 188. 1842. **(Fig. 1E)**

≡ ***Lecidea sorediata*** Ach., Syn. Meth. Lich. : 54. 1814. (Physciaceae)

Thallus corticolous, foliose; lobes 1.0–2.0 mm broad, pearl- white to light grey or dull yellow, branching sub dichotomous, tightly or loosely adnate to the substrate; pseudo-cyphellae well developed along the margins but rare on the lamina; pruina restricted to the lobe tips; soredia coarse, grey. Medulla yellow or light yellow, the soralia which may be on marginal isidia- like lobules. Apothecia very rare, internal stipe colourless to pale brown, K-; ascospores 12–17×6–8 µm. Thallus

K+ yellow; medulla, K-, Pd-, triterpenes at 4-5 detected upon TLC.

Remarks: The species is known from Arunachal Pradesh, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Manipur, Nagaland, Sikkim, Tamil Nadu, Uttarakhand and West Bengal. The species is rare as it is known from two different localities in the outskirts of Tanda and near to Unchahar thermal power plants growing on *Mangifera indica*.

Specimens Examined: Ambedkar Nagar district, Tanda thermal power plant, Rajesultanpur road, Ismailpur beldaha, Heerapur, on bark of *Mangifera indica*, 02^nd^ April, 2015, N. Gupta 015-031723 (LWG); Raebareli district, Unchahar thermal power plant, Manirampur, on tree trunk of *Mangifera indica*, 13^th^ August, 2013, N. Gupta. 013-023711 (LWG).

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RESEARCH ARTICLE

PHYSIOLOGICAL VARIATION AND ACCUMULATION OF METALS IN TWO GROWTH FORMS OF LICHENS GROWING AROUND PANKI THERMAL POWER PLANT OF UTTAR PRADESH, INDIA.

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Abstract

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The present study deals with an analysis of inorganic pollutants, their possible sources and effect on naturally growing *Pyxine cocoes* (Sw.) Nyl., a foliose lichen and *Rinodina sophodes* (Ach.) A. Massal., a crustose lichens around Panki Thermal Power Plant, Kanpur, Uttar Pradesh. The east direction of the thermal power plant which experiences heavy traffic activity showed complete absence of lichens while west side has the maximum number of lichen thalli.

The result indicated that correlation analysis revealed that chlorophyll a, b, total chlorophyll, carotenoid, chlorophyll degradation was significantly correlated with each other whereas protein content showed negative correlation with chlorophyll a (-0.981), chlorophyll b (-0.97), total chlorophyll (-0.976), carotenoid (-0.935) and chlorophyll degradation (-0.994) in *R. sophodes*. All metals studied for both the species showed positive correlation matrix between the metals. The highest concentration of Fe, Mn, Zn and Pb were found at highly polluted areas with heavy traffic and road construction. The present study has established the utility of crustose and foliose growth forms of lichens in monitoring of environmental pollution in an area

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Introduction:-

The Kanpur city is situated in the tropical Gangetic plains of India, has an area of over 300 km^2 with an approximate population of 3 million inhabitants. It is one of the oldest industrial townships of North India with major industrial and commercial place. It is also known as Leather City of India as it contains a number of the tanneries around the city.

A large number of pollution monitoring studies with higher plants are available in India; however, such studies with utilizing lichens have been started recently. The primary sources of energy in India are renewable resources such as coal and wood its utilization in power generation is emerging as the biggest environmental problem because it emits fly ash, acid precursors, greenhouse gases, non-combustible hydrocarbons, heavy metals and particulates matters. The pollutants emerged can be dispersed to a long distance by wind and ultimately have a negative impact on both biotic and abiotic environment (Cicek et al., 2001).

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Lichens are slow growing and assimilate metals at a rapid rate but release them at a low rate. Metal concentration in lichen thalli have been shown to correlate with atmospheric levels. Lichens were first used as bio-accumulative indicators in relation to point-emission sources, where decreasing metal concentration in species correlated with increasing distance from the source (Burton, 1986).

Lichens are peculiar plants in having special sensitivity for acidic gases but accumulate several organic compounds and elements in a large amount beyond their physiological needs and thus can be utilized as biological indicators of air quality. Lichen have been used as accumulating indicators which provides information especially about the amount of different heavy metals absorbed in the lichen thalli. The epiphytic lichens have been used extensively to monitor air quality around urban areas, industrial sites and to document spatial distribution and accumulation of air borne pollutants (Purvis et al., 2004; Bargagli- Pertrucci, 1915; Singh et al., 1994).

Lichens, a symbiotic association between fungi and algae, are common organisms all around the world and have capacity to colonize on a great diversity of substrates. In the recent years, due to their sensitivity to acidic gases and excellent metal accumulating nature, lichens are presently used for monitoring pollutant in different regions of the world. Lichens have ability to accumulate both organic and inorganic metals beyond their physiological needs.

Biomonitoring studies using lichen have been carried out in different cities of India having varid climatic conditions (Dubey et al., 1999; Upreti and Pandey, 2000; Pandey et al., 2002; Bajpai et al., 2004; Mishra et al., 2003; Saxena et al., 2007; Shukla and Upreti, 2007a, b, 2008; Bajpai et al., 2010 a, b; 2013a, b; Gupta, 2014; Gupta et al., 2015). A single report about the concentration of carbon and sulphur content that affects the physiology of *R. sophodes*, growing naturally in the city of Kanpur is available (Satya and Upreti, 2009; 2015). Lichens are used as passive pollution monitors because they accumulate a variety of pollutants in their thalli at levels well above environmental concentrations and their own physiological needs. The thermal power plants in the country are the major source of power generation which not only deteriorate the natural resources but also affects the human health upto a greater extend.

The present study is aimed to assess the impact of thermal power plant emission on two naturally growing commonly occurring lichen species *P. cocoes,* a foliose and *R. sophodes,* a crustose lichen, to determine the inorganic metals accumulated and changes in their chlorophyll content.

Materials and Methods:-

Study Area:-

Kanpur city, with a population of about 3 million, is situated in North central part of India at 88º22'E and 26º26'N in Gangetic plain, is the second largest and most populated industrial city in the state of Uttar Pradesh, India (Fig. 1A, B).. Panki thermal power plant is situated in the Panki town of Kanpur district about 20 Kms from Kanpur Railway Station on Kalpi road, between co-ordinates 26º28'35"N and 80º14'31"E (Fig. 1C). The coal-based Panki thermal power plant has electricity production capacity of 210 MW (2 x 105). The coal to all units is fed from coal mines of BCCL and ECL by means of railways. The study area is situated in the zone of humid subtropical climate and the year is divided into three seasons: the cold season (November- February), the hot season (March- June) and the monsoon season (July- October). Heavy rainfall (generally 70-80% of the total rainfall) occurs during the monsoon season in the months of July, August and September. The fast pace of industrialization, urbanization together with the destruction of forest resulted in few scattered, open canopy deciduous forests in the district.

Sample Collection:-

The area around thermal power plant was randomly surveyed for collection of lichens from 34 localities in all four directions i.e. east, west, north and south of the power plant. Lichens especially, *P. cocoes* and *R. sophodes* were growing abundantly in all four directions on the bark of *Mangifera indica* tree around power plants in all direction except the east direction showed complete absence of lichens (Fig. 1). These species were widely distributed in the area thus both the species were sampled for pigment and metal analysis.

The collected samples were dried and kept inside the paper packet. The lichen samples were determined by their morphological, anatomical and chemical characters by using LABOMED dissecting microscope for external morphology, while LEICA ATC 2000 compound microscope was used for microscopic anatomical details of the samples. The chemical substance present in the lichen thallus were identified through TLC in solvent system A

(Toluene: 1-4 Dioxane and Acetic acid; 180:60:4) (Orange et al., 2001). The voucher specimens of each species were preserved in the Lichen Herbarium (LWG) of CSIR- National Botanical Research Institute, Lucknow, India.

Pigment Analysis:- The chlorophyll content was calculated from absorbance values at 663 and 645nm according to the equation of Arnon (1949). The total carotenoid content was calculated according to Parsons et al. (1984) from absorbance values at 480 and 510 nm.

Chlorophyll Degradation:- The method developed by Ronrn and Galun (1984) was used to measure intensity of the photobiont chlorophyll. The chlorophyll was extracted overnight in the dark in 5.0 ml dimethyl sulfoxide (DMSO, Merck, analytical grade). The ratio of chlorophyll a to phaeophytin a (OD 435/415nm ratio) was determined.

Protein Estimation:- The protein content was measured using Folin phenol as reagents with bovine serum albumin (BSA) as standard and calculations were made from absorbance values at 700nm (Lowry et al., 1951).

Metal Analysis:- The lichen thalli were removed from the bark with sharp knife. The samples (constant weight) were oven dried for 12 hrs at 90°C. The dried lichen samples (n=3) were grinded in a mortar pestle (1.0g) and each sample was digested in mixture of concentrated HNO_3 and $HClO_4$ (v/v, 9:1) for 1 hour. Residues were filtered through Whatman Filter paper No. 42 and diluted up to 25 ml with double distilled water. Analysis was done with ICP MS (Perkin Elmer SCIEX ELAN DRCe). Stock standards were from Merck India and traceable to NIST (National Institute of Standards Technology). Working standards were prepared from the stock using deionised water.

Statistical Analysis:- Differences in chlorophyll response to air pollution and elemental content were compared using One-way analysis of variance (ANOVA) with least significant difference (LSD) and coefficient of variance (CV%). Pearson correlation was obtained using Statistical program SPSS 16.0.

Results and Discussion:-

The study area showed occurrence of 8 epiphytic lichens species belonging to 7 genera and 7 families found growing at 34 monitoring sites upto a distance of 20 km in west, north and south directions of the Panki Thermal Power Plant. *Pyxine cocoes* and *Rinodina sophodes* showed their dominance over other species in the area surveyed.

It is clear from the observation that the diversity of lichens increased with increasing distance from the source of pollution. Panki Thermal Power Plant is located about 20 kms from the Kanpur railway station and has the agricultural land and canals as well as flyash dumping sites around the power plant. *P. cocoes* and *R. sophodes* exhibit their presence in west, north and south directions and it is observed that the number of lichen thalli increases with increasing distance from the power plant of which west direction exhibited the maximum number of lichens.

The results of the physiological (Table-1 & 2) and elemental analysis (Table-3 & 4) were evaluated by one way ANOVA, thus evaluating the effects of the sampling sites on the bioaccumulation and the physiological status of the photobiont.

Comparative physiological response of *P. cocoes* and *R. sophodes* around Panki Thermal Power Plant, Kanpur:-

P. cocoes (foliose) and *R. sophodes* (crustose) lichen commonly occurring within the contaminated and non-contaminated area were selected for photosynthetic pigment analysis and metal concentration. In *P. cocoes,* chlorophyll a showed minimum concentration at 0.01±0.002 μgg^{-1} in west whereas maximum concentration at 0.02±0.003 μgg^{-1} in south direction. Chlorophyll b content ranged from 0.00±0.001 μgg^{-1} (west) to 0.01±0.002 μgg^{-1} (south) in the outskirts of thermal power plant. The total chlorophyll (chlorophyll a + chlorophyll b) ranged from 0.01±0.003 μgg^{-1} in west to 0.02±0.004 μgg^{-1} in south direction respectively. All the above three photosynthetic parameters showed similar trend of concentration in settling of pigment in lichen thalli.

Highest concentration of carotenoid was detected in *P. cocoes* found in south (0.01±0.002 μgg^{-1}), while lowest concentration was detected in north and west directions (0.01±0.001 μgg^{-1}). Chlorophyll degradation concentration was ranged from 0.77±0.015 μgg^{-1} in west to 1.00±0.011 μgg^{-1} in north direction. Protein concentration ranged from 1.31±0.089 μgg^{-1} in west to 1.54±0.088 μgg^{-1} in south direction. The samples collected from the west showed lower concentration values of all parameters, while samples from south direction showed higher concentration of all parameters except chlorophyll degradation (Table-1). The east direction showed complete absence of lichens as the sites has residential and commercial areas together with roads with high traffic activity. LSD analysis in *P. cocoes* showed highly significant difference only in chlorophyll degradation at p< 0.01% level whereas total chlorophyll and carotenoid showed significant differences at p< 0.05% level. Chlorophyll a and b along with protein estimation showed non-significant difference (Table-1).

Chlorophyll content and its degradation are often used as one of the cheapest and most accurate methods of biomonitoring. *R. sophodes* showed minimum chlorophyll a concentration (0.49±0.07 μgg^{-1} Fresh weight) in west direction whereas maximum concentration (0.79±0.02 μgg^{-1}) in north direction. Chlorophyll b content ranged from 0.16±0.02 μgg^{-1} in west to 0.44±0.06 μgg^{-1} in north direction. The total chlorophyll (chlorophyll a + chlorophyll b) ranged from 0.65±0.09 μgg^{-1} in west to 1.23±0.08 μgg^{-1} in north direction respectively. According to Carreias et al. (1998), the concentration of total chlorophyll is governed by the ambient environment, anthropogenic sources, vehicular traffic pollution and urban emission. Lowest concentration of carotenoid was detected in samples of *R. sophodes* in west (0.24±0.05 μgg^{-1}), while highest concentration was detected in north direction (0.55±0.02 μgg^{-1}). The ratio of optical density of chlorophyll samples read at 435 and 415nm is the most frequently used parameter for chlorophyll degradation (Garty et al., 2000). Chlorophyll degradation concentration was highest in north decreased with increasing distance in west and south direction from NTPC and it ranged from 0.70±0.01μgg^{-1} in west to 1.05±0.01 μgg^{-1} in north direction. All the photosynthetic parameters (chl. a, b, total chlorophyll, carotenoid and chlorophyll degradation) showed the same pattern of variation in higher and lower concentration which might be due to effect of wind direction and pollution loads.

Protein concentration ranged from 1.50±0.17 μgg^{-1} in south to 7.19±0.12 μgg^{-1} in west direction. The increased level of protein in the present study, at most contaminated sites corresponds with the findings of Gonzaléz et al. (1996) for the *Ramalina ecklonii.* The area Airport road Kataraghan Shyam west to thermal power plant; Airport road Kataraghan Shyam west to thermal power plant near Sachendi; Airport road near Sachendi; Aligarh- Kanpur road, Bagdudi Bazar, Amiliha near choubeypur kalan near tatiyaganj; near Panki thermal power plant, Rampur, Bhimsen and Canel road Meharavan Singh Purwa, Patarsa near Mardanpur showed lichen diversity in the areas.

In the present study, the ratio was highly affected at 10km to 15 km radius of Panki thermal power plant in *R. sophodes*, the highest amount of degradation was observed at outskirt of the point sources. LSD analysis in *R. sophodes* at p< 0.01% level showed significant difference in chl. a, total chlorophyll, carotenoid, chlorophyll degradation and protein content, while only chl. b showed significant differences at level of 0.05% (Table-1).

Correlations of various physiological parameters (Table-2) shows significant correlation of total chlorophyll content with chlorophyll b (p<0.01) in *P. cocoes* but *R. sophodes* showed significant correlation of chlorophyll b with chlorophyll a and total chlorophyll with chlorophyll a and chlorophyll b at p<0.05 level while protein had negative correlation with chlorophyll a, b, total chlorophyll, carotenoid and chlorophyll degradation. Increase in protein due to stressed condition has been reported in higher plants by Neumann et al. (1994). Overall pattern showed the concentration varied with the wind direction of the area as well as increasing trend with the increasing distance from the thermal power plant. In the area with fly ash dumping sites, vehicular exhausts are the main source of metals that can alter the biosynthesis of protein.

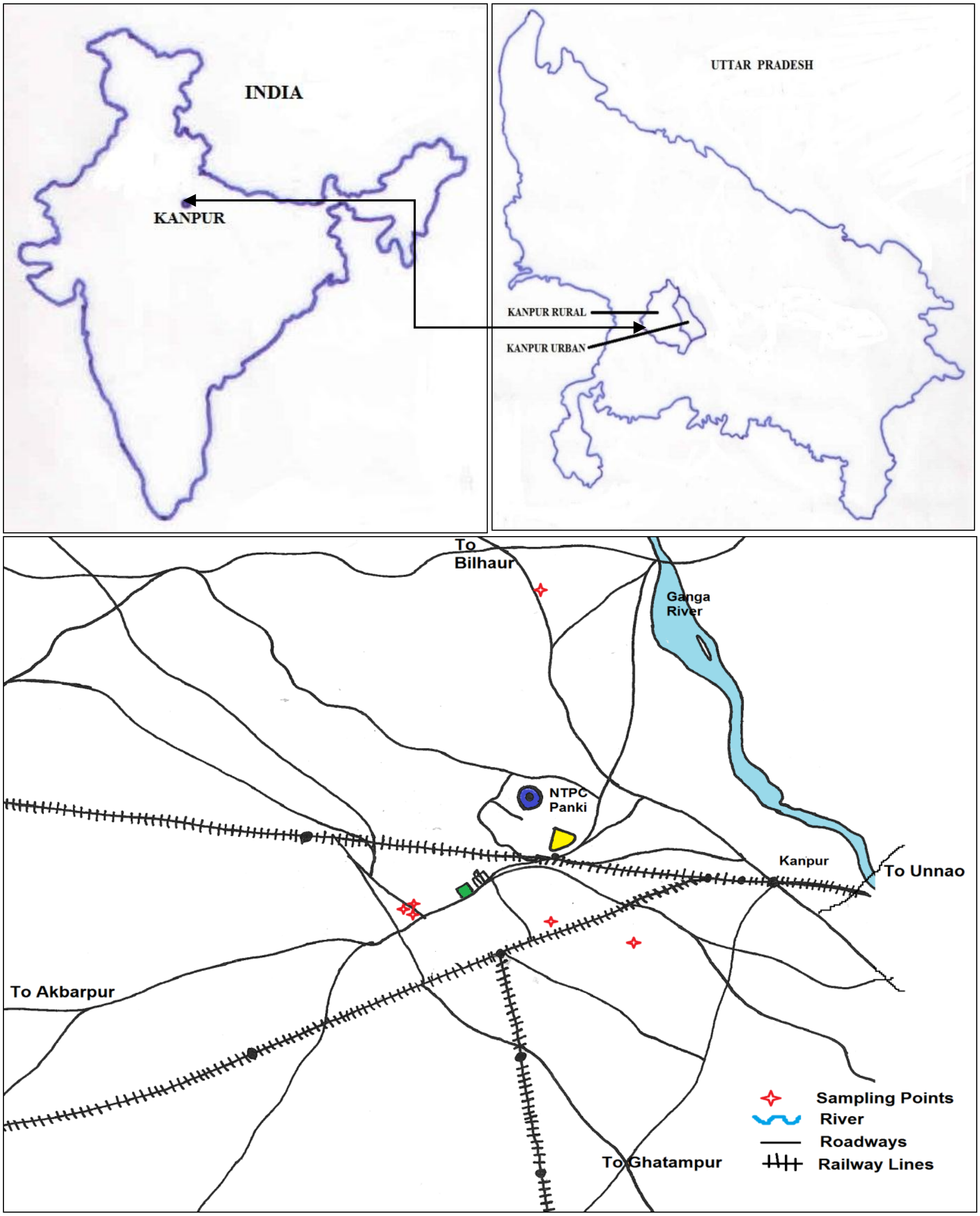

Fig. 1:- (A) Map of India showing Kanpur district; (B) Uttar Pradesh Region; (C) Location of sampling sites around Panki thermal power plant

Table 1:- Photosynthetic pigment analysis and protein content of lichens around Panki Thermal Power Plant, Kanpur

Directions	*P. cocoes* (concentration in μgg^{-1})					
	Chl. a	**Chl. b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
North	0.01±0.003	0.01±0.001	0.02±0.003	0.01±0.001	1.00±0.011	1.35±0.230
West	0.01±0.002	0.00±0.001	0.01±0.003	0.01±0.001	0.77±0.015	1.31±0.089
South	0.02±0.003	0.01±0.002	0.02±0.004	0.01±0.002	0.97±0.016	1.54±0.088
CV%	21.70	22.01	18.83	17.42	1.54	10.81
LSD (p< 0.05%)	0.005^{NS}	0.002^{NS}	0.006*	0.003*	0.025**	0.269^{NS}
Directions	***R. sophodes*** **(concentration in μgg^{-1})**					
	Chl. a	**Chl. b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
North	0.79±0.02	0.44±0.06	1.23±0.08	0.55±0.02	1.05±0.01	1.53±0.12
West	0.49±0.07	0.16±0.02	0.65±0.09	0.24±0.05	0.70±0.01	7.19±0.12
South	0.73±0.10	0.37±0.12	1.10±0.22	0.44±0.13	1.01±0.01	1.50±0.17
CV%	10.92	23.87	14.52	19.05	1.15	14.10
LSD (p< 0.05%)	0.146**	0.155*	0.288**	0.157**	0.021**	0.279**

Mean±S.D., n=3 in μgg^{-1}
*** Significance at the level of 0.01%.*
** Significance at the level of 0.05%.*

Table 2:- Values of correlation matrix between the physiological parameters studied found in lichen thalli around Panki Thermal Power Plant, Kanpur

P.cocoes	**Chl.a**	**Chl.b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
Chl.a	1	0.5	0.5	.a	0.392	0.987
Chl.b		1	1.000**	.a	0.993	0.634
Total Chl.			1	.a	0.993	0.634
Carotenoid				.a	.a	.a
Chl. deg.					1	0.537
Protein						1
R. sophodes	**Chl.a**	**Chl.b**	**Total Chl.**	**Carotenoid**	**Chl. deg.**	**Protein**
Chl.a	1	.999*	1.000*	0.986	0.996	-0.981
Chl.b		1	1.000*	0.993	0.99	-0.97
Total Chl.			1	0.99	0.994	-0.976
Carotenoid				1	0.968	-0.935
Chl. deg.					1	-0.994
Protein						1

a. Cannot be computed because at least one of the variables is constant.
**. Correlation is significant at the 0.05 level (2-tailed).*
***. Correlation is significant at the 0.01 level (2-tailed).*

Table 3:- Metal accumulation in the thalli of lichens around Panki Thermal Power Plant, Kanpur

Directions	*P. cocoes* (concentration in µgg^{-1} dry weight)											Total metal
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**	
North	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
West	60.07±0.17	456.04±0.25	32603.04±0.78	13.11±0.67	49.45±0.21	53.23±0.23	206.18±0.05	14.0±0.37	5.75±0.28	3.32±0.23	217.09±0.49	**33681.28**
South	49.7±0.95	487.44±0.47	26223.04±0.46	10.9±0.05	28.36±0.08	28.53±0.11	168.64±0.46	19.56±0.19	4.42±0.37	BDL	BDL	**27020.59**
Total metal	**109.77**	**943.48**	**58826.08**	**24.01**	**77.81**	**81.76**	**374.82**	**33.56**	**10.17**	**3.32**	**217.09**	
CV%	1.515	0.097	0.002	4.849	0.501	0.527	0.212	2.125	7.900	12.201	0.392	
LSD(p< 0.05%)	0.924**	0.508**	0.875**	0.647**	0.216**	0.239**	0.443**	0.396**	0.446**	0.225**	0.473**	
Directions	***R. sophodes*** **(concentration in µgg^{-1} dry weight)**											**Total metal**
	Cr	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**	
North	87.13±0.52	1281.04±0.58	34703.04±0.57	19.2±0.19	61.91±0.31	57.33±0.15	154.38±0.17	36.19±0.08	6.62±0.17	2.14±0.15	441.09±0.41	**36850.07**
West	81.39±0.38	1088.06±0.41	34023.04±0.90	21.34±0.30	56.56±0.23	56.33±0.09	206.28±0.08	28.92±0.30	5.52±0.16	2.37±0.16	405.89±0.21	**35975.7**
South	1.11±0.13	93.44±0.55	156.54±0.49	0.49±0.05	3.88±0.13	26.07±0.07	108.78±0.21	2.04±0.07	2.03±0.03	1.48±0.28	39.09±0.04	**434.95**
Total metal	**169.63**	**2462.54**	**68882.62**	**41.03**	**122.35**	**139.73**	**469.44**	**67.15**	**14.17**	**5.99**	**886.07**	
CV%	0.673	0.063	0.023	1.499	0.577	0.226	0.102	0.811	2.850	6.744	0.089	
LSD(p< 0.05%)	0.634**	0.860**	9.078**	0.341**	0.392**	1.756**	0.267**	0.302**	0.224**	0.224**	0.441**	

Mean±S.D., n=3 in µgg^{-1} dry weight, BDL= Below Detection Limit

*** Significance at the level of 0.01%.*

** Significance at the level of 0.05%.*

Table 4:- Values of correlation matrix between the elements found in lichen thalli around Panki Thermal Power Plant, Kanpur

P.cocoes	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**
Cr	1	0.976	1.000*	1.000**	0.962	0.949	1.000**	0.904	.998*	0.633	0.633
Mn		1	0.971	0.977	0.879	0.858	0.974	0.975	0.961	0.449	0.449
Fe			1	1.000*	0.968	0.956	1.000**	0.894	.999*	0.651	0.651
Co				1	0.961	0.948	1.000**	0.906	.998*	0.63	0.63
Ni					1	.999*	0.965	0.753	0.977	0.821	0.821
Cu						1	0.952	0.724	0.967	0.845	0.845
Zn							1	0.9	.999*	0.641	0.641
As								1	0.877	0.242	0.242
Se									1	0.679	0.679
Cd										1	1.000**
Pb											1
R.sophodes	**Cr**	**Mn**	**Fe**	**Co**	**Ni**	**Cu**	**Zn**	**As**	**Se**	**Cd**	**Pb**
Cr	1	0.996	.999*	0.988	1.000*	1.000*	0.814	0.99	0.985	0.952	1.000*
Mn		1	0.991	0.97	.998*	0.992	0.756	.999*	0.997	0.92	.997*
Fe			1	0.994	.998*	1.000**	0.838	0.983	0.977	0.964	.998*
Co				1	0.984	0.993	0.893	0.956	0.948	0.988	0.985
Ni					1	.998*	0.799	0.993	0.989	0.944	1.000**
Cu						1	0.831	0.985	0.979	0.961	.999*
Zn							1	0.722	0.702	0.953	0.802
As								1	1.000*	0.898	0.992
Se									1	0.886	0.988
Cd										1	0.946
Pb											1

**. Correlation is significant at the 0.05 level (2-tailed).*
***. Correlation is significant at the 0.01 level (2-tailed).*

Comparative response of metal accumulation in *P. cocoes* and *R. sophodes* at different directions of Panki Thermal Power Plant:-

Accumulation of eleven metals viz; Chromium (Cr), Manganese (Mn), Iron (Fe), Cobalt (Co), Nickel (Ni), Copper (Cu), Zinc (Zn), Arsenic (As), Selenium (Se), Cadmium (Cd) and Lead (Pb) were estimated in thalli of both lichens in all three directions from the Panki thermal power plant to compare the bioaccumulation of metals (Table-3). Both the species exhibited dissimilar sequence of concentration for all metals. Enhanced level of Fe clearly indicate vehicular activity as the originator (Pirintsos and Loppi, 2008). The study area showed higher accumulation of Fe, Mn, Zn, Pb metals, while Cr> Cu> Ni> As> Co> Se> Cd accumulated in lower concentration in both the species.

Lichens *P. cocoes* and *R. sophodes* showed accumulation of all the heavy metal within the ranges of 0.49 to 34703.04 μgg^{-1} dry weights as total metal contents. Both the species accumulated Fe in higher concentration followed by the sequence of Mn> Zn> Pb> Cr> Cu> Ni> As> Co> Se> Cd with concentration of 58826.08, 943.48, 374.82, 217.09, 109.77, 81.76, 77.81, 33.56, 24.01, 10.17 and 3.32 μgg^{-1} dry weight in *P. cocoes*. More or less similarly *R. sophodes* exhibit metal concentration sequence of Fe> Mn> Pb> Zn> Cr> Cu> Ni> As> Co> Se> Cd as 68882.62, 2462.54, 886.07, 469.44, 169.63,139.73, 122.35, 67.15, 41.03, 14.17 and 5.99 μgg^{-1} dry weight (total metal) respectively. The Pb, Cr, Ni and Cd metals showed clear increasing trend of their concentrations in areas associated with high vehicular activities as well as coal burning.

Higher accumulation of Fe with concentration of 32603.04±0.78 μgg^{-1} in west site and minimum concentration of 26223.04±0.46 μgg^{-1}in south clearly indicates that the wind direction may be the probable reason for the settling of this metal in south direction. Loppi et al. (1998a, b) and Bajpai et al. (2010b) also reported that Fe in the earth's crust are strongly correlated in lichens and environmental contamination and lichens have an especially affinity for Fe.

Manganese and As showed similar accumulation pattern as Mn ranged from 456.04±0.25 μgg^{-1} to 487.44±0.47 μgg^{-1} and As ranged from 14.0±0.37 μgg^{-1} to 19.56±0.19 μgg^{-1} in west and south directions respectively. Zinc had maximum accumulation (206.18±0.05 μgg^{-1}) in west and minimum in south direction (168.64±0.46 μgg^{-1}). Higher concentration of Zn around the thermal power plant may be due to the high vehicular activity involved in the disposal of coal waste. Lubricant oil often contains Cd, Cu and Zn. Zinc may be emitted by automobile tires and brake pads (Berry and Wallace, 1981; Ward, 1989). Lead (Pb) and Cd showed their presence only in west direction with concentration of 217.09±0.49 μgg^{-1} and 3.32±0.23 μgg^{-1} respectively. The metal content exhibit descerasing trend at a distance of few kilometers from the source of pollution. Chromiun (Cr), Cu and Ni showed similar range of accumulation of 49.7±0.95 μgg^{-1} to 60.07±0.17 μgg^{-1}; 28.53±0.11 μgg^{-1} to 53.23±0.23 μgg^{-1} and 28.36±0.08 μgg^{-1} to 49.45±0.21 μgg^{-1} respectively. Some of the metals lighter in weight dispersed to long range while, according to Loppi et al. (1994), Cu is large particle metal emitted from the source are incapable of long-range dispersion. The concentration of metals of Co ranged between (10.09±0.05 μgg^{-1} to 13.11±0.67 μgg^{-1}); Se (4.42±0.37 μgg^{-1} to 5.75±0.28 μgg^{-1}) in south and west directions respectively. In *P. cocoes*, total metal concentration was highest in west (33681.23 μgg^{-1}) and lowest in south direction (27020.59 μgg^{-1}) of the study area but north direction showed all metals below detection limit (BDL).

R. sophodes exhibit higher concentration of total metals accumulated in north direction (36850.07 μgg^{-1}) followed by west direction (35975.7 μgg^{-1}) and south direction (434.95 μgg^{-1}). According to Garty (2001), Dispersion and distribution of metals depend on wind speed and direction as well as the density of the element under consideration. LSD analysis at $p< 0.01\%$ level showed significant difference in chlorophyll estimation as well as protein content, while only chl. b showed significant differences at level of 0.05% (Table-3).

The correlation coefficient were calculated for concentration in paired element and for the element content in the lichen in different directions (Table-4). The possible source of element may be indicated by significant correlation between elements in the lichen thallus. The correlations (all significant at $p<0.01$ level) of Co and Cr, Zn and Cr, Zn and Fe, Zn and Co, Pb and Cr in *P. cocoes* but the correlations of Cu and Fe, Pb and Ni in *R. sophodes* indicates motor vehicles as possible originators (Table-4). Nickel is found in car metal using plating in welded plates (Ward, 1989) and in tires (Sadiq et al., 1989). Among the eleven metals analyzed, Cu, Pb and Zn seems to cause extensive damage to the biological apparatus by causing alteration in the vital physiological process (Shukla and Upreti, 2008).

Conclusion:-

Both *P. cocoes* and *R. sophodes* at all the sites showed more or less similar selectivity sequence of metals and similar chlorophyll degradation with positive correlation matrix; whereas protein content had positively correlated in *P. cocoes* and negatively correlated with all photosynthetic parameters in *R. sophodes*. The level of concentration of different metal present in the lichens provide information about the risk to the population living in the vicinity of the power plant together with long-term hazard due to metal accumulation. The reason for the higher accumulation of metals may be due to anthropogenic activities together with pollutants emerging from thermal power due to coal burning.

Since the area is close to Panki thermal power plants, therefore, the probable source of metals in species may be attributed to the emission of thermal power plant. The study provided an understanding about the mechanisms adopted by different growth form of lichens for bioaccumulation of metals emitted by thermal power plant and indicates that the particulate bound adsorption is the major factor responsible for bioaccumulation in lichens irrespective of their growth form.

The physiological studies carried out on lichens together with metal accumulation, degradation of chlorophyll and change in protein and carotenoid will help to understand the damage caused by the pollutants to the living organisms around thermal power plant. The study also provide baseline data on levels of metal accumulation around the thermal power plant which will be helpful for carrying out future biomonitoring studies in the area.

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Studies on Uptake and Localization of metals in lichens growing around Thermal Power Plant through application of SEM and FTIR techniques

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ABSTRACT

Coal based thermal power plants are considered as major point sources emitting considerable amount of particulate matter, fly ash, greenhouse gases, non-combustible hydrocarbons and metals. In order to assess the impact of thermal power plant in Eastern Uttar Pradesh, India, two morphologically distinct lichen species *Pyxine cocoes* and *Bacidia incongruens* have been used for conducting biomonitoring studies around thermal power plant located in Tanda district (Uttar Pradesh). Result shows that both the species differs in morphology and anatomy but bioaccumulates more or less similar concentration of metal through adsorption and absorption, as validated by SEM and FTIR respectively. The bioaccumulation in particulate form absorbed on the surface of the lichen thallus further support the particulate bound association of the pollutants emitted from thermal power plant a source of metals.

INTRODUCTION

Lichens are most valuable biomonitors of atmospheric pollution as well as sensitive indicators to assess the effect of air pollutants by measuring changes at different level (Loppi and Bonini 2000). The decreasing metal concentration in lichen species correlated with increasing distance from the source of pollution i.e. thermal power plant. Lichens are peculiar in nature, having a special sensitivity for acidic gases but accumulate several organic as well as inorganic compounds in a large amount beyond their physiological needs and thus can be utilized to monitor pollutant load of a particular environment (Pirintsos and Loppi 2008).

A number of studies on pollution monitoring utilizing lichens as bioindicator are available from different regions of the world (Conti and Cecchetti 2001; Kircher and Darllant 2002). Recently few passive as well as active (transplant) biomonitoring studies using lichens have been carried out in India in different climatic regions of the country to monitor various pollution sources (Dubey et al. 1999; Upreti and Pandey 2000; Pandey et al. 2002; Mishra et al. 2003; Bajpai et al. 2004; Saxena et al. 2007; Shukla and Upreti 2007, 2008; Bajpai et al. 2010 a, b; 2013a, b; Gupta 2014; Gupta et al. 2015).

The epiphytic lichens have been used extensively to monitor air quality around urban areas, industrial sites and to assess spatial distribution and accumulation of airborne pollutants (Purvis et al. 2004). According to Carignan et al. (2002) described that due to atmospheric fall out any integrated signals can be minimized because of seasonal atmospheric circulation patterns. Few reports on the effect of thermal power plants on vegetation and deterioration of air quality in localities around thermal power plants in India are available (Singh et al. 1994; Rao et al. 1990), however, studies done by Bajpai et al. (2010a, b) on bioaccumulation of metals, its spatial distribution and effect on the physiology of lichens in Feroze Gandhi Unchahar Thermal power plant, Raebareli, Uttar pradesh is known from India.

In the present study, an attempt has been made to elucidate the metal uptake mechanism in two common lichen species *Pyxine cocoes* and *Bacidia incongruens* and their localization in lichen thalli with the aid of FTIR and SEM.

MATERIALS AND METHODS

Study area

The study area is situated at Tanda in Ambedkar Nagar district, located on North-Eastern part of Uttar Pradesh, India; lies between 26°09 N to 26°40 N latitudes and 82°12 E to 83°05 E longitudes. The total area of the district is 2520 km² and the total length of the district from east to west is approximately 75 km and the breadth from north to south is about 42 km. Tanda thermal power plant coordinates between 26º33’00"N and 82º39’00"E (Fig-1a, b) and is

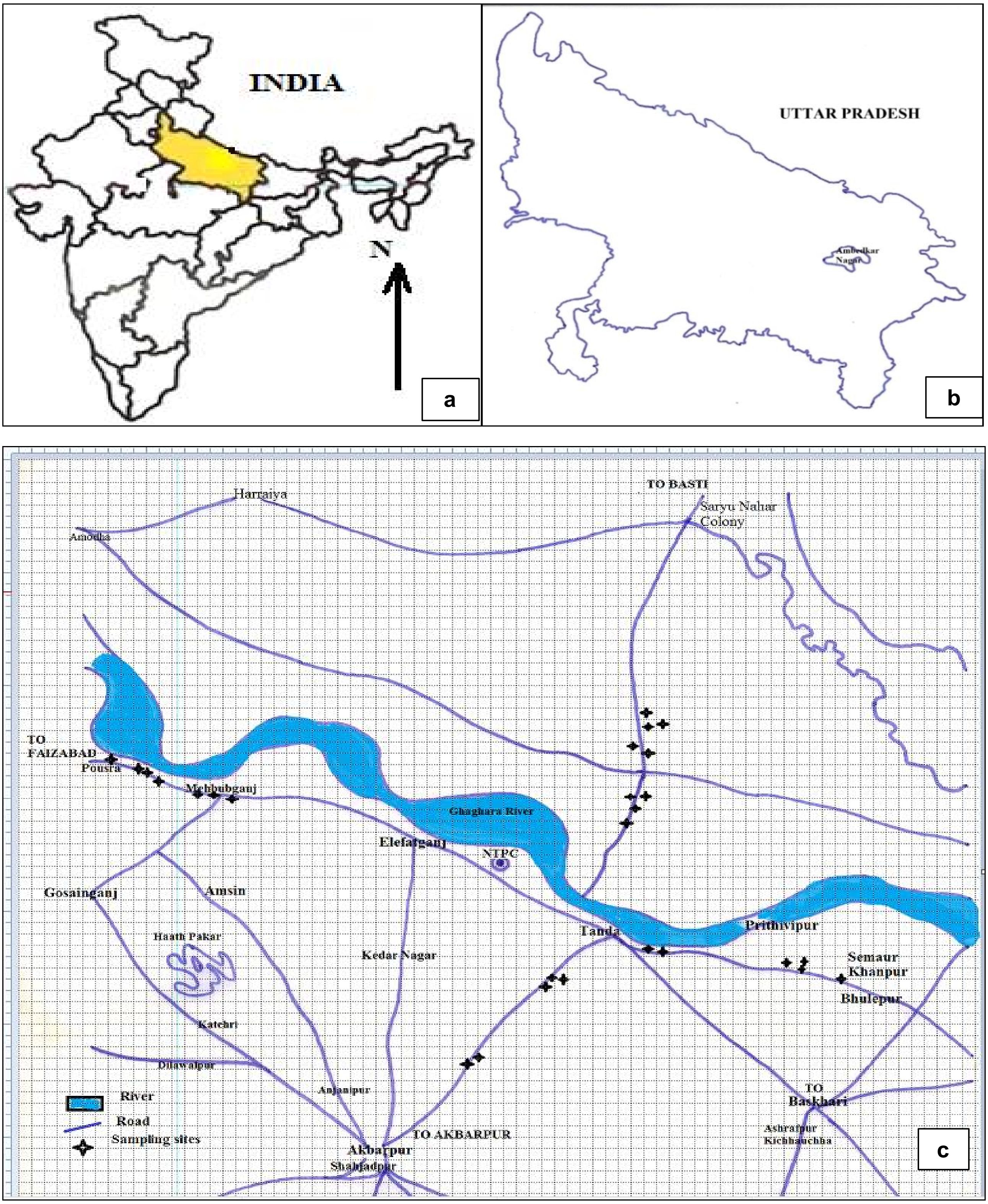


Fig. 1. (a) India Map; (b) Uttar Pradesh Region; (c) Sampling sites around Tanda thermal power plant, Ambedkar Nagar, Eastern U. P.

Table 1. Elemental composition of particulate matter of lichens by EDX around Tanda thermal power plant

Elements	*P. cocoes*				Elements	*B. incongruens*			
	East	South	West	North		East	South	West	North
C	17.6	14.8	20.59	33.35	C	55.7	53.25	22.78	43.65
O	53.53	53.32	52.3	41.1	O	38.64	43.03	55.13	36.17
Al	0.23	ND	ND	3.3	Al	ND	0.27	0.71	1.33
Si	0.35	ND	ND	6.84	Si	0.33	1.08	19.66	11.59
K	0.22	ND	ND	1.74	K	0.45	0.9	ND	0.74
Ca	20.8	23.82	21.63	ND	Ca	1.01	ND	ND	3.27
Zr	0.79	ND	ND	1.97	Zr	1.3	0.77	ND	0.08
Pt	ND	0.99	5.48	ND	Pt	ND	ND	1.45	1.67
Mg	ND	ND	ND	1.63	Mg	0.34	0.33	ND	ND
Fe	ND	ND	ND	9.73	Fe	ND	ND	0.27	1.01
Sb	4.54	5.28	ND	ND	S	2.23	0.36	ND	0.5
I	1.93	1.8	ND	ND					
Ti	ND	ND	ND	0.34					

surrounded by agriculture fields and mango orchards along with two National Highways 233A & 232 (India) also passes through the town. The coal for the power plant is sourced from North Karnpura Coal Fields, while source of water for the power plant is from Tanda Pump Canal of Saryu River. It has 4 units of 110 MW (4 x 110MW=440 MW) capacity of generation of electricity. The climate of the region is classified into three distinct seasons- Cold weather season (November to February), Hot weather season (March to mid-June) and Season of rains (mid-June to October). The reversal of winds takes place twice a year. The cold weather season lasts from November to February. In November, the belt of high pressure extends from north-west India and covers the whole of the Uttar Pradesh. The temperature beings to decline and the maximum and minimum are 32.15°C and 8.95°C respectively, in this month. The prevailing winds blow from west to east and are influenced by the pressure distribution and pattern of the Himalayas.

2.2 Sample collection

The area around thermal power plant was randomly surveyed for collection of lichens from 27 localities in all four directions i.e. east, west, north and south of the power plant (Fig-1c). Lichens especially, *P. cocoes* and *B. incongruens* were growing abundantly in all four directions on *Mangifera indica* tree trunk, branch and thus both the species were sampled for metal analysis, followed by SEM and FTIR analysis.

The collected samples were dried and kept inside the paper packet. The lichen samples were identified based on their morphological, anatomical and chemical characters by using LABOMED dissecting microscope for external morphology, while LEICA ATC 2000 compound microscope was used for microscopic anatomical details of the samples. The chemical substances present in the lichen thallus were identified through TLC in solvent system A (Toulene,1-4 Dioxane and Acetic acid, 180ml: 60ml: 8ml) (Orange et al. 2001; Culberson 1972; Walker and James 1980). The voucher specimens were preserved in the Lichen Herbarium (LWG) of CSIR- National Botanical Research Institute, Lucknow, India.

2.3 SEM (Scanning Electron Microscopy) & EDX (Energy Dispersive Microanalysis) Analysis

Lichen samples were cleaned and fixed with 2.5% glutaraldehyde for 2-6 hours at 4°C and washed in 0.1 M Phosphate buffer for changes each of 15 min. at 4°C. After that, the lichen samples were fixed with 1% Osmium tetroxide as postfixation for 2 hrs. The fixed samples were dehydrated in 0.1 M Phosphate buffer using 30%, 50%, 70%, 80%, 90%, 95% and 100% acetone (i.e. dry acetone; 30gm $CuSO_4$ add in 100ml absolute acetone). Then the dried samples were kept in desiccators for the removal of the moisture present in the sample. The dehydrated lichen samples were mounted on to the Aluminium stubs with double-sided carbon tape. These stubs were coated with gold-palladium in a sputter coater (JFC 1600; JEOL, Tokyo, Japan) at 20 mA and equipped with an EDS 133, EV Dry Detector (INCAx-act) of OXFORD Instruments, UK and viewed under Scanning Electron Microscope (JSM-6490LV; JEOL, Tokyo, Japan). EDX spectra of individual aerosol particles were obtained by scanning an electron beam with an accelerating voltage of 15 kV for determination of the individual elemental composition of particles (USIC facility, Babasaheb Bhimrao Ambedkar University, Lucknow, India).

2.4 Fourier Transform Infrared Spectrometer (FTIR) Analysis

The pellets of lichen samples were dried for 4 to 5 hrs in an oven at 40-50ºC to remove moisture content. One mg of lichen samples was mixed with 100 mg of potassium bromide (KBr) using an agate mortar and pestle. The KBr based pellet was compressed into a thin disk using a hydraulic press (CAP-15T) by establishing ten tons pressure. The disks were fixed in an FTIR spectrophotometer (Thermo-Nicolet 6700) and analyzed in the spectral region 4000-400 cm^{-1} against KBr background.

2.5 Metal analysis

The lichen thalli were removed from the bark with a sharp knife. The samples (constant weight) were oven dried for 12 h at 90°C. The dried lichen samples in triplicate (n=3) were grinded in a mortar (0.2 g); each sample was digested in 5 ml mixture of concentrated HNO_3 and $HClO_4$ (v/v, 9:1) (beakers covered with watch glasses) for 1 hour and heated until close to dryness. The analysis was done with ICP MS (Perkin Elmer SCIEX ELAN DRCe). Stock standards were from Merck India and traceable to NIST (National Institute of Standards Technology). Working standards were prepared from the stock using deionised water.

2.6 Statistical analysis

The data obtained were subjected to one-way analysis of variance (ANOVA) to evaluate the probable correlation between the metal content using statistical SPSS 16.0 program.

RESULTS AND DISCUSSION

The study area revealed the occurrence of 11 species of lichens belonging to 7 genera and 6 families. Among them *Pyxine cocoes* and *Bacidia incongruens* were found growing luxuriantly on trunks and branches of *Mangifera indica* tree in all four directions (east, west, north and south) (Fig-1).

3.1 Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) analysis

The morphological assessment and quantification of elements of *P. cocoes* (Fig-2) and *B. incongruens* (Fig-3) in comparison to standard was performed by Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray analysis (EDX) analysis (Fig-4 & 5).

3.1.1 SEM analysis on *P. cocoes* (Fig-2): Lichens depend partly on the chemical characters of the substrate such as the calcium content. The whitish pruina (powdery substance) deposited on the upper surface of lichen thalli appears as crystals which are composed of calcium oxalate (Budel and Scheidegger 2008).

The calcium oxalate crystals especially the weddellite crystals which contains zeolitic water which can leave the crystals when they dry and are implied as a possible source of water in the lichen. The size of the crystals and their proximity to the algal cells have important factors in the mechanism and the weddellite crystals alternately trap and release zeolitic water. The algal cells in the lichens have the capacity to use water vapor for photosynthesis (Nash 2008). Besides their role in trapping water for the lichen, calcium oxalate crystals also provide mechanical protection, serve as deterrents against herbivores (Reutimann and Scheidegger 1987) and provide protection against excessive light by deflecting some light rays from reaching the lichens (Purvis 2000).

The study provide rapid qualitative or adequate standards, and quantitative analysis of elemental composition with a sampling depth of 1–2 ìm (Srivastava et al. 2009; Sielicki et al. 2011; Pipal et al. 2011) and EDX spectra of blank filter were also recorded and its composition was manually subtracted during the evaluation of the elemental composition of individual aerosol particles of different groups. EDX spectra in *P. cocoes* (Table-1; (Fig-4) showed the weight percentage of elements in all directions in which oxygen as oxides is the most abundant element (41.1 to 53.53%) followed by carbonaceous element (14.8-33.35%) and Ca (20.8-23.82%) from the study area.

3.1.2 SEM analysis on *B. incongruens* (Fig-3): The adsorption of particulate matter is more prominent in *P. cocoes* as compared to *B. incongruens.*

EDX spectra of *B. incongruens* (Table-; Fig-5) showed the weight percentage of elements i.e. carbon (22.78-55.7%) and oxides (36.17-55.13%) are dominating in east and west directions respectively. Si (0.33-19.66%) is also present in lower concentration in the thallus. The sources

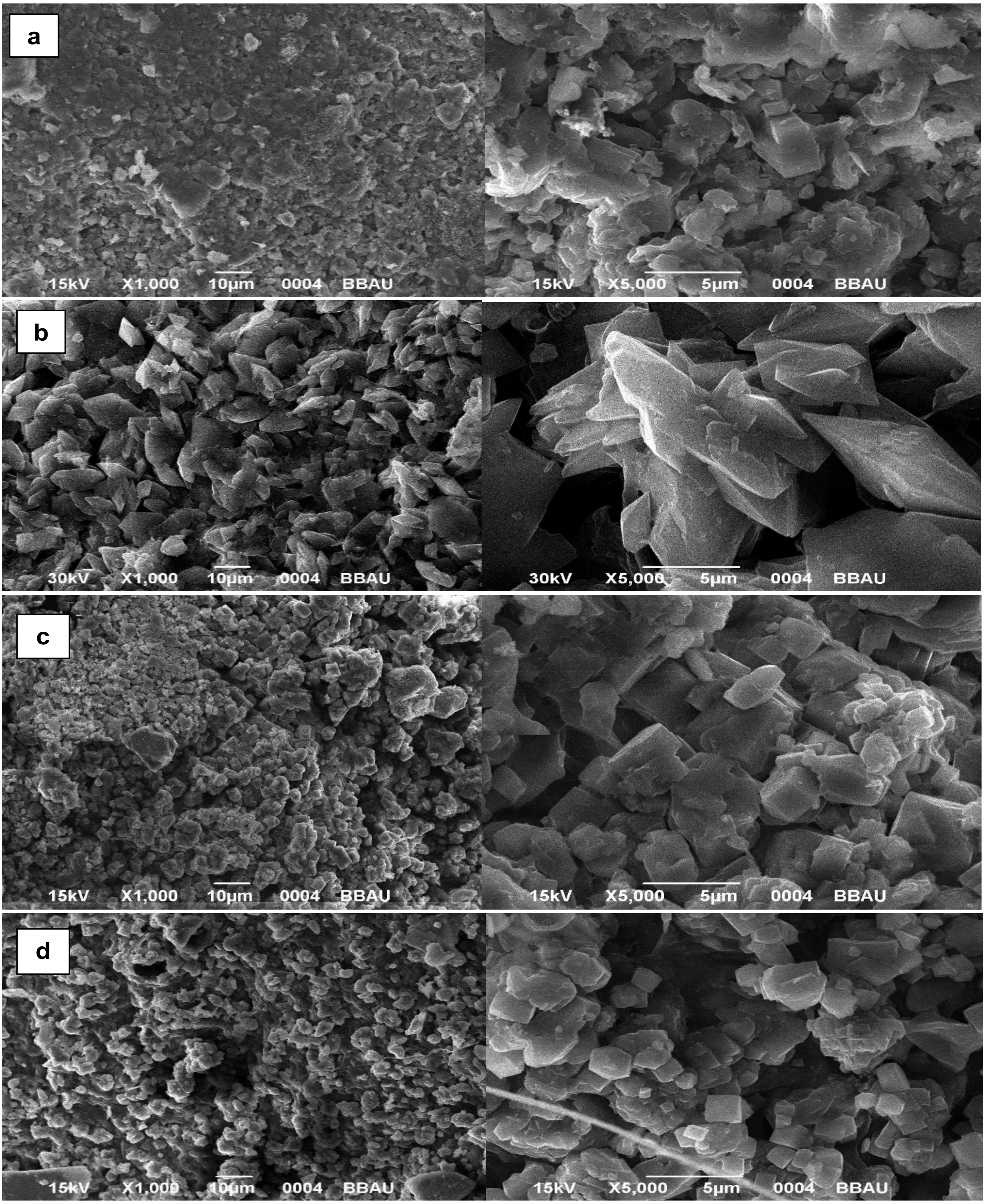


Fig. 2. Scanning Electron Microscope images of lichen species *P. cocoes;* (a) East direction, (b) South direction, (c) West direction and (d) North direction

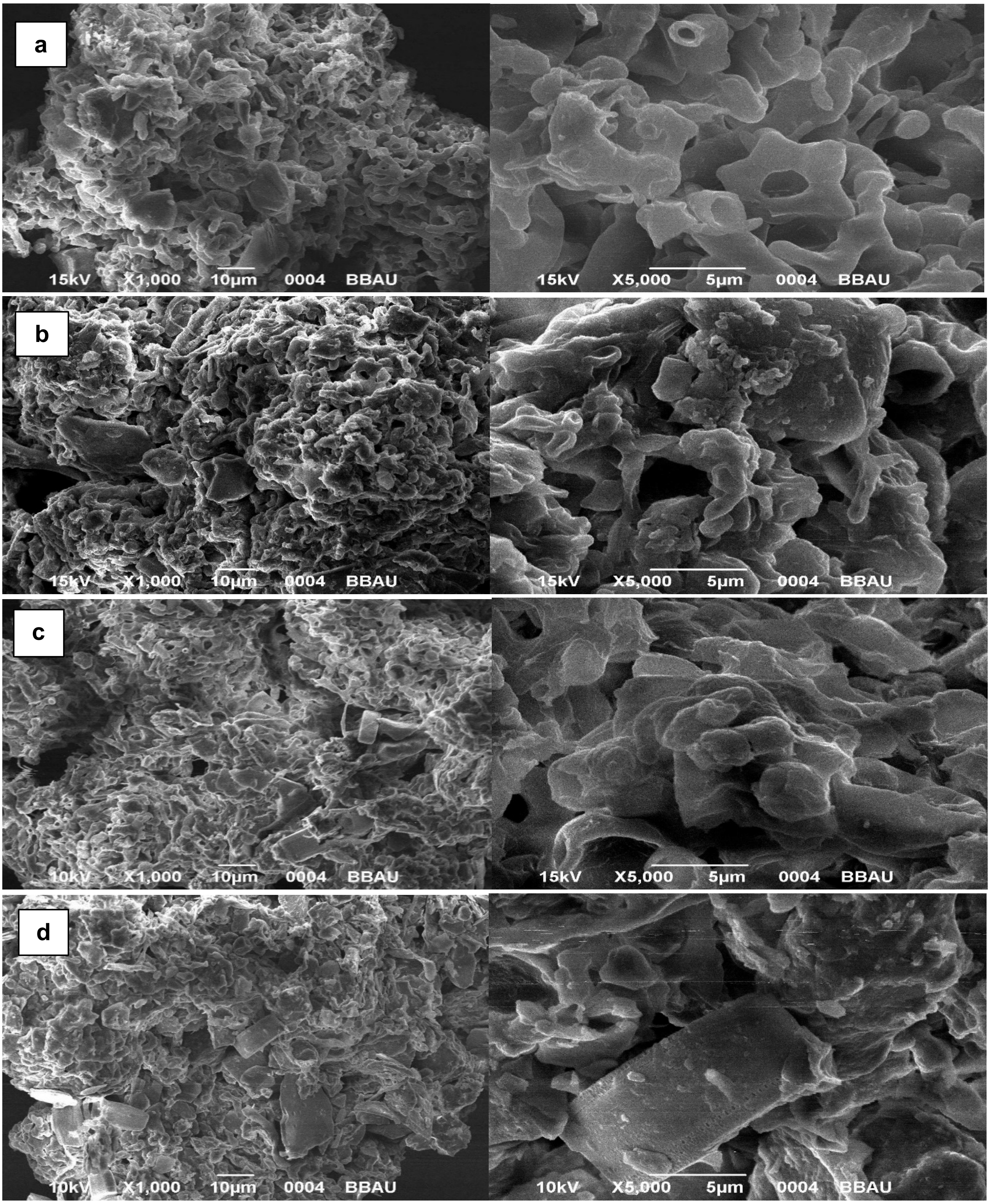


Fig. 3. Scanning Electron Microscope images of lichen species *B. incongruens;* (a) East direction, (b) South direction, (c) West direction and (d) North direction

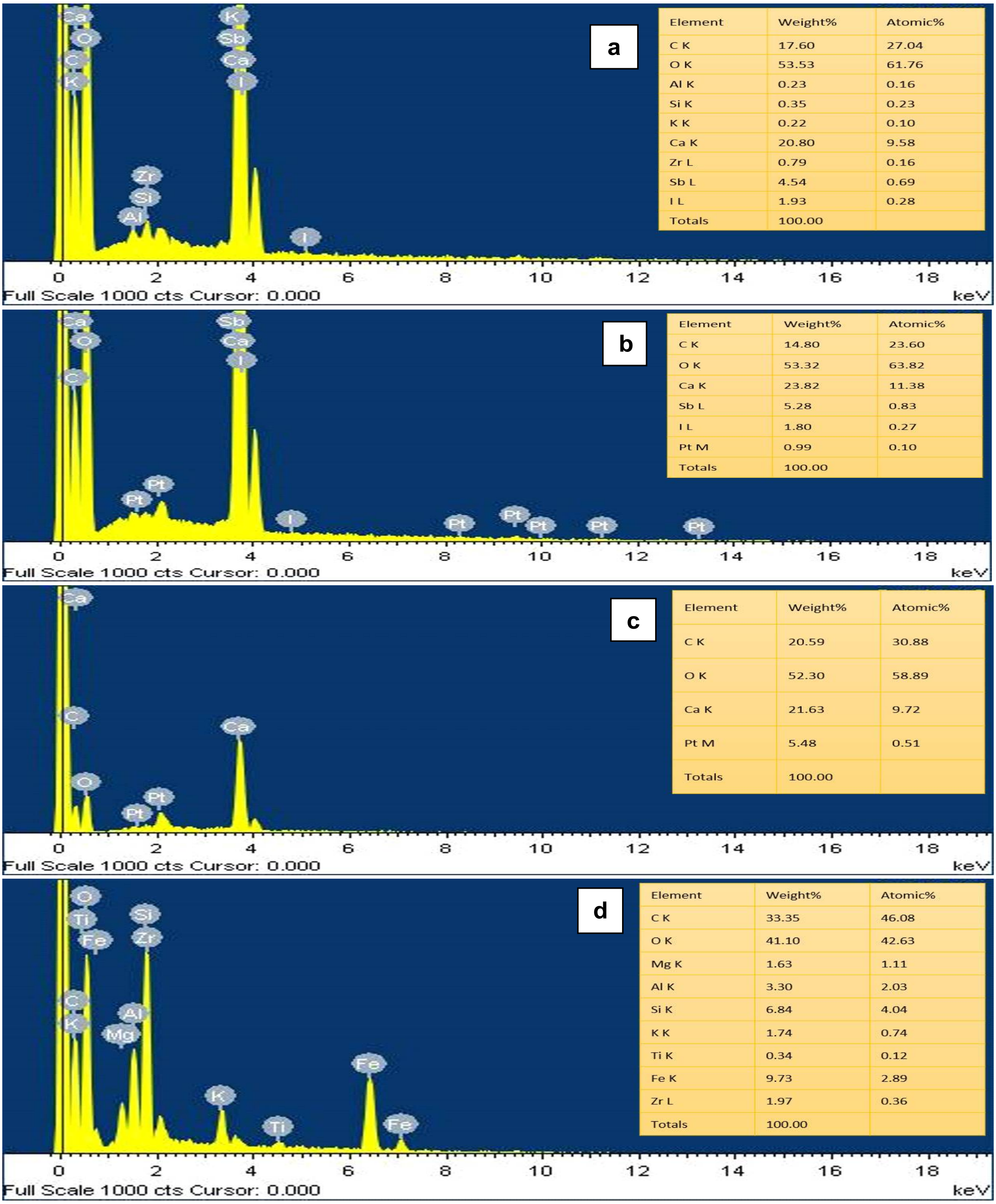
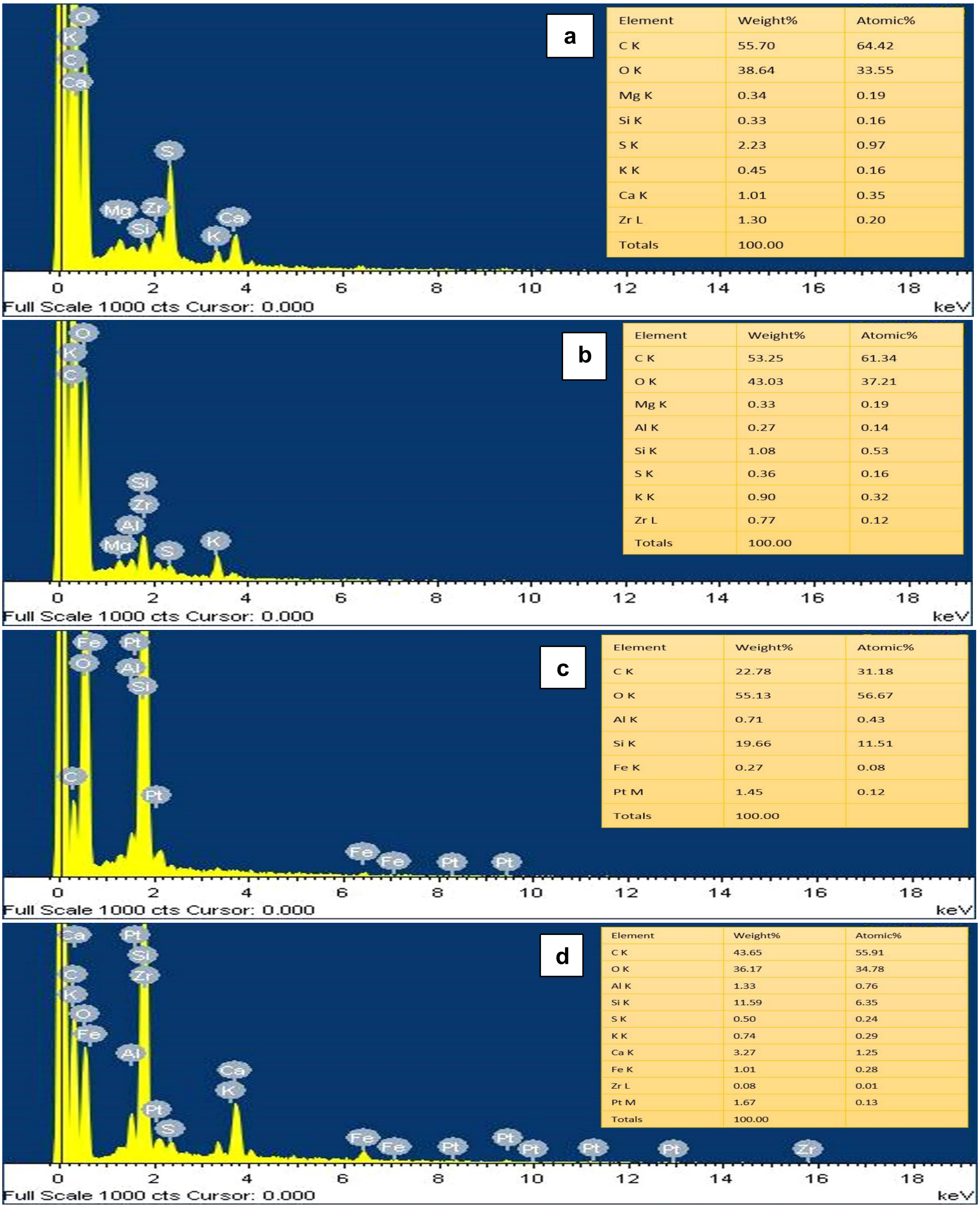


Fig. 4. Energy Dispersive X-ray analysis of the lichen species *P. cocoes* of all the directions around Tanda thermal power plant, Ambedkar Nagar; (a) East, (b) South, (c) West and (d) North direction



(a)

Element	Weight%	Atomic%
C K	55.70	64.42
O K	38.64	33.55
Mg K	0.34	0.19
Si K	0.33	0.16
S K	2.23	0.97
K K	0.45	0.16
Ca K	1.01	0.35
Zr L	1.30	0.20
Totals	100.00	

(b)

Element	Weight%	Atomic%
C K	53.25	61.34
O K	43.03	37.21
Mg K	0.33	0.19
Al K	0.27	0.14
Si K	1.08	0.53
S K	0.36	0.16
K K	0.90	0.32
Zr L	0.77	0.12
Totals	100.00	

(c)

Element	Weight%	Atomic%
C K	22.78	31.18
O K	55.13	56.67
Al K	0.71	0.43
Si K	19.66	11.51
Fe K	0.27	0.08
Pt M	1.45	0.12
Totals	100.00	

(d)

Element	Weight%	Atomic%
C K	43.65	55.91
O K	36.17	34.78
Al K	1.33	0.76
Si K	11.59	6.35
S K	0.50	0.24
K K	0.74	0.29
Ca K	3.27	1.25
Fe K	1.01	0.28
Zr L	0.08	0.01
Pt M	1.67	0.13
Totals	100.00	

Fig. 5. Energy Dispersive X-ray analysis of the lichen species *B. incongruens* of all the directions around Tanda thermal power plant, Ambedkar Nagar; (a) East, (b) South, (c) West and (d) North direction

of carbonaceous elements indicate the biomass burning and dominance of soot particle from biomass burning similar to the studies by Zhang et al. (2010).

The SEM and FTIR studies carried out on the production of calcium oxalate by lichens exhibited that the calcium oxalate production of different lichen taxa are associated with their effective biodeterioration activities (Edwards et al. 1997) or adaptation to the air pollution (Garty et al. 2002).

3.2 Analysis of Lichens by Fourier- Transform Infrared Spectroscopy (FTIR)

3.2.1 FTIR spectra measurement of *P. cocoes*

The spectra of *P. cocoes* showed the stretching of bonded N-H/ O-H and the presence of alcohol and phenol groups (Table-2; Fig-6a) at a strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3408.3 cm^{-1} (east), 3435.0 cm^{-1} (south), 3436.0 cm^{-1} (west), 3443.7 cm^{-1} (north). The spectral band observed between 3300- 2500 cm^{-1} due to symmetrical stretching of bonded O-H showed the presence of carboxylic acid. The absorbance bands observed at ranged between 2200- 2000 cm^{-1} due to NH_3^+ torsional vibration (Mohan 2005). The wave numbers observed at 1725.9 cm^{-1} due to C=O stretching showed the presence of carbonyl group.

The minor absorption bands ranged between 1680-1640 due to C=O showed the presence of primary amines. The wave numbers observed 1560-1530 cm^{-1} due to asymmetric stretch vibration of N-O at 1548.7 cm^{-1} and 1555.8 cm^{-1} respectively showed the presence of nitrogen compounds in the isolates. The bonded C-H bending in alkanes observed at 1457.6 cm^{-1} and bonded C=O symmetric stretching absorbed infra-red at 1416.1 cm^{-1} and 1419.3 cm^{-1}. The spectra observed at 1368.6 cm^{-1} showed stretching of C-H and presence of alkanes.

The absorbance bands ranged 1350-1300 cm^{-1} showed components of á- helix protein. The absorbance bands ranged between 1250- 1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters. The range of wave number 1080-1010 cm^{-1} showed asymmetric stretching and C-O bonding due to polysaccharides. The wave number 897.9 cm^{-1} showed O-CH_2 stretching of methoxy groups (Movasaghi et al. 2008). C-H stretching vibration (Jilie and Shaoning 2007) represents 800-640 cm^{-1} absorbance band.

The bands range 770-620 cm^{-1} represents N-H bending with the presence of amine- V. The peaks range between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides. The peaks observed at 469.2 cm^{-1} and 467.0 cm^{-1} showed the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated).

3.2.2 FTIR spectra measurement of *B. incongruens*

For lichen *B. incongruens* (Table-2; Fig-6b), the strong absorbance bands ranged between 3500- 3300 cm^{-1} and observed at 3431.6 cm^{-1} (east), 3410.2 cm^{-1} (south), 3378.4 cm^{-1} (west), 3386.5 cm^{-1} (north) showed the stretching of bonded N-H/ O-H and the presence of alcohol and phenol groups. The spectral band observed between 3000- 2800 cm^{-1} due to asymmetrical vibration of C-H showed the presence of protein and phospholipids (Ramrakhiani et al. 2011). The absorbance bands observed at 2033.9 cm^{-1} due to NH_3^+ torsional vibration (Mohan 2005). The wave numbers observed at 1728.9 cm^{-1} due to C=O stretching showed the presence of carbonyl group.

The minor absorption bands observed at 1654.1 cm^{-1} due to C=O stretching with the presence of primary amines. The wave numbers observed at 1650-1580 cm^{-1} range due to bending of N-H with the presence of primary amines. The range of wave numbers1560-1530 cm^{-1} showed the presence of C-N stretching, N- H bending with the presence of secondary amines. The bonded C=O symmetric stretching (Naumann 2000) absorbed infra-red at 1408.4 cm^{-1} and 1407.6 cm^{-1}. The spectra observed at 1368.5 $cm^{-1,}$ and 1367.3 cm^{-1} showed stretching of C-H rocks as well as the presence of alkanes.

The absorbance bands observed at 1293.5 cm^{-1} showed components of á- helix. The absorbance bands ranged between 1250- 1220 cm^{-1} were attributed to P=O asymmetric stretching and phosphodiesters (Naumann 2000). The range of wave number 1080-1010 cm^{-1} showed SO_3 asymmetric stretching (Cirik et al. 2012); and C-O bonding due to polysaccharides. The range of wave number 900-600 cm^{-1} showed O-CH_2 stretching of methoxy groups (Movasaghi et al. 2008) and wave number 770-620 cm^{-1} showed the presence of amines-V with out of plane NH bending (Jilie and Shaoning 2007). The peaks range between 690-515 cm^{-1} resulted in absorption due the vibration modes of C- Br stretching coupled to alkyl halides.

The peaks observed at 469.2 cm^{-1} and 467.0 cm^{-1} showed the presence of vibrational frequencies of Al-O stretching (AlO_8 Octahedral; isolated). The observation are useful to detect rapidly and characterized the occurrence of lichen *B. incongruens* with different level of metal accumulation around thermal power plant.

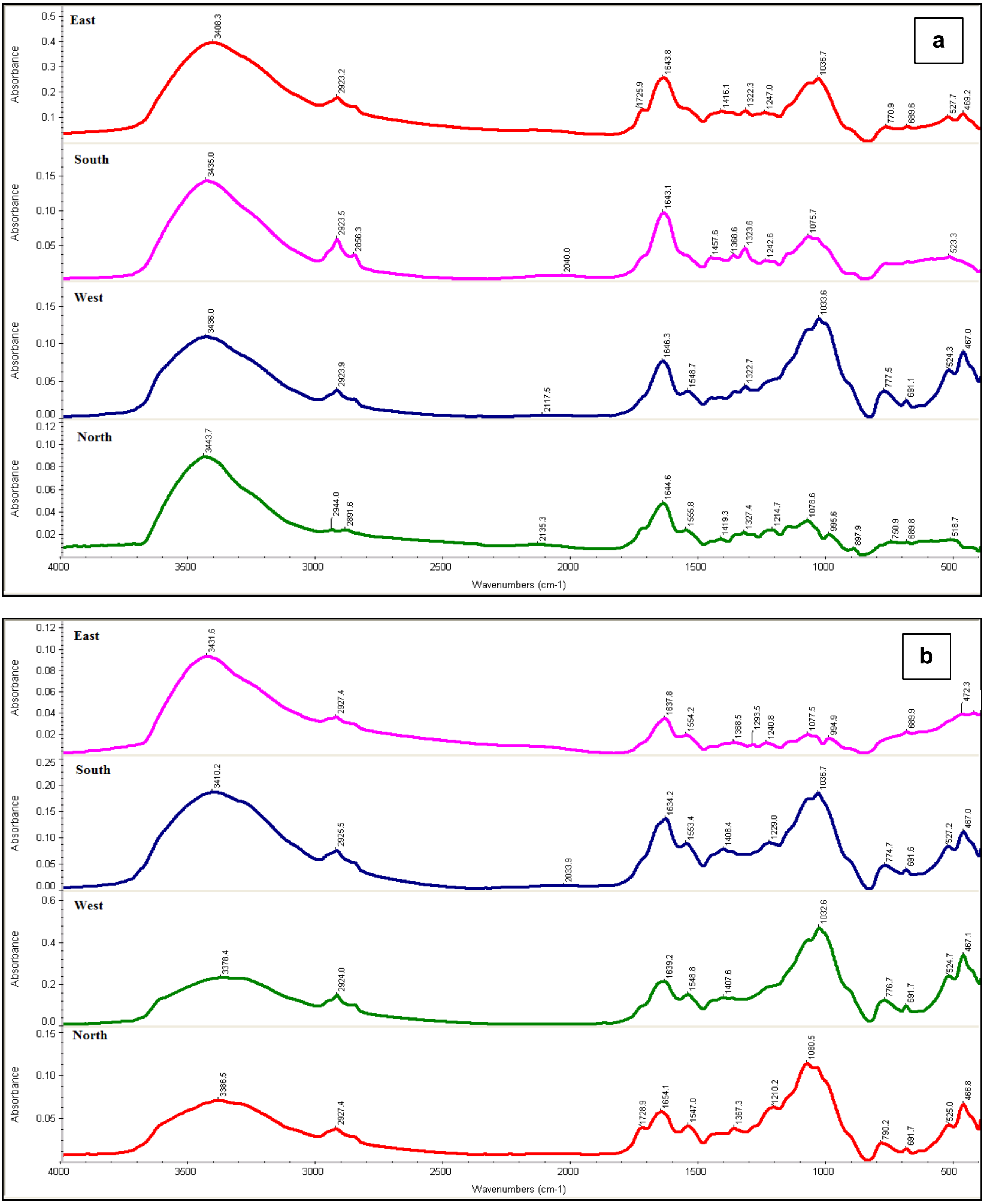


Fig. 6.Direction-wise FTIR spectra of lichen species found around Tanda thermal power plant; (a) *P. cocoes*, (b) *B. incongruens*

Table 2. Absorption frequencies of FTIR spectra of lichens around Tanda thermal power plant

S. No.	Range of wave number (cm^{-1})	*P. cocoes* Band Position (in cm^{-1})				*B. incongruens* Band Position (in cm^{-1})				Band Assignment
		East	South	West	North	East	South	West	North	
1	3500-3300	3408.3	3435.0	3436.0	3443.7	3431.6	3410.2	3378.4	3386.5	N-H stretching Amide- A, O-H stretching of hydroxyl groups (primary, secondary, amines and amides) (Ramrakhiani et al., 2011)
2	3000-2800					2927.4	2925.5	2924.0	2927.4	Asymmetric vibration C-H of CH_2, protein and phospholipids (Ramrakhiani et al., 2011)
3	3300-2500	2923.2	2923.5	2923.9	2944.0					O-H stretching (carboxylic acid)
		-	2856.3	-	2891.6					
4	2200-2000	-	2040.0	2117.5	2135.3	-	2033.9	-	-	NH_3^+ torsional vibration (Mohan, 2005)
5	1760-1665	1725.9	-	-	-	-	-	-	1728.9	C=O stretching (Carbonyls group)
6	1680-1640	1643.8	1643.1	1646.3	1644.6	-	-	-	1654.1	Amide- I, C=O stretching (Jilie and Shaoning, 2007)
7	1650-1580					1637.8	1634.2	1639.2	-	N-H bending (primary amines)
8	1560-1530	-	-	1548.7	1555.8	1554.2	1553.4	1548.8	1547.0	Amide- II, CN stretching, NH bending (Jilie and Shaoning, 2007)
9	1470-1450	-	1457.6	-	-					C-H bending (alkanes)
10	1450-1400	1416.1	-	-	1419.3	-	1408.4	1407.6	-	C=O symmetric stretching $–COO^-$ (Naumann, 2000)
11	1370-1350	-	1368.6	-	-	1368.5	-	-	1367.3	C-H rock (alkanes)
12	1350-1300	1322.3	1323.6	1322.7	1327.4	1293.5	-	-	-	components of α- helix proteins
13	1250-1220	1247.0	1242.6	-	1214.7	1240.8	1229.0	-	1210.2	P=O stretching (asym.) of PO_2^- phosphodiesters (Naumann, 2000)
14	1080-1010	1036.7	1075.7	1033.6	1078.6	1077.5	1036.7	1032.6	1080.5	SO_3 asymmtric (Cirik et al., 2012); C-O bonding due to polysaccharides
		-	-	-	995.6	994.9	-	-	-	
15	900-600	-	-	-	897.9	-	774.7	776.7	790.2	O-CH_3 stretching of methoxy groups (Movasaghi et al., 2008)
16	800-640	770.9	-	777.5	750.9					C-H out of plane bending vibrations (Jilie and Shaoning, 2007)
17	770-620	689.6	-	691.1	689.8	689.9	691.6	691.7	691.7	Amide- V, Out of plane NH bending (Jilie and Shaoning, 2007)
18	690-515	527.7	523.3	524.3	518.7	-	527.2	524.7	525.0	C-Br stretching (alkyl halides)
19	530-400	469.2	-	467.0	-	472.3	467.0	467.1	466.8	Al-O stretching (AlO_8 Octahedral, isolated)

Presence of both secondary metabolites and primary metabolites in *P. cocoes* enhances the probability of detection of IR bands in 3500-2800 cm^{-1} region due to the presence of more COOH and OH groups. While *B. incongruens* which lacks the secondary metabolites the number of band detected are less than *P. cocoes*. The FTIR analysis provides spectroscopic evidence of the role of chemicals in metal absorption as the variation in the frequency is affected by bond dissociation and bond formation which plays important role in metal chelation. The variation in the functional group bands in IR region shows the effect of pollutant on the functional group chemistry of the species (Table-2). This phenomenon is principally involved in metal absorption by formation of chelates or bond dissociation due to the presence of phytotoxic gases mainly SO_2.

3.3 Metals accumulation in lichens thalli around Tanda thermal power plant (Table-3)

The accumulation of seven metals viz; Aluminum (Al), Iron (Fe), Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Zinc (Zn) were estimated in thalli of *P. cocoes* and *B. incongruens* in all directions from the thermal power plant i.e. point source.

P. cocoes (Table-3) showed higher total metal (180.43 µgg^{-1}) concentration in south and lowest in north (116.17µgg^{-1}) direction of the study area. Among seven metals Zn was accumulated in maximum concentration followed by the decreased accumulation sequence of Al > Cu > Fe > Pb > Cr > Cd. Highest Zn accumulation of le102.5±0.36 µgg^{-1} was recorded in east and minimum 59.71±0.14 µgg^{-1} in north that indicates settling of this metal in the south direction.

P. cocoes accumulated Al in the range between 2.47±0.20 µgg^{-1} in east to 25.47±0.03 µgg^{-1} in south direction while Cu had maximum accumulation (25.16±1.24 µgg^{-1}) in south and minimum in east direction (7.45±0.08 µgg^{-1}). The distance near the thermal power exhibit higher concentration of Cu than the distant locality as Cu being a larger particle metal unable to disperse in long ranges. Accumulation of Fe ranged from 10.25±0.42 µgg^{-1} in east to 17.56±0.13 µgg^{-1} in south direction. Lichens have an affinity with Al and Fe metals and collected both metals in higher concentration.

The site in north and south exhibited Pb accumulation ranged from 8.14±0.16 µgg^{-1} in north direction to 16.77±0.12 µgg^{-1} in a south direction respectively and shows close similarity. The maximum level of Cr was recorded in South (19.59±0.52 µgg^{-1}) and minimum in east direction (0.56±0.03µgg^{-1}). Cd was recorded in the lowest concentration in the range of 0.98±0.09 µgg^{-1} in west to 2.85±0.07 µgg^{-1} in south direction. Dispersion and distribution of metals depend on wind speed and direction as well as the density of the element under consideration (Garty 2001).

In the present study, the directional accumulation of most of the metals may be due to directional deposition of pollutants from the source of pollution and exhibited a sequence of accumulation as south > west > east > north i.e. decreasing concentration with increasing distance from the centre of the study area. The south direction of the study area exhibited higher concentration of Zn and Al metals. The probable reason for higher concentration of metals Zn and Al around thermal power plant may be due to anthropogenic activities as well as natural origin. *P. cocoes* showed more or less similar selectivity sequence of metals as Zn> Al> Cu> Fe> Pb> Cr> Cd in all the four directions, while *B. incongruens* exhibited a different sequence (Table-3).

Out of the four directions, samples from east have a minimum concentration of Al, Cr, Cu and Zn while south direction has the maximum concentration of most of the metals. The total metal concentration in *B. incongruens* was recorded higher in north (488.39 µgg^{-1}) and lower in south direction (336.27 µgg^{-1}).

Thalli of *B. incongruens* accumulated lower concentration of Cd (0.44±0.02 µgg^{-1}) and higher accumulation of metal Fe (293.46±0.42 µgg^{-1}) in east direction followed by west, north and south direction. *B. incongruens* also exhibit the metal selectivity sequence similar to *P. cocoes* except higher concentration of Fe than Zn (Table-3).

Accumulation of Zn and Fe in the thalli of *P. cocoes* and *B. incongruens* respectively showed significant difference in LSD analysis at $p < 0.01$ in all directions from the thermal power plant (Table- 3). According to Loppi et al. (1998) and Bajpai et al. (2010a), Al and Fe are the two important metals in the earth's crust are strongly correlated in lichens and environmental contamination besides that Al also has limited metabolic significance and contamination by wind-borne soil, rock dust. Both *P. cocoes* and *B. incongruens* showed higher accumulation of Al and Fe and lower accumulation of Pb, Cr and Cd in all directions (Table-3). Cr and Fe are normally coupled with fly ash, which tends to fall out close to the source (Fernandez et al., 1992). Thalli of *P. cocoes* around Tanda thermal power plant accumulated more concentration in comparison of *B. incongruens*. Higher concentration of Pb and Zn around the thermal power plant may be due to the high vehicular activity involved in the

Table 3. Metal accumulation in lichen thalli in all directions around Tanda thermal power plant

Directions	*P. cocoes* (concentration in µgg[-1] dry weight)							Total metal
	Al	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**	
East	2.47±0.20	10.25±0.42	0.98±0.13	0.56±0.03	7.45±0.08	BDL	102.5±0.36	124.21
West	21.26±0.24	12.44±0.26	0.98±0.09	0.96±0.05	9.46±0.47	BDL	85.06±0.11	130.16
North	19.33±0.08	11.28±0.24	1.06±0.07	1.02±0.09	15.63±0.09	8.14±0.16	59.71±0.14	116.17
South	25.47±0.03	17.56±0.13	2.85±0.07	19.59±0.52	25.16±1.24	16.77±0.12	73.03±1.75	180.43
Total metal	68.53	51.53	5.87	22.13	57.70	24.91	320.3	
CV%	0.944	2.188	6.189	4.795	4.599	1.589	1.120	
LSD(p< 0.05)	0.323**	0.563**	0.182**	0.530**	1.325**	0.198**	1.791**	
Directions	***B. incongruens*** **(concentration in µgg[-1] dry weight)**							**Total metal**
	Al	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**	
East	16.56±0.49	215.34±2.70	0.44±0.02	0.87±0.09	16.5±0.09	10.61±0.34	94.94±0.08	355.26
West	14.17±0.30	229.20±0.81	0.42±0.03	1.07±0.12	28.05±0.09	12.74±0.24	147.73±0.03	433.38
North	15.7±0.43	293.46±0.42	0.39±0.01	0.97±0.08	30.86±0.34	9.44±0.10	137.57±0.28	488.39
South	12.59±0.23	137.96±0.12	2.05±0.06	12.76±0.43	41.83±0.13	10.58±0.08	118.5±0.35	336.27
Total metal	59.02	875.96	3.3	15.67	117.24	43.37	498.74	
CV%	2.567	0.650	3.974	5.867	1.876	2.021	0.181	
LSD(p< 0.05)	0.757**	2.842**	0.065**	0.459**	0.388**	0.438**	0.450**	

Mean±S.D., n=3 in µgg[-1] dry weight

** Significance at the level of 0.01.

Table 4. Correlation coefficient of lichens between metal accumulations in all directions around Tanda thermal power plant

P. cocoes	**Al**	**Fe**	**Cd**	**Cr**	**Cu**	**Pb**	**Zn**
Al	1	0.735	0.564	0.568	0.721	0.65	-0.747
Fe		1	.960*	.966*	0.889	0.839	-0.348
Cd			1	.999**	0.916	0.897	-0.294
Cr				1	0.906	0.884	-0.277
Cu					1	.993**	-0.648
Pb						1	-0.65
Zn							1
B. incongruens	Al	Fe	Cd	Cr	Cu	Pb	Zn
Al	1	0.696	-0.821	-0.833	-0.879	-0.316	-0.341
Fe		1	-0.859	-0.845	-0.434	-0.239	0.405
Cd			1	.999**	0.788	-0.116	-0.194
Cr				1	0.808	-0.118	-0.165
Cu					1	-0.113	0.406
Pb						1	0.356
Zn							1

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

disposal of coal waste. Pb released from engine exhaust whereas other elements and Zn may be emitted by automobile tires and brake pads (Berry and Wallace, 1981; Ward, 1989) and Cr enter the surrounding environment due to metallic parts of the vehicles.

The correlation coefficient were calculated (Table-4) for concentration in paired element and for the element content in the lichen in different directions. The correlations (all significant at $p<0.01$ level) of Cd and Cr in both the species, Cu and Pb only in *P. cocoes*. Zinc (in *P. cocoes*) and Pb (in *B. incongruens*) had negative correlations with other elements (Table-4).

CONCLUSION

The present study illustrates the emission of coal-based thermal power plant on metal accumulation pattern of two commonly occurring lichen species i.e. *P. cocoes* and *B. incongruens* around the study area. The study indicates that the concentration of metal increases with decreasing distance from thermal power plant and provide direct evidence about the air quality status of the area. Both the lichen species growing in all the four directions showed more or less similar concentration of metal accumulation. FTIR spectra showed structural peculiarities of metabolites in the lichens as well as variation in the functional groups O-H, C-H, C=O and C-O indicating the role of metabolites in sequestration of metals (absorption phenomenon), while SEM analysis showed adsorption of particulate bonded matter on the surface of lichen thallus which is responsible for bioaccumulation of most of the metals mainly Fe and Al detected in high concentration in both the species. Based on the observation it is clear that surface adsorption is the key phenomenon of bioaccumulation of metals in both the lichen species studied.

The level of concentration of different metal present in the lichens helped in assessment of risk to the population living in the vicinity of the power plant together with long-term hazard due to metal accumulation. The study provided an understanding about the mechanisms adopted by different growth form of lichens for bioaccumulation of metals emitted by thermal power plant and indicates that the particulate bound adsorption is the major factor responsible for bioaccumulation in lichens irrespective of their growth form. The study also provide baseline data on levels of metal accumulation around the thermal power plant which will be helpful for carrying out future biomonitoring studies in the area.

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