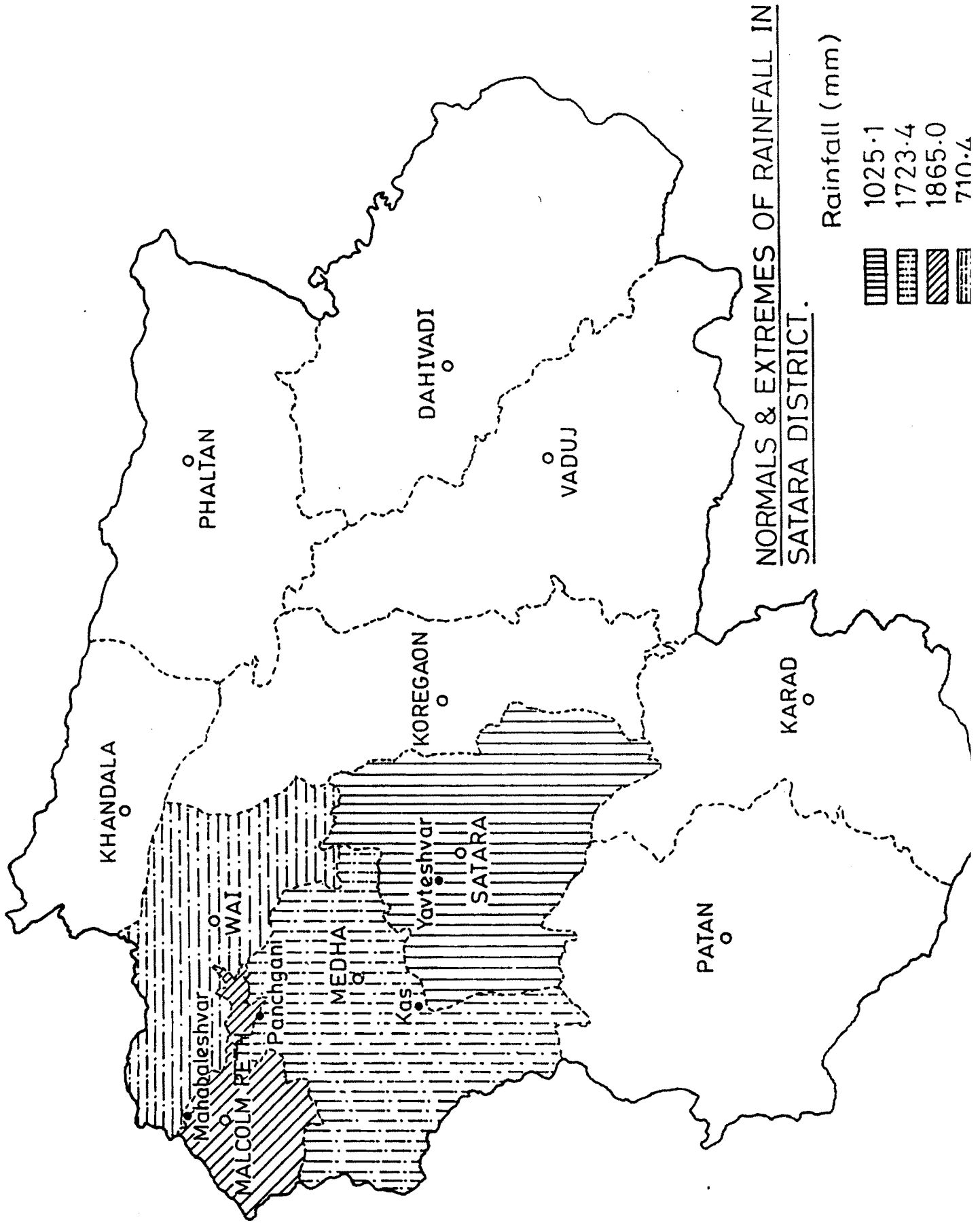


# *Review of Literature*

Satara district at the Western limit of the Deccan table land lies between 16°50' and 18°10' N and 73°45' and 15° E. It has an area of 4022.6 Sq.miles with eleven talukas and 1152 villages (Maharashtra State gazetteers, Satara district, 1963). The political situation of the district is about 110 Km South West of Poona and 125 Km North-East of Kolhapur situated on the main National Highway No.4 running from Poona to Bangalore. Out of 11 talukas five talukas including Satara are on the Western sides of the district and rest of them are on the northern side of the district. Because of the Satara ranges on the West, the talukas such as Patan, Satara, Medha, Wai and Mahabaleshwar have cool, humid weather and relatively denser vegetation. Amongst the talukas as we move north-west of Satara, the altitude also increases and the rainfall also increases (Fig.1). The highest rainfall and the dense forest with a very high altitudinal peak of about 4500 feet from MSL of Mahabaleshwar, a famous hill station, is ideal for the growth of lichens. Nevertheless, Mahabaleshwar is not free from environmental pollution mainly caused by frequently visiting population with their automobile vehicles. The ideal place for the dominant lichen flora is mainly represented by Parmelina wallichiana Tayl. (formerly Parmelia wallichiana Tayl., Leptogium cyanescens (Ach.) Karb. and Usnea ghattensis G. Awanthi, are chosen for the investigation. These lichens are

Ref. missing  
11 sp.

8 sp. "



Rainfall (mm)

- 1025.1
- 1723.4
- 1865.0
- 710.4



a. 'Kas lake' ( Sahyadri Forest )



b. Hills around Kas lake



a.

Natural view of Kas lake



b.

Kas lake



a.

Hill top flora of Bamnoli



b.

Back water of Shivsagar in Bamnoli

are mainly arboreal (corticolous) lichens and hence they are intimately associated, for their part of nutritional requirement, with the bark of the tree and hence their nutritional status is likely to be influenced by the nutritional status of the plants.

Amongst the three localities chosen, mainly Yavteshwar~~s~~, Kas and Mahabaleshwar, Kas has the vargin forest which is away from the human activities. It's geographical situation is 17°-40' N and 73°-56' E on the border of Jawali taluka, Satara taluka; and on the northwest Yavteshwar~~s~~. It has an altitude of 1310 m MSL. The land mass is made up of lateritic soil enriched with organic debris of the falling litters of forest plants and a pH of 6-6.5, ideal for the growth of forest species. So far as the nature of the soil is concerned, it is similar to that of Mahabaleshwar.



1. Parmelina wallichiana (Tayl.) (formerly Parmelia wallichiana Tayl.)

Thallus mineral grey to dull grey, closely adnate to the substratum, carticolous, 4-5 cm broad, thallus further divided into sublinear to subround lobes; 1-3 mm broad, isidiate; isidia cylindrical, simple, upper surface smooth, may be cracked in older thallus, lobes ciliate, cilia very small and inconspicuous, lower surface black, to the margin, rhizinate; rhizines simple, rarely squarrosely branched, upper cortex 6.6 to 9.9  $\mu\text{m}$  thick; algal layer continuous, medulla colourless, 80.5-90.0  $\mu\text{m}$  thick, lower cortex faint brown, 19.8-29.7  $\mu\text{m}$  thick.

Reactions : Thallus; K+ve yellow,  
 Medulla; K+ve yellow to red,  
 C-ve, KC+ve orange red,  
 P+ve yellow.

Chemical constituents : Atranorine, Salicinic acid.

Remarks : Parmelina wallichiana is characterised by cylindrical isidia, small cilia and presence of salicinic acid, it may be confused externally with P. awasthi, Hale and Patwardhan, which is a non-ciliate species and with P. simplicior Hale, which is a non-isidiate species.





a

Parmelina wallichiana



b

Parmelina wallichiana



Parmelia simplicior



Anaptychia diademata  
Parmelina wallichiana

2. Leptogium cyanescens (Ach.) Korb.

Thallus corticolous, saxicolous, terricolous or musci-  
colous, loosely to closely attached to substratum, 1 to 6 cm  
in length, foliose, usually lead grey when dry, olivaceous,  
such green, glossy and swollen when <sup>it</sup> set; lobes orbicular  
2-13 mm wide in peripheral region somewhat broader in central  
part, margin entire to isidiate and rarely lobulate upper  
surface smooth, sparsely to densely isidiate, isidia cylin-  
drical, upto 1 mm long, rarely squamuliform and 2 mm wide, lower  
surface smooth. Thallus 55-130  $\mu$ m thick, rarely fertile,  
apothecia uncommon, laminal, sessile upto 1.5 mm in diameter,  
disc concave, reddish brown smooth, thalline exciple entire,  
isidiate, 6-9 cell layer cortex at base and 2-3 cell layer at  
margin, proper exciple euparaplectenchymatous at the margin,  
indistinct at the centre, spores ellipsoidal, muriform, trans-  
versely 2-4(5) septate, longitudinally one septate, 9-20 x 5-9  $\mu$ m.

Leptogium cyanescens is distinguished by a thin lead  
grey thallus with a cylindrical isidia. It is widely distri-  
buted in tropical to temperate regions of the world.

Usnea ghattensis G. Awasthi.

Thallus corticolous, erect, upto 6 cm tall light brown  
to dark brown trees intermitantly black, basal disc black,  
branching sympodial, branches compact, stiff, terrate, upto  
3 mm in diameter, tapering, lateral branchlets stiff, very dense,

simple or branched, upto 1 cm long, flexuose apices, blackish; surface sparsely papillate towards basal region papillae concolourous to thallus, pseudocyphellae, soredia and isidia absent, cortex palisade like, 100-150  $\mu\text{m}$  thick algal layer discontinuous, 30-60  $\mu\text{m}$  thick patches, medulla dense wear algal stratum, lax inwards, 240-560  $\mu\text{m}$  thick; axis solid, about 520  $\mu\text{m}$  in diameter, colourless with scattered blackish deposition. Apothesia terminal, geniculate, upto 8 mm in diameter, disc concave to plain, brownish, epruinose margin, ciliate, cilia simple, thick upto 3  $\mu\text{m}$  long; receptacle scrobiculate, shortly ciliate, epothecium brown; hymenium colourless, 80-90  $\mu\text{m}$  high, initially blue later turns black; hypothecium yellowish 40-50  $\mu\text{m}$  thick, asci 8 spored; spores simple, colourless (12) 16-18 x 18-10  $\mu\text{m}$ .

Chemistry - Usnic acid only.

The taxon is distinguished by the stiff dense thallus, dense lateral branchlets and brown epruinose apothecia. The taxon is restricted to western ghats of India. U.ghattensis is somewhat close to U.complanata but differs in its very stiff thallus with dense lateral branches and papillae.



Leptogium cynescens



Usnea ghattensis with Apothechia



a.

Usnea ghattensis



b.

Usnea ghattensis





Usnea ghattensis

Leptogium cynescens

Anaptychia diademata

Lecidea sp.



Anaptychia diademata



Arthothelium



a.

Anaptychia diademata



b.

Anaptychia podocarpa



Graphis contoruplicata

1) Lichens whether a fungus !

Whether is lichen a fungus ? The answer to this question can be had by the statement made by the great lichenologist Mason Hale (1973) in the preface to the book "The Lichens".

I quote,

"Ironically the success of lichen has caused a major problem for those who study them - the one of identity. Logically they should be classified with the fungi, practically, however, this causes difficulty because of the wide differences between the two groups and because of the large number of lichens they are the single largest group of ascolichens. For these reasons mycologists have been reluctant to deal with lichens and lichenologists have been content to master the separation. In recent years there have been more movement towards incorporating lichens in the fungal classification. For example, the sixth edition of (dictionary) of fungi includes lichens for the first time. We are encouraged by such action .....

I unquote. From this statement of the great lichenologist Hale, it appears that most lichenologists are interested in treating this group in fungi. Although the algal phycobiont is



deeply associated with these group and play a prominent role in the completion of life cycle, due the fact sexual differentiation taken place in the mycobiont it is felt reasonable to treat this group under fungi by majority of the workers, as a separate group. The rules of International Code of Botanical Nomenclature clearly states that the names given for the lichens are to refer only to fungal components (Patwardhan, personal discussion).

missing year? Erik Acharius a Sweedish Doctor (1803) singularly credited for initiating the study of lichens and hence he is regarded as a father of lichenology. He has created several terminology of description such as Soredia, ~~Idia~~ <sup>s</sup>Ididia, Cephelodia etc. (Hale Jr. 1967). missing Later on in 1866 a German mycologist Bary, first brought out a treatise of the morphology of lichens which makes an excellent reference book even today. missing 1867 In 1867 Schwender showed that lichen is a symbiont where the fungus grows on green algae. Subsequently good many workers have worked on lichen phycobionts and showed that not only lichens have green algae but even blue green algae is associated in many genera. It is noteworthy to pointout here, amongst the green algae the two genera Trebouxia and Trentepholia sp? are mainly associated with this group of symbionts. Trebouxia alone has 40 species which have symbiotic partner of thousands of lichen forms and yet these phycobionts are able to grow freely in nature without lichenising with the mycobiont (Ahmadjian, 1973). missing

An elegant experiment conducted by Schwendener in 1868 clearly demonstrated that the synthesis of symbiont in the artificial condition brings the two partners mycobiant and phycobiant together under the culture condition, opened a vistas in the study of a synthesis of lichens. According to Ahmadjian (1973) the algae in a lichen are specifically adapted to acting as a symbiant. For removal of alga from its special and interactive environment within the lichen caused significant changes within the algal cells. The success of resynthesis lied in maintaining the isolated symbiants under conditions that stimulated their natural symbiotic environment. The fungus tend to fruit only in association with algae. The fungus alone did not fruit (Ahmadjian, 1973). This clearly shows that for the purpose of sexual reproduction the mycobiant must be associated with the phycobiant and hence lichen is more alien with fungi.

## 2) Lichen Phycobiant :

As already pointed out the main genera associated, though apparently are Trebouxia and Trentepohlia form the green algal group the Nostoc. From the blue green algae; there are 15 genera of the chlorophyta and 7 genera of cyanophyta, one genus of Xanthophyta and three genera are of uncertain positions and are known to have been associated in the process of lichenization (Jagtap, 1985). Although many lichen phycobiant such as Nostoc, Trentepohlia are known to occur as a free lining algae in nature. Trebouxia rarely occurs as a free alga in nature



possibly, because there are about twenty thousands species of fungi which are known to lichenize with Trebouxia. As soon as Trebouxia is found free and fungal species comes in contact, the process of lichenization starts and moreover, without the fungal association the alga exhibits lot of morphological and physiological changes. Ahmadjian (1973) has recorded the following changes in the Trebouxia phycobiant, when isolated from the thallus. MS/11/8

Table 1

Morphological and Physiological changes

Morphological changes	:	Physiological changes
a) Cells develop gelatinous sheath.		a) Proportion of ribilose to sucrose diminishes.
b) Cell forms a fibrillar sheath.		b) More radioactivity found in ethanol insoluble compounds.
c) Cells become larger.		c) Only a trace of $^{14}\text{C}$ is incorporated during photosynthesis in ribilose.
d) Cell wall becomes thinner.		d) Less photosynthate is released in to the medium.
e) Pyrenoglobules are fewer in number and small in size.		e) Type of compounds excreted are different.
f) Appearance of polyphosphate bodies and other storage bodies.		-
g) More starch in cells.		-
h) Pyrenoid less evident.		

Jordan and Rickson (1971), Jordon (1972) studying the development of cephalodia on lichen thalli showed that when filamentous Nostoc becomes associated with some lichen thallus, it provokes a specific response from the fungus that leads to the incorporation of alga and formation of internal cephalodia. The interesting observation that has been made is, the fungus, in association with a green phycobiant forms the Lobaria thallus, but, in association with blue green symbiont it forms a totally different thallus i.e. fruticose instead of foliose. According to them green algal cells that are pushed in to fungal hyphae cephalodia out growth stimulates forming lobules similar to the foliose thallus. This shows that the morphological expression of the natural population is profoundly influenced by the phycobiant associated with it.

missy Honegger (1986) carried out the scanning electron microscopic study and transmission electron microscopic study in an ascolichen where the phycobiant is Trebouxya. She examined 150-530 algal cell halves per species in order to calculate the predominant type of interaction and reported that, single wall to wall opposition predominated. The predominant intracellular haustoria were observed in majority of photobiant each of Lecanorales with crustose non-stratified thalli containing lichens where 3 different types of intracellular haustoria were distinguished in lichen with stratified thalli. Intraparietal haustoria of the type are consisting of a tiny infection plug

formed by a slightly adhering hypha within the largely cellulose phycobiant cell wall. These are predominant in crustose species with a stratified thallus. But this haustoria type represents also developmental stage in intraparietal haustoria of type two or three. The intraparietal haustoria of type two were seen in majority of photobiant cells which according to her can be recorded as a protrusion formed by a tightly adhering hypha. The tiny infection plug is sheathed by the algal cell wall. Intraparietal haustoria of type 3 was predominant in foliose lichen Parmelia. In brief the study has tried to unveil the mycobiant association with the true phycobiant or in other words photobiant where the mycobiant tries to extract the nutrient and the food through haustoria from the algal autotrophs associated with them. Laliamart et al. (1986) studied symbiotic relations in lichen with a new angle. Predominantly, they emphasise the architecture of the thallus, the composition of the wall, the way it is built. They showed that there is a lysosomal system clearly visible and along with many more other concentric body and organelles. According to them the presence of glucidic reserves in the cyanobiants is playing an important role in the symbiosis. The hydric relationship between symbiants and their influence on the photosynthesis are specific. The photobiants are resistant to desiccation. The interesting noteworthy aspect of their study in the glucosidic metabolism of photobiants is modified in the lichised cyanobacteria or algae compared to

that of free living ones. They further showed that when Nostoc is cultured it shows morphological cycles while 'inside the thallus they are stopped at one particular stage.

These studies showed that not only the mycobiant, but even the phycobiant shows, if not greater morphological alteration, but certainly the physiological alterations.

The above observation is in support of the report made by James and Henssen (1976) who noted that the lichen fungus could form two different independent thalli, the form or morphology depending on whether the fungus associates with green or blue green algal symbionts. According to them the algal partner plays a determining role in the "phenotypic expression of the genotype of the fungal partner. This interaction initiated stimulated and directed by the presence of algal partner effectively determines the fungal morphology, anatomy, physiology, sexuality and probably many aspects of chemistry of each mycobiant, thus determining the shape and biology of each lichen species so formed" they observed. This above observation of James and Jenssen (1976) is firm and concrete. sp?

On the other hand Ahmadjian et al. (1980) studied the effect of artificial reestablishment of lichens on morphological interactions between the phycobiants of different lichens. They observed that the different algal symbionts that were

combined with the Cladonia crystatella fungus did not influence the general morphology of the resulting lichens. According to them although the morphogenetic stimulus for the fungus is still derived by the algal symbionts, the manner by which the fungus differentiates appears to reside within its own genus. They further remarked that the lichen fungus was specific to its phycobionts at the generic level but not at the species level of the algae involved in their study. The Cladonia crystatella mycobiont formed lichenised associations with twelve isolates of Trebouxia phycobiont other than its own, but it would not associate with any of the ten isolates of Pseudotrebouxia that they used in their study.

Ahmadjian and Jacob (1981) tried to examine the relationship between fungus and algae in the lichen Cladonia crystatella. Their observation of artificial synthesis of the mycobiont Cladonia crystatella with different algae suggested that the relationship in this lichen is one of the controlled parasitism. The mycobiont formed squamules mostly with algae related to its natural phycobionts. Based on this, they concluded that it is an indication perhaps of long period of co-evolution between the symbionts of these lichens because algae that were incompatible with the fungus were parasitized and destroyed. In the natural lichen, although more than 50% of the Phycobiont cells were penetrated by haustoria, the algal population seemed healthy.

Lichen Mycobiant :

The term "lichenised fungi" is used as synonymous of 'lichens' not only because this is in accordance with the increase in taxonomic practice but also to reflect the fact that, the greater part of the lichen thalli is composed of fungal hyphae, with the algae restricted to a thin layer near the surface, (Smith, 1975). The estimate of algal component made on Peltigera showed that the algae was reported to occupy 3 to 10% by weight of the thallus (Drew and Smith, 1966; Kershaw and Millbank, 1970; Millbank, 1972). This shows that the phycobiant is only the sustaining part of the heterotrophic mycobiant for the lichenised fungi are large groups. According to Ainsworth (1971), the total number of species in various fungal group noted by him goes to 71,700 of which 18,000 i.e. 25% are lichenised. Lichenised fungi belongs to a variety of taxonomic groups out of which the ascomycetes fungi are about 26,000 followed by basidiomycetes fungi. In other words, ascolichens are in larger number. New lichen thallus can only develop in favourable environment. If the biotype is unsuitable for the lichen, the development stops at an early stage. Even under the favourable conditions a lichen thallus can only evolve if both partners of symbiosis are present at the same time. Therefore, these methods of reproduction which disperse both partners in close union are the most valuable to the lichen. The mycobiant is responsible to the growth of the thallus. At the margin of

the thallus the growth of the fungal hyphae may be so vigorous that an undifferentiated zone free of algae is formed around the lichen (Johns, 1973). The hyphae emerging from germinating spores can be of different shapes. The fungus is the active partner in the development of the primary stages of thallus, although the hyphae do not grow towards the algae. Those hyphae which make contact with algae become hook shaped and clasp the algal cells. According to Scott (1971), probably only a very few germinating spores succeed in forming a new lichen. If lichenisation is achieved the young mycetium and acquired algae at first formed an undifferentiated lump. The same undifferentiated mass of algae and hyphae can be observed, if the development, starts from a vegetative (disperse.) The first hyphae growing from vegetative propogule function as hapters attaching the dispore to the substrate. The subsequent differentiation of thallus layers is as slow a process as in thalli developed from germinating ascospore. For example in Xanthoria parietiana, it takes two months before cortex, algal layer and medulla are differentiated. The habit of the lichen is mainly determined by the mycobiant and not by the phycobiant.

As we have, symbiotic lichens, it is felt strange that we will find species containing algae which regularly parasitize other lichens or sometimes masses. There are actually numerous species which live as parasites in various degrees. Most, such species are by definition excluded from lichens proper and their

names are not included in Zahlbruckners catalogues. However, in the recent year more attention is being paid to such group and more parasitic species have been described. Many are facultatively parasitic species such as the group in Rhizocarpon seographicum yet one also finds widely dominant group of obligate parasites which because of their dependance as parasitism often reduced in size and thallus structure. These organisms have been referred to as parasymbiants (Poelt, 1973).

Taxonomic classification of Lichens :

So far classification of lichens is concerned, it is considered with fungi. Growth form was used as basic criterion in the earlier systems i.e. the most early recognisable microscopic characteristic beginning with Micheli (1729) to Linnaeus (1753) and Acharius (1798). It remained as a character even with the advancement in microscopy (Poelt, 1973). Later modified and was finally employed as late as in the early, 1900's as a primary classification character (Harmand, 1905). Growth form was used because quite different growth form could occur together with natural groups and conversely similar growth forms can develop in quite different groups. Zahlbuckner (1907, 1926) used growth form to differentiate families within a homogenous development series, but the principle was not always followed. Fries proposed a system based on the most part of the type of alga, but it remained incomplete. Vainio in 1890 and Reinke 1894-1896 (Cf. Poelt, 1973) laid the foundation for a system



later used and popularised by Zahlbruckner. Watson (1929) suggested a more rational system for number of groups based on spore types. In the mean time Nannfeldt (1932) proposed a fungal system where two divisions were made, Ascoloculares and Ascohymeniales. These grouping have retained a considerable degree of validity upto the present time (Poelt, 1973).

Even with the superficial analysis of any of the earlier systems one cannot really speak of true integration of lichenised fungi. According to Poelt (1973) lichen systematists have not been really familiar with a corresponding fungal groups and mycologists had enough difficulties with their own groups without bringing in the lichenised fungi. He has given following taxonomic categories for lichenology. ~~Forma~~, variety, subspecies, species, genus, and according to him ~~forma~~, variety and subspecies should be dropped and genus and species be retained.

While considering the genus, he emphasized, that the rank of genus has long been used for large schematically delimited generic group though cryptogamic botanists used genus for the smaller species group that are not always well delimited. Therefore, he felt, it is essential to examine the genus concept in nonlichenised fungi and to standardise it in lichens for smaller more natural groups. According to him, species rank in lichens should be considered for a distinct populations, that are different from the others in morphological traits

combined with geographical difference and chemical characters.

The chemical substances of lichens is of varied form and widely used in lichen taxonomy. Chemistry is introduced by <sup>my 11/19</sup> Nylander as early as in 1867 (Cf. Poelt, 1973) for a colour spot test that have a real diagnostic value. Since then enormous means of chemical data have been accumulated. Recent lichenologist often specify the lichen substances in a species as a matter of course as one would cite spore characters etc. Many papers have been written in the last forty years or so on systematic value and meaning of lichen substances, both at the species level and in terms of generic and familiar relationships. Hawksworth (1976) from commonwealth mycological Institute, Kew has exhaustively discussed lichens chemotaxonomy during the International Symposium held at the University of Bristol.

Lichenologists have been using Iodine test for systemic classification from the time it has been introduced by Nylander (loc cit). However, little is known about the chemical and physiological basis for it. The iodine list is very dependent <sup>test</sup> on the concentration of the solution, temperature, and other conditions.

Iodine reactions have been given for the medulla of lichens but only rarely for the cortex. For example, in groups such as Lecidea Sec. Silaceae, the medullary reaction usually

indicated as 'I<sup>+</sup>' has been found to be remarkably constant and useful characters for definition of species and even species groups. Iodine reactions have also been reported for fruiting bodies and used systematically for the cortex of crustose lichens. Nylander (1866, Cf. Hawksworth, 1976) discovered that bleaching powder (C) also served as a useful taxonomic tool. For example, while supporting the recognition of Parmelina (Parmelia) perlata and P.olivetorum as distinct species, this test has been employed. Shortly afterwards, he also found that KOH was equally valuable in distinguishing some species.

In India lot of work has been done on lichens. The first description of lichens of Himalayas was brought out by Chopra (1934) and later the first catalogue of lichens of India, Nepal, Pakistan and Ceylon was published by Awasthi (1965). Subsequently there is systematic collection and identification of lichens in India which has been enriched by Awasthi and Singh (1973, 1973 A, 1975); Patwardhan and Kulkarni (1976, 1977, 1979); Patwardhan and Nagarkar (1979), Awasthi and Tewari in 1987. Today from North to South and East to West few if any lichens are left unknown.

Patwardhan has described following foliose, lichens, from the Western ghats. Erioderma, Punnaria, Collema, Physma, Leptogium, Umbilicaria, Dermatocarpon, Endocarpon, Peltigera, Lobaria, Sticta, Coccocopia, Pseudocyphellaria, Anaptychia,

Physcia, Dirinaria, Pyxina, Parmelina (Parmelia), Meneguzzia, Hypogynnia; from fruticose lichens : Cladonia, Stereocaulon, Teloschists, Romalina, Roccella, Usnea; form the crustose lichens : Lecanora, Caloplaca, Haematomna, Phlyctella, Phlyctis, Diploschistis, Ocellularia, Thelotrema, Phaeotrema, Leptotrema, Gryphis, Meducilina, Sarcographa, Sarcographina, Melaspilea, Graphis, Graphina, Phaeographis, Phaeographina, Lacidea, Catillaria, Megalospora, Bacidia, Bombyliospora, Lopodium, Buellia.

Morphology of Lichens :

a) Colour of the thallus : Most lichens are grey or brown when dry. Only under humid conditions or when the thallus is wetted, the colour of algae can be seen more distinctly, through the cortex and such lichens become more or less green. Many species are brightly coloured by incrustation of special lichen pigments in the colour. For example some look orange or yellow because of the substance called 'parietin' found in it. Green and yellow pigments are common in lichens. While red, blue, blue violet colours are rare.

b) The Cells : The spores of the lichenised and unlichenised fungi germinate and produce hyphae which are divided into cells by means of cross wall called Septa. These cells are characterised by their basic cylindrical form and thin wall. Cells of different hyphae may become secondarily connected when adjacent

hyphae touch one another and their cell walls develop inter-connecting pores. Cells which are connected by pores are chiefly confined to lichens with highly differentiated thalli. The fungal cell retained in cylindrical form in loosely organised tissues. In most lichen tissues, the cells show less regular form than in the ultimate cells of paraphysis.

c) Tissues : The structure and development of tissues depend on the form of the cells and or particular type of contact between them. This is achieved either by the mutual adherence of the cell walls or by gelatinisation of the cell wall. In the tissues the hyphae are either parallel resulting in a fastigate arrangement or they are irregularly bent to produce a tissue of interwoven threads. In lichens the most characteristic tissue arrangement is a net like structure composed of branched anastomosing hyphae. The cells of this tissue usually have angular or irregular lumina. This net like tissue is really found in unlichenised ascomycetes.

The development of true parenchymatous tissue in lichens is rare. Such tissue is formed by cells dividing in 3 planes. This kind of cell division which is characteristic for higher plants is found in stroma of some ascolocular fungi. Barring a few, lichen tissues are plectenchymatous in origin. The cells divide in only one plane forming cellular hyphal threads. In plectenchyma the hyphae are loosely interwoven, interconnected

by anastomolus or firmly glued together, therefore, it resembles the parenchyma of higher plants. The tissue is called pseudoparenchymatous or paraplectenchymatous.

The habit of some primitive lichens where mycobiant and the phycobiant are not yet definitely established resembles the thallus of free living fungi. In some species, the primitive, lichen thalli consist of a loose fungal mycelium enclosing scattered groups of algae which spread over the substrate while other thalli resemble a gelatinous algal colony penetrated and interwoven by fungal hyphae. The lichen thalli described above characterised by simple and undifferentiated thallus with irregularly distributed algae are termed homoisomerous. Only a few lichen genera have this type of thallus.

d) Algal layer : Lichen origin form ideally accomplished symbiotic relationship of algae and fungi. The relation between algae and hyphae vary considerably. Mycobiant and phycobiant are either without direct contact or the hyphae of the fungus more or less completely clasped and surrounded the algae. In some lichens each of the mycobiant pressed against the algal cells and are called appressoria. In other genera haustoria penetrate the algal cell membrane. In some lichens algae and attacking haustoria divide simultaneously. The two daughter cells of alga are clasped by the two branches of the haustorium.

In the algal layer the algae multiply by mitotic cell

division and by aplanospores. In Trebouxia for example, the protoplast of an algal cell divides into several protoplast. Each of which subsequently secrete a cell wall. These aplanospores are freed by the rupture of wall of mother cell. The thickness of algal layer vary in different lichen genera and the position of the algal zone in the thallus is not invariable. The algae are situated in that part of the thallus where these hyphae are sufficiently loosely interwoven to leave enough space for the algae and where they have an optimum light intensity.

e) Medulla : The medulla consist of loosely interwoven hyphae in a particular arrangement. The hyphae are in general only weakly gelatinised and often have a fibrous or cottony appearance. The medulla has greater water holding capacity than any of the other tissues and is a region of food storage. The individual hyphae are not easily moistened and this together with their loose interweaving, facilitate gas exchange within the thallus. Many lichen substances are deposited extra cellularly in the medulla and other layers of the thallus.

f) Cortex : Most lichens are protected by a cortical layer which is some times pigmented and always cover the upper side of thallus and sometimes also the lower surface. The cortical layer is comparable with epidermis of a green leaf. The thickness of cortex vary in different lichen genera and layer does not always form a continuous stratum.

In some lichens cortex can be differentiated into lower and upper layers. The anatomy of lower cortex of the thallus can differ from that of the upper cortex even in the same species. The shape of the outer most cells of the cortex has an important influence on the habit of the lichen.

g) Vegetative diaspores : Many lichens, develop, vegetative organs of diaspores called isidia, soralia and hormocystangia. It is believed that isidia always act as vegetative propagules. However, it is interesting to note that lichens producing isidia or soredia do not freely produce ascocarp. In some lichens isidia probably only increase the surface area. In the soredia vegetative diaspore the soredia are produced. Lichenised harmocysts are the diaspores formed in harmocystangia of some lichens with blue green phycobionts. Soredia and harmocysts are separated from the lichens by the active growth of the thallus. While isidia can only serve as organs of dispersal if they are passively broken off. Soredia, harmocysts and isidia are an adaptation to symbiotic role as these diaspores disperse both partners of symbiosis together (Jahns, 1973).

h) The growth of Lichens : Over the last 40 years or so many lichenologists have been engaged and interested in the problem of measuring Lichen growth rate the factors that influence lichen growth, the methodology of study and so on (Platt and Amble, 1955; Barkman, 1958; Rydzak, 1956, 1961;

Sp. l.

year

1959



Spf Smith, 1962; Habe, 1959, 1967, 1970; Armstrong, 1976, Hill, 1981).

The study of lichen growth rate is specially important in two ways (1) it enablesto estimate both the age of the thallus and the period of exposure of a substratum, (2) to estimate the age of the rock or archaeological remains (Armstrong, 1976). One of the interesting studies carried out is of Beschee (1964) who applied the technique to the dating of glacial moraines. sp?

#### Mechanism of growth :

Increase in size or weight of the thallus is largely attributable to the fungal component which comprises 90 to 95% of the plant body. The algae are apparently carried along passively by the growing hyphae and remain as a thin scattered layer of only 20-40  $\mu\text{m}$  thick (Habe, 1973). Assimilate synthesized by the algae are utilized by the fungus at the growth site. The growth pattern in lichens is mainly centripetal and apical. The central part whose growth has ceased only contributes for thickness (by accumulation of material) permitting body formation. According to Hale (1470) each lobe of foliose species grows independently of other lobes, even adjacent one. year? Linkola in 1918 was the first to observe this phenomenon and to measure individual lobe.

i) Factors affecting growth : Growth in lichen occurs when there is accumulation of net assimilation. This occurs in response to the proper conditions of moisture temperature, light

etc. Another important factor that influence the directional growth especially in vertical orientation of frutescent lichen is gravity. Although lichen never stops growing, the typical morphological habit of the species is preserved as the growth is limited in same directions. Most frutescent species of e.g., Lichina are foliose when young. The vertical growth of foliose lichen is so slow that it only replaces the uppermost cells of cortex which are continuously sloughed off. The growth of hyphal tissue in lichen sometimes seems to be cumulative in presence of algae.

In lichen the growth is mainly restricted to the tip of thallus. The zone of growth does not exceed a few mm an year and intercalary growth is negligible. In fructose lichens the proportion of newly developed dead part of the thallus becomes increasingly unfavourable as only the upper part of lichen continues to grow, while the lower unproductive part accumulate. In crustose lichens, the annual increase of the thallus surface measured on the percentage of the actual size of the thallus is smaller in old thalli than it is in young one. The inner part of the thallus has no means of transporting photosynthetic products to the growing outer squamules, so that only the photosynthetic products of marginal parts of the thallus can be used for the growth process. In many foliose lichens the old part in the middle of the thallus die and disappear, while the young marginal parts of the lichens continue to grow outward. As a

result of this, ring shaped thallus is formed. The rings may reach a diameter of one meter as found in Parmelina (Parmelia) centrifuga. If the lichens add about 2 mm each year such a thallus might have began its development some five hundred years ago; but the living, ring shaped part of the thallus measures only about 6-10 cm in diameter. The oldest living part of the lichen is 32 to 50 years old. Crustose lichens may be much older e.g. thalli of Rhizocarpon are said to reach an age of thousand years or more (Jahns, 1973).

j) Growth measurements : There is only one way of measuring the growth of lichen i.e. indirect method. Indirect measurement involves (1) selecting colonies of lichens on substrates of known age measuring their size or biomass or extrapolating growth rate; (2) by dividing the lichen dimension by the age of the substrate (Hale, 1973). In this method, however, there is obviously some loss in precision compared with the growth measurements as applied in Blackman's method. The indirect measurements are made in the following ways :

(i) Terminal twigs measuring method, (ii) Lichenometry method, (iii) Length of internodes measurement method and (iv) marginal zonation method.

i) Terminal twigs measuring method :

This method is applied to measure the growth rate of lichens growing in temperate zones. Many trees in temperate

zones produce terminal bud scars. The internodes between these can be accurately dated and the age of lichens growing on them estimated. Platt and Amster (1955) proposed an interesting modification of this method especially in those growing on twigs of Juniperus. Lichens were cleanly removed from areas on twigs which were dated by ring counts of the woody tissues. Dry weight of the samples plotted against age of the substratum showed a high degree of correlation.

ii) Lichenometric Method :

It is a converse of twig method. One uses the estimated age of lichen colonies to date the substratum on which it is growing. This method is employed especially in Arctic lichens which grow extremely slowly. Beschel (1961) estimated some colonies to be as much as 4000 years old.

iii) Length of internodes measurement method :

Here the podetia of the common Reindeer mosses grow upward as loose mat on soil. The internode between branches is believed to represent one year growth so that, the age of Podetium is estimated by dividing the number of joints into the total height. The average annual growth rate determined by this method are comparable to these obtained by direct method. This is applied in Cladonia.

iv) Marginal Zonation Method :

Certain species of lichens such as Pertusaria, Lecanora etc. have concentrically zoned margins. The zones arise because rapid summer growth is whitish and the narrow dormant zone in winter is darker. Each zone, therefore, is of one year growth and the width is an accurate measurement of radial growth which may be traced back to 3-7 years. However, the constraint in this method is the vast majority of lichens do not manifest any annual zonation.

k) Method of measuring lichen growth :

There have been several attempts at constructing hypothetical models to explain the growth rate of circular lichen thalli. Woolhouse (1968) suggested that the important parameter in measuring growth was the area of the thallus by analogy similar to the growth analysis in the higher plants. He proposed the use of the concept Relative Growth Rate (RGR) which has developed by Blackman to measure the growth rate in higher plants where he believed, that the growth in higher plants follows compound interest formula. This means that there is a relationship between the LAR and rate of growth and hence area and initial size may be important in determining the growth rate of any plant. Armstrong (1974) in studying the growth of Parmelia sp. confirmed the observations of earlier authors that small thalli grow more slowly than large ones and found that the rate

increases with radius until it reaches the maximum and then proceeds at a constant rate. He suggested that relative growth rate (RGR) of Woolhouse which he later called 'r' (Armstrong, 1976) declined as the thallus grew larger. The formula given by Armstrong is as follow :

$$W_1 = W_0 e^{rt}$$

where :  $W_1$  = Final weight of the plant

$W_0$  = Initial weight of the plant

$r$  = Rate at which material already present  
is used to make new material i.e. capital

and,

$t$  = Time

$e$  = Natural base of the logarithms.

He modified the formula to apply it for lichen as follows :

$$A_2 = A_1 e^{r(t_2 - t_1)}$$

Where  $A_1$  and  $A_2$  are the thallus area at the beginning and of time interval  $t_2 - t_1$ .

Taking natural logarithms =

$$\log \frac{A_2}{A_1} = r (t_2 - t_1).$$

By rearrangement of the equation the relative growth rate (r) could be found as follows :

$$r = \frac{\log A_2 - \log A_1}{t_2 - t_1}$$

According to Hill (1981) by applying Armstrong's formula, it is not possible to determine precise relationship between growth rate and thallus zone for the estimation of growth rate were very variable.

Aplin and Hill (1979) adapted rather different approach. They constructed a model using functional approach applicable only to lichens and involving five separate contents denoting the various hypothetical processes contributing to growth rates. These contents represented the rate of net photosynthesis, the proportion of photosynthetic (as carbohydrate) contributing to radius (m) and to weight (1), the ability of the photosynthate to move radially towards the growth point (n) and the relationship between photosynthetic concentration and rate of radial growth (d). In other words the links to mass of the thallus of the rate in which the photosynthate move to the rate of synthesis to the growth point.

1) Mineral Nutrition : In 1973 Tuominen and Jaakkola wrote an article on "Absorption and accumulation of mineral elements and radioactive nuclides in the book, 'The lichen' ed. Ahmadjian and Hale. They stated that this subject is the most imperfectly explored field of lichen biology when compared with huge amount of experimental facts published on metal cation uptake of translocation in vascular plants. Whatever may be the reason, it is partly true that the mineral nutrition of lichen, with respect

to its substrate has not been explored in the temper as it should have been. However, the fact that the large amount of metal ions and radionucleids and heavy metals recorded from lichens, though not led to concentrate the attention of lichenologists to establish the inter-relationship between the substratum of the lichen, definitely directed them to link up with the experimental pollution. It is true that the lichens are compared as pollution indicators because of their tendency to accumulate cations of the atmosphere, it should not dissuade the lichen physiologist to closely investigate the interrelationship between lichen growth and the substratum.

There are many reports on the ability of lichens to take up and accumulate metals and nutrient substances from the substratum even through the dead basal part of the thalli. According to Tuominen and Jaakkola (1973) accumulation of certain metals is due primarily to the slow growth rate and longevity of lichens. Lounamaa (1956) studied the trace element content of lichens, mosses, ferns, conifers, deciduous trees, shrubs, dwarf shrubs, grasses and herbs. According to him lichens differ considerably from higher plants and mosses in trace element concentrations. Most of the elements studied occurred in greater amount in lichens than in any other plants. Manganese is the only trace element that was found in lower amount in lichen than in higher plants. Co, Ni, Mo and Ag occurred in same amount in lichens as in other plants from



corresponding habitats whereas Zn, Cd, Sn and Pb were in much higher concentration in lichens. Lounamaa (1905) who showed that effect of the substrate on the metal contents of the lichens was revealed in the trace element comparison of species growing on silicic and ultrabasic rocks. The metal element 'Cr', 'Mn', Co, Ni, Zn, Ga, Y, Zr, Sn and Pb contents of lichens on ultrabasic rocks were higher than those of samples from silicic rocks.

Many workers have carried out that term laboratory experiments with the range of heavy metals to know the mechanism of absorption (Tuominen, 1967; Handley and Overstreet, 1968; Puckett et al., 1973) and it has been observed that, the absorption of these metals is more as passive physical cation uptake mechanism rather than the substantially slower biological process.

Brown (1976) studied the ability of lichen to influence the uptake of cation. Although single cations were supplied in his experiment at the same initial concentration, different proportion were absorbed. The relative affinity of the lichen to different cation was independent of concentration. With the increase in initial cation concentration, the sequence of decreasing binding affinity was still,  $Pb > Cu > Zn > Ni > Co$ . Puckett et al. (1973) found however, that cation selectivity appear to be concentration dependant in the lichen Umbilcaria mühlenbergi.

Puckett and Finegan (1980) have analysed 20 different elements from '14' lichen species of North West territories of Canada. They reported considerable interspecific variation in the element composition of lichen. Lawrey (1980) studied nutrient element transfer between lichens and lichen herbivore. According to him lichen herbivores represents a potentially important mode of element transfer in terrestrial ecosystem.

With the help of X-ray fluorescence technique Tomassini et al. (1976) have detected Cu, Fe, Ni and S contents in lichen thalli. Burton et al. (1981) have studied the metal ion affinity in Cladina rangiferina and found that there is very low affinity for Ni than for copper and Thallium. Nash (1975) correlated the metal ion content cadmium and zinc with the photosynthetic rate showed that these ions will reduce the rate of photosynthesis. On the other hand Johnson (1975) found no adverse effect of cadmium lead and vanadium on dark respiration of lichens.

Jagtap (1985) studied the metal ion constituents of the thallus of corticose lichens, Parmelia simplicior and Leptogium azureum. He reported Na, K, Ca, Mg, Fe, Al, Cu, Co, Ni, Cd, Pb, Zn, B, Ba, Sb, Li, Ge, La, Au, Sr, Rb, Be, Cs, Mo, V, T, Zr, As and Cr. He correlated the mineral constituents of the thallus with that of the substratum bark and proportion of the same of the elements potassium, calcium,

Aluminium, Strontium Lead is well correlated with that of the bark..

m) Lichen as Pollution indicator : The growth of lichen has been well correlated with environmental pollution. As early as in 1866 Nylander pointed out that the absence of lichens in the outskirts of the Jardins de Luxembourg in Paris was due to air pollution, originating from the surrounding buildings (Gilbert, 1973). The atmospheric pollution caused due to the industrial effluent and its impact on the environment is being attended only in the recent years. According to him, Sernander appears to have been first worker to make a critical study of the lichens around the towns. Recent concern with all forms of pollution has stimulated research into the use of lichens to monitor air pollution and today there is a large literature on the subject. The fact that the lichens have been shown to accumulate radionuclides and heavy metals in thalli when even their trace is not found in substratum led to suggest their possible implication in pollution monitoring (Brown, 1976).

The striking observation, that the SO<sub>2</sub> fumigation emerging out of industrial chimni leads to the formation of lichen deserts has been made by number of workers. This led them to think that, lichen is the best indicator of SO<sub>2</sub> pollution (Tallis, 1964; Fenton, 1964; Skye, 1964; and Gilbert, 1965). The property of lichens as a pollution indicator has been

exploited in geological exploration where the lichens have been used as an indicator plants for locating the marbles and limestone deposits. The variability of many lichen species to specific air pollution such as  $\text{SO}_2$ , fluorides, Nitrous oxide, Ozone and heavy metal have been documented in the literature. (Ferry et al., 1973; Nash, 1976; Nash and Sigal, 1979; Skye, 1979).

Roberts and Thompson (1980) demonstrated lichen as indicators of fluoride emission from a phosphorus plant. They showed that fluoride concentration in terrestrial lichen Cladina rangiferina and C.stellaris were correlated inversely with distance from an industrial plant producing elemental phosphorus at long harbour in the direction of the prevailing wind. Hawksworth and Rose (1970) showed that  $\text{SO}_2$  in the air can be estimated qualitatively by studying the lichens growing on trees.