IV RESULTS AND DISCUSSION
1 Floristic Survey of Lichens
1. Floristic survey of lichens:

A) Dominant lichens from Panhala:

In Maharashtra, Mahabaleshwar, Panhala, Fadhanagari, Gaonawada, Vishalgad, Khandala, Lonawala are the parts situated at high altitudes of Western Ghats. They show luxuriant flora of different types of lichens. Amongst these hill stations, Panhala is situated at about 954 m above M.S.L and is 25 km North-West of Kolhapur. It receives an annual rainfall of 180-200 cm. Lichens of the present study were selected from this area. There are about 11 genera which could be noticed at Panhala and these area as follows:

Parmelia simplicior, Parmelia tinctorum, Leptogium azureum, Dermatocarpon moullinsie, Anaptychia diadamata, Anaptychia podocarpa, Dirinaria picta, Pyxine soreata, Arthothelium verrucolosum, Collema deoolim, Cryptothecia sp., Lecidea sp., Graphis contortuplicate, Graphis aphanes, Graphis sp.

Specialized morphology and identification on the above lichens:

1) Parmelia simplicior Hale.

Family: Parmeliaceae

Bryologist, 75:99, 1972


P. simplicior (Hale) (Plate No.1) thallus corticolous foliose, loosely adnate to substratum, 6-10 cm in diameter, whitish gray to dark gray or olive gray in colour. Irregularly
Plate 1: Parmelia simplicior
Plate 2: Parmelia tinctorum
Plate 3

Plate 3a: *Leptogium indicum*
Plate 4: Anaptychia diadamata
Plate 5: *Anaptychia podocarpa*
Plate 6: *Arthotherium verrucolosum*
Plate 7: *Collema* sp.
Plate 8: Lecidea sp.
Plate 9

a) *Graphis contortuplicatus*

b) *Graphis aphanes*

c) *Graphis sp.*
Plate 10: *Trebusia humicola*

Plate 11: *Nostoc* sp.
sinuate lobate; lobes sublinear, convolute and imbricate 3-5 mm wide, margin eciliate to sparsely ciliate especially in axils; upper surface plain, dull emaculate; isidia and soredia are absent; lower side is black; sparsely rhizinate, marginal narrow zone shrizinate shining or with rhizinal papillae; rhizinate simple; medulla white. Apothecia common, adnate, 3-6 mm diameter, margin inflexed; disc brown, smooth; hymenium 55-65 μM high, asci 40 to 45 μM, 8 spored, spores very rarely matured, colorless, simple, oval, ellipsoidal (9) 12-16 x 5-8 μ (spores vide Hale 6 x 4 μM).

Reaction: Thallus K + yellow, Medulla K + yellow turning red, C -, F + orange; atranorin and salacinic acid present.

*Parmelia simplicior* shows some resemblance to *Parmelia aurulenta* group in the nature of lobes; but the medulla in this species is white and contains salacinic acid. Hale (1972) indicated relationship to *Parmelia wallichiana* which, however, has much larger lobes and is isidiate, though in their chemistry the two taxa show similarity.

Hale mentioned the spore size 6 x 4 μM but in the isotype (initially designated as Holotype by Hale) the spores are larger. Since the spores are rarely matured are rarely liberated from asci. The dimensions show the variation in two observations. The taxon is restricted in Western India.
2) *Parmelia tinctorum* Nyl.

Family: Parmeliaceae

*Flora* 55: 547, 1872.

Thallus of this lichen (Plate No. 2) corticolous or saxicolous, foliose, loosely attached to substratum, 8-20 (largest seen 25 x 22 cm) in diameter, glaucos gray, grayish white to gray, sometimes turning brownish black in central part and breaking up in pieces; lobes rotund, 10-20(30) mm wide, somewhat longitudinally folded in marginal region; margin entire, eciliate; upper surface smooth, dull, plane, emaculate, isidiate, isidia mostly laminate in the central part of the thallus, rarely marginal, granular to filiform or becoming branched and rarely somewhat flattened micropyline, generally upto 1.5 mm long and upto 0.3 mm thick at base; younger isidia often with a brown black punctate dot at the tip; lower side minutely wrinkled and rough, black, sparsely rhizinate in the central part, marginal about 10 mm wide zone erhizinate reddish brown to dark tan and shining, rhizinate short, thick, occurring in groups in the central part.

Apothecia rare, stipitate upto 10 mm in diameter, imperforate; disc dark brown, smooth; amphithecium regose and densely isidiate; hymenium 70-80 µm high; asci 8 spored; spores colorless, simple, oval, ellipsoidal (13) 15-18 x 6-9 µm; episporium 1.5 µm thick.
Parmelia tinctorum is distinctive in its large lobed isidiate thallus; broad erhizinate shining zone along the margin on the lower side and medulla C+ red instantaneously. The C+ reaction on medulla is often, therefore, used to test the effectiveness of C solution before applying it to other lichens. The isidia are mostly granular to filiform but, variations to caralloid branches and in extreme case becoming flattened microphylline also occurs and is probably an ecological modification in warm moist conditions. It does not seem to be of taxonomic importance. Between the saxicolous and corticolous plants the former more generally possess granular isidia. The taxon is widely distributed in India and in pantropical regions of the world throughout.


Family: Collemataceae

Lichens azureus Sw. in Agr. Suec. Prodr. 137, 1798.

Thallus corticolous, foliose, bluish gray and gelatinous when wet. Statw gray and papery when dry, 10-12 cms across, much lobed; lobes roteand; 1-2 cms long, 1.0 - 1.5 cms broad more or less ascending, irregularly branched; surface smooth, nonisidiate, never wrinkled, margin entire, smooth, revolute,
lobes 42 - 50.4 \( \mu m \) thick, unstratified, homocmerous, cortex of irregularly isodimetric cells, 4.8 - 8.0 \( \mu m \) in diameter, 5 - 8 rows developed below apothecia where cells 16.8 - 21.0 \( \mu m \) in diameter; algal cells spherical, 4.8 - 6.4 \( \mu m \) in diameter, in chains, throughout the thallus but most abundant near the upper cortex forming almost a continuous layer 8.0 - 12.6 \( \mu m \) thick.

Ascocarp's apothecia, lacanorin many, sessile, on upper surface, rounded to orbicular, never deformed, 1-2 mm in diameter, 396-468 \( \mu m \) in height, disc plane, scarlet red when wet, dark brown when dry; thalline exciple entire, cream coloured, 105-126 \( \mu m \) thick, proper exciple faint, reddish brown cellular, 33.6 - 42.0 \( \mu m \) thick, hymenium hyaline, I +ve blue, 159.6 - 176.4 \( \mu m \) in height, hypothecium yellowish to pale brown, 105-126 \( \mu m \) thick; epitheciun uniform, brown, 21.0 - 29.4 \( \mu m \) thick, paraphyses simple, unbranched, slightly thickened at the apices; asci cylindroclevate, I +ve blue at the tip, unitunicate, shortly stalked, 103.2 - 159.6 x 21.0 - 29.4 \( \mu m \), octosporous, with biseriate or irregular spores.

Ascospore ellipsoidal, hyline, muricate, transversely 3-5 septate, longitudinally 1-2 septate, 19.8 - 25.6 x 9.6 - 12.8 \( \mu m \), apices pointed.

Reactions: Thallus: K +ve, reddish, C -ve, KC -ve, P -ve
Remarks: This lichen *Leptogium azurinum* (Plate No. 3) is characterised by smooth, thin, bluish, thallus without isidia; lobes more than 3 mm in breadth, spores muricate, 19.8 - 25.6 μm long, with 1-2 longitudinal septa and 3-5 transverse septa, thallus becoming reddish with KOH.

4) *Dermatocarpon moulinsii* (Mont):

**Family:** Dermatocarpaceae


Thallus saxicolous, foliose, peltate, 1.5 to 3.5 cms in diameter, ashy gray, attached to the substratum by an umbilicus marked by a whitish patch in otherwise black rhizinate lower surface; upper surface spotted in black dots marking the positions of ostioles of deeply situated perithecia or pycnidia, cartilaginous and continuous (entire) when fresh; crispy, folded irregularly or cracked when dry. Outer cortex brown, pseudoparenchymatous, 12.6 - 16.8 μm thick, algal layer continuous 42.63 μm thick, interrupted at perithecial or pycnidial locations, algae spherical, medulla 315 - 336 μm thick, lower cortex 31.8 - 50.4 μm thick, pale brown; rhizines simple, 63 - 126 μm in diameter at base. Ascocarp's perithecium immersed deeply in the
thallus, subglobose, 126 - 210 \( \mu \text{m} \) in breadth, 294 - 365 \( \mu \text{m} \) in height with long neck and straight dark brown ostiole; exciple formed of longitudinally running compressed hyphae, 21.0 - 33.6 \( \mu \text{m} \) thick, hymenium hyaline, 210.0 - 256 \( \mu \text{m} \) in height, 142.8 - 189.0 \( \mu \text{m} \) in breadth, I +ve faint blue, with dissolved paraphyses; Asci subcylindrical, I +ve faint blue unitunicate, shortly stalked, octosporous, 42.63 x 12.6 - 16.8 \( \mu \text{m} \). No distinct seriation of spore. Ascospores hyaline, simple, ovoid, ellipsoid, cytoplasmic strands, thin walled 8.0 - 12.8 x 3.2 - 4.8 \( \mu \text{m} \).

**Remarks:** *Dermatocarpon moulinii* is characterised by presence of umbilicus and black rhizines on the lower side. It occurs normally where water trickles on the basalt rock.


**Family:** Physciaceae

Thallus corticolous, foliose, yellowish to grayish, laciniate, laciniae distinct throughout, linear, dichotomously branched, 1.0 - 1.5 mm broad adpressed to the substratum, minutely notched, without soredie or isidia; lower surface corticate, white at periphery and brown at the centre, sparsely rhizinate; rhizines dark brown at the centre, rhizines dark brown to black, laminal and marginal, irregularly branched, laciniae 294-336 \( \mu \text{m} \) thick; upper cortex uniform,
67.2 - 84.0 \( \mu m \) thick, with a grayish surface layer 21-25.2 \\( \mu m \) thick, algal layer continuous, 37.8 - 46.2 \( \mu m \) thick, medulla hyaline, 105 - 128 \( \mu m \) thick, lower cortex 33.6 - 46.2 \( \mu m \) thick. Apothecia many, subsessile, 1.0 - 3.5 mm in diameter, 450 - 720 \( \mu m \) in height; epithecium brown, 21.0 - 29.4 \( \mu m \), hypothecium pale yellow 37.8 - 46.2 \( \mu m \), Asci subcylindrical, I +Ve blue at tip, unitunicate, shortly pedicellate, 96.6 - 113.4 \( \times \) 25.2 - 33.6 \( \mu m \), octosporous, spores biseriate. Ascospores brown ellipsoidal, one septate, thick walled, 22.4 - 30.4 \( \times \) 8.0 - 11.2 \( \mu m \), l-cules subglobose to obconical, cells without sporoblastidia.

Reactions: Thallus K -Ve yellow

\[ \text{C -Ve, KC -Ve, P -Ve} \]

Medulla K +Ve, P +Ve yellow

Cortex of receptacle: I -Ve

Chemical constituents: Atranorine, zeorine

Remarks: This Anaptychia diadamata (Plate No.4) is close to A. pseudoscissosa, Kurok, but for two characters.

1. absence of soredia

2. absence of norstictic and Salacinic acids
6) *Anaptychia hodocarpa* (Bel.) Mass:


Family: Physiaceae.

Thallus usually originating as discrete, narrow and + Stellate adpressed laciniae which soon are broadened, become suberect to errect apically so that ultimately the mature fertile thallus is rosulatous or caespitose and the primary adpressed parts of the laciniae are obscure or indistinct. The widening and erect nature of the laciniae is usually associated with fertile thallus. Some times the thallus caespitose from the very beginning. Laciniae of the mature fertile thallus is upto 3 mm broad (rarely broader), convex, subtubular and imbricated or superposed; above convex, smooth, glaucous white ~, glaucous gray to rarely brownish; below concave, white farinose in older parts and usually colored light ochraceous or croceus ferrugineous in apical parts. Laciniae margins beset with fibrils rarely simple, usually variously irregular branched or squarrose or thyrsoid, concolorus or brown black. No soredia and isidia. Thallus 250 - 300 µm thick. Corticated only on the upperside and along the margins by longitudinally disposed conglutinate hyphae. Cortex 40 - 250 µm thick, irregularly wavy or inner outline: exterior 15-20 µm regions obscure Palegray. Algal stratum not continuous, algal cells 8-14 µm in size, greenish,
in 40-80 µm thick groups. Medulla thin, colourless or pale
croceous or reddish; hyphae densely superficially granular,
Granules dissolve in K, and hyphae then 4-5 µm thick, marginal
fibrils upto 2.5 mm long and 0.25 mm thick at the base.
Cortex : K+ yellowish, I =ve blue Cl -ve, Pd -ve, Thallus
lower side (= medula), K + croceus ferrugineous, ochraceous
red or red violet. Apothecia subterminal, usually upto 5 mm
(rarely 10 mm) in diameter, pedicillate, stalk tubular, disc
convex, plane to convex, caesiopruinose (rarely in over
matured stages, incised dentate to proliferate lobulate;
lobules at the same size all round or the one disposed on
the above. Margins of the lobules usually without fibrils
(in few cases small and upper most, 10 µm region and colorless
inwards, I +ve blue; hypothecium light pale, 40-60 µm thick,
Asci 140 - 160 x 32-40 µm in size, 8-spored; spores brown to
dark brown, 2-celled, ellipsoidal to oval, ellipsoidal thick
walled (32) 36-48 (52) x (16) 20-24 (28) µm inside, Cell
lumen rounded globular to elongate; in over mature spores
oily globules present, paraphyses slender conjugate.
Habit : On twigs trees and shurbs (rarely over stone).

The lichen Anaptychia podocarpa (Plate No.5) is wide
spread in temperate regions of Himalaya and exhibit certain
variations due to which clearcut circumscription of this
species has not been possible to be made out here in the
absence of the type specimen.
7) *Dirinaria picta* (Sw). :

**Family:** Dirinaceae

Clem and Shear in *genera of fungi*, 323, 1931.

Lichen *picta* Sw in *Nova Genera it Spec. Plant* 1788, pp. 146.


Thallus corticolous, foliose, closely adpressed to the substratum, orbicular, 7.5 cms across; lacinae discrete only at the periphery, 0.5 - 1.0 mm, broad confluent in centre, (crustose appearence) greenish white sorediate; soredia in globose, soralia, farinose, greenish, lowerside black, rhizines absent, Thallus 105 - 155 (273) µm thick, algal laver 8.4 - 33.6 µm thick, medulla white, 63.0 - 92.4 µm thick, lower cortex. Paraplectenchymatous 8.4 - 16.8 µm thick, Anothecia rare in central part of thallus, 1 mm in diameter, sessile; disc plane, black, opuinose margin entire, thalline; theciun hyline, 63 - 71.4 (84) µm height, I +ve blue, hypothecium dark brown, lenticular 63.0 (84) - 126 µm thick, asci : subelavate, unitunicate, octosporous, 37.8 - 50.4 x 12.6 - 16.8 µm; ascospores brown, ellipsoid, one septate (sometimes septum not seen), 12.6 - 16.8 x 6.3 - 10.5 µm.
Reactions : Thallus : - K +ve yellow
Medulla : - K +ve yellow (I)
C -ve, KC' -ve P -ve.

Chemical constituent : Atranorin, Divaricatic acid.

Remarks : The species is distinguished by the stellate radiate lacinae, which are generally pinnatified and discrete for the greater part of the thallus. The apices are not flabellate confluent. The taxon is closely related to Dirinaria applanata (Fee).

8) Pyxine soreata (Ach.) Mont.
Family : Physciaceae

Cagra, Hist Cuba, 8 : 188, PLY and 41838.48.
Lecidea sorediata Ach. Syn Lich. 54. 1814.


Thallus corticolous, foliose, closely depressed to the substratum, 4-6 cms, across, laciniated, lacinae disfrac throughout, 1.0 - 1.3 mm broad, with special soredia, soredia bluish gray, granular; lower surface black, rhizines not seen. Lacinae 126 - 210 μm thick; algal layer continuous, 25.2 - 42.0 μm thick, medulla pale to distinctly yellow, 42 - 105 μm thick, lower cortex 12.6 - 16.8 μm thick.
Apothecia laminer, sessile, 0.5 - 1.0 (1.2) mm in diameter disc convex, black, epruinose, without pseudothalline margin: exciple, hypothecium brown; thecium hyaline, 84 µm high. I +ve blue; epithecium KOH +ve blue; epithecium KOH +ve violet; amphithecium differentiated into greenish parenchymatous corte and yellowish medulla; stipe not developed, Asci clevate, unitunicate, octosporous 54.6 - 63 x 16.8 - 21.0 µm. Ascospores brown, ellipsoid, one septate, mishoblastomorhic. 16.8 - 21.0 x 6.3 - 8.4 µm.

Reactions: Thallus : - K +ve yellow

Medulla : - K -ve not purple

C -ve, KC -ve, P -ve

9) Arthothelium verrucolosum Patwardhan and Makhija (Plate No.6)

Family : Arthoniaceae

Thallus corticolous, crustose, greenish white to green, smooth or unevenly thickened, verruculose, cracked with age, 60-160 µm thick ecorticate, indeterminate.

Asccarps: Pseudothecia large, solitary or lie close together, brown to black, flat immersed inwarts or emergent covered by white thallus or totally exposed; hypothecium pale brown; hymenium pale brown to almost hyaline, 120 - 140 µm high; paraphyses branched at apices, coherent and giving a pseudoparenchymatous appearance to the interthecial tissue.
Asci: pyriform, bitunicate, thick walled padicillate, 28 - 36 x 64-100 μm in size.

Reaction: Thallus: K -ve yellow  
           C -ve, K -ve, P -ve yellow.

10) Collema sp. (Wigo)

Family: Collemataceae

Collema sp. (Plate No.7) is characterised by having thallus foliose, or squamulos to almost crustose, gelified when moist, laying on the substrate without rhizine, homocomerous, ecorticate hyphal system loose, algae nostoc; apothecia at first sunken, orupent sessile, or scutellate and consticted below, with amphithecium; parathecium either present or absent both parathecium and hypothecium either of interwoven hyphae or pseudoparenchymatous. Paraphyses simple, adherent, mostly septate, asci 8-spored; ascospores colorless, cylindric acicular fusiform, long ellipsoidal or ovoidal to almost cubical, ends obtuse or acute, sometimes becoming muriform, thin walled, without gelified sheath.

The genus Collema varies in many morphological and anatomical respects, especially with regard to the ascospores and the form of the thallus.

In addition there are differentiation in other respects e.g. in the structure of the excipulem; in the occurrence of
the pseudocortex in the thallus and apothecia; in the hyphal system of the thallus etc.

Deaelius (1954) pointed out that earlier attempts to carry out a division into different sections of minor genera were highly artificial and must, therefore, be rejected. The genus has very wide distribution covering most parts of the world in the temperate and tropical regions.

11) Cryptothecia sp.

Family: Arthoniaceae

The genus is characterised by corticolous, crustose, effuse thallus, fertile parts of the thallus, extensive, extremely invisible, asci bitunicate, globose or subglobose, interthecial tissue loose, made up of branched and anastomosing sterile hyphae. Ascospore hyaline, muriform 1-8, ascus ovate.

12) Lecidea sp (Ach.) A. Zahlbr.

Family: Lecideaceae

Thallus of Lecidea sp. (Plate No.8) saxicolous, crustose, yellow, determinate with thin black hypothallus, smooth, subarcolate, 100.8 - 109.2 μm thick, without areoles and crystals, cortex and medulla not well differentiated, algal layer continuous alga spherical.
Ascocarps apothecia, licidine black, minute, 0.3 - 0.5 mm in diameter. 142.8 - 176.4 μm in height, many, solitary. Distressed when present one per areole, rounded to orbicular, disc convex, black shining epruniöse, margin hypose, radiate, hvaline, compact. I+ve blue, 50.4 - 67.2 μm in height; epithecium brown, crustose 8.4 - 16.8 μm thick, subhyphal zone brown, 126 - 168 μm thick, paraphyses simple, unbranched, uniform breadth, coherent, with moniliform apices; Ascii elevate to cylindrical, pedicillate, I+ve blue at tip, unitunicate, 46.4 - 54.4 μm octosporous, spores biseriate. Ascospores hyaline, simple, ovoidal, thin walled, 4.8 - 8.0 x 3.2 - 4.8 μm with inwardly projecting endosporum in some cases.

Reactions: Thallus: K +ve yellow C - ve

KC -ve; P -ve, I -ve

13) **Graphis contortulplicate** (Adans)

Family: Graphidaceae.

Thallus of *G. contortulplicate* (Plate No.9) corticolous, crustose, ashy white to gray, indeterminate, smooth or rough or annular, cracked, 50.4 - 92.4 μm thick, cortex hyaline, algae spherical in groups. Ascocarp apothecium, lirelline, solitary, elispersed, rarely branched, erumpent, long, fluxuous, 1.5 - 7.0 mm long, 189 - 39C μm wide, 113 - 310 μm height thalline veil distinct; exciple totally non carbonized;
labium entire, convergent, base pale brown; lateral walls 33.6 - 50.4 μm thick, hymenium hyaline, fusiform tapering at one end, transversely 6 - 12 septate, 21.0 - 59.2 x 4.8 - 8.0 μm.

Reactions: Thallus: K -ve yellow turning red,
               C -ve, KC +ve, P -ve yellow,
               turning orange.

Chemical constituents: Cestratic and stictic acid.

Remarks:

This species is characterised by
1. Long flexuous erumpent lirellae.
2. Totally non carbonized exciple convergent and non-straited labium.
3. Spore length about 50 μm and
4. Presence of nonstictic and stictic acids.

There are many variations as regards colour and nature of thallus, mode of branching, length and width of lirellae and spore size; however, exciple characters and T.L.C. results are the same for all the variants and hence it is considered as a single variable species.

Amongst these 13 different lichen species collected at Panhala, Parmelia simplicior Male. and Leptogium azureum (SW) Font. have found to be more dominant lichen species. Since the phycobiont of these two lichens are
different, it is thought worth while to select them for studying the physiological aspects.

The phycobiont isolated and identified from \textit{Parmelia simplicior} is a green alga \textit{Trabouxia humicola} (Plate No. 10) whereas in \textit{Lentogium azureum} it is a blue green alga \textit{Nostoc} sp. (Plate No. 11).
2 Elemental Composition & Seasonal Variation
2. Elemental composition and seasonal variation:

It has been amply made known through number of publications (Crehura 1977, Doyle et al. 1973, Puckett and Finegan 1980), that the study of mineral composition of lichen thallus are of immense importance. In the recent year greater emphasis has been given to relate it with air quality or the environmental study (Drown 1976, Gar y et al. 1977, Laaksovirta and Ulkkonen 1977, Pilegward 1973) and lichens are considered as indicators of many environmental factors. According to Puckett and Finegan (1980), the factors that regulate elemental level of the lichen are poorly understood and data on both the type and magnitudes of the element sources and on the element deposition to the lichen surfaces are lacking. The present study therefore aims to project light on two aspects of elemental composition in the lichen. Firstly the seasonal variation with its relevance to the sustaining bark and secondly variation with respect to algal components of the lichens.

A. Sodium (Na⁺) and Potassium (K⁺)

Sodium (Na⁺) and potassium (K⁺) are more often dealt together with point of view of their relations in periodic table for both are monovalent dielectrolytically active elements. Moreover correlative study of the mineral composition of lichen thalli and its substrate hitherto known is mainly with respect to rocky substrate (Lounamaa 1965, Jaakkola et al. 1967, Jaakkola...
1969, Puckett and Finegan 1930) and also very little information is available on seasonal changes in the level of elements. Whatever is known is mainly confined to about terricolous xerophyton lichens (Kovasand and Verseghy 1974). As a matter of fact in biological system they must be evaluated with reference to even Calcium (Ca<sup>++</sup>). In case of lichens it is established that varieties of even unconventional, elements are accumulated whose role in lichen biology is yet to be properly understood. Our elemental analysis in Parmelia simplicior, a nongelatinous green algae containing lichen and Leptogium azureum the gelatinous blue green algae containing lichen are also with respect to seasonal variation as well as pertinent to the barks of their respective host plants.

Even analysis of elements have also been made in the thalli of these lichens notwithstanding seasonal variations. These values are given in Tables No. 1, 2 and 3.

It is clear from the table 1 that the thallus of the gelatinous lichen L. azureum has Na<sup>+</sup> as high as 19.23 mg 100<sup>-1</sup>g dry wt. whereas in P. simplicior the non gelatinous lichen it is 25.00 mg 100<sup>-1</sup> g dry wt.

If we see K<sup>+</sup> level in these lichens we find that the situation is converse in the sense that the thallus of L. azureum has 69.39 mg 100<sup>-1</sup>g dry wt. while it is 47.10 mg 100<sup>-1</sup> dry wt. in P. simplicior. Such converse situation could also be seen between these two lichens with respect to the seasonal variations.
Table 1. Inorganic constituents from the thallus of lichen Parmelia simplicior and Leptogium azureum

<table>
<thead>
<tr>
<th>Element</th>
<th>P. simplicior (Gree alga)</th>
<th>L. azureum (Blue-green alga)</th>
<th>Error %</th>
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<tbody>
<tr>
<td>Sodium</td>
<td>25.00</td>
<td>19.23</td>
<td>± 1</td>
</tr>
<tr>
<td>Potassium</td>
<td>47.10</td>
<td>69.39</td>
<td>± 1</td>
</tr>
<tr>
<td>Calcium</td>
<td>6904.77</td>
<td>1131.17</td>
<td>± 2</td>
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<td>Magnesium</td>
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<td>429.34</td>
<td>± 2</td>
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<td>Manganese</td>
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<td>13.85</td>
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<td>Iron</td>
<td>297.36</td>
<td>975.64</td>
<td>± 2</td>
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<td>Cobalt</td>
<td>0.43</td>
<td>0.70</td>
<td>± 5</td>
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<td>Nickel</td>
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<td>2.26</td>
<td>± 3</td>
</tr>
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<td>Cadmium</td>
<td>0.07</td>
<td>0.23</td>
<td>± 5</td>
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<tr>
<td>Lead</td>
<td>1.88</td>
<td>1.97</td>
<td>± 3</td>
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<tr>
<td>Zinc</td>
<td>13.92</td>
<td>28.27</td>
<td>± 2</td>
</tr>
<tr>
<td>Aluminium</td>
<td>327.33</td>
<td>210.83</td>
<td>± 2</td>
</tr>
<tr>
<td>Arsenic</td>
<td>N.D.</td>
<td>N.D.</td>
<td></td>
</tr>
<tr>
<td>Chromium</td>
<td>N.D.</td>
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<td></td>
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<tr>
<td>Molybdenum</td>
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<tr>
<td>Vanadium</td>
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<td>N.D.</td>
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<tr>
<td>Tungsten</td>
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</tr>
<tr>
<td>Zirconium</td>
<td>N.D.</td>
<td>N.D.</td>
<td>± 2</td>
</tr>
<tr>
<td>Antimony</td>
<td>0.725</td>
<td>N.D.</td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td>Trace</td>
<td>Trace</td>
<td></td>
</tr>
<tr>
<td>Berellium</td>
<td>N.D.</td>
<td>N.D.</td>
<td></td>
</tr>
<tr>
<td>Barium</td>
<td>N.D.</td>
<td>N.D.</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>1.45</td>
<td>4.52</td>
<td></td>
</tr>
</tbody>
</table>

Values expressed are in mg 100^-1 g dry wt.

ND - Not detected.
Table 2. Inorganic constituents from the thallus of lichen *Parmelia simplicior* and *Leptogium azureum* during different seasons.

<table>
<thead>
<tr>
<th>Element</th>
<th>P. simplicior (Green alga)</th>
<th>L. azureum (Blue-green alga)</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainy</td>
<td>Winter</td>
<td>Summer</td>
</tr>
<tr>
<td>Sodium</td>
<td>19.41</td>
<td>41.05</td>
<td>19.8</td>
</tr>
<tr>
<td>Potassium</td>
<td>283.81</td>
<td>347.21</td>
<td>328.22</td>
</tr>
<tr>
<td>Calcium</td>
<td>3650.97</td>
<td>4771.60</td>
<td>2630.80</td>
</tr>
<tr>
<td>Magnesium</td>
<td>158.55</td>
<td>239.52</td>
<td>256.18</td>
</tr>
<tr>
<td>Manganese</td>
<td>3.97</td>
<td>9.32</td>
<td>11.06</td>
</tr>
<tr>
<td>Iron</td>
<td>346.23</td>
<td>485.38</td>
<td>534.62</td>
</tr>
<tr>
<td>Cobalt</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Nickel</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cadmium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Lead</td>
<td>1.548</td>
<td>2.05</td>
<td>1.28</td>
</tr>
<tr>
<td>Zinc</td>
<td>4.367</td>
<td>6.477</td>
<td>3.48</td>
</tr>
<tr>
<td>Aluminium</td>
<td>394.59</td>
<td>486.36</td>
<td>524.32</td>
</tr>
<tr>
<td>Antimony</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Barium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>
Table 2 (contd.)

<table>
<thead>
<tr>
<th>Element</th>
<th>P. simplicior</th>
<th>L. azureum</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rainy</td>
<td>Winter</td>
<td>Summer</td>
</tr>
<tr>
<td>Cerelium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Boron</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Rubidium</td>
<td>2.28</td>
<td>3.40</td>
<td>3.2</td>
</tr>
<tr>
<td>Cesium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Lithium</td>
<td>0.138</td>
<td>0.279</td>
<td>0.22</td>
</tr>
<tr>
<td>Strontium</td>
<td>15.61</td>
<td>28.23</td>
<td>16.14</td>
</tr>
<tr>
<td>Germanium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Copper</td>
<td>1.38</td>
<td>1.63</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Values expressed are in mg 100⁻¹ g dry wt.

Cu, Pb, Rb, and Li are low to the optimum working range for atomic absorption spectra hence error is more.

ND = Not detected.
Table 3. Inorganic constituents from the bark sustaining lichens Parmelia simplicior and Leptogium azureum

<table>
<thead>
<tr>
<th>Element</th>
<th>P. simplicior</th>
<th>L. azureum</th>
<th>Error %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mango bark</td>
<td>Jamune bark</td>
<td>Bougainville bark</td>
</tr>
<tr>
<td>Sodium</td>
<td>19.80</td>
<td>30.29</td>
<td>29.28</td>
</tr>
<tr>
<td>Potassium</td>
<td>136.38</td>
<td>149.49</td>
<td>152.33</td>
</tr>
<tr>
<td>Calcium</td>
<td>2534.13</td>
<td>1109.5</td>
<td>3521.03</td>
</tr>
<tr>
<td>Magnesium</td>
<td>107.80</td>
<td>103.13</td>
<td>273.89</td>
</tr>
<tr>
<td>Manganese</td>
<td>6.05</td>
<td>2.57</td>
<td>10.35</td>
</tr>
<tr>
<td>Iron</td>
<td>127.05</td>
<td>141.57</td>
<td>168.54</td>
</tr>
<tr>
<td>Cobalt</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Nickel</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Cadmium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Lead</td>
<td>1.13</td>
<td>1.15</td>
<td>2.58</td>
</tr>
<tr>
<td>Zinc</td>
<td>1.48</td>
<td>6.91</td>
<td>2.36</td>
</tr>
<tr>
<td>Aluminium</td>
<td>118.83</td>
<td>23.02</td>
<td>162.45</td>
</tr>
<tr>
<td>Barium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Antimony</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Lithium</td>
<td>ND</td>
<td>0.184</td>
<td>0.16</td>
</tr>
<tr>
<td>Germanium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Gold</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Strontium</td>
<td>28.61</td>
<td>18.0</td>
<td>47.44</td>
</tr>
<tr>
<td>Rubidium</td>
<td>1.02</td>
<td>0.37</td>
<td>1.035</td>
</tr>
<tr>
<td>Berillium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td>Ceasium</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
</tbody>
</table>

Values expressed are in mg 100⁻¹ g dry wt.

ND - not detected.
In *P. simplicior* during the rainy and summer seasons Na⁺ values are more or less equal and during winter there is more than one fold increase which is 41.05 mg 100⁻¹ g dry wt. Whereas in *L. azureum* during rainy and summer seasons the Na⁺ values are respectively 60.68 and 53.24 mg 100⁻¹ g dry wt., but in winter season the value has gone down to 33.71 mg 100⁻¹ dry wt.

Similarly K⁺ in *P. simplicior* thallus is also lowered during rainy and summer seasons which are respectively 283.79 and 328.22 mg 100⁻¹ dry wt. and in winter value is highest which is 347.21 mg 100⁻¹ dry wt. But in *Leptogium*, similar to that of Na⁺ during rainy and summer seasons the K⁺ values are higher which are respectively 626.70 and 628.93 mg 100⁻¹ g dry wt., whereas in winter it is as low as 447.95 mg 100⁻¹ g dry wt.

These contrasting differences in the levels of these elements are only attributable to the nature of thalli organisation; in other words possibly the phycobionts associated with them.

Thomas (1985, personal discussion) working with blue green algae has noticed that Na⁺ uptake by blue green algae has close positive correlation with nitrogenase activity. This observation leads us to argue that irrespective of the season the higher level of Na⁺ especially in *Leptogium* is mainly due to its cyanobacterial association as phycobiont. Our analysis of these elements from the barks of the trees which sustain these organisms are also presented in the table 3. In order to know the relationship between the mineral composition of the *Parmelia*
thalli and the substratum over which it is growing, sodium $Na^+$ and potassium $K^+$ were analysed in the bark of mango as well as Jambul for this lichen grows on both. It is also clear from the table that $Na^+$ level in Leptogium sustaining bark is 29.28 mg 100$^{-1}$g dry wt, whereas Parmelia sustaining barks of the two different host plants range from 19.30 to 80.29 mg 100$^{-1}$g dry wt.

These values are more or less well within the range and in agreement with those of the lichen thalli themselves. The $K^+$ values of the bark are also higher than those of the lichens. This parallelism between the barks and the lichen thalli irrespective of their nature led to infer that, possibly, they are absorbed from the bark of these respective trees.

Puckett and Finegan (1980) in their analysis of element contents of lichens showed that there is a good correlation between the elemental levels of thalli in Citraria spp. and Cladina stellaris with their sustaining crustal rock, however, there is no information available on corticolous lichens. They did noticed the larger variations in the lichen element concentrations growing at different geographical areas - but what we find here is the seasonal variation.

Puckett and Finegan (1980) could find a distinction in the elemental composition and ability to trap the elements from the free atmosphere between gelatinous and non-gelatinous lichens. No doubt they have valued even the surface characteristics but our analysis of these lichens exhibit clear cut variation with
the seasons where gelatinous lichens have more K\textsuperscript{+} and Na\textsuperscript{+} during rainy and summer seasons, while non-gelatinous has more of these elements during winter than either of the other two seasons. It is difficult to say that these variations have direct relationship with moisture contents of their ability of water retaining capacity. One thing is clear that the general level of these elements irrespective of the season is more in gelatinous lichen *Leptogium* than non-gelatinous *Parmelia* (Table 1). When we compare level of Na\textsuperscript{+} and K\textsuperscript{+} between these two genera we find that the level of K\textsuperscript{+} is many fold higher than that of Na\textsuperscript{+}. There is no necessity of emphasizing here that K\textsuperscript{+} has greater metabolic role to play than Na\textsuperscript{+} and is still considered to be unessential element in all non hallophytes. Nonetheless it shows the parallel variation between the two elements in both the genera.

3. Calcium (Ca\textsuperscript{++}) and Magnesium (Mg\textsuperscript{++})

These two divalent cations are very important ones in growth of plants irrespective of whether they are chlorophillous or non-chlorophilous ones. They belong to major group of elements in the biological systems. However, Mg\textsuperscript{++} has great functional role, even it is found in relatively very low concentration in the tissue. This is because Ca\textsuperscript{++} is an integral part of the structural elements of the plants, while Mg\textsuperscript{++} maintains the integrity of ribosomes and participates in key metabolic elements. It is also a metal ion found in chlorophyll molecules.
Despite it is the divalent cation, it has far more greater mobility in the system and hence possibly its requirement is relatively in lower amount.

Let us examine first of all these elemental levels in the barks of the tree over which a Leptogium and Parmelia grow. The values (Table 3) clearly reflect that Ca\(^{++}\) in the bark of trees over which Leptogium and Parmelia grow are very high, whereas Mg\(^{++}\) level in these barks are relatively very low, as low as or less than 1/10 that of Ca\(^{++}\). However, bark of the plants over which Parmelia grows exhibits relatively lower level of Ca\(^{++}\) and Mg\(^{++}\).

Analytical data of these lichens sampled randomly are given in Table 1. They reveal that the level of calcium in Parmelia is five-fold higher than that of Leptogium which is 6904.77 mg \(100^{-1}\)g dry wt. whereas level of Mg\(^{++}\) is three-fold higher in Leptogium over Parmelia. This reflects on overall requirement of calcium for Parmelia has much higher level of Ca\(^{++}\) compared to Leptogium. This is possible because Leptogium has blue green alga as phycobiont while Parmelia has the green. It is known that the cell wall of the blue green alga is gelatinous and mucilaginous and has an ability to trap especially Ca\(^{++}\) in its mucilaginous sheath.

When we examine the seasonal variations in the level of these elements similar to that of K\(^{+}\), here the two species show distinct variation. The Calcium level of Parmelia during
rainy and summer season is lower than that of winter. However, in *Leptogium* it is during rainy and summer seasons that increases while during winter its level decreases. Similarly Mg$^{++}$ level in *Parmelia* during winter is higher although highest could be seen in summer; whereas in *Leptogium* during rainy and summer season the Ca$^{++}$ level is respectively 459.8 and 571.05 mg 100$^{-1}$ g dry wt. and during winter it is estimated to be 370.56 mg 100$^{-1}$ g dry wt. In other words similar to that of calcium (Ca$^{++}$) the level of Mg$^{++}$ is also reduced during winter.

Puckett and Finegan (1980) working on north-west Canadian species of lichens *Cetraria* and *Cladina* showed that the level of Ca$^{++}$ in these species is highest ranging from 1013.1 to 9093.2 ppm while Mg$^{++}$ level in *Cladina stellaris* is 350.8 ppm and in *Cetraria nivalis* it is 916.5 ppm. These range of variations in different species of lichens growing on rocks reveal that our results are quite in agreement with them. However, these values do not reflect seasonal variations and variations with respect to phycobionts.

Pike (1973) emphasized importance of epiphytic lichens in mineral cycling. However, he failed to correlate the mineral levels with the minerals of respective barks which sustains the lichens.

Lawrey (1980) in the *Aanthoparmelia* sp. and other related lichens by careful monitoring showed that lichens have tendency to accumulate large quantity of Ca$^{++}$. Energy dispersive x-ray
Macro-analysis of lichen material revealed observable peak for Ca$^{++}$. Garty et al. (1979) could successfully demonstrated the localization of the metals in medullary regions using x-ray emission technique. Lawrey (1980) has recorded 242.3 $\mu g \ g^{-1}$ to 22,395.0 $\mu g \ g^{-1}$ of calcium in lichens collected from two different regions. Similarly he showed range of variation in Mg$^{++}$ accumulation from 631.2 $\mu g \ g^{-1}$ to 3862.5 $\mu g \ g^{-1}$. These variations clearly reflect not on the metabolic role of these elements in lichens for that cannot exhibit such wide range but on the tendency of tissue accumulation. Nevertheless protective role of Ca$^{++}$ in cell wall covering the nitrogenase from oxidation has been demonstrated through an elegant experiment on Nostoc linckia in culture condition by depleting cell wall calcium with the help of ethyleneglycol-bis(2-aminoethyl ether)-$N,N,N'$-tetra-acetic acid (EGTA) in light (Mishra et al. 1985). But the analytical data in the present investigation does not provide a base in the sense that amusingly cyanobacteria containing Leptogium has far more lower level of calcium in the thalli than in the non-gelatinous Parmelia. Based on these findings and findings of our own it is inferred that excessive calcium at least in this example is accumulative in nature and possibly derived from the bark. The fluctuation in the level of calcium as well as magnesium with respect to season is a reflection on the growth of lichens which is distinct between the two. In other words, Parmelia grows more rapidly in winter while Leptogium during rainy and summer seasons. In support of this observations is also level of potassium.
C. Aluminium ($\text{Al}^{3+}$) :

Aluminium levels in lichen thalli of the two representative species of two different genera *Leptogium* and *Parmelia* have great relevance to both geological strata as well as ecological conditions in which both epiphytes as well as the respective host are growing. Ranhala from which these lichens are collected is part of western Ghat ranges and is known for Bauxite. The analytical data of Aluminium from *Leptogium* and *Parmelia* thalli are given in Table 1. The Aluminium level is 210.8 and 320.8 mg 100$^{-1}$g dry wt respectively in the thalli of former and latter.

It should be remembered here that this analysis is made in the randomly sampled material after thorough washing and cleaning the thalli. However Aluminium level is relatively very less in gelatinous lichen than non-gelatinous ones. Surprisingly enough Aluminium level of the barks over which these lichens are growing are not as high as the values of the thalli (Table 3). The maximum level of $\text{Al}^{3+}$ in the bark is 162.45 mg 100$^{-1}$g dry wt. over which the *Leptogium* is growing and the minimum level is 23.00 mg 100$^{-1}$g dry wt. in the bark of one of the trees over which the *Parmelia* is growing. This makes very clear that the higher level of Aluminium in the thalli as analysed after thorough washing and it is not due to external deposition from the atmosphere nor due to trapping from the atmosphere superficially but is mainly accumulated in the thallus of the lichens.
The highest level of aluminium hitherto reported is 940.7 ppm in *Cladina stellaris* (Puckett and Finegan 1930) a terricolous lichens of North Western territories of Canada. It is not known whether the area from which this lichen is collected is rich in aluminium. That means the accumulation of this unbiological metal is much higher in the present investigation than that has been reported in *Cladina* sps. As such we know aluminium is not a toxic substance and it can be accumulated in large quantity without any harmful effect to the plants. The tendency of accumulating this mineral has appeared to be mainly through atmosphere. In other words the lichen appear to be scavenging aluminium from the atmosphere.

If we see the seasonal fluctuation of aluminium in *Leptogium* and *Parmelia* we find unlike that of Ca it is lowest during rainy season and the level goes on increasing from fall to spring. This situation is parallel in both the type of lichens *Parmelia* and *Leptogium*. The highest level of aluminium can be seen in *Leptogium* during summer which is 1188.0 mg 100-1g dry wt. and 524.3 mg 100-1g dry wt. in *Parmelia* during the same season. In contrast to this parallel increase in the level of aluminium has been higher in *Leptogium* than in *Parmelia* (Table 2). These observations mainly strike at two things.

1. The tendency of accumulation is possibly due to the increasing atmospheric concentration of aluminium with the season changing from monsoon to summer, so that there is greater accumulation during summer season.
2. It also strikes at unbiological role of Aluminium in these organisms so that its seasonal fluctuation is not inkeeping with that of other essential major elements such as calcium and potassium.

D. Iron (Fe):

This element though belongs to minor group in the sense that it is a trace element, its requirement in any biological system is indispensable. The analytical data in the randomly sampled Leptogium and Parmelia given in Table 1 indicate that the former accumulates or requires in a very large quantity for it is 975.6 mg 100^-1 g dry wt. while it is only 297.0 mg 100^-1 g dry wt. in the latter. In other words tendency of accumulating iron is more in Leptogium than in Parmelia, the nongelatinous lichen. If we examine the level of iron in the bark (Table 3) sustaining these lichens we can clearly see that there is no wide fluctuation in the level between the two despite that Parmelia is growing on distinctly two different types of plants. However, considering the point that iron is a trace element, the level in the bark itself is sufficiently high. Under the light of this if we evaluate the iron value in randomly sampled and prewashed Parmelia (Table 1) it is definitely higher and reflect on the tendency of accumulation in the tissue and not simple external deposition as could be seen in many other cases. The maximum detectable amount of iron as analysed from ash is 78000 ppm (Lounamaa 1965) and 16000 ppm, expressed on dry wt. basis (Lambinon et al 1964) from the nonspecific lichens.
However, as reported by Puckett and Finegan (1980) the range in two Cetraria sps. is 257-478 ppm and in Cladina stellaris it is highest (568.7 ppm). It should be borne in mind that these lichens are terricolous types and their analytical data is not evaluated under the light of their substratum content. Nevertheless it reflects the iron accumulating tendency of these lichens.

Our analytical data reflecting the seasonal variation in these gelatinous and non-gelatinous lichens given in the Table 2 clearly indicates the parallel tendency in both these types i.e. the level increases from rainy season to winter to summer both in Leptogium and Parmelia. Iron level of the thallus in summer is almost doubled than that of the rainy. However, the two genera exhibit the geometric difference in the level i.e. Leptogium has much higher level which is almost double in all the three seasons compared with those values of respective seasons in Parmelia. There is no necessity to emphasize here nor it is necessary to contend these in such a high amount in the thallus irrespective of the season is essential for lichen metabolism. It is amply known that there are a few plants, if any, which require iron more than 100 ppm (Epstein 1965). On the contrary excessive iron in the tissue is more harmful than the level which is below the optimum requirement.
Tomassini et al. (1976) who screened iron level in 21 different species of lichens with 63 samples have recorded range of variation 160 ± 90 ppm. They recorded however, 1330 ± 460 ppm of iron as average value observed for Peltigera aphthosa collected from specific regions. They attributed this high level of iron accumulation in this species, to the high concentration of the element in metal polluted area where this lichen is growing. In other words they concluded that the lichens absorb iron even from the atmosphere. As such it is known that the metal iron uptake capacities of lichens depends upon the availability of cell wall anionic functional group (Tuominen and Jaakkola 1973, Grace 1976). Now it becomes clear that high level of iron in Leptogium, that we have seen (Table 1) even after thorough washing and analysing the thalli is neither that is accumulated in the gelatinous substance of the associated phycobiont nor, as a part of surface deposition but it is partly absorbed by the thallus through the process explained earlier and relatively higher level in this cyanobacteria containing lichen is a reflection of two things: (1) The possible availability of cell wall anion functional group in higher proportion, (2) The phycobiont is a cyanobacteria which has inherent ability to fix nitrogen and the nitrogen is a metaloprotein and iron is a major metal found in it. The seasonal variation studied (Table 2) has clearly reflected that inherently Leptogium has ability to accumulate much higher level of iron. This also raises immediate question where such a high level of iron comes.
from the substratum. The former possibility is more probable because the substratum does not show greater fluctuation in the level. As the geological strata is rich in aluminium bauxite so also in ferromanganese and hence there is a reason to believe that it comes from atmosphere in the greater proportion.

E. Manganese (Mn)

Manganese, another important cation belonging to the trace element group similar to that of iron has antagonistic relation with the latter. Its requirement for the organism is always in a very small quantity. The analytical data presented in (Table 1) which is based on after thoroughly washing the thalli clearly reflects that basically it is in a very small quantity in the tissue. However, the gelatinous lichen Leptogium shows relatively three-fold higher level of iron than that of the non-gelatinous lichen. Although it is not immediately possible to relate its level with any metabolic role we can very well compare with the substratum.

Mn values for the bark sustaining Leptogium and Parmelia reflect that there exists some amount of parallelism between that in the thallus and the bark. The Mn value of the bark over which the Leptogium grows is 10.33 mg 100^-1 g dry wt. which is higher than that in those two different types of barks over which the Parmelia grows.
Puckett and Finegan (1930) have recorded as low as $13.2 \pm 22.23$ ppm in \textit{Cladina} species and as high as $34.5 \pm 86.0$ ppm in \textit{Cetraria} species. These lichens are terricolous type and appear to be absorbing more manganese. There are certain reports where wide range of variation in the manganese level is as high as 2.5 to 27.0 ppm (Podkorytov 1967a). This reflects that true to its sense even in trace quantity it is adequate for normal metabolism of the plant. As such its requirement has been much lower than that of iron.

The seasonal variation in the level of manganese is given in the Table 2. At the outset what is striking is \textit{Leptogium} exhibiting higher level of manganese irrespective of the seasons. However, in the non-gelatinous \textit{Parmelia} its requirement or the accumulation rate appears to be low. Moreover in the two types there appears to be no parallelism between the levels of the element accumulated seasonwise. Nevertheless maximum accumulation in both these organism could be seen during the summer season. In \textit{Leptogium} both in the rainy as well as winter seasons the values are on par and in summer the level has gone up which is more than twice as high as that of \textit{Parmelia} of the same season. In the latter however, accumulation of manganese in the tissue appears to be gradually increasing from rainy season to winter to summer. In other words in these two distinct representative of the genera \textit{Leptogium} and \textit{Parmelia} similar to that of iron, manganese level also increases during summer. This tendency is more or less parallel with the level of many other minerals.
F. Copper (Cu²⁺) :

Copper is an essential element though its requirement is in trace quantity. Its role in photosynthetic electron transport need not be emphasized here. Our analytical data of Copper in Leptogium and Parmelia thalli after thoroughly washing is given in Table 1. It can be clearly seen that its requirement is in trace quantity and there is no sign of accumulation. Nonetheless the gelatinous lichen Leptogium has four times higher Copper level which is 4.52 mg 10⁻¹ g dry wt. while in Treuboxia containing Parmelia has only 1.45 mg 10⁻¹ g dry wt. Although the proportion of the difference in the two is wide, it is within a small geometry. These levels of Copper in the tissue have to be evaluated under the light of elemental level of bark over which the lichens are growing. In this respect we do not find greater difference between the level of barks, no matter how widely these types differ. One thing is true that the elemental level in the lichen tissue has always been higher than that of the source is a reflection of lichen tendency to pick up the element possibly from the atmosphere.

The reports available so far reveal that in general Copper level of the tissue is low. Puckett and Fingan (1980) have estimated copper from representative genera from more than 20 different sites in Canadian North-west territories of Canada but did not find more than 8.5 ± 4.7 ppm of Copper. Now these lichens are sustained on rocks. On the other hand analytical
data of Copper level in arctic lichens reported by Tomassini et al. (1976) records as high as 480 ppm in the thallus. According to them this is an indication of wide departure in different specimen. Now such a high level of Copper is nothing but a simple reflection of tissue accumulation and it no longer warrants that it is required for metabolism of the lichen. Whatever may be the nature of lichen, above certain threshold level element like Copper have always been toxic. Puckett (1976) could clearly demonstrate that Copper and Mercury were very toxic to Usnea and Hamelina sp. as measured by depressed respiration. There are also reports on the metal toxicity on lichens where photosynthetic membrane integrity and overall growth has been shown to be reduced (Nash 1975). Mathur and Sanderson (1930) showed that high Copper level of the substratum has been shown to be negatively correlated with lichenase enzyme. This is suggestive of Copper toxicity affecting the enzymatic machinery of the organism.

Tomassini and his associates based on the metal analysis in wide range of saxicolous and terricolous lichens observed that certain species of saxicolous lichens have tendency to accumulate large quantity of metal such as Copper, Iron and Nickel while terricolous species accumulate sulphur. They noticed on the other hand that the arctic lichens exhibited high sulphur levels independent of collection site and they were also found to have relatively high concentration of Nickel and Copper. Based on their study they
concluded that higher concentration of elements found in some lichen is a reflection of the efficiency of these lichens in absorbing elements from the substratum and this observation might be useful in geobotanical studies. Nevertheless some lichens serve as monitor of atmospheric pollution. Now, our analytical data given in Table 1 and 3 clearly reflect that neither the substratum nor the lichens have high level of Copper and as such the area from which these lichens are collected are free from pollution and moreover there is very little data available on corticolous lichens (on bark).

To examine whether there is any seasonal fluctuation in this elemental level and also to know is there any bearing with the phycobiont association, we have analysed Copper in Leptogium and Parmelia thalli seasonwise and presented in Table 2. We do not find any wide range of variation of Parmelia from rainy to winter to summer. However, in Leptogium we do find slight appreciation during summer and rainy season but this does not make any significance. However, we would like to correlate the higher level of Copper in the tissue of Leptogium more with the phycobiont that it has, rather than any other factor. We have reason to argue because there are reports where Copper increased spectral changes in range of lichen algae. It has been shown among lichens, containing the alga Trebouxia, however, that the chlorophyll reaction to this metal is to be inconsistent (Puckett 1976). This makes clear that for obvious reason in
Parmelia the Copper level is low, for the phycobiont in this lichen is also Trebouxia (green alga). Due to lack of study on seasonal variation in corticolous lichens the present study opens a new dimension to the lichen physiology.

G. Zinc (Zn):

Zinc is also an essential element required for the growth of the organism in traces. This essential element is estimated from the washed and thoroughly cleaned thalli, of randomly sampled Leptogium and Parmelia. The results given in the Table 1 clearly exhibits that gelatinous lichen Leptogium has one-fold higher level of Zinc which is 23.27 mg 100⁻¹ g dry wt. while it is only 13.92 mg 100⁻¹ g dry wt. in Parmelia. No doubt relative to the level of Copper these values are very high. But when we examine the level of Zinc in the respective barks we find there is no appreciable difference between those of Leptogium and Parmelia either due to atmospheric absorption or due to the tendency of tissue accumulation by continuous efflux from the bark.

The seasonal variation in the level of Zinc is given in the Table 2. It is clear from the table that as in the case of many other essential elements so also here there has been higher level of Zn in Leptogium compared with that of Parmelia. And more over the two types are marked by the difference that, in the former level of the element is higher during rainy and summer season while it is during winter in the latter. Such consistent difference is the reflection of difference in growth pattern of the two.
Puckett and Fingan (1981) in their comparative study of minerals constituents in two different saxicolous genera recorded highest level of Zinc in Cetraria which is 25.0 ± 15. This is consistent with collection from 38 different sites. Of course there are records to show that as high as 93400 ppm (expressed on dry wt. basis) of Zinc could be stored by the thalli of lichen (Lambinon et al. 1964). This is a reflection of a metal accumulation in the lichen thalli. Wealth of information is available on the toxic and deleterious effect of heavy metal on various metabolic events. Zinc in this respect is one of those heavy metals which is known to cause purging off of important essential element such as potassium (Puckett 1974, Tomassini et al. 1976).

Lawrey (1980) with a view to study mineral cycling process in lichens and to correlate the level of minerals with their environment and also to study role of lichen herbivory in mineral transfer estimated number of minerals. They showed that there is considerable variation in the level of zinc relative to environment. Such studies clearly reflect on many factors involved directly or indirectly in the accumulation of the minerals in the lichen thallus. As such Zinc is also an essential element for the growth of the fungi because of its involvement in amino acid metabolism. Lack of wide variation as per the season or relative to the bark in the present investigation is the reflection of more or less clean environment and the level of Zinc in these lichens appear to be quite optimum.
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H. Cobalt (Co) and Molybdenum (Mo):

These elements also belong to trace element group. In many cases they are in undetectable quantity even with atomic absorption spectroscopic method. Nevertheless their requirement is mainly confined to specific enzyme activities. Our analysis of randomly sampled and thoroughly cleaned thalli of Leptogium and Parmelia do show the presence of Cobalt in trace but molybdenum is not detectable at all. Cobalt level in Leptogium is more than that in Parmelia. The analysis of these elements in the bark has also been done but could not detect in the sources. Similarly even samples collected from the specific regions for seasonal variation study also gave negative results. The reason as to why cobalt is detectable in randomly sampled material is possibly due to some host barks contained in trace, which are being absorbed by the lichens. But the atmosphere in which Parmelia and Leptogium are growing is free from trace of these elements. Most of the available literature clearly indicate that these elements could not be detected (Puckett and Fingan 1980). Whatever that has been detected is mainly attributed to unbiological role (Puckett 1976, Tuominen and Jaakkola 1973).

Brown (1976) in his critical study on mineral uptake by lichens evaluated the relative affinity of the lichen for different cations. According to him the Cobalt has least affinity of binding and he observed that it is independent of concentration. This observation makes clear that Cobalt like many other
unbiological elements are also not much required for lichen metabolism and growth. What is perplexing is role of Cobalt and Molybdenum in many metabolic events is well illustrated. For example molybdenum is a metal ion component of nitrate reductase in both eukaryotic as well as prokaryotic organisms. The structural organization of nitrogenase enzyme of blue green algae has clearly shown the Molybdenum involvement. The protein sub-unit has Fe-Mo complex. In one of the genera Leptogium cyanobacteria is a symbiont. It is also known that lichens are able to fix nitrogen (Millbank 1976) and these lichens have invariably cyanobacteria in them.

Non detectability of Molybdenum is not only in our study but also in many others (Puckett and Finegan 1980, Jaakkola 1973). This raises a question that whether in the nitrogenase enzyme of lichen, Mo is replaced by some other element or differ in its structural organization. A careful examination of lichen phycobiont especially cyanobacteria in the isolated condition under culture form for nitrogenase should make the picture clear. As such Leptogium phycobiont is Nostoc which has extensively been studied for its activity to fix nitrogen and also for the structural component of the nitrogenase enzyme, which is known to contain Fe-Mo complex. Even the heterocyst of the Nostoc phycobiont of the lichen is detectable and there is no necessity to reiterate here that heterocyst is the site where atmospheric nitrogen is being reduced. Such organism whether undergoes some
sort of transformation with respect to nitrogenase enzyme without losing its ability to fix nitrogen even when Molybdenum is missing. Alternatively it can also be speculated that Molybdenum is replaced by some other equally active element.

I. Strontium (Sr):

Strontium is considered to be one of the unbiological metal elements of lichen (Tuominen and Jaakkola 1973). Although we did not estimate Strontium in randomly sampled material the analytical data of the barks over which Leptogium and Parmelia are growing reflect on the accumulation of this divalent cations in large quantity. In Leptogium sustaining bark, for instance it is 47.4 mg 100⁻¹ g dry wt. while it ranges from 18 to 28.68 mg 100⁻¹ g dry wt. in the two different barks over which Parmelia grows. In other words the substratum of the Leptogium has relatively very high quantity of this element. If we examine the seasonal fluctuation in the Leptogium and Parmelia thalli, we find that there has been higher level in Leptogium than in Parmelia. Nevertheless Parmelia has maximum Strontium during winter which is 29.23 mg 100⁻¹ g dry wt. while it is 18.8 mg 100⁻¹ g dry wt. in Leptogium during same season. The Strontium level of Parmelia during winter somehow coincides with that of bark over which it grows. We do not want to attach any special significance to such a coincidence but to surmise that in most of the thalli Strontium is coming from or in
other words derived from the respective bark. We have justification to believe that because of clean environment in which these two genera are growing, there is remote chance it is being absorbed from the atmosphere.

Whatever study that have been carried out on Strontium level in lichen, by and large, is in connection with cation exchange. Burton et al. (1981) demonstrated in one of such studies that there was a stoichiometric exchange of Nickel for Strontium and Copper for Strontium. Such studies only project light on the elemental interaction and their uptake by the lichens. We are not in the position to explain here how excessive accumulation of this unbiological element Strontium occurs and what is given out in exchange. Most of the cationic exchanges are between unbiological elements only.

This cation exchange study has clearly shown that it is not accompanied by any Potassium loss. But they agree with the observation made by Nieboer et al. (1979), that such accumulation is important in modifying the effect of pollutants. As we have already discussed earlier, the area from where these samples are collected, is free from any atmospheric pollution but still these distinct genera exhibit accumulation of Strontium in relatively large quantity. We take the liberty to argue here that either these types possess inherent potentiality to accumulate metal or Strontium has some unknown role to play in metabolism. Alternatively geological strata of the soil is
rich in Strontium which is being absorbed by the host plant and eluted through bark.

Earlier reports of Strontium analysis of lichens show that as high as 5000 ppm of Strontium in 100 g of ash (Le Roy and Koksoy 1962). This is nothing but accumulation, may be from the source or from the atmosphere. High level of the Strontium is definitely to be toxic even to the lichen.

J. Lead (Pb) :

Lead is another heavy metal which is almost invariably known to be accumulating in lichen tissue. There are number of reports extensively contemplated the effect of the Lead on various physiological activities of lichen more about the toxic effect (Brown 1976, Lawrey and Hale 1981, Puckett 1976, Lawrey 1980). Our analysis of Lead from randomly sampled and washed thalli of Leptogium and Parmelia could detect Lead 1.97 and 1.88 mg 100^-1 g dry wt, respectively. However, Lawary and Hale (1981) analysed Lead in three different genera of lichens growing in different areas both after washing and without washing and showed wide range of variation between these two as well as samples of two different localities. For example in Pseudoparmelia baltimoransis collected from Plummulor island as high as 1893.5 ± 342.2 µg g^-1 prior to washing has been reported which is shown to be reducing to 914.0 ± 12.0 µg g^-1 after washing. Similarly when the same species was collected from Bear island the Lead level of the tissue is shown to be
273.0 ± 50.6 µg g⁻¹ prior to washing which is reduced to 191.5 ± 35 µg g⁻¹ after washing. Even in other genera such differences could be recorded. Such variation clearly indicates two things (1) there is tendency of metal trapping by lichen from the atmosphere and also incorporation of the elements by the thallus tissue. They correlated such a wide difference in the level of lead in these lichens from two different region with the atmospheric pollution such as atomobile exhaust or dust or soil from mines. Although we find no greater loss in Lead from the tissue after washing, for there is no greater difference between washed and unwashed samples taken for seasonal variation study. The level of Lead in the tissue is not as high as that of any of the previously reported studies. On the contrary the Lead level of the bark is relatively higher (Table 3). Bark over which Leptogium grown show 2.58 mg 100⁻¹ g dry wt. while Parmelia exhibits 1.1 mg 100⁻¹ g dry wt.

The seasonal variations in Lead level also do not show the greater differences. In Parmelia there is slightly higher value during winter while in Leptogium values go on increasing from rainy to winter to summer respectively. The analytical data in two species of Parmelia has showed as high as 200 µg g⁻¹ dry tissue of Lead in washed sample (Saeki et al. 1975, Erdman and Gough 1977). However, Puckett and Finegan (1980) have recorded 4.2 and 5.6 ppm respectively in Cladina and
sp. which appears to be very low value. It is noteworthy to mention here that not only in our own study but in many other reports Lead, although considered to be essential element in lichen, is not traceable. Such situation can only be attributed to greater affinity of lichen for Lead. The binding efficiency study of Brown (1976) has showed that Lead has a highest binding efficiency as compared with Copper, Nickel, Zinc and Cobalt. Now such affinity possibly leads to either from surrounding atmosphere or from the substratum. This affinity no longer warrants that Lead has any physiological role to play in the positive sense of the term. The study of the effect of heavy metal on photosynthetic $^{14}$C-fixation by Puckett (1976) has clearly showed that greater is the binding affinity greater is the toxicity of these metals to photosynthesis. He also showed that Lead impaired $^{14}$C fixation but did not modify the chlorophyll spectrum. Our analytical data reveals that there is no accumulation or entrapment of Lead to a level so as to cause toxicity. This reflects that possibly it does not appear to cause any inhibition of photosynthesis.

K. Lithium (Li) and Rubidium (Rb):

Lithium and Rubidium are also belonging to the heavy metals having unbiological role. That means whatever we have detected are mainly accumulations by some means. In randomly collected and washed Leptocium and Parmelia samples Lithium could not be
traced, and Rubidium has not been determined. However, the analysis of bark sustaining Leptogium and Parmelia do show the presence of these elements. Although Lithium could not be detected in one of the barks sustaining Parmelia, the level of Lithium is in trace, but that of Rubidium is relatively high. It ranges from 0.87 to 1.03 mg 100^-1 g dry wt. On the other hand Rubidium level determined in Leptogium and Parmelia to study the seasonal variation reflect that it is relatively much higher. In Leptogium during rainy winter and summer Rubidium level is 3.03, 6.03 and 4.78 mg 100^-1 g dry wt. respectively. Similarly in Parmelia during these three seasons it is respectively 2.28, 3.40 and 3.2 mg 100^-1 dry wt. No doubt the tendency to accumulate more Rubidium during winter appears to be common in both Leptogium and Parmelia. But it should be borne in mind here that it is in washed sample. Similar tendency of fluctuation can also be noticed with respect to Lithium. However, the lithium, relative to that of Rubidium is much lower. Reports available in literature shows as high as 24.6 ppm of Rubidium expressed on dry wt. basis (Bertrand and Bertrand 1947). And the Lithium level has been in the order of 0.02 to 0.29 ppm on dry wt. basis.

These elements which do not have any biological role can only be attributed to have come from natural atmosphere though automobile exhaust which are being trapped by the lichens or absorbed by ion exchange from the bark of the supporting plant.
The accumulation of such unessential elements is only a reflection of lichen affinity for metal accumulation.

L. Nickel (Ni), Barrium (Ba), Boron (B), Berellium (Be), Ceasium(Cs), Germanium (Ge), Gold (Au), Cadmium (Cd), Vanadium (V), Titanium(T) and Zirconium (Zr):

Since lichens are known to accumulate or entrap large number of heavy metals from the atmosphere, these metals have also been analysed from our lichen material. However, almost all of these elements were below the detectability of atomic absorption spectrometer. As a matter of fact Nickel and Boron are belonging to trace elements group, and they are considered as essential elements for the growth and metabolism of higher plants. Their non-detectability here is a reflection of non-essentiality of these elements to the lichens under investigation.

This no longer leads us to conclude that these lichens totally lack the tendency to trap or accumulate these elements but it is possibly due to the clean atmosphere which does not tend to load lichens with a unessential toxic elements.
3 Organic Constituents
3. Organic Constituents:

Normal growth of the plant whether it has adapted to xeric habit, or is a parasite whether it is an epiphyte or a saprophyte, whether it is an autotroph or a heterotroph ultimately is dependent upon its ability to generate its own food or pool the resource. A heterotroph absorbs food from the host but an autotroph is able to produce its own food through photosynthesis. The situation in lichens is peculiar in the sense that it is a symbiotic association of an autotrophic and a heterotrophic organisms, where the fungal part derives its food from algae (Smith 1975). Nonetheless, algae multiplies to give more and more food to the mycobiont. In other words, the mycobiont in turn possibly gives essential nutrients which keeps algae growing. It is, therefore, interesting to know and examine the overall interaction between the symbionts and ultimately how the lichen grows. It is in this context we have analysed the organic constituents such as, different types of sugars, both reducing and nonreducing, polyphenols, proline and chlorophylls.

We wish to discuss here the level of each one of these organic constituents that has been estimated.
A) Sugars:

Soluble sugars both reducing and non-reducing and starch have been examined season wise in Parmelia and Leptogium thalli and presented in the Table 4. It is clear from the table that both Parmelia as well as Leptogium, though differed widely, have same tendency of variation with respect to the seasons. Maximum, both reducing, and non-reducing, sugars can be seen during winter, which is almost ten fold higher, Similarly even the maximum level of starch could be recorded during winter season. This reflects on the fact that both the lichens though they differ in their phycobiont component, have maximum growth during winter rather than summer season and rainy season. On the contrary, if we look into the level of reducing sugar, during summer season their growth appears to be drastically reduced. But the level of starch is not curtailed to such an extent. This leads us to speculate that because of reduced growth most of the soluble sugars are directly converted into starch, so that this stored food can be utilized during dry season to keep their life activities on.

If we compare these gelationus and non-gelatinous lichen taken for investigation, we find that the gelatinous Leptogium has relatively far lower level of reducing sugar and higher level of non-reducing sugar. Contrary to this is a situation
<table>
<thead>
<tr>
<th>Season</th>
<th>P. simplicior</th>
<th>L. azureum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rainy</td>
<td>Reducing sugars</td>
<td>2.0 x 10^-2</td>
</tr>
<tr>
<td></td>
<td>Non-reducing sugars</td>
<td>1.6 x 10^-1</td>
</tr>
<tr>
<td>Winter</td>
<td>Reducing sugars</td>
<td>0.064</td>
</tr>
<tr>
<td></td>
<td>Non-reducing sugars</td>
<td>0.058</td>
</tr>
<tr>
<td>Summer</td>
<td>Reducing sugars</td>
<td>0.065</td>
</tr>
<tr>
<td></td>
<td>Non-reducing sugars</td>
<td>0.075</td>
</tr>
</tbody>
</table>

Values expressed are in g/100 g dry wt.
in Parmelia a non-gelatinous lichen where the level of reducing sugar is relatively higher than that in Leptogium and non-reducing sugar is lower. This no way leads to argue against the accepted fact that both these genera have maximum growth in early winter. Especially in Parmelia the starch level is significantly lower in other seasons than in winter. Whereas in Leptogium levels of starch both in rainy and summer seasons are on par.

Hale (1967) while discussing growth and longevity emphasized on seasonal variation study and reported that there is measurable growth from late summer through the winter. Such growth could be attributed to the preceeding precipitation rather than temperature. Our conjecture is that, in this tropical types there is maximum sugar in winter; and it is supported by even the mineral uptake, especially potassium and calcium. Smith (1975) through an experiment of wetting and air dry in lichens demonstrated that substantial loss of both inorganic and organic substances occurs from the thallus and it takes significant time to re-establish. He ruled out the possibility that such thing would occur in nature because the rain pattern would be soft and water drops fall more slowly. We feel that this may be the situation in the temperate region. But in the tropics especially in regions such as Panhala where rains are torrential during monsoon there is every likely hood of the minerals being drained.
Extensive work is published on the carbohydrate types mobilized or transferred from the phycobiont system to mycobiont with the help of labelled carbon (Richardson 1968, Hill 1976, Smith et al. 1969). There is more or less common agreement in these workers that, the types of sugar being transferred from the autotroph distinctly differed with the type of phycobiont, whether it is cyanobacteria or green algae. Under the light of this if we examine our results we find that in gelatinous lichen *Lentogium* where the phycobiont is blue green algae the level of reducing sugar is very low while the non-reducing sugar is relatively very high. This is possibly because in these types the major carbohydrate that is being transferred is glucose whereas in *Parmelia* containing green algae it is not.

According to Hill (1976) *Parmelia saxatilis* the carbohydrate that is transferred is ribitol. This sugar though a hexose structurally dissimilar with the glucose in the sense that, is a five carbon compound. We believe that the low level of reducing sugar of the *Lentogium* is due to direct assimilation of glucose, produced during photosynthesis by mycobiont. Whereas in case of *Parmelia* there is a time lag between photosynthetic production of glucose and its subsequent conversion of ribitol, for, as yet we do not know an autotrophic organism, where the primary sugar is other than glucose. We therefore, feel, whatever reducing sugar that is accountable is a transitory.
Higher level of non-reducing sugar in *Leptogium* is possibly due to rapid conversion of glucose into it. Whereas in case of *Parmelia* mostly it goes into hydrolyzable carbohydrate. Picture will be more clear when we study the photosynthesis.

B) *Nitrogen*:

There is no need to emphasize here that nitrogen is an indispensable element required for photosynthesis of alga and growth of the fungus. It is more pertinent to *Leptogium* because it contains blue green alga the *Nostoc*. Our analysis of nitrogen from these material is given in the table 5. It is clear from the table that *Parmelia* has 2.37% and *Leptogium* has 3.7% nitrogen expressed on dry wt. basis. This reflects that *Leptogium* which contains gelatinous alga has one and half times higher amount of nitrogen that *Parmelia*.

Smith (1962) reports 3.62 to 4.5% nitrogen from *Peltigera polydectala*. According to Huneck (1973) protein content of lichens varied from 1.6 and 11.4% of dry wt. but could go as high as 20%. If we compare our analytical data of nitrogen to protein we find it falls well within the range. Nonetheless *Leptogium* has higher nitrogen than *Parmelia*. We feel that the possible reason to this is *Leptogium* has blue green algae and hence it is able to
Table 5. Nitrogen and proline content of lichen thallus.

<table>
<thead>
<tr>
<th>Plant material</th>
<th>Moisture (%)</th>
<th>Nitrogen*</th>
<th>Proline*</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. simplicior</td>
<td>5.43</td>
<td>2.34</td>
<td>4.12</td>
</tr>
<tr>
<td>L. azureum</td>
<td>7.11</td>
<td>3.7</td>
<td>125.4</td>
</tr>
</tbody>
</table>

* g 100^-1 dry wt.

* mg 100^-1 dry wt.
fix nitrogen; whereas Parmelia which has green alga as a phycobiont has to derive its nitrogen from substratum (Cooke 1977). There is no need to substantiate the evidences that blue green algae (especially Nostoc) containing lichens are able to fix nitrogen. As early as in 1955, by Bond and Scott using labelled nitrogen demonstrated nitrogen fixation ability of the lichens. Subsequent to that, Katanebe and Kiyohara (1963) with Poltigera virensens could show the mechanism. Since then a large number of workers have investigated lichens for N fixation by means of $^{15}$N labelling technique. Now it is a proven fact that most blue green algae containing lichen are able to harness atmospheric nitrogen for their metabolism. We have, therefore, reason to believe and feel justified that Lomentium has higher level of nitrogen than that of Parmelia.

C) Proline:

This metabolite is much talked of in higher plants facing extreme environmental conditions such as water stress and in many cases even under salt stress. Although the mechanism by which proline gives protection to the cell under such condition is not thoroughly understood, by and large, it is considered that proline level is an index of the environment that an organism is facing. We thought it will be interesting to know the level of proline in lichens
which are typical examples of taxa facing extreme environment. Our analysis of proline from the dry sample of Parmelia and Leptogium given in table 5 clearly indicates that two genera differed widely in the level of proline. Since we have not examined large number of species in these two genera, we do not wish to generalise the observation, but confined to the types observed here. As could be seen from the table 5 Parmelia has 4.12 mg/100 g dry wt. proline while it is 125.4 mg/100 g dry wt. in Leptogium. As such in Parmelia Trebouxiella (green alga) as a phycobiont while in Leptogium it is nostoc (blue green alga).

So far as occurrence of this amino acid is concerned no doubt it is one of the amino acids found in protein of the most organisms, so also in lichens. The synthesis of proline is mainly through glutamate which is the first dicarboxylic amino acid formed after amination of \( \alpha \)-keto-glutarate during nitrogen assimilation. With the help of \( ^{14} \text{C} \)-glutamate de novo synthesis of proline from glutamate in plants under stress, has been amply demonstrated by Stewart and his co-workers (1980). High level of proline in Leptogium obviously becomes a sequence in nitrogen fixation by this blue green algae containing lichen rather than an indicator of the extent of physical stress that this organism is undergoing. Paradoxically there
are examples of lichen such as *Sarcogynae similis* a green alga containing lichen which has been shown to be grown best on medium containing proline. However, he further showed that there is no generalization of this observation for most amino acids gave satisfactory results and the lichens not withstanding the type of phycobiont that they carried, responded in different ways to different amino acids. We, therefore, feel safer to argue here that manifold higher level of proline in *Lentogium* is not an indication of its ability to withstand drought, for both these lichens are growing more or less in identical environmental conditions, but is a corollary to the nitrogen fixation ability of *Lentogium*. As such there is little information available about the types of protein depending upon the types of phycobiont because related lichens have more proline, asparagine and glutamine whose precursor is glutamic acid.

As such hydrolysis of lichen product such as picrorocellin and cyclic tetrapeptide has been shown to yield L. Proline and D-f-amino-β phenylpropionic acid (Huneck 1973). However, this cannot be correlated with the phycobiont types in it. Analysis of large number of lichens for this parameter, their classification may possibly project light over this.
D) Chlorophylls:

Chlorophyll pigments have not only great significance in autotrophic organisms but even in evolution of the very system of symbiotic organism such as lichen where autotrophs are algae and mostly they belong to green or blue green group. They provide photosynthetically produced food to growing mycobiont. In this respect amount of chlorophyll present in the algal system should reflect on overall efficiency of photosynthesis.

We have determined the chlorophylls in two genera Parmelia and Leptogium and presented in table 6. The Parmelia has 21.05 and 9.27 mg 100⁻¹ g fresh wt. chl a and b respectively and total chlorophyll value is 30.32 mg 100⁻¹ g fresh wt. Whereas in Leptogium there are 60.6, 12.07 and 72.67 mg 100⁻¹ g fresh wt. of chlorophyll a, b and total chlorophylls respectively. These values make clear that Leptogium though a blue green algae containing lichen has almost three times higher chlorophyll a value over that of Parmelia with the total chlorophyll being more than double that of Parmelia. This appreciable higher value of chlorophyll appears to have great influence on overall growth, photosynthesis and productivity. The appreciation is not only with respect to chlorophyll level but also in chlorophyll a/b ratio. In Parmelia chlorophyll
Table 6. Chlorophyll and polyphenol content of lichen thallus.

<table>
<thead>
<tr>
<th>Plant material</th>
<th>Chl. a</th>
<th>Chl. b</th>
<th>Chl. a/b</th>
<th>Total chlorophylls</th>
<th>Polyphenols*</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>P. simplicior</em></td>
<td>21.05</td>
<td>9.27</td>
<td>2.27</td>
<td>30.32</td>
<td>1005.0</td>
</tr>
<tr>
<td><em>L. azureum</em></td>
<td>60.6</td>
<td>12.07</td>
<td>5.02</td>
<td>72.67</td>
<td>465.0</td>
</tr>
</tbody>
</table>

Values expressed are in mg 100^-1 g fresh wt.
*  mg 100^-1 g dry wt.
a/b ratio is 2.27 whereas in Leptogium it is as high as 5.02. Such difference is mainly due to the fact that there is no significant difference between Parmelia and Leptogium so far as chlorophyll b is concerned. It is noteworthy to mention here that 3 times higher level of chlorophyll in Leptogium over Parmelia is a reflection of high photochemical energy flow through Photosystem II.

The relatively lower level of chlorophyll in Parmelia has a great bearing with the nature of phycobiont associated with it. It need not be mentioned here that most green algae containing lichens have Trebouxia as phycobiont. Hill (1976) has correlated growth of lichen with growth of phycobiont because he found that growth of symbiont in culture has positive correlation with carbohydrate released by the phycobiont alga. Studies on the culture and physiology of Trebouxia by Fox (1967) could demonstrate that this alga could fix $^{14}$CO$_2$ almost as rapidly as a strain of free living Chlorella. But still Trebouxia grew at a very low rate relative to Chlorella. He attributed this phenomenon to the difference in chlorophyll content.

Richardson (1973) while examining the photosynthetic product of lichen alga observed that the pigment systems are unusual as they form chlorophyll in complete darkness.
and are very sensitive to strong light. This observation is made mainly in *Trebouxia* containing lichens, where they further noticed that some strains of *Trebouxia* at light intensity about 2000 to 5000 lux would bleach irreversibly. Finally these algae shows a progressive change in photosynthetic pattern after isolation from the thallus.

It becomes now clear that *Parmelia* has lower chlorophyll level and possibly slow rate of growth is due to both quantitative as well as qualitative difference in the chlorophyll system. It will not be out of context to attribute high level of chlorophyll in *Leptogium* to high rate of photosynthesis which leads to high rate of carbon skeleton generation required for harnessing the reduced nitrogen that has been entering through nitrogen fixation mechanism of the phycobiont *Nostoc*. As such there is no report of pigment bleaching under sun in blue green algae. However, in addition to chlorophyll blue green algae known to contain large number of accessory pigments such as carotinoids and anthophyll etc. And carotinoids are known to exert a protective effect on the green pigment. (Nichols 1973). This may be one of the possible reasons as to why pigment bleaching does not occur in *cyanobacteria* of lichens.
E) Polyphenols:

The role of polyphenols is almost enigmatic in plant systems. Nonetheless, it is correlated with many aspects of metabolic systems such as disease resistant or and under conditions of extreme environment. However, there is little, if any, study on polyphenols in lichens. Our analytical data in Parmelia and Leptogium presented in the table 6 clearly indicate that polyphenols are in large quantity even in the lichens. In Parmelia we find as high as 1005 mg 100\(^{-1}\) g dry wt. and in Leptogium 465 mg 100\(^{-1}\) g dry wt.

Large number of lichen substances have been analysed and reported (Huneck 1973). Even their biosynthesis has been studied (Klaus and Mosbach 1973). Most compounds found are cyclic. Large number of compounds belonging to schikimate such as terpinine, quinones, diketopiperanthans and pulvic acid derivatives have been reported. The fact that schikimic acid pathway is known, possibly even polyphenols are also known. Since lichens are in general adapt to xeric habit, classification as saxicolous, terricolous, corticolous etc. are relative terminologies. However, we can safely take lichens as highly drought tolerant plants. The role of polyphenols in this respect is very well known and, therefore, we feel such a high level of polyphenols found in lichens of the present investigation has a reason to occur.