THE TRENTEPOHLIACEAE OF SINGAPORE ISLAND

by

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INTRODUCTION

The Trentepohliaceae are a family of aerial algae, abundant in the tropics but also found in temperate regions. They grow on rocks, soil, the bark of trees, or as epiphytes or parasites of leaves. The vegetative cells may appear green if the plant is growing in the shade but they are normally brick-red in colour due to a pigment, formerly known as "haematochrome," which is a mixture of α and β carotenes (Tischer, 1936; Czyan & Kalb, 1960) dissolved in oil droplets in the cell. Pyrenoids are absent and starch is not formed, the product of photosynthesis being apparently a polyhydric alcohol, erythritol, (Bourne, 1958) which may occur in *Trentepohlia* in up to 1.4% concentration (Tischer, 1936). As in other terrestrial algae, large vacuoles containing water are absent.

EARLY TAXONOMIC WORK

The earliest recognisable member of this family, *Byssus Jolithus*, was described by Schwenckfelt in 1600 as "Jolithus f. Lapis violaceus" — i.e. Jolithus variety violet stone. In Species Plantarum, 1753, Linneaus included a mixture of blue-green algae and fungi in the genus *Byssus*, including Michelius' *Aspergillus* and *Botrytis*. However two of the twelve Linnean species of *Byssus* may now be placed in the genus *Trentepohlia*. These are:- (i) *Trentepohlia aurea* which Linneaus placed in the sub-genus Filamentosae and described as having golden or saffron-coloured filaments, growing on rocks and lacking a smell; and (ii) *Trentepohlia Jolithus* which he placed in the sub-genus Pulverulentae and described as blood-coloured, like wine, growing on rocks and with the smell of violets.

The genus *Trentepohlia* was defined by Martius in 1817. In 1824 C. Agardh divided this genus into (a) *Chroolepus* with rigid, solid, torulose filaments, having a powdery nature, and (b) *Trentepohlia* with flexible filaments, bearing sporangia at the ends of their branches. Species of *Trentepohlia* were described as purple, golden or verdigris coloured, while those of *Chroolepus* varied in colour including golden, blood-coloured, yellow-brown, reddish gold, greenish red, silky rose or black. *Chr. Jolithus* and *Chr. odoratus* were said to be perfumed, smelling of violets.

In 1849 Kützing put all species, except for a few doubtful ones, into the genus *Chroolepus* and reported an additional species *Chr. hercynicum* with the smell of violets. During the second half of the nineteenth century copious literature on *Trentepohlia* (*Chroolepus*) was concerned with the structure of the zoospores, the contents of the cell, the structure of the cell wall, sporangial forms and the part played in the constitution of lichens. This literature was reviewed by Karsten in 1891.

In 1870 Millardet (*fide* Engler et Prantl, 1897) described *Phycopeltis* as a new genus which he had found on the needles of *Abies pectinata.* It resemble *Coleochaete* in structure but contained the pigment "haematochrome." *Phycopeltis epiphyton* was also found on the leaves of *Hedera* and *Rubus* in Europe. These specimens were all epiphytic. In 1877 Cunningham found a pigmented parasitic species which he called *Mycoidea parasitica.* This new genus, *Mycoidea,* was found to be synonymous with De Toni's *Hansgirgia,* and later Hariot pointed out that the genus had been described by Kunze in 1827 as *Cephaleuros,* the names *Mycoidea* and *Hansgirgia* being superfluous.

The first account of the Trentepohliaceae of S.E. Asia was made by De Wildeman in 1891. This was a report on a collection made mainly in Java, Sumatra, New Guinea and Celebes by Mme. Weber van Bosse. De Wildeman stated that the previous taxonomic work on *Trentepohlia* based on the colour and odour of filaments had been defective since these properties depend on the circumstances of collection, surrounding vegetation and degree of desiccation. He divided the genus into (i) those with cylindrical cells, and (ii) those with oval, elliptical or round cells. In this work he stated that about 40 species of *Trentepohlia* are known, of which about a dozen occur in the East Indies including three endemic species. He placed all species in the genus *Trentepohlia* and within the two divisions of the genus based species definitions on width of cell, and position and type of sporangia.

Karsten (1891) described many new species of *Trentepohlia* for Java, as well as three new species of *Phycopeltis* and six new species of *Cephaleuros.* He also reported *Cephaleuros virescens* (*Mycoidea parasitica*) from Java. In his Prodomus (1897) and Supplement (1899) De Wildman listed 21 species of *Trentepohlia* from the East Indies together with an anomalous species, *Chroolepus* (non Agardh) *amboinensis.* This new concept of *Chroolepus* was defined by Karsten in 1891 as having a thallus like *Phycopeltis* with filaments like *Trentepohlia* arising from it.

By the beginning of this century the three genera *Trentepohlia, Phycopeltis* and *Cephaleuros* had been well-defined; *Chroolepus* Agardh had been dropped and the doubtful genus *Chroolepus* Karsten had been created. *Trentepohlia* was used for all species having free filaments, never forming a continuous thallus. *Phycopeltis* contained those species which had a flat thallus consisting of a single layer of cells, which was never parasitic and which might bear short upright filaments but never long hairs. In *Cephaleuros* the flat thallus had one to many layers of cells; it might be epiphytic or parasitic, and it bore elongated upright filaments terminating in pedicellate sporangia or forming long hairs.

In the genus *Trentepholia* emphasis was placed on the degree of heterotrichy. De Wildeman (1900) classified species into (a) those with reduced prostrate growth, (b) those with well-developed erect and prostrate systems, and (c) those with only a prostrate system of creeping filaments.

MODERN WORK

Modern work (Hariot and Printz, 1939) has divided *Trentepohlia* into three sections:- (i) *Chroolepus* (which according to Borrelly, 1966, would be better named *Trentepohlia* since it contains the type genus, *T. aurea*) which is not distinctly heterotrichous, and does not bear unicellular hairs.

(ii) *Heterothallus* with primary filaments forming a rosette like *Phycopeltis* but far less organised and regular, and bearing upright filaments like *Trentepohlia.* Karsten's anomalous *Chr. amboinensis* should be included here.

(iii) *Nylandera* in which the filaments bear cylindrical unicellular hairs as in *T. peruana* (Kütz.) Printz.

The genus *Phycopeltis* is normally divided into (i) *Phycopeltis* with a regular disc of radial filaments not bearing upright hairs, and (ii) *Hansgirgia* with irregular disc with marginal indentaton and lobes, sometimes bearing upright hairs.

Cephaleuros (including the monospecific *Chrooderma* Fristch, fide Borrelly, 1966) has about 12 species including some dangerous parasites of tea, coffee and other plants. Although keys normally separate epiphytic and parasitic species, and those with a single layered thallus from those with a multilayered thallus, no clear division of the genus has been proposed.

Stromatochroon is a new genus proposed by Palm in 1934. It consists of a swollen lobed structure found in the stomatal chamber of tropical plants from which a short filament emerges through the stomate. This filament may bear a sporangium. This monospecific genus has not been reported from S.E. Asia.

Akiyama, 1971, has reviewed the taxonomic criteria used at specific level in *Trentepohlia* which in the past has been based on cell shape and size; presence of hair-like cells; the branching pattern; cell-wall features; type of cell division; size, shape, type and location of sporangia etc. Size and shape of the cell varies with both climate and season, as does the length of hair-like cells in the section *Nylandera*. Most species of *Trentepohlia* have a wide range of shape of cell and cell-size in natural populations. It was however possible to distinguish some species from one another from scatter diagrams relating cell length to breadth in Brazilian material. In the species, *Trentepohlia monilia*, there was a correspondence between Japanese and Brazilian material. (Akiyama and Hirose, 1967; Akiyama, 1971).

TRENTEPOHLIACEAE OF SINGAPORE ISLAND

Singapore Island is roughly diamond-shaped and has a total area of 543 sq. k. (greatest length 40 k., greatest width 24 k.). Two-thirds of the Island is below 15.3 m. elevation and a single granite mass in the centre of the Island (Bukit Timah Hill) reaches to 160 m. The Island which lies at a latitude of 1° 21' N has a typical equatorial climate with lack of seasonal variation and heavy rainfall throughout the year. More rainfall falls on the Western than on the Eastern side of the Island.

Singapore Island was originally covered with tropical lowland dipterocarpous forest. Most of this was cleared for cultivation of pepper and gambier in the second half of the nineteenth century. These plantations were soon abandoned and the cleared forest area became covered with scrubland (belukar). Since the second world war the population has risen from 700,000 to over two million, and much of the belukar area has been used for building high-rise flats, factories, ship and timber yards. In an effort to conserve water and soil as well as to improve the appearance of the city, the Government has launched a tree-planting campaign. Trees are found along all major roads and in many other open areas. These trees provide favourable habitats for the various species of *Trentepohlia*, especially in the West of the Island. Because of the activity of planters in the last century, very little primary forest remains: the two existing areas being Bukit Timah Forest Reserve and a small area in the Botanical Gardens.

Although much work was done on the Trentepohliaceae of Indonesia by De Wildeman (1891, 1897, 1899, 1900) and Karsten (1891) there have been no previous accounts of the Trentepohliaceae of Singapore Island. *Trentepohlia Jolithus* has been recorded from Gunong Jerai (Kedah Peak) by Ratnasbathapathy (1972) in Malaysia and *Trentepohlia aurea* has been found in quadrat studies in the National Park, Kuala Tahan, Malaysia (Johnson, 1969). *Trentepohlia* is, however, extremely common in Singapore especially in the wetter Western part of the Island. Tree trunks, cement drains, buildings etc. are coloured with the brick-red rusty stain of *Trentepohlia.* Sometimes it is found on banks of earth where it contrasts with the red colour of the lateritic soil. It is occasionally found on rocky outcrops but, since most of the Island is alluvial or sedimentary, these are rare. On Bukit Timah Hill, where such rocky outgrowths do occur, the light intensity appears to be too low under the cover of the primary forest for *Trentepohlia. Trentepohlia* is rare in the deep shade of the primary forest but it is particularly common in open situations. If it grows in permanent shade it is green not red in colour, although the red colour can be detected microscopically. In very wet places it may be found growing over both stems and leaves forming a furry mat. Its presence in Singapore lichens has not yet been investigated.

Phycopeltis is common on leaves in the primary forest but is not found elsewhere. It occurs indiscriminately on a large number of different species, both monocotyledons and dicotyledons, particularly in the lower shrub layer. Humidity decreases from ground to canopy level in the forest. This appears to be correlated with the disappearance of *Phycopeltis* towards canopy level. *Phycopeltis* may even be found on some fern fronds. It is easily removed from the leaf surface by a knife or needle, and its removal does not damage leaf tissue in any way. It is usually brick-red in colour (in spite of the heavy shade in the forest), but green patches of cells may occur. These appear to be old cells, rather than cells affected by shade conditions.

Cephaleuros is extremely rare in Singapore, in contrast to its abundance in the tea estates in Malaysia. It has only been found once in this survey.

Many specimens of *Trentepohlia* were sterile when first collected and their identity was not immediately established. However after they had been dried in newspaper and kept for a few days, they often produced sporangia which was an invaluable help in their identification.

1. *Trentepohlia aurea* (L.) Martius forms cottony patches on the rough bark of *Fagraea fragrans* and *Eugenia grandis* or is terrestrial on banks of earth. Copious branching usually occurs, the angle of branching being 60–90°. Sessile, lateral and terminal pedicellate sporangia are plentiful in most specimens. Cells are cylindrical without constriction at the cross wall with average length 30u. and average width 18u. Sporangia are approximately 25u. in diameter. These dimensions correspond with those given by Akiyama for Brazilian material (1971). (Fig. 1).

2. *Trentepohlia monilia* De Wildeman (*Physolinum monilia*) (De Wildeman) Printz; *T. moniliformis* Karsten). Forming minute colonies of filaments, each of a few cells, 10 x 12u. on bark of *Jacaranda filicifolia* and *Casuarina equisetifolia.* Cells spherical, deeply constricted at cross walls. No reproductive cells. The cells are distinctly smaller than Brazilian material (Akiyama, 1971). (Fig. 2).

3. *Trentepohlia arborum* (C. Ag.) Hariot (T. *bisporangiata* Karsten). Forming a cottony colony on the smooth bark of *Ficus benjamina* and *Acacia auriculiformis* or attached to cement drains and rocky outcrops. The filaments are well

developed and there is a distinct difference between the diameter of main and lateral branches. These may be extremely narrow and coil round the main axis when young. Cells are long and cylindrical without constrictions at the cross walls. Branching is usually at right angles. Cell size, average 18.6 x 46.2u. (main axis), is similar to Brazilian material. Although it may bear lateral or terminal single pedicellate sporangia, the species is best distinguished by the clustered groups of 2–5 pedicellate sporangia found at the apex of a swollen sub-terminal cell on a short side branch. (Fig. 3, 4, 5).

4. *Trentepohlia odorata* (Wigg.) Wittr. (*T. umbrina* Karsten). Forming a crustaceous or penetrating layer on drains or cement buildings, cells rounded to elliptical, with only slight constriction between them, 9.0 x 8.2u., extremely powdery. Sporangia are terminal or intercalary, pear-shaped with a thick cell wall, about 8 x 12u., opening by a terminal pore. Although the size and shape of cells corresponds to that recorded by De Wildeman from Java, the sporangia, while of the same form, are smaller. Javanese material was only found on the bark of trees. (Fig. 6).

5. *Trentepohlia* sp.

A specimen forming a haircoating on the bark of *Eugenia reticulata* has been found. All filaments are upright, only four to five cells long; each cell is about 7.5–10u., extremely small and torulose but with very thick rough wall. Sporangia appear to be terminal only. (Fig. 7).

6. *Phycopeltis treubii* Karsten.

Found on upper surface of leaves in primary forest but not elsewhere, e.g. on leaves of *Calophyllum inophyllum, C. pulcherrimum, Vitis gracillis, Pithecellobium dulce, Ficus benjamina* and *Lygodium circinnatum.* Forming irregular colonies by irregular radial growth of filaments. Each colony invaginated at margin; when colonies overlap concentric patterns are formed. Sporangia of two types (i) borne on a short filament arising at 90° to thallus, (ii) borne on the flat thallus by the swelling of the end cell of a filament. Cells usually red brown in colour but whole files of old cells may turn green or colourless giving a patterned effect visible to the naked eye. Cells very variable in size, about 4.4 x 7.5u. (This is slightly smaller than Javanese materials). Ascending filaments with four to six cells, usually narrow, 2u., but occasionally with a fat ascending filament 4u. wide. Upright hairs are sparse. (Fig. 8).

7. *Cephaleuros virescens* Kunze (C. *mycoidea* Karsten; *Mycoidea parasitica* Cunn.)

On leaf of *Ixonanthes icosandra,* forming patches between the veins. Extremely difficult to remove without damaging leaf tissue. Thallus several cells thick, sub-cuticular with rhizoids fixing alga to leaf. Upright filaments breaking through cuticle and some bearing pedicellate sporangia. (Fig. 9).

CONCLUDING REMARKS

Although the genera *Trentepohlia* and *Phycopeltis* are common in Singapore Island in their respective habitats, there is little diversity of species. Only five species of *Trentepohlia* and one of *Phycopeltis* have been found, compared with 21 species of Trentepohlia and 3 species of *Phycopeltis* recorded by De Wildeman

from Indonesia. There are several reasons for this lack of diversity. The climate of Singapore is more equable than that of Indonesia and there are no definite wet and dry seasons. Species requiring temperature or humidity variations will not be able to grow. There are no mountainous regions or land over 160 m. Species like *T. Jolithus* which occur in the mountains will not be able to live here. In considering Singapore Island we are dealing with an extremely small area of only 543 sq. k. compared with the vast area of Indonesia with its numerous islands. Much of the Island is urban which reduces the variety of habitats available. The primary forest is very limited in extent. There is no limestone or calcareous rocks on which calcicoles could grow. Rocky outcrops are limited. Typical hosts of *Cephaleuros* such as tea and coffee are not grown on the Island.

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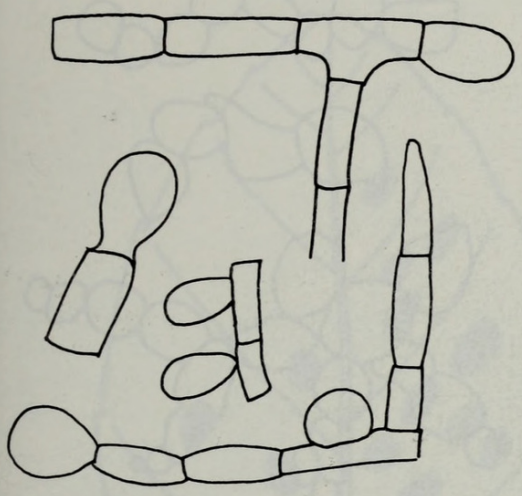

Fig. 1 *Trentepohlia aurea* (L.) Martius, filaments and sporangia (x 600)

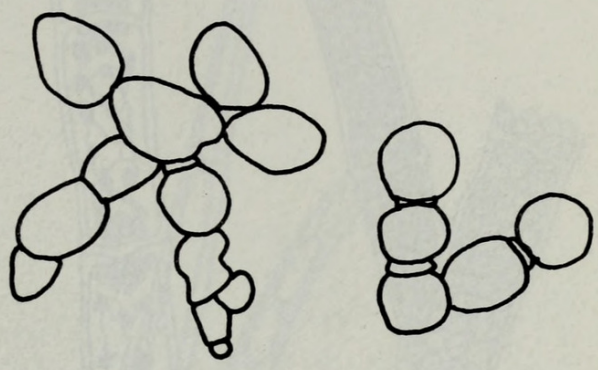

Fig. 2 *Trentepohlia monilia* De Wildeman, branching filaments (x 1,000)

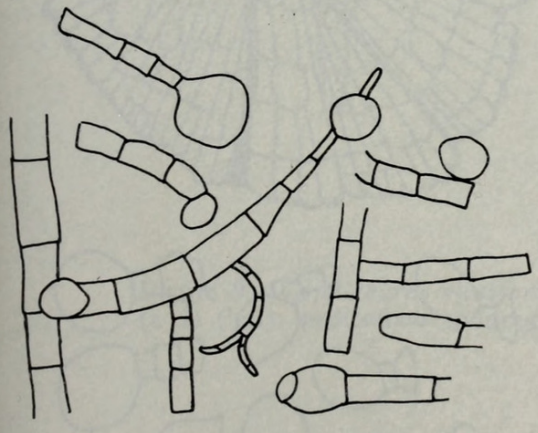

Fig. 3 *Trentepohlia arborum* (C. Ag.) Hariot, main and branch filaments of different diameters and sporangia (x 450)

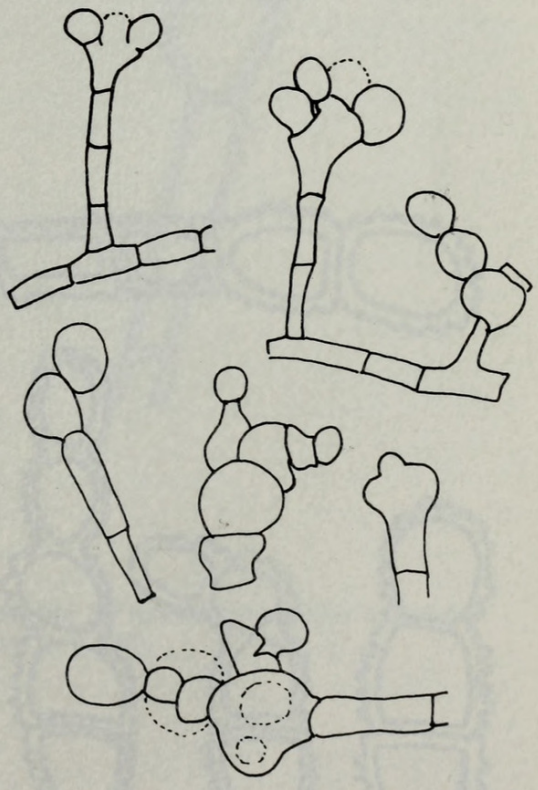

Fig. 4 *Trentepohlia arborum* (C. Ag.) Hariot, clustered groups of pedicellate sporangia on side branches. (x 450)

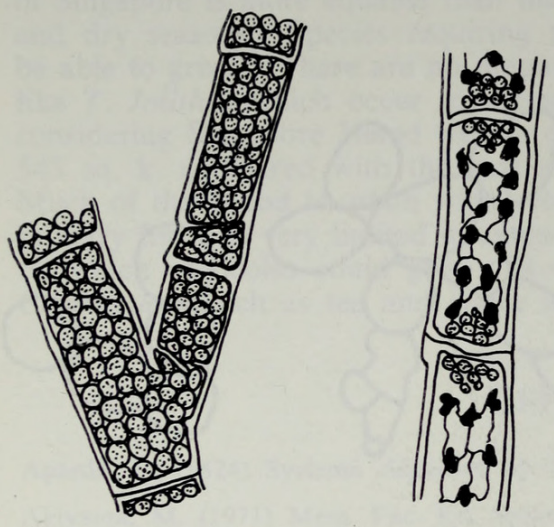

Fig. 5 *Trentepohlia arborum* (C. Ag.) Hariot, comparison of filaments in light (left) with copious production of oil drops containing carotene, and in shade (right) with few oil drops near cross wall and exposure of chloroplast. (x 1,000)

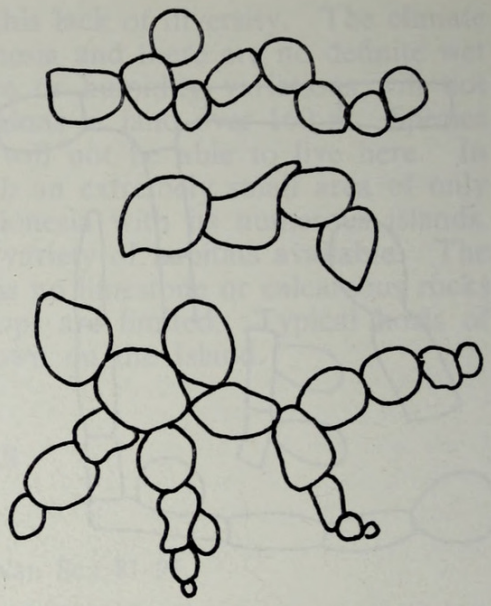

Fig. 6 *Trentepohlia odorata* (Wigg.) Wittr., branching filament with terminal sporangia (x 1,000)

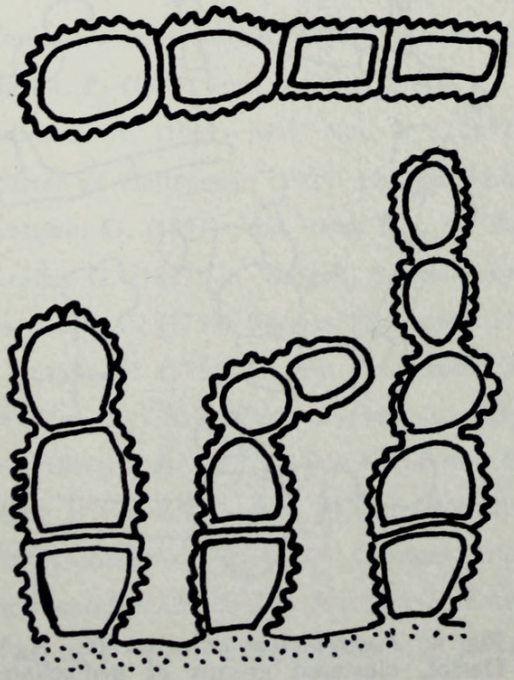

Fig. 7 *Trentepohlia* sp. found on the bark of *Eugenia reticulata* (x 1,200)

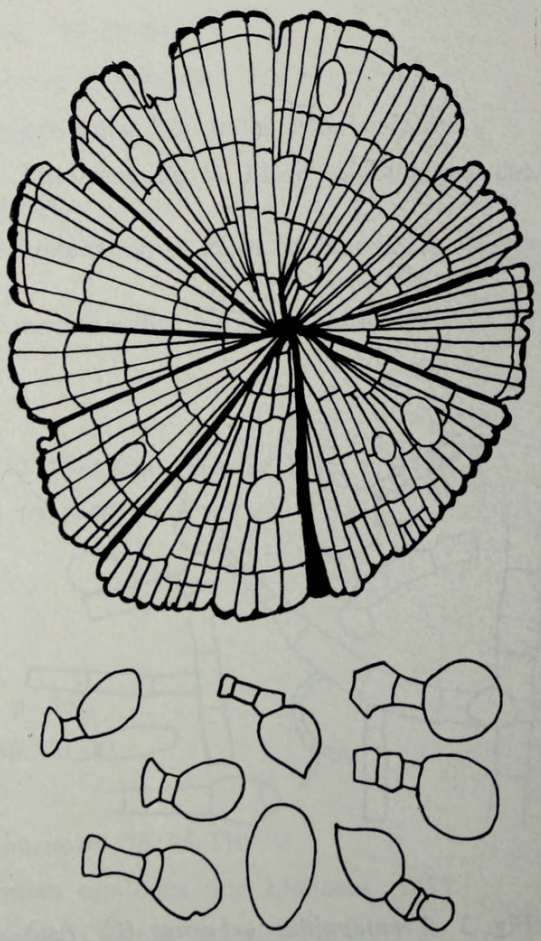

Fig. 8 *Phycopeltis treubii* Karsten, epiphytic plant on leaf (above) (x 1,000); ascending filaments (below with sporangia (x 1,500)

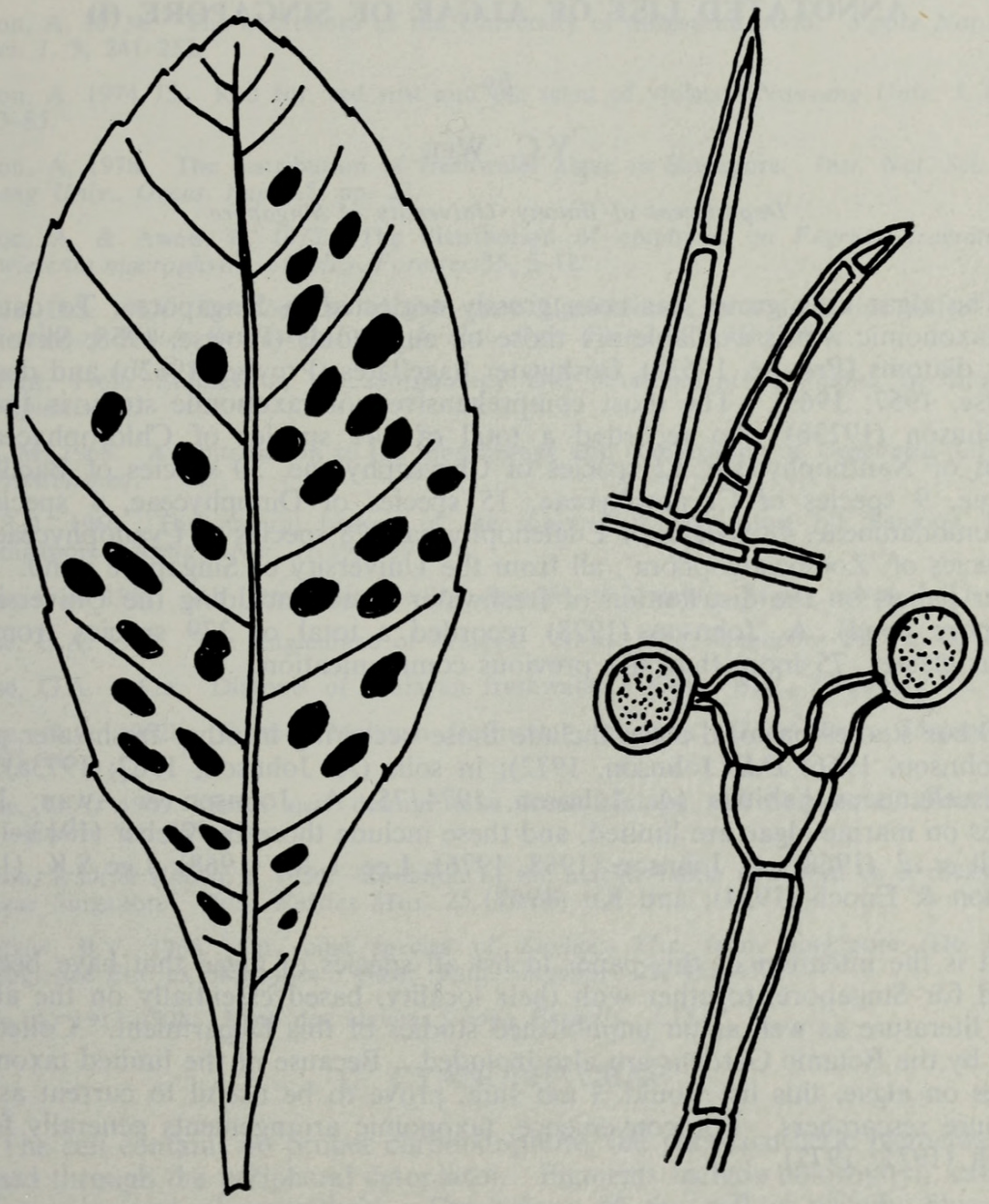

Figure 9. *Cephaleuros virescens* Kunze, parasite on leaf of *Ixonanthes icosandra* (x 1) (left); pedicellate sporangia and hairs (x 1,500).