The role of Aërophilous Algae in producing colour-effect on the bark of Oreodoxa regia of the Oreodoxa Avenue in the Royal Botanic Garden, Calcutta.

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(With Plate I and one Figure in the Text.)

The colour of the bark of *Oreodoxa regia* forming one of the avenues stretching South to North from the river gate of the Royal Botanic Garden, Calcutta, is a special feature of the trees growing in this garden. Red, green and narrow black streaks of colour running from top to bottom on the bark of these trees illustrate, in more or less regular alternating stripes, the habit and growth of the three species of aërophilous algae. The red (deep rusty) colour is due to the presence of *Trentepohlia umbrina*, the green to *Protococcus viridis* and the black to *Scytonema ocellatum*. The occurrence of these epiphytic algae producing such a remarkable display of colour on the bark of *Oreodoxa regia* attracted my attention and they have been the subject of my study for some time. Dr. Hans Molisch, the Emeritus Professor and Director of the Plant Physiological Institute of the University of Wien, while paying a visit to this garden in the beginning of the year 1929 during his stay in Calcutta at Sir J. C. Bose's Institute, was also much impressed at the sight of the striking effect of the variation of colour on the bark of these trees. At his request the writer in a short note explained the origin of the colours on the bark of these trees. Prof. Molisch subsequently mentioned in brief my observation on these algae in his splendid book on India entitled „Als Naturforscher in Indien", P. 34, 1930. Here in the present paper I put down in detail the nature and habit of these algae effecting such colour variation on the bark of *Oreodoxa regia* of the Oreodoxa Avenue and other palms growing here and there in this garden.

The two rows of Oreodoxa trees run North to South along the avenue which is open at both ends. These trees are again followed by rows of *Swietenia Mahagoni* trees of equal height or sometimes over-

topping them. The presence of these Mahogani trees both on the eastern and western sides behind the two rows of *Oreodoxa regia* brings about the ideal conditions, namely suitable amount of moisture and degree of diffused light and shade, for the growth of the three common epiphytic tropical algae mentioned above. Although the shade afforded by these Mahogani trees is suitable for the development of these subaerial algae it must be remembered that the two guiding factors, viz., temperature and rainfall and the particular nature of the climatic conditions in this part of the country control the life history and periodicity of these bark algae growing so luxuriantly everywhere as has been already indicated by F. E. Fritsch in his paper on „A General Consideration of the Subaerial and Freshwater Algal Flora of Ceylon. A Contribution to the Study of Tropical Algal Ecology. Part I. Subaerial Algae and Algae of the Inland Freshwaters" (Proc. of the Roy. Soc. of London, Vol. LXXIX, B., p. 197—254, 1907). But as climatic conditions here are different from those of Ceylon and as the algae occurring in exposed surfaces have not yet been dealt with in detail, it will not be out of place to give here a short sketch of the climatic and other factors on which the development of vegetation depends so much.

During the cold weather, from November to January, there is an almost entire absence of cloud and rainfall. The total mean rainfall for these three months is very little over one inch. The mean temperature falls from 72° in November to 65° in December and January, but humidity continues high. A feature of the cold season is the occasional occurrence of low-lying fogs, which dissipate with the rising sun. In February the temperature begins to rise, the mean for the month being 69°. Southerly winds become more frequent with the advancing year, and there is a period of transition characterized by occasional thunderstorms, accompanied by rainfall. The average amounts to 1 inch in February and 1,7 inches in April. The mean maximum temperature is 96° in April, and there is a decline of 1° in May. Night temperature increases slowly, and the highest monthly average is not reached till June and July, when it is 79°. The mean temperature for the whole year is 78°.

In May, monsoon weather is occasionally experienced when cyclonic storms occur near the head of the Bay. These storms bring heavy rainfall, and the average consequently rises from $1^1/_2$ inches in April to $5^1/_2$ inches in May. In some years the fall is far heavier, e. g., in 1893 the total fall at Calcutta during May was 25 inches, in 1878 it was 15 inches, and in 1865 it was 16 inches. With the commencement of the south-west monsoon, which generally occurs

in the latter half of June, but sometimes is deferred till the beginning of July, humidity increases to 90 per cent. of saturation, while heavy cloud is continuous and rainfall of daily occurrence. The average rainfall is 11 inches in June, 13 inches in July and August and 10 inches in September. The mean temperature slowly diminishes from 85° in June to 80° in October. During the latter half of September, and throughout October, cloudy weather alternates with bright sunshine, the bright periods lengthening until they merge into the continuous fine weather of the cold season[1]).

The nature of temperature and rainfall is represented in the following table:

Months	Maximum Temperature	Minimum Temperature	Rainfall
January	77,3	55,5	0,34
February	82,0	60,0	1,10
March	90,9	69,3	1,44
April	95,6	75,7	1,89
May	94,5	77,5	5,75
June	91,5	78,8	11,90
July	88,4	78,6	12,51
August	87,6	78,4	12,69
September	88,0	78,0	9,87
October	87,2	74,3	4,19
November	82,0	64,3	0,66
December	77,0	56,0	0,20
Year	86,8	70,5	62,54

There is more or less a uniform growth of *Trentepohlia umbrina* along the South Western sides of the trees of the Western row of Oreodoxa Avenue and South Eastern side of the Eastern row, whereas *Protococcus viridis* preferring the more shady and humid situation for its development covers the North Western sides of the trees. It (*Protococcus viridis*) frequently occupies also less exposed areas towards the bases of trees of both the rows. *Trentepohlia umbrina* and *Protococcus viridis* thus covering the two flanks of the trees

[1]) Bengal District Gazetteers, 24 Pergannahs, Vol. XXXI, p. 23, 1914.

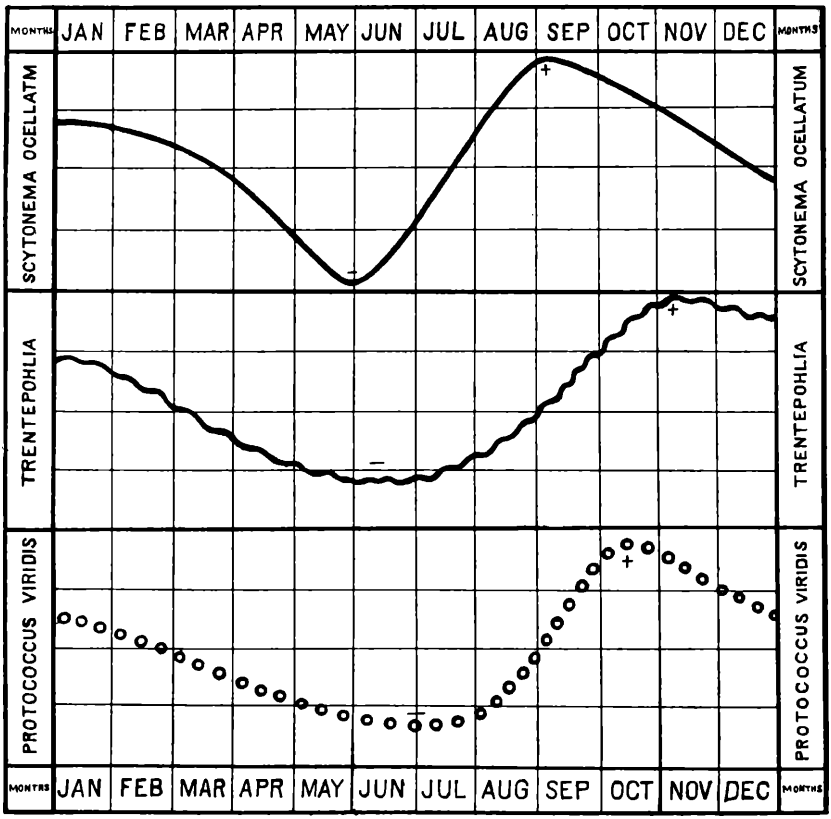
lend a distinct sombre hues of a beautiful rusty red and a dull green colours which are often separated by a black line of about three to four inches in width stretching from the base of the sheaths of leaves above to the ground below. This black stripe is composed of *Scytonema ocellatum.* Although red and green portions of the bark are quite distinct yet there is no definite demarcation of the area of the bark on which spread the two algae *Trentepohlia umbrina* and *Protococcus viridis* responsible for the red and green colours on the stems of *Oreodoxa regia.* Any one of them may overlap and dominate over the other to a certain extent as soon as conditions are favourable for one or the other. It has been observed that during the rains when all the subaerial algae of this country reach their climax in growth activities, *Protococcus viridis* too, predominates over the other species owing to abundance of moisture, humidity and shade, but at the beginning and end of the rains it is *Trentepohlia umbrina* which becomes more prominent and throughout nearly all the rest of the year its supremacy over *Protococcus viridis* on the bark of these trees and elsewhere is well marked. The bases of these trees are spotted with yellowish or orange red areas due to extensive development of *T. odorata* which alternates with isolated or expanded patches of crustaceous Lichens with their wavy or fringed margins. A few of these patches sometimes extend upwards particularly following the line of the growth of *Scytonema ocellatum* whose development is always restricted to the path of the rainwater trickling down from the bases of the crown of leaves. The trees situated at the southern end exposed to full glare of sunlight are practically devoid of any epiphytic growth and the bark is quite smooth. But the trees at the northern extremity especially the two standing in front of both the sides of the avenue are decked all over with patches of Lichens alone.

Trentepohlia odorata is only confined to the rough and crusty portion of the bark at the base and is quite abundant on the trunk of larger trees situated elsewhere in the garden like *Trentepohlia torulosa,* but unlike *Trentepohlia aurea* which prefers smoother and thinner surfaces occurring abundantly on the scaly bark of trees such as of *Terminalia* and other species as noted in our previous paper on Indian Bark Algae — „Algae Epiphyticae Epiphloiae indicae or Indian Bark Algae", by Paul Brühl and Kalipada Biswas, Jour. of the Dept. of Science, Calcutta University, Vol. V 1923. The South eastern and South western position of *Trentepohlia umbrina* and North western situation of *Protococcus viridis* in the main body of the stems may be explained by the fact that the respec-

tive sides of the trees occupied by the particular alga covering that portion of the trunk obtain through the ranges of Mahogani trees the requisite amount of subdued light, shade and suitable degree of moisture for its development. The South eastern and western sides are illuminated by the rays of the rising and setting sun. The intensity of the sun's rays is diminished while passing through the barrier of trees behind the Oreodoxa Avenue. Consequently *Trentepohlia umbrina* favours this more exposed situation, that is, the South western and South eastern sides and *Protococcus viridis* the more shady and humid positions, that is, the North eastern sides of the trees. *Scytonema ocellatum* appears to be rather indifferent to shade and light and follows the path of the rainwater coming down from the top of these trees. These factors more or less govern the occurrence of these algae growing on the *Oreodoxa regia* and other palms in different parts of this garden. Another species of narrow *Trentepohlia* — *Trentepohlia gracilis* recently discovered as mentioned in our paper on „Indian Bark Algae", grows chiefly on the iron posts, wires, and other metal parts of the Palm houses and similar shady portions in the hot houses of this garden. Again the exposed areas receiving greatest amount of diffused sunlight such as cement walls of buildings, especially Northern face, are frequently observed to be covered with yellowish red, orange red or deep rusty colour produced by the presence of another sturdy species of alga, namely, *Trentepohlia jolithus*.

The red colour of *Trentepohlia*, as is well known, is due to the presence of haematochrome in the cells and the degree of redness varies with the intensity of illumination. Thus the filaments lying away from the light are green, in more exposed portion yellowish red and in the areas almost open to the direct sunlight deep red. The reproductive cells, gametangia or zoosporangia as may be called, are marked by the presence of brilliant globules of haematochrome. These zoosporangia are abundant normally after the rains or after a shower of rain during the period of drought. The green colour is due to the abundance of green chloroplasts in the cells of *Protococcus viridis*. The black colour is due to the deep brown sheath of *Scytonema ocellatum*. The darkness of the sheath varies also with the intensity of light, shade and humidity as during the rains the sheath becomes less dark and the trichome more deeply blue green with enlarged cells and heterocyst. One fact may also be mentioned that after the death of any of these trees (*Oreodoxa regia*) all these epiphytic subaerial algae are replaced by rapid growth of Fungus and due to the covering of masses of mycelia the tree looks white or grey.

The general law of periodicity of algae in this country seem to be equally effective in guiding the nature of growth and distribution of these subaerial algae as well. Thus, when the southwest monsoon commences from the middle of July these algae recover from their dormant dessicated life and vegetative growth sets in with the increase of atmospheric humidity and daily heavy showers in August and up to the middle of October the growth of these algae reaches its zenith. This revival of vital activities is greatest at this time in the case of *Scytonema ocellatum* and other subaerial blue green algae in general. Next in luxuriance comes *Protococcus viridis*, then *Trentepohlia odorata* and lastly *Trentepohlia umbrina* and *Trentepohlia jolithus*. From October onwards with the advent of occasional fair and cloudy weather and bright sunshine in the presence of abundant moisture, requisite amount of illumination and drier atmospheric conditions the reproductive activities of *Trentepohlia* become quite apparent up to the end of November and continues till the beginning of December. The activity of growth and reproduction is not much affected during December to February due to heavy condensation in the form of dewfall at night and the fog which disappears with the rising sun. Occasional short showers in cold months of January bring them to temporary freshness, but gradually the vital activity is decreased to a minimum with the advancement of the period of dessication followed by gradual rise of temperature from the end of February onwards. The period of drought reaches its climax in May and June when the growth activities cease until the rain breaks in. In these months the temperature and intensity of light is highest accompanied by months of extreme dessication. These conditions reduce these algae — *Trentepohlia umbrina* and *Protococcus viridis* to almost powdery state of existence. *Scytonema ocellatum* shrivels up into small loose pustules. Thus becoming loose they are easily dislodged from the surface of their substrata with the least force such as that of a gust of wind. Then in the end of May to June during the time of thunderstorms these loose powders of *Trentepohlia umbrina* and *Protococcus viridis* and small flakes and pustules of *Trentepohlia odorata*, *Trentepohlia jolithus* and *Scytonema ocellatum* with their dormant reproductive cells are blown away and carried by wind and storm to different parts. Thus distributed these algae settle down by short showers on new substrata and with the commencement of the rains start their life anew. This is the reason of their wider distribution in this country. This periodicity of these few aerophilous algae like many others may be illustrated by the following diagrams:



— Least growth.
+ Greatest growth.

Description of Species.

Myxophyceae.

Scytonema ocellatum Lyngbye.

The description more or less agree with our former description as noted in our „Indian Bark Algae" referred to in this paper. The dimensions of the cells, trichomes and filaments are subject to variation in different seasons. In the period of extreme drought the sheath becomes very deep brown and the thalli look deep black panose expansion. The cells and heterocyst become very short. During the rains the alga assumes its normal characters.

Chlorophyceae.

Protococcus viridis Agardh.

A detailed description of this alga as growing in this country is already given in my paper entitled „Flora of the salt-lakes, Calcutta", in the Jour. of the Dept. of Science, Calcutta University, Vol. VIII., p. 28—29, 1926. This is one of the most common subaerial green algae found everywhere on hard substrata such as wood, stone, iron and other metalic surfaces. Slight morphological variations are met with, as indicated in previous pages, according to the climatic conditions in different parts of the year. As a rule, four celled packets and colonial tendency of this alga seem to be more prevalent in this country in subaerial habitat.

Hence I am more inclined to consider this species on *Oreodoxa regia* and elsewhere in similar situation as an intermediate form of *Protococcus viridis* and *Protococcus lobatus* of Chodat. It is perhaps more allied to Paschers new species *Protococcus anulatus*.

Trentepohlia odorata (Wiggers) Wittrock.

Stratum thin, extensive, when fresh golden yellow or orange coloured, densely felty or forming close-packed cushions; filaments rather short, much branched, erect, more or less parallel, flexuously curved and when old forming basal layer; vegetative cells cylindrical, in the middle often slightly irregularly inflated, rarely somewhat torulose, 8—10 μ in width, 12—16 μ in length, zoogonidangia lateral and terminal either spherical and about 12 μ in diameter or somewhat obovoid and 12—20 μ long and 12 μ broad, contents coarsely granular. Plate I, Fig. 1 (a—c).

Habitat. On the bark of Oreodoxa regia, along rough basal portions as also hard trunks of other tall trees, in and outside the Royal Botanic Garden, Calcutta.

This garden specimen, as can be seen from the description of previous authors and of De Toni and Heering, varies in dimensions of the cells. The cells are smaller and narrower than the typical forms. The filaments are often mixed up with lichens. This alga was also recorded by West and G. S. West in their monograph on „A Contribution to the Freshwater Algae of Ceylon", Trans. Linn. Soc. Bot. Ser. 2, Vol. VI, 1902 occurring on the bark of trees of the Royal Botanic Garden, Peradeniya, Ceylon. This is distributed in Europe, North America and New Zealand.

Trentepohlia umbrina (Kützing) Bornet.

Stratum thin, extensive, somewhat crustaceous, brownish red or rust coloured, more or less powdery when dessicated; filaments prostrate, irregularly branched, branches short and not well developed, rather fragile; cells subglobose or elliptical, almost equal in dimensions, 10—12 μ in width and 10—16 μ in length; zoogonidangia cannot be easily distinguished from the adult vegetative cells and are of the same dimensions or slightly larger; contents coarsely granular. Plate I, Fig. 2.

Habitat on the bark of Oreodoxa regia on smoother and more exposed portions of the trunk producing beautiful colour effect discussed before. It is also frequently met with on the bark of other palms in suitable areas of the stem.

This specimen too, which is more allied to Woole's Pennsylvania form, differs in dimensions being smaller than the typical forms described by earlier authors. This species was also recorded by West and G. S. West occurring on the bark of trees in Peradeniya. The Ceylon form appears to be slightly larger than the Bengal form. It is distributed in Europe and North America.

Trentepohlia jolithus (L.) Wallroth var. **bovina** (Flot.) Rabenhorst.

Stratum thin, crustaceous, during period of dessication becoming somewhat powdery, golden yellow, reddish brown or yellowish red, orange red or deep rust colour; filaments elongated, prostrate, decumbent or variously curved or erect, profusely irregularly branched; cells elongate, cylindrical, irregularly swollen in the middle, sometimes oval, obovate or torulose, 8—12 μ in diameter, 10—20 μ in length, zoogonidangia, lateral or terminal, oval, round or obovate or irregularly spherical, 12—30 μ in diameter, haematochrome abundant and contents coarsely granular. Plate I, Fig. 3 (a—f); 4 (a—b).

Habitat on sand and cement plastered walls growing in suitable shady portions in and outside Royal Botanic Garden, Calcutta.

Comparatively smaller dimensions of the alga than the typical form characterises this species as well and considerable variations in the structure of the cells and cell walls and gametangia are observed in different times of the year under different situations. During drought when the vegetative activity is dormant, cells are more inflated and the cell walls are thickened, the thallus due to the abundance of haematochrome in the cells and zoosporangia look

deeper brownish red in colour assuming more or less form of *Trentepohlia umbrina*. This species is recorded here for the first time from India and is distributed in Europe and North America.

Herbarium,
Royal Botanic Gardens, Calcutta.
The 12 th November 1931.

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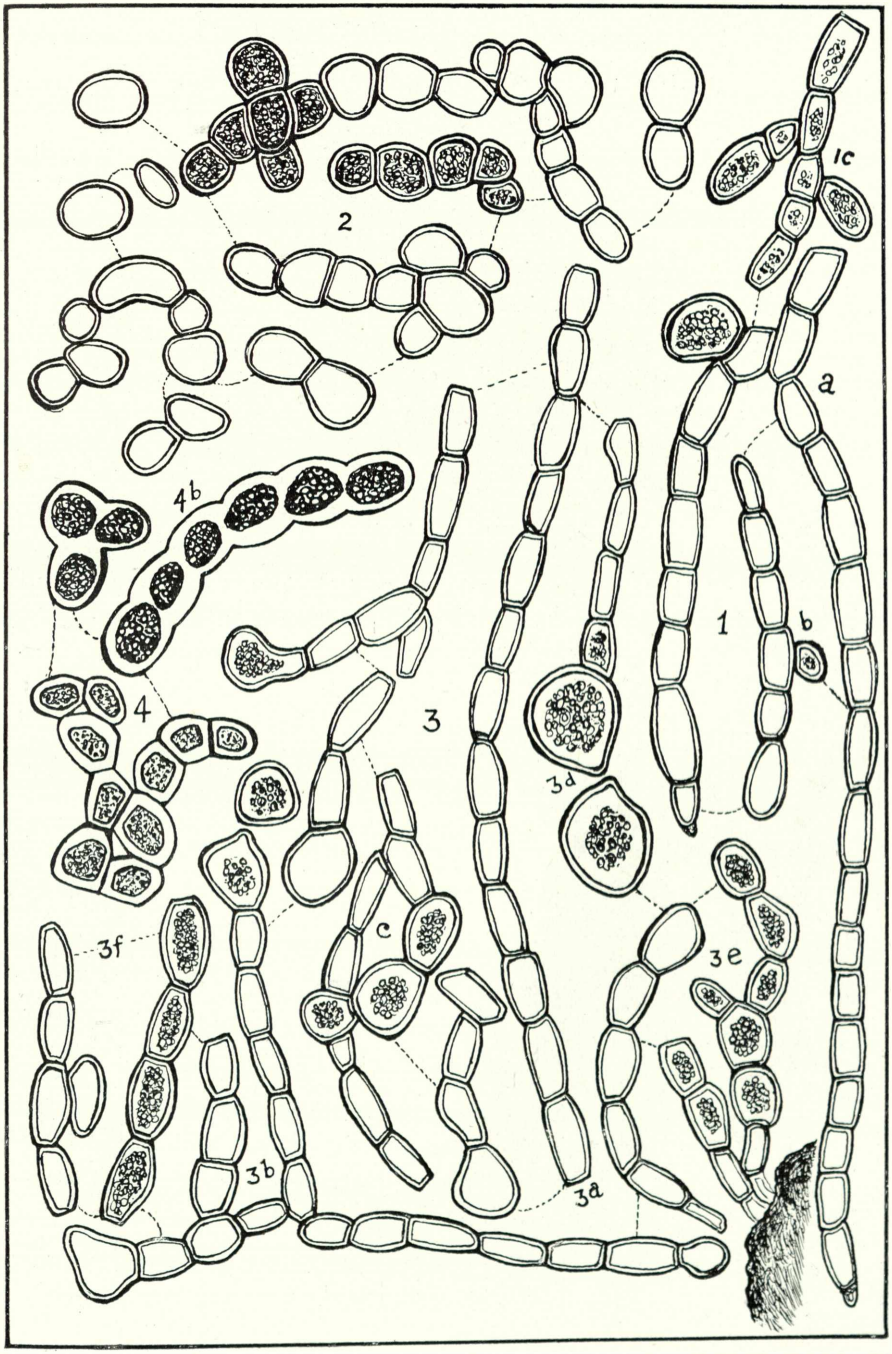
Explanation of figures.

Tafel I.

Fig. 1. *Trentepohlia umbrina*:
a = vegetative filament with a gametangium, × 500;
b and c = filaments showing different stages of development of gametangia, × 500.
Fig. 2. *Trentepohlia umbrina*, × 900.
Fig. 3. *Trentepohlia jolithus*:
a = vegetative filament, × 500;
b, c. d, e = filaments with gametangia, × 500;
f = filament with rather torulose cells, × 500.
Fig. 4. *Trentepohlia jolithus*, filaments as grown on cement walls during the hottest part of the year, × 650.



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