A survey of the occurrence of epiterranean soil algae in Singapore Island

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Epiterranean soil algae found in the upper layers of soil are of considerable importance in soil economy since they increase the organic content of the soil by photosynthesis, disintegrate soil particles to increase the water-holding capacity of the soil and secrete mucilaginous material binding surface particles together to form a matrix; while heterocystous blue-green algae fix atmospheric nitrogen increasing the nitrogen content of the soil (Johnson, 1962). Subterranean soil algae which live in complete darkness and may lose their photosynthetic pigment (Tiffany, 1951) are less important to soil economy.

Few investigations have been made on the soil algae of tropical areas and include those of Fritsch (1970) in Ceylon; Prasad (1949), Gonzales and Valavigi (1960), Singh (1940-41), Sulaiman (1944) and Ghose (1923) in India; Bristol (1919) in Malaysia and Johnson (1962, 1969) in Malaysia and Singapore.

Over a large area of Singapore Island the soil is derived from sedimentary parent rocks of the Triassic or Carboniferous period, with small areas derived from igneous rocks of acid or basic composition, as well as alluvial soils in swamps or valley bottoms. Most areas in the West of the Island the soil was derived from argillaceous series including red iron-rich strongly lateritic soil, light coloured to white iron-poor shale-derived soil, as well of soils mixed composition (Panton, 1955). Sedimentary soils of arenaceous series are commoner in the East of the Island including both coarse and find-grained series. The red colour of laterized soils is due to their high iron content since laterisation leads to an accumulation of iron and aluminium in the upper layers (Becking, 1961). Most of the iron is unavailable to the plants being in the form of insoluble iron-aluminium sequioxides or ironstone concretions. Most soluble cations such as calcium, magnesium, potassium and sodium have been leached away, and Singapore soils are extremely deficient in cations. The soils are also low in available phosphate due to loss by leaching and have a rather low pH. The rapid decomposition of organic matter under tropical conditions and subsequent leaching make them typically moderately low in nitrogen.

Singapore Island was originally covered with tropical lowland forest with dipterocarps as the dominant type of trees. During the second half of the nineteenth century considerable areas of the Island were cleared for the planting of gambier and pepper (Jackson, 1968). The soil rapidly became exhausted leaving a very infertile soil. When gambier and pepper cultivation was abandoned early this century, the land was allowed to revert to grassland and scrubland (belukar). In other areas the top soil has been removed in reclamation operations and exposed

subsoil (B layer) remains. Forest is extremely limited in extent. Cultivated areas support vegetable crops, and estates have rubber, coconuts, rambutans and other fruit. Disturbed areas are city dumps, abandoned building sites, army camps etc.

Materials and Methods

Surface soil was collected from 100 habitats in the rural area of Singapore to a depth of 2 cm. Two series of cultures were set up for each type of soil:—

(i) *Plate culture,* consisting of soil placed to a depth of 1 cm. in sterile petri-dishes, moistened with sterile distilled water and

(ii) *Liquid culture,* consisting of small quantities of soil introduced into sterile Knop's solution in conical flasks under sterile conditions. Both types of culture were exposed to 12 hours natural light per day. Observations on the algae appearing in the cultures continued for two months.

After setting up the cultures the remaining soil was air-dried and sieved through a 2 mm. sieve before analysis. The soil type was characterised into clay, clay-loam, loam, sandy-loam, loamy-sand, sand and sandy-clay according to the method of Leamy and Panton (1966). The soil was analysed for percentage of water, percentage of organic matter, ppm. nitrate, phosphate, calcium, ammonium nitrite, magnesium, iron, aluminium, sulphate, chloride, potassium and carbonate using the methods of Jackson, 1958 and those of the Edwards Laboratory, Ohio. pH was determined by use of a pH meter on soil paste. Colour was determined using standard Munsell Colour Charts to give hue, colour value and chroma on both wet and dry soils.

Results

1. *Soil type*

The soil type characterised according to Leamy and Panton (1966) in different habitats is seen in Table I. Surface soil consisted predominately of clay (24%) or clay loam (39%). Sandy loam and loamy sand amounted to 10% and 13% respectively. Sands (6%), sandy clays (2%) and loams (6%) are rare. Forest soil is usually clay loam (66.7%) but clays and loams occur. Alluvial soil is usually clay (57.2%) with some occurrence of clay loam, loam and sandy loam. Exposed subsoil (B-layer) is usually clay or clay loam with rare occurrence of loamy sand and sand. Grassland may be found on all types of soil. Scrubland (belukar) occurs on all except sand and sandy clay. Estate soil (rubber, banana, rambutans etc.) included no example of clay or sandy clay; while disturbed soil (dumps etc.) may be found on clay, clay loam or sandy loam.

Note. In the tables the following abbreviations are used for different habitats:—

F = forest soil; A = alluvial soil; E = exposed sub-soil (B-layer);

G = grassland; S = scrubland (belukar); C = cultivated soil;

Est. = estate soil; D = disturbed soil (city dumps etc.).

Samples were collected in the Jurong, Bukit Panjang, Serangoon and Katong districts of Singapore.

TABLE 1

Percentage samples with different types of soil

	F	A	E	G	S	C	Est.	D	Total
CLAY	16.7	57.2	35.4	25.2	10	33.3	..	16.7	24
CLAY-LOAM	41.7	14.3	47.2	43.0	40	22.1	9.1	66.7	39
LOAM	41.7	14.3	..	2.9	10	11.1	9.1	..	6
SANDY-LOAM ..	..	14.3	..	2.9	30	11.1	27.3	16.7	10
LOAMY-SAND ..	..	..	5.9	17.4	10	11.1	36.3	..	13
SAND	..	..	11.8	2.9	..	11.1	18.2	..	6
SANDY-CLAY ..	..	..	..	5.8	..	..	..	..	2

2. *Soil Analysis*

The percentage water in air-dried soil, percentage organic matter; and nitrate, phosphate, calcium, ammonium, nitrite, magnesium, iron, aluminium, sulphate, chloride and potassium in ppm. are given in Table 2. No soluble manganese was detected by the methods used. The percentage of soils containing carbonate is given in Table 3.

The water holding capacity of dry soil is closely correlated with the organic content being high in forest soils and alluvial soils but low in all other soils. Nitrate and calcium levels were normally at moderate to moderately low levels especially in alluvial or cultivated soils but all other ions were at extremely low levels. The values for phosphate, sulphate and potassium are critically low in most soils.

Most soils are acid, forest soils having an average pH of 3.83 with the pH somewhat higher in other types of soil especially in disturbed soil where an average pH of 6.45 was observed. This is correlated with the higher levels of potassium, calcium and carbonate in this type of soil.

Carbonate was detected in only 17% of the samples. It is completely absent from alluvial and estate soil, but occurrs in 83.3% of disturbed soil (dumps etc.). There are no calcareous rocks on Singapore Island.

TABLE 2
Soil Analysis. Mean values for different soils

	F	A	E	G	S	C	Est.	D	Total
% water (dry soil) ..	6.29	10.81	1.47	1.54	2.33	1.92	1.09	1.45	2.53
% organic matter ..	18.09	12.62	4.95	7.66	6.29	7.17	5.19	6.47	7.18
NO_3 (ppm.)	8.6	14.16	6.00	9.56	11.00	21.11	13.60	17.50	10.04
PO_4	0.16	1.08	0.23	0.56	0.70	1.33	1.50	0.33	0.66
Ca	10.00	11.66	14.12	14.37	8.00	13.30	12.70	13.30	13.09
NH_4	2.33	0.67	0.70	1.87	2.40	3.50	3.60	2.33	1.95
pH	3.83	4.88	4.95	5.80	5.00	5.67	5.40	6.45	5.26
NO_2	0.50	..	..	0.66	..	0.11	0.09	0.17	0.08
Mg	0.66	4.83	1.88	2.31	1.80	2.66	3.70	3.00	2.41
Fe^{++}	1.66	1.00	1.65	0.65	0.80	0.89	1.80	0.33	1.02
Al	..	..	..	0.17	0.40	..	..	1.33	0.18
Mn	..	..	..	..	..	..	..	..	..
SO_4	..	6.67	3.53	2.35	..	..	3.60	6.66	2.41
Cl	..	3.33	1.76	0.03	..	0.11	1.80	0.83	0.86
K	..	..	..	..	1.50	1.67	..	5.00	0.60
Colour value (dry) ..	5.0	5.3	6.7	6.0	5.9	5.9	6.1	6.3	5.9
(wet) ..	3.3	4.0	4.7	4.2	4.3	4.2	4.6	4.0	4.2
Chroma (dry)	2.8	4.3	4.9	3.6	3.6	3.0	3.0	3.1	3.5
(wet)	2.3	1.2	4.7	4.0	3.2	2.7	3.5	4.1	3.2

TABLE 3
Percentage Samples Containing Carbonate

	F	A	E	G	S	C	Est.	D	Total
+ CO_3	16.7	..	11.8	9.4	30	33.3	..	83.3	17
− CO_3	83.3	100	88.2	90.6	70	66.7	100	16.7	83

3. *Soil Colour*

The colour values in Table 2 reflect the somewhat lower values of alluvial and forest soil, and the relatively higher values for exposed and estate soil. The chroma is lowest in forest soils. The hue of wet soils all occurred on the YR colour range of the Munsell colour charts (Table 4). In spite of the uniformity of hue with 60% of the soils in the 10 YR range, Singapore soils are very variable in colour (Table 5).

TABLE 4

Distribution of hue in 100 samples (wet soil)

Hue	F	A	E	G	S	C	Est.	D	Total
10 YR	6	5	4	24	4	6	8	3	60
5 YR	0	1	5	3	4	0	3	3	19
5 YR	0	1	3	6	2	1	0	0	13
2.5 YR	0	0	5	1	0	2	0	0	8
									100

TABLE 5

Number of soils with different surface colour (Standard Munsell terminology-wet soil)

	F	A	E	G	S	C	Est.	D	Total
Strong brown			2	1				2	5
Dark brown	1		1	2		2	3	2	11
Brown	1	1	1	6	2	1	2	1	15
Pale brown					1	1			2
Very pale brown ..							1		1
Very dark greyish brown ..	3			4	1				8
Dark greyish brown ..	1	1		1	3			1	7
Greyish brown			1	2		1			4
Dark Reddish brown ..	1								1
Reddish brown				4	2	1			7
Light reddish brown ..		2							2
Dark yellowish brown ..	1								1
Yellowish brown ..		1	2			1			4
Pale yellowish brown ..			1		1				2
Black			2						2
Very dark grey	2						2		4
Dark grey	1	1			1				3
Red		4	1						5
Yellowish red		2	3		1				6
Pink		1							1
Reddish yellow		1	2	1					4
Brownish yellow ..			3			1			4
Light yellowish brown ..						1			1
									100

4. *Soil Algae*

(*a*) *constancy of occurrence*. The appearance of algae in sterile culture indicates the presence of these algae, at least as resting spores, in the soil. As has been reported frequently, the frequency of algal species in culture does not necessarily reflect their frequency in the soil since the conditions of culture may favour some species more than others. Although frequency estimates of growth in culture were made, these were considered to have no direct relationship with the actual frequency in the soil and these results are not reported here. The *constancy* rather than the frequency of occurrence of algal species was considered to be of greater significance since it gives a measure of the number of soil samples in which the algal species occurs.

80 species of algae were recorded in the cultures and they were distributed with constancies shown in Table 6. The soil examined show a great diversity of algal flora with very few constant species. The typical J-shaped curve of constancy/no. of species is common in tropical floras (Johnson, 1966).

TABLE 6

Contancy and number of species

(Constancy = no. of samples; total no. of samples = 100)

Constancy ..	85	29	19	17	7	6	5	4	3	2	1
No. of species ..	1	1	1	1	5	1	1	5	7	14	43

Total no. of species = 80

Table 7 gives the habitat occurrence of species with a constancy of more than 5% (only 11 species have a constancy of more than 5%). Although the list includes 5 species of blue-green algae (with asterisk) none of these are capable of fixing nitrogen under aerobic conditions.

TABLE 7

Number of Occurances of Algal species with a constancy of more than 5%

———	F	A	E	G	S	C	Est.	D	Total
DESMOCOCCUS VULGARIS Brand.	5	5	15	30	7	8	10	5	85
PALMELLA MINATA Näg. ..	2	1	7	10	3	2	4	..	29
HORMIDIUM FLACCIDUM (Kütz.) Br.	0	1	2	13	0	1	1	1	19
*OSCILLATORIA JASORVENIS Vouk.	0	2	0	11	3	0	0	1	17
*OSCILLATORIA OBSCURA Brühl. et Biswas ..	0	0	1	1	0	3	1	1	7

TABLE 7 — *continued.*

Number of Occurances of Algal species with a constancy of more than 5%

	F	A	E	G	S	C	Est.	D	Total
*SYNECHOCOCCUS AERUGINOSUS Näg.	0	0	4	2	0	1	0	0	7
TROCHISCIA ASPERA (Reinsch) Hansg.	1	0	0	1	2	1	1	1	7
PINNULARIA sp. ..	0	2	0	3	0	0	2	0	7
NAVICULA sp.	0	0	2	1	0	1	1	2	7
*CHROOCOCCUS MINUTUS (Kütz.) Näg. ..	0	2	2	0	0	0	2	0	6
*CHROOCOCCUS TURGIDUS (Kütz.) Näg. ..	0	0	1	3	1	0	0	0	5

(*b*) *Blue-green algae*. As in other tropical soils, blue-green algae (Cyanophyceae) form a conspicuous part of the algal flora. In this investigation 41 species of blue-green algae are reported from Singapore soils. These may be divided into the non-heterocystous algae which do not normally fix nitrogen under aerobic conditions, and the heterocystous algae which are capable of nitrogen fixation.

Of the 26 species of non-heterocystous blue-green algae (Table 8) none are found in forest and only 3 in estates. They are characteristic of open areas such as exposed sub-soil, grassland and scrubland where the light-intensity is high.

TABLE 8

Number of Occurrences of non-heterocystous blue-green algae

	F	A	E	G	S	C	Est.	D	Total
CHROOCOCCUS MINUTUS (Kütz.) Näg. ..		2	2				2		6
C. TURGIDUS (Kütz.) Näg. ..		1	3	1					5
C. SCHIZODERMATICUS West				1					1
CHROOCOCCUS sp. ..			1		1				2
MICROCYSTIS AERUGINOSA Kütz.			1			1			2
CHAMAESIPHON FUCUS (Restaf.) Hangs. ..			1						1
OSCILLATORIA JASORVENSIS Vouk.		2		11	3			1	17

TABLE 8 — *continued.*

Number of Occurrences of non-heterocystous blue-green algae

	F	A	E	G	S	C	Est.	D	Total
O. OBSCURA Brühl. et Biswas			1	1		3	1	1	7
O. ANNAEA Van Goor ..		1	1			2			4
O. CHALYBYA (Mertens) Gom.			1	3					4
O. FREMYI De Toni ..					2	1			3
O. MINIATA (Zanard) Hauck		1		1		1			3
O. TEREBRIFORMIS Ag. ..				1			1		2
O. CHLORINA Kütz. ..					1	1			2
O. OKENI Ag.		1			1				2
O. LIMOSA Ag.		1	1						2
O. SUBTILLISSIMA Kütz. ..				1					1
O. GEITLERIANA Elenkin. ..				1					1
SYNECHOCOCCUS AERUGINOSUS Näg.			4	2		1			7
ARTHROSPIRA TENUIS Stikenb.			1		1				2
SPIRULINA LABYRTHIFORMIS (Menegh.) Gom. ..		1							1
PHORMIDIUM TRUNICOLA Ghose			1						1
PH. SUBINCRUSTATUM Fritsch and Rich			1						1
LYNGBYA POLYSIPHONAE Frémy					1				1
L. BIRGEI Smith			1						1
TOTAL NO. OF SPECIES	0	7	15	10	9	7	3	2	26

Table 9 shows the occurrence of 16 heterocystous blue-green algae which are capable of nitrogen-fixation. They occur in just over a quarter of the soil samples. None are found in forest soil but at least one species of nitrogen-fixing algae has been found in all other types of habitat. Their occurrence is sporadic in these habitats and nearly three quarters of the samples showed no evidence of the presence of nitrogen-fixing algae.

TABLE 9

The Occurrence of heterocystous blue-green algae

———	F	A	E	G	S	C	Est.	D	Total
ANABAENA FERTILISSIMA Rao		1				1	1		3
ANABAENA SPIROIDES Kleb. . .		1						1	2
ANABAENA FUELLEBORNII Schmidle		1							1
ANABAENA ORYZAEA Fritsch				1					1
ANABAENA ANOMALA Fritsch					1				1
ANABAENA sp.				1					1
NOSTOC MICROSCOPICUM Carm.							1		1
N. MUSCORUM Ag. . .				1					1
N. PUNCTIFORME (Kütz.) Hariot				1					1
TOLYPOTHRIX PHYLLOPHILA West			1					1	2
SCYTONEMA HOFMANNI Ag.						1			1
CYLINDROSPERMUM SPHAERICA Prasad								1	1
AULOSIRA AERIGMATICA Frémy			1						1
HAPALOSIPHON WELWITSCHII West				1					1
NOSTOCOPSIS RADIANS Bharadn.				1					1
WESTIELLOPSIS PROLIFICA Janet				2		1			3
TOTAL NO. OF SPECIES	0	3	2	7	1	3	2	3	16

(*c*) *Green algae*. The occurrence of green algae (Chlorophyceae, Xanthophyceae, Euglenophyceae) is seen in Table 10. The highly constant species *Desmococcus vulgaris, Palmella miniata* and *Hormidiun flaccidum* are widely distributed, but most of the 31 species are very sporadically distributed and include some species as *Gonium pectorale* and *Euglena elongata* which are characteristic of freshwater habitats.

TABLE 10

(Cholorphyceae, Xanthophyceae and Euglenophyceae).

———	F	A	E	G	S	C	Est.	D	Total
DESMOCOCCUS VULGARIS Brand.	5	5	15	30	7	8	10	5	85
PALMELLA MINIATA Näg. ..	2	1	7	10	3	2	4	..	29
HORMIDIUM FLACCIDUM (Kütz.) Br.	..	1	2	13	..	1	1	1	19
TROCHISCIA ASPERA (Reinsch) Hansg.	1	..	..	1	2	1	1	1	7
MURIELLA TERRESTRIS Petersen	..	..	..	4	..	..	..	..	4
EUGLENA ELONGATA Schewiakoff	..	..	1	..	..	1	1	..	3
CHLAMYDOMONAS sp. ..	..	..	1	..	..	1	1	..	3
SCENEDOSMUS FLEXUSOS (Lemm.) Ahlstrom ..	..	..	..	3	..	..	..	..	3
CYLINDROCYSTIS sp. ..	..	..	3	1	..	..	..	..	4
BUMILLIERA EXILIS Kleb ..	..	1	1	..	..	..	2	..	4
SPONGIOCHLORIS SPONGIOSA (Vischer) Starr ..	..	..	1	1	..	..	..	..	2
MICROSPORA sp. ..	1	..	..	..	1	..	..	..	2
GONIUM PECTORALE Müll ..	..	..	..	1	..	..	..	..	1
OEDOCLADIUM sp. ..	..	..	..	..	..	..	1	..	1
EUASTRUM TORUM ..	..	..	..	1	..	..	..	..	1
BINUCLEARIA TECTORUM (Kütz.) Beger ..	..	..	..	1	..	..	..	..	1
LEPTOSIROPSIS TORULOSA Jao	..	..	..	..	..	..	..	1	1
DICTYOCHLORIS FRAGRANS Vischer	..	..	..	..	1	..	..	..	1
ZYGOGONIUM sp. ..	..	..	..	1	..	..	..	..	1
TRENTEPOHLIN AUREA (L.) Mart.	..	..	..	1	..	..	..	..	1
STIGEOCLONIUM sp. ..	..	..	..	1	..	..	..	..	1
ANKISTRODESMUS FALCATUS (Corda) Ralfs ..	..	..	..	1	..	..	..	..	1

TABLE 10 — *continued*

(Cholorphyceae, Xanthophyceae and Euglenophyceae)

———	F	A	E	G	S	C	Est.	D	Total
CEDERCUREUTZIELLA SAVONENSIS Vischer	..	1	..	..	..	..	..	..	1
DACTYLOCOCCUS INFUSIONUM Näg.	..	..	1	..	..	..	..	..	1
MACROCHLORIS DISSECTA Korch.	..	..	..	..	..	1	..	..	1
PENIUM sp.	..	..	..	..	..	..	1	..	1
SCENEDESMUS OBLIQUS (Turp.) Kütz.	..	1	..	..	..	..	..	..	1
ASTEROSIPHON TERRESTRE Dangeard	..	1	..	..	..	..	..	..	1
PLEURASTRUM INSIGNE Chad.	..	1	..	..	..	..	..	..	1
SCENEDESMUS FALCATUS Chad.	..	1	..	..	..	..	..	..	1
CLOSTERIOPSIS sp. ..	..	1	..	..	..	..	..	..	1
No. of species	4	10	9	15	5	7	9	4	31

(*d*) *Diatoms*. Diatoms are surprisingly rare in Singapore soils. Owing to the absence of a definite taxonomic work on terrestrial diatoms of this area, they were difficult to identify. Nevertheless their rarity is evident from Table 11.

TABLE 11

Number of Occurrences of diatoms

———	F	A	E	G	S	C	Est.	D	Total
PINNULARIA sp. ..		2		3			2		7
NAVICULA sp.			2	1		1	1	2	7
NAVICULA PYGMEA Kutz. ..	1								1
NAVICULA CONFERVACEA Kütz.			1						1
NAVICULA HUDSTEDTII Krasske		2							2
GOMPHONEMA sp. ..		1							1
FRUSTULIA sp.			1						1
Total no. of species ..	1	3	3	3	0	1	2	1	7

(*e*) *Diversity of algal flora.* Table 12 shows the occurrence of different kinds of algae in the different habitats. Tree communities tend to lack diversity in algal flora. In forest only 4 species are present, none of which is blue-green. Scrubland and disturbed land have 15 and 16 species respectively. Algal flora is best developed in exposed sub-soil (29 species) and grassland (35 species). As mentioned above nitrogen fixing blue-green algae may occur in all kinds of habitat except forest.

TABLE 12

Summary Table for number of species of different groups of algae

———	F	A	E	G	S	C	Est.	D	Total
Non-heterocystous blue-greens	0	7	15	10	9	7	3	2	26
Heterocystous blue-greens ..	0	3	2	7	1	3	2	3	16
Green algae	4	10	9	15	5	7	9	4	31
Diatoms	1	3	3	3	0	1	2	1	7
Total no. of species ..	5	23	29	35	15	18	16	10	80

Discussion

Although 80 species of algae have been found in the soil of Singapore Island in this investigation, most of these show low constancy of occurrence in the Island as a whole or in an individual type of habitat. The phenomenon of a large diversity of species distributed with low frequency is familiar amongst tropical organisms and occurs amongst such diverse groups as lowland tropical forest angiosperms, beetles (Wallace, 1969) and tropical fish.

When the natural vegetation is completely cleared and the top soil removed by man or erosion, an exposed sub-soil is devoid of any type of higher plant vegetation. This is subject to excessive leaching by torrential rain, strong isolation from the tropical sun and considerable temperature fluctuation day and night (Hill, 1966). Despite these severe conditions 29 species of soil algae were found some of which may act as first colonisers of the bare ground before the establishment of a higher plant flora. Non-heterocystous blue-green algae predominate in this habitat.

When colonisation by higher plants commences, grassland becomes established. The soil surface becomes protected from excessive leaching and there is an increase in available ions for plant growth (Table 2.) Light intensity is still high but there is less fluctuation in temperature day and night. 35 species of soil algae were found including 7 species of heterocystous blue-green and 15 species of green algae.

Grassland progressively develops into scrubland (belukar) with colonisation by woody species such as *Adinandra dumosa* Jack and *Melastoma malabathricum* Linn. These species increase the shading of the ground layer. The light intensity

decreases and there is an increase in available nitrate. The algal flora loses some of its diversity and only 1 species of heterocystous blue-green algae was found.

In the undisturbed forest the organic matter content is high but most cations and anions remain low, since the ionic reserve in tropical forest is directly absorbed by the shallow feeding roots of the trees and does not persist in the soil (Jackson, 1968). The light intensity is very low being only about 0.1% of the illumination outside the forest (Johnson, 1970). No blue-green algae are found here and there are only four species of green algae and one diatom.

Cultivated soil in Singapore has been subjected to various manures and organic fertilisers and usually has a relatively high nitrate level. The algal flora is limited but heterocystous blue-green algae can occur. Estates are also subject to disturbance by man. Since these are predominately tree crops (e.g. rubber, banana, coconut, rambutans, durian, citrus etc.), the light intensity is usually lower than in cultivated soil; but, since such estates are quite open, about 10% light penetrates. The algal flora is limited but less so than in undisturbed forest.

Disturbed soil has been subject to all kinds of dumping and building operations by man, including industrial pollution and general devastation. The occurrence of such areas near a city of over two million population is to be expected. Chemical analysis of the soil gives very erratic results often with high figures for one or more ions. Ten species of algae were found in this kind of habitat.

Summary

The surface soil was collected in 100 localities in the rural area of Singapore. The samples were cultured by liquid and plate culture to determine the algae occurring, and the soil was subjected to physical and chemical analysis.

The surface soil consisted predominately of clay and clay-loam, with some sandy loam and loamy sand, other types of soil being rare. The water-holding capacity of dry soil is closely correlated with organic content being high in forest and alluvial soils but low in all other types of soil. Nitrate level was normally at moderate to moderately low levels, but the values for phosphate, sulphate and potassium are critically low in most soils. Most soils are acid, forest soils having an average pH of 3.83 with pH somewhat higher in other types of soil. Carbonate was detected in only 17% of the samples. Although the soils were somewhat uniform in hue with 60% soils in the 10YR range, they were very variable in colour.

80 species of soil algae were found in the soil. Tree communities lack diversity in algal flora, which was best developed in exposed subsoil and grassland. Most species show low constancy of occurrence in the Island as a whole or in individual habitats.

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