CHAPTER - IV

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Soil algal flora of Bangalore district:

The data presented in the foregoing chapter project a clear picture of the qualitative and quantitative nature of the algal flora of Bangalore district. The understanding of the pattern of distribution of algae in different soils is of importance from the point of view of improving soil fertility and the data gathered provide ready check-lists of algae in each of the eleven taluks of the district which could be used by agricultural scientists in determining the soil fertility status.

From the investigations some general conclusions have been arrived at and these are discussed here. The predominance of blue green algae in the cultures from the 110 samples was very pronounced. Esmarch (1914), Wyllie (1943), John (1942), Mitra (1951), Marathe (1967), Anantani and Marathe (1972) and Bongale and Bharathi (1980) have also obtained similar results with reference to soils of other regions in India and elsewhere. Out of the 85 species of algae recorded here from all the 110 soil samples, as many as 68 species belong to blue-greens (Cyanophyceae) which amounts to more than 80% of the total species recorded. According to Esmarch (1914) this can be attributed to the fact that in cultivated soils there are improved conditions
of growth as a result of cultivation, manuring, and availability of water etc. Wyllie (1943) has also concluded that the preponderance of Cyanophyceae is connected with soil fertility. Anantani and Marathe (1972) working on semi arid soils of Rajasthan have concluded that the poor algal flora in these soils is due to acute deficiency of nitrogen, phosphates and potassium (nutrient materials); in other words, poor soil fertility conditions. Lund (1947) has recorded good growth of Cyanophyceae in the soils containing optimum amounts of phosphates and nitrates. As all the 110 soil samples studied here are from cultivated fields the larger number of blue-greens in these soils is understandable.

The Chlorophyceae and Bacillariophyceae are represented by 14 and 2 species respectively and none of the Phaeophyceae and Rhodophyceae members have been met with. Majority of the Chlorophyceae were restricted to liquid cultures only. Amongst them Chlorococcum humicolum and C. humicolum var. incrassata, were dominantly occurring in almost all the samples. These were the first to appear in the cultures and grow vigorously, and in about 3-4 weeks period they filled the entire culture flasks. The early appearance of these species in almost all the samples indicates that they were present in abundance in the soil samples in the dormant conditions. As the growth of these species was very vigorous the cultures used to get overcrowded very soon with these fast growers and leave very little chance for
other slow growing forms to grow. Moreover, in some cases there used to be resting spore formation with lot of hematochrome or in some cases oil, and the entire cultures used to look orange coloured. The other Chlorophyceae like Uronema terrestre, Klebsormidium flaccidum, Cladophora crystallina var. nov., Gongrosira terricola, Chlamydomonas elliptica var. britannica, and the remaining species of Chlorococcum viz., C. oleofaciens, C. minutum, C. vacuolatum and Chlorococcum sp. mostly occurred in liquid cultures but in limited number of soils. Occurrence of C. oleofaciens and C. minutum in Indian soils is the first record. In case of the former species the cultures used to get oily due to the presence of oil in cells as reserve food. Secondly it occurs only in three soils of Bangalore South with pH 6.3 - 6.6, which indicates its preference for acidic soils. Cladophora crystallina var. nov. which has occurred only in two samples is of rare occurrence in soil habitat. The samples in which it has occurred are mostly the tank irrigated fields. Probably this alga has been carried to these fields by the tank water. Similar is the case with Gongrosira terricola which is restricted to 2 samples only. These can be termed as 'ephemerals'.

The occurrence of Oedocladium operculatum and Oedocladium sp. in moist cultures of these samples is noteworthy. The occurrence of Oedocladium operculatum in Dharwad soils by Gonzalves and Yalvigi (1957) is the only other record for Karnataka so far. The occurrence of this species in four
Samples and the occurrence of *Oedocladium* sp. in two samples in the moist cultures only, indicates the preferential environmental conditions in which they can thrive. The record of *Oedocladium* sp. in these samples seems to be the first one for soil habitat. The presence of this species only in vegetative state has made the identification incomplete.

The occurrence of only one desmid species - *Cosmarium speciosum* var. *simplex* form *intermedia* seems to be very peculiar as compared to the report of as many as 14 spp. of desmids from cultivated soils of Karnataka (Bongale and Bharathi, 1980). However, there is no record of any desmid in the cultivated soils of Maharashtra by Marathe (1967) and in certain other Indian soils by Mitra (1951). The occurrence of this species in a number of samples both in liquid and moist cultures indicates its preference for red sandy loams. Another interesting record is that of *Klebsormidium flaccidum* in 28 samples, which are slightly acidic. This species has not been recorded in India whereas John (1942) has recorded three species of *Klebsormidium* mostly in acidic soils of Breckland, England. So, it can be concluded that *Klebsormidium flaccidum* requires acidic soils. As in the temperate regions, the members of *Chlorophyceae* prefer acidic soils here in the tropics also, because all the 14 species of *Chlorophyceae* recorded here were very commonly occurring in the soils having pH 5.3 - 7.0. This confirms the earlier findings of Fogg (1956), Holm-Hansen (1968), Brock (1973), and King (1975).
The two diatoms - *Hantzschia amphioxys* and *Nitzschia amphibia* var. *acutiuscula* were found occurring in a majority of the soil samples. The former was found in almost all the 110 samples growing in both liquid and moist cultures with a few exceptions. This can be termed ubiquitous form for Bangalore district soils also, as in the case of many other soils (John, 1942; Mitra, 1951). *Nitzschia amphibia* var. *acutiuscula* is a restricted form occurring only in a very limited samples and that too mostly in liquid cultures. *Bongale* and Bharathi (1980) have reported as many as 53 species of diatoms from Karnataka soils, but Mitra (1951) has reported only 3 spp. of which *Hantzschia amphioxys* and *Nitzschia* sp. are two of them. The meagre presence of only two diatoms in Bangalore district soils may be due to their incompatibility with the physical and chemical composition of the soils as in other Indian soils (Mitra, 1951).

The blue-greens, as stated earlier, form the bulk of the algal population occurring in these soils. As many as 68 species have been recorded from all the 110 soil samples. These can be regarded as the dominant species and this finding is in accordance with the earlier reports for tropical soils (Singh, H.D., 1933; Mitra, 1951; Marathe, 1967; Bongale and Bharathi, 1980). The dominance of these blue-greens in the tropical regions and their important role in sub-aerial and fresh water algal flora had been stressed by
Fritsch (1907). Amongst the blue-greens occurring in these soils, *Nostoc* with 15 species is the most dominant followed by *Phormidium* with 10 species. The remaining occur with 1 - 3 species only. *Nostoc muscorum, N. calcicola, N. ellipsosporium, N. ellipsosporium* var. *voilaceae, N. paludosum* forma *Rao, N. carneum, N. punctiformae* and *N. piscinale* are occurring in majority of the soil samples, in liquid, moist or in both the cultures. Hence these can be called as the indicators of Bangalore district soils. *N. entophytum, N. sphericum, N. humifuscum, N. pessarisanum* are occurring in a restricted manner in a few samples and mostly in the moist cultures only. *N. rependum* and *N. linckia*, have not been reported in the Karnataka soils (Bongale and Bharathi, 1980) and Maharashtra soils (Marathe, 1977). However, *Nostoc linckia* has been mentioned by Mitra (1951). So, this is the first report of *N. rependum* from Indian soils. This occurs both in liquid and moist cultures, in Nelamangala taluk in five samples whose pH ranged between 5.7 - 6.6. It indicates that this particular species of *Nostoc* thrives well in acidic soils. Majority of these edaphic *Nostoc* spp. are responsible for dinitrogen fixation in the fields.

*Phormidium foveolarum* with two varieties namely var. *major* and var. *nov.* are very prominently occurring in almost all the samples in both liquid and moist cultures, the former being more common. This can be compared with the diatom, *Hantzschia amphioxys* and can be termed as an ubiquitous form. Surprisingly this form which is so common here
has not been reported in the Karnataka soils earlier explored by Bongale and Bharathi (1980). However, it has been reported from Maharashtra (Marathe, 1965) and in other Indian soils (Mitra, 1951). Among the other species of Phormidium, P. corium, P. africanaum, are the two which occur only in a limited number of samples of Bangalore South, Kanakapura and Nelamangala taluks, and that too being restricted mostly to the moist cultures. The other species - P. mucosum, P. frigidium, P. jadianum, P. retzii, P. molle var. tenuior and P. tenue, occur mostly in moist cultures and are abundant in majority of the samples preferably alkaline soils.

Prasad and Srivastav (1968) studying several alkaline Indian soils have reported that only blue-greens form the algal flora of soils with pH 8.5 - 11.0. The present findings are almost in agreement with these findings. All the seven spp. of Chroococcus, recorded here have also been reported from Karnataka soils by Bongale and Bharathi (1980). These species occurred in liquid, moist and in both the type of 5 cultures. One or more species of this genus are present in all the 110 samples. The genera occurring with only one specie are - Gloecapsa, Gloeothecce, Chlorogloea, Aphanothece, Merismopodium, Borzia trilocularis, Aulosira implexa, Schizothrix cricetorum, var. major, Napalosiphon hibernicus, Cylindrospermum var. major, alatosporum, Microcoleus paludosus, Dermocarpa olivacea var. nov. and Westiellopsis prolifica. The occurrence of Dermocarpa olivacea nov. in the two soils samples of Bangalore
south is an interesting finding, as this is found usually in aquatic habitat as an epiphyte on other algae, in waste waters etc. Its occurrence here is probably due to the transferring of this alga with irrigation waters to the field from the tanks. The above species may be termed as "ephemeralis". *Anabaena* with six species is an edaphic genus of common occurrence in majority of the samples. These are occurring both in moist and liquid cultures. Similarly two species of *Scytonema*, *Stigonema*, *Calothrix*, and *Microcystis* are of common occurrence. *Oscillatoria* with three spp. occurs in many soil samples, but not in abundance. Of these *O. sancta* is very common.

The most interesting alga, *Westiellopsis prolifica* was occurring in several samples and was vigorously growing in moist cultures throughout the period of investigation. The interesting feature of this alga was its capacity to retain the moisture content of the culture in which it was growing throughout the period of its existence. This retention of moisture content in the soil for a long period may be due to the formation of "Crust" by this alga as in the Nagpur soils by other blue-greens such as *Aphanothecae pallida*, *Michrochaetae tenera* and *Oscillatoria obscura* (Marathe and Choudhari, 1975). In general, there was preponderence of blue-greens in almost all the samples, more so in the alkaline soils. Several of these algae have direct role in dinitrogen fixation in the soils. Stewart (1975) in his review has reported that heterocystous nitrogen fixing algae were more abundant in the
tropical and sub-tropical soils than in the temperate soils. Thus the presence of several of the above species in the cultivated soils of Bangalore district is noteworthy from the view of future programme of research.

From the foregoing discussion it appears that in one or the other culture (liquid or moist) of the soil samples like Chlorococcum humicolum, C. humicolum var. incrassata, Hantzschia amphioxys, Phormidium foveolarum var. major, P. foveolarum var. nov., Nostoc spp., Chroococcus westii etc., occurred constantly and grew vigorously, dominating the entire culture containers. This indicates that these species are present abundantly in the soil in the dormant stage, as none of them were observed during the direct examinations of the soil samples, immediately after collections in the laboratory.

Based on the data gathered from liquid, moist and dilution cultures, an attempt has been made to analyse the quantitative variation in the algal population within the samples from each taluk and between different taluks of the district. The data have been correlated with soil factors like pH and fertility status. The algal population of dry and wet samples have also been compared from the quantitative aspect.

In Table-35 the number of species and number of algae per gram of soil (algal population) in each taluk are
given. The various parameters used here are mean, standard
deviation (SD) and coefficient of variation (CV). Total
number of species and total population for the entire
district along with SD and CV, are also represented in the
same table. Allen (1974) has used multivariate statistical
analysis (Cluster and association) for analysing the distribu-
tion of algae on rock surface and has concluded that this
multivariate analysis did not eliminate bias and its use was
limited. Hence only three parameters viz., mean, SD and CV
are used for the present discussion.

In all, 85 species of algae belonging to different
taxonomic groups have been recorded from all the 110 samples
from the eleven taluks of Bangalore district. The mean number
of species per sample for the entire district was 15.5, with
S.D. 5.05 and C.V. 32.5%. This shows that variation between
samples with regard to number of species was not abnormally
high. Since sample mean is 15.5 and total number of species
is 85, it can be deduced that while some species were common
between samples, others were unique to particular samples.

From Table-35 it can be seen that the least number
of species i.e., 27 occur in Anekal taluk with a mean of 10.6,
S.D. 3.97 and C.V. 37.51%. Eventhough the number of species
is the least the variations are larger than many of the other
taluks. This may be due to variations of the samples in their
pH and fertility status (Table-37). As many as 8 samples have
the level of pH between 6.1 - 7.0 only. In case of Kanakapura, the total number of species is 34, mean 17.5, S.D. 3.25 and C.V. is only 18.5% which is almost half that of Anekal. Here 9 soil samples are having pH range between 7.1 - 8.8 all alkaline and the fertility of the soil - Nitrogen (N), Phosphate, (P), and Potash (K) contents are good, hence less variation. The highest number of species i.e. 50 recorded from Bangalore South with a mean of 19.8, S.D. 3.29, and C.V. 16.6%. Here the C.V. is less than Kanakapura because, among the ten samples 9 have pH level 6.1 - 7.0 and N and K are low to medium but P is normal. Hoskote samples are mostly acidic with pH level 5-7, but with better content of N, P and K; here the mean is 13.45, S.D. 3.36 and C.V. 24.9%, higher than Bangalore South and Kanakapura, which have larger number of species. The maximum S.D. 9.37 and C.V. of 48.8% which is above the district average was recorded for Bangalore North. Here the number of species is 48, and mean 19.2 almost same as Bangalore South but the distribution of species is uneven. Here five samples have pH level 6.1 - 7 and other five 7.1 - 8.8, and majority of the soils have good fertility status with N, P and K in good amounts. This large variation indicates that pH of the soil plays a very significant role on the algal species occurring in them.

Soil fertility status varies from soil to soil and place to place, depending on availability of nitrogen (N), Phosphorus (P) and Potassium (K), the major elements. Table-37
shows the relative fertility status and pH levels of each taluk. Out of 110 soil samples as many as 73 samples had pH level between 5-7, which indicates acidic type. Majority of the samples were having mostly normal to high N, P and K contents. As far as the density of population is concerned, the density was highest in Kanakapura (0.841 x 10^4) per gram of soil) with a C.V. of 28.6% which is below the district average of 71.7% (Table-35). This shows that the taluk had rather even distribution of population, the variation between samples being lower than the district. Bangalore North with a population mean of 0.460 x 10^4 showed the highest C.V. of 95.4% just as in the case of number of species. Bangalore North taluk, therefore, stands out from all others in having highest dispersion of algal population as well as species. This indicates that the soils of this taluk are highly varied in nature. Sample number 8873 from this taluk showed 31 species and sample number 8871 showed only 7 species. This demonstrates the patchy distribution of algae parallel to the findings of Broady (1979) with reference to terrestrial algae. The C.V. was the lowest in Anekal taluk (23.7%) indicating meagre variation and low dispersion. In the Bangalore South 9 samples had pH level between 6.1 - 7.0. The N content was a little low but both P and K were in the medium range. Here the algal population 0.469 x 10^4 per gram is almost nearing the district average. In case of Anekal, Hoskote and Doddaballapur taluks where the mean of
algal population is lower than district average, the C.V. is also less. Here the samples are mostly acidic, N low to medium, P and K are normal. All other taluks have the mean of populations higher than the district average; however the C.V. is less than the average for the district.

Table-36 shows a comparative account of mean, S.D. and C.V. of both species and population of algae per gram of soil separately for dry and wet samples of each taluk, as well as for the entire district. The average in each case is based on 5 samples, and for the entire district 55 samples. A total of 85 species have been recorded from 55 wet samples whereas in dry samples only 83 have occurred. The two species which are restricted to wet soils are Cladophora crystallina var. nov. and Dermocarpa olivaceae var. nov. As stated earlier these are purely hydrophytic, and have probably been brought to the fields through irrigation waters. The difference between the two types of samples (dry and wet) is not very high and is negligible. The wet fields were irrigated only seasonally and not flooded throughout. So there was no difference in the number of algae between the two.

Mitra (1951) has shown higher number of species in irrigated fields of paddy. Akiyama (1961) has reported that algae were more abundant in moist areas than in arid sites. Table-36 shows that the highest mean, S.D. and C.V. for number of species was in Bangalore North dry samples and the highest C.V. of 131% for population was also recorded here in wet samples. It is an abnormal recording as far as
variation is concerned. As stated previously this shows a patchy distribution of population in the five wet samples. Another reason for this apparently abnormal recording may be the small number of samples - restricted to 5. If we take into consideration the density of algal population per gram of soil, the dry and wet samples have very little difference in the mean $0.459 \times 10^4$ and $0.489 \times 10^4$. The S.D. was 0.329 and 0.353,, and hence the difference in the variation was also negligible. This small difference in the numbers may be due to the presence of few hydrophytic species like *Chroococcus* spp., *Microcystis viridis*, *M. robusta*, *Aphanocapsa grevellei*.

Thus from the above findings it can be concluded that pH plays an important role in deciding the number of species, and the density of algal population of soils. The moisture content, and the soil fertility status have the secondary role and act as accessory requirements of the terrestrial algal flora. This conforms to the findings of Marathe (1963, 1969, 1972), Arvik (1970) and Raju (1972). Lund (1947) has suggested that along with pH other factors such as nutrient status are responsible for the distribution of diatoms. Broady (1979) also suggested that in addition to pH, soil moisture, plant cover, the nutrients may play a role in deciding the algal species and number in the fields. However he concluded that further investigation is necessary in this line. The establishment of the secondary role of moisture content and soil fertility in supporting algal populations in
the soils of Bangalore district is, therefore, useful in providing much needed corroboratory evidence.

The findings of the part - II of this investigation reveals that the algal species occurring in the rhizospheres of ragi, bean, pigeon pea, and sunflower are almost the same as found in the soil samples of some of the taluks. Totally fifteen species occurred, of which 10 were Cyanophyceae, 3 Chlorophyceae and 2 Baccillariophyceae. The soils were mostly having pH 6.8 in all the fields. The nitrogen content was quite high, as also the phosphates and potassium. Investigations on other soil microorganisms have revealed that the "rhizosphere effect" varied with the kind of crop. Zukovskaya (1941) as quoted by Katznelson et al. (1948) claimed that "each plant grown in the same soil enhanced the activity of a specific microflora of its own". Gonzalves and Yalavigi (1959) have also observed that the "rhizosphere effect" varied with the crop plant. However, here eventhough four different crop plants viz., ragi belonging to Gramineae, bean and pigeon pea belonging to Fabaceae and sunflower to Asteraceae family, each having different kind of root system viz., fibrous, nodule bearing and tap root respectively, there was no marked effect found on the algal species recorded in their rhizospheric regions.

The maximum of 15 species were recorded from pigeon pea and 14, 13 and 12 species from sunflower, bean and ragi respectively. The respective control samples showed 13, 8, 13 and 10 species in the manured field samples. In the
unmanured field samples sunflower rhizosphere harboured 11 species followed by bean, pigeon pea and ragi with 10, 9 and 7 species respectively. In the controls of these samples ragi had 7, bean 5 and sunflower and pigeon pea 6 each. This shows that the manured samples had greater number of species than the unmanured ones eventhough the crops were the same. Regarding the algal population per gram of soil in the manured samples the highest number 0.212 x 10^4 has been recorded for bean and the least 0.146 x 10^4 for sunflower. The population in the control soils was lesser than rhizosphere population of all the crops. The highest was 0.155 x 10^4 in bean and the least 0.106 x 10^4 in ragi and pigeon pea. In case of the unmanured samples also the highest is recorded for bean only with 0.191 x 10^4, and the least for pigeon pea with 0.107 x 10^4. In the control samples it is less in all the cases as in case of manured control samples. The highest is 0.106 x 10^4 recorded for sunflower and least 0.092 x 10^4 in case of pigeon pea.

The R/S ratio ranges from 1.05 (sunflower) to 1.971 (ragi) in manured soils. In the unmanured soils the R/S ratio ranges from 1.07 (sunflower) to 1.89 (bean).

The influence of the plant on the algal numbers in both the manured and unmanured samples is definitely pronounced in the case of ragi and bean followed by pigeon pea and sunflower.
That ragi has larger amount of root influence on the number of soil algae is probably due to its fibrous root system which occupies a larger area on the surface area, not penetrating deep as in case of sunflower. In case of bean and pigeon pea the roots harboured bacteria in their nodules and this may be interacting to some extent with the growth of algae in the rhizosphere.

The unmanured samples harboured lesser number of species and less amount of algae per gram of soil. Probably the addition of nitrogenous farmyard manure has stimulated the proliferation of larger number of species and larger number of algal cells and filaments than in the unmanured samples. These results from the rhizospheric studies of this investigation confirm the findings of Gonzalves and Yalavigi (1959). Though only one sampling has been done for each group, since the time of sampling coincided with the period of flowering of the crops, maximum rhizospheric effect, if any, can be expected (Gonzalves and Yalavigi, 1959).

Plants are known to exude several amino acids, sugars and other chemicals from the roots at the period of maximum metabolic activity i.e. during flowering (Rovira, 1965). From the present study, a pronounced rhizosphere effect as was found in the case of bacteria and fungi was not found with algae. This is understandable as algae are autotrophs, whereas bacteria and fungi are mostly heterotrophs, totally dependant for their carbon requirements on other sources. Host specificity in the rhizosphere effect was not very pronounced in the case of algae.
John (1942) has reported that the liquid cultures do not present a true picture of the algal flora of the soils, as majority of them in this investigation also showed the presence of species of Chlorophyceae. These used to appear first and grow so vigorously that within 2-3 weeks, the entire culture flasks were filled with them. Naturally, their preponderence did not allow other algae even to germinate. Probably these Chlorophyceae were in dormant state and no sooner the additional nutrients were made available in the form of culture solution, they germinated and grew vigorously. In case of *Oedocladium* species probably it remained in the vegetative stage in the soils and hence it could not proliferate as much as the other forms which were in the form of dormant propagules.

In the moist cultures, the soil which was dry was made wet in the laboratory and this proved a very congenial habitat for the Cyanophycean algae to proliferate by hormogone formation. So, within a very short period of 2 - 3 weeks the entire Petri dishes used to get covered by species of *Phormidium, Nostoc, Anabaena, Scytonema, Stigonema, Westiellopsis* etc. In some cultures there used to be regular succession of the blue-greens throughout the year. So the blue-greens can be regarded as the real edaphic algae, whereas the Chlorophyceae and diatoms can be regarded as hydrophytic species brought to the soil by wind or by water during irrigation and other cultural practices.