CHAPTER 1

INTRODUCTION
The soil formation dates back to 400 million years ago, that is, the Silurian period. The term soil is derived from Latin word “solum” means floor. The soil is the product of weathering of rock, which includes physical, chemical, and biological action. Both climate and living organisms are active factors in soil formation. It refers to an outer loose material of earth’s surface, a layer distinctly different from the underlying bedrock. Agriculturally and economically it is the region, which supports the plant life, and provides mechanical support and nutrients. Chemically, the soil contains a multitude of organic substances not found in the underlying strata. For a microbiologist, the soil environment is unique, because it contains a vast array of bacteria, actinomycetes, mycorrhiza, fungi, algae, protozoa, crustacea, nematodes and annelids. This soil environment is one of the most dynamic sites of biological interactions in nature.

The soil is composed of the five major components, such as air, minerals, organic matter, water and living organisms. The quantity of these components is not the same in all the soils and varies with localities. The amount of mineral and organic matter is relatively fixed at a single point. The mineral fraction is slightly less than half of the soil volume, where organic matter accounts for three to six percent. The proportion of air and water fluctuates and they account for half of the soil volume. In fact, the living portion of soil body including small animals and microorganisms is less than one percent of the total soil volume (Alexander, 1977).

The texture of soil is very important for the biological activity and to establish a relationship between aeration and moisture. Similarly, one should understand the soil profile for the appreciation of biological productivity. All microbiologists have an
eye on the surface soil because of its dense population and nutrient supply. Whereas, the beneficial and detrimental effects of micro flora on higher plants are exhibited in the "A" horizon of soil profile. On the other, subsoil modifies the characteristic of surface layer as a habitat for both macro and micro space organisms. There will be local differences from one area to the other with respect to depth, colour, pH, chemical composition etc; the differences may be small or large. For example, microorganisms found in the rhizosphere may not be the same or uniform which is just a centimeter away from rhizosphere. Therefore, soil type is of great consequence in its microscopic involvement within any one soil structure.

In environment free vegetation, algae may play a critical pioneering role. Their early appearance in barren or denuded areas is especially noteworthy. Another environment in which algae could have agronomic significance is in paddy fields. In recent years, there has been an upsurge of interest in agronomic contribution of certain blue-green algae and their capacity to utilize nitrogen as a source of growth (Alexander, 1961).

The porosity of heavy soils is affected by the state of aggregations. Aggregates are temporary structures whose stability depends on management practices, meteorological condition, microbiological activity and other factors. Aggregates are of microbiological interest, since the cell material and extra metabolites of bacteria and fungi are factors affecting the formation and stability of granules. The aeration and moisture are inversely proportional to pore space. The difference in the composition of above and below ground atmosphere arises from respiration of microorganism and plant roots. The gaseous diffusion rate and the rate of respiration govern the concentration gradient.
As a rule carbon dioxide and oxygen is inversely proportional to the depth of the soil (Alexander, 1977). Tillage leads to mechanical destruction of the soil structure and promotes microbial degradation of the organic matter by increasing the oxygen availability. While the latter increases the nutrient availability to the crop plants, the former reduces the soil tilth. Most of the soil algae possess mucilaginous sheath and have profusely branched thalli, which help in binding the soil particles together. This cementing effect increases the size of the soil aggregates. Algal crust on the soil surface minimizes soil erosion, increases the soil aggregate size and optimises aeration, water movement, root development, fertilizer utilization and use of algae has been found to be very successful in increasing the size of soil aggregates (Goyal, 1997). Soil compaction is the ultimate process observed in the fields under intensive cultivation with heavy irrigation. This is caused by the breakdown of soil structure creating high bulk density and robbing the soil pore space. Puddling is also aimed at compacting the soil to reduce water percolation in a rice field.

The inorganic nutrient varies with depth of soil. Organic fraction of soil is often termed as humus and it is the product of decomposing activity of microflora. Since, it contains the organic carbon and nitrogen needed for microbial development, the decomposition leads to the loss of some of the carbonaceous material and leading to the generation of new “microbial tissue”. The rate of carbon loss can be related to structure and fertility of soils. It also reflects the level of biological activities. In an undisturbed land, the organic matter is relatively constant and modification of the habitat by cropping or by altering the aeration, changes in the level of humus. In a soil ecosystem the bacteria are especially prominent because of much population in a given soil
and they are most abundant group, usually more numerous than fungi and algae. The algal members are not numerous as others. Further, the algae are photosynthetic organisms that require sunlight and their existence are too precarious in the soil, hence they are not significant. These organisms are abundant in habitats in which moisture is adequate and light is accessible. Their development on the surface of cultivated or virgin land is frequently noted with naked eyes. In nature or in laboratory their presence can be observed by the addition of nitrate, potassium, phosphate, magnesium, sulphate, calcium and iron salts with inorganic nutrients.

Algae which occur on and beneath the soil - constitutes what is known as soil algae or edaphic algae. Soil algae are referred to as the sum total of various ecological groups, namely, terrestrial, aquatic-terrestrial, growing on permanently damp soil or soil algae proper found below the soil surface. The importance of soil algae came to limelight about 200 years ago and it was known to occur as ubiquitous organisms and available at all various depths and in all kinds of soils. On the other hand, an extensive amount of literature reflects the attention directed towards aquatic forms (Chapman, 1946 & 1957 and Blum, 1956). Later various investigators have explored the possible significance of soil fertility of photosynthetic microflora-which as a group, independently synthesizes carbon and free nitrogen. Many cause-effect relationship, however, remain to be established between environmental variables and the incidence and composition of the soil algal populations (Prescott, 1956).

Large majority of the phycologists consider the terrestrial algae to be depauperate forms, which make a more natural growth
in aquatic habitat. The existence of a definite algal flora of soil seems to be well established, however though certain species do occur in water (Tiffany, 1951). *Botrydium, Protosiphon, Buillaria exalis, Chlorococcum hunicola* and a number of other species of *Zygnema, Zygozium, Oedogonium, Botrydiopsis, Vaucheria and Microcoleus* are also known to occur as terrestrial forms (Fritsch, 1907 and Wilson and Herman, 1957).

Morphologically, algae may be unicellular or they may occur in short filaments, but the soil strains as a group are characteristically smaller and structurally less complex than aquatic counterparts. The soil alga has an important role in plant succession, because of its ability to grow even in the soils that are very poor in plant nutrient. Later on these soil algae covers, the soil surface which helps in conservation and reclamation of soil (Singh, 1961). The presence of soil algae in great number is an important point to be considered; apart from this, the capacity of the algae to survive even in darkness below the soil upto one meter and to retain its vigour even after undergoing for a longer period of storage and desiccation (Alexander, 1977).

Bristol (1919) reported that some of the species viz. *Protosiphon, Cinnamonous, Schizothrix calcicola, Nostoc ellipsoidum* and *Microcoleus* species have been revived even after periods of drying for upto 70 years as herbarium sheets. The algae, especially the blue green algae are able to survive prolonged period of drought. Successful revival of algae has been possible even after 83 years of preservation in dried forms. Many of the xeric forms are able to survive temperatures exceeding 100° C when dormant in the soil. Forms, which do not form resting propagules, are able to resist the dry and warm conditions because of the presence of
the mucilage, viscous cytoplasm, absence of vacuoles, aggregation of several trichomes and pigment adaptations. Graebner (1895), who for the first time listed soil algae from heaths of Northern Germany and most of the algae observed, belonged to Blue Green Algae. After this work, the presence of soil algal flora was considered as one of the important parts of soil microflora.

Terrestrial algae, in fact, play a major role as primary colonizers, which help in the establishment of other members of the soil flora and accumulation of humus. They bind sand and soil particles and prevent erosion. This has helped by their gelatinous sheaths and in some cases, some species like *Porphyrosiphon*, *Microcoleus*, *Plectonema*, *Schizothrix* and *Scytonema*. All these forms closely intertwine to form rope like bundles which help in binding the soil particles and in maintaining the moisture of the soil. Booth (1941) found in the soils of Oklahoma, that soil with an algal covering had moisture of 8.9% in comparison to that of 1.3% of the soil without algal mats.

Microalgae are ubiquitous components of the soil microflora. They are cosmopolitan in distribution, as they require only little moisture and diffused light for their growth. However, being photoautotrophic in nature, they have restricted distribution along the soil profile. In fallow fields, algae are generally found upto two to three centimeters depth. In light and sandy soils some unicellular forms like *Chlorella*, *Chlamydomonas*, *Chlorococcum*, and *Diatoms* may be carried to the deeper layers by the percolating water. The grasslands, during the rainy seasons generally show very good growth of *Scytonema* and *Nostoc*. Cameron and Blank (1966) have earlier reported the microstratification of algal populations in the soil. Over a period of time, these forms have
been seen, resulting in the formation of soil crust, sufficiently thick and rich in organic matter to support the growth of moss plants and grasses during the cooler and moist months of the year (Goyal, 1997).

Soil algae are usually located in top 0.5mm layer and the viable cells of blue green algae may occur at depths. Feher (1948) had observed that many algae occur at the depth of 15 – 20 cm below the soil surface & has considered that layer as active algal zone. According to Petersen (1935) large, algal members are observed at depths and are transported vertically by rain or perhaps by earthworms. Vaidya (1964) who investigated soils from the vicinity of New Delhi found blue green algae at depths of 5.5 meters and suggested that the possible carriers are ants.

Algae are also involved in generation of organic matter from inorganic substances, although the importance of soil algae has been well recognized in recent years. There are few studies concerned with their vertical distribution Trainor (1978) and Mitra (1951) have studied the distribution pattern of the algae in the tropical soil of India. An alga constitutes a dynamic component of the soil, which add and increase the availability of crop nutrients. They help in improving the soil structure and amend the chemical nature of the soil. Algae form a rapidly multiplying cover crop of microscopic plants which are capable of colonizing almost all the types of the soils with ease. Algal crusts on the soil surface add organic matter, reduce evaporation from the soil surface and remove compaction. Proliferation of algae increases the productivity of the soil through, encouraging the growth of other soil microorganisms, increasing the availability and ensuring better crop nutrient management by amending the physical and chemical
nature of the soil and increase the nutrient utilization efficiency of the plants. Augmentation of the algal component of the soil through the introduction of selected algal forms leads to bio-enrichment of the soil which enhances their influences and ensures sustained long range agro ecological security. As a group algae are of heterogeneous assemblage of organisms ranging from a motile unicell to complicated heterotrichous thallus construction with both prokaryotic and eukaryotic cellular organization. Although they are predominantly true hydrophytes, aerial and subaerial forms are not rare (Goyal, 1997).

Ability of many forms to withstand adverse ecological conditions, capacity to thrive well in hostile environments and respond to the onset of dry conditions by entering into a dormant resistant state, have distinguished this group as pioneers of plant succession. Both in xerosere and hydrosere, algae appear as first plant community leading to the establishment of higher plant communities. Algae play an important role in primary and secondary plant community succession by acting as an integral part of colonial synusium.

The algae form an important component of the ecosystem. They account for about 40% of the total carbon fixed annually on this planet. The spontaneous fertility of the soil of the tropical rice fields is largely because of the activity of the algae. But it is difficult to believe the effectiveness of a "cover crop" which one can hardly see. One has to have perseverance to realize the effect of this important self-regenerating system, which has sustained cumulative effect.
The interpretation of edaphic algae as soil microorganisms is more widespread today, because of the realization that as a component of the soil microflora, algae acts as reservoirs for the plant nutrients, as organisms influencing the soil structure and the activity of other microorganisms and as an agent for the incorporation of organic carbon and nitrogen through photosynthesis and nitrogen fixation. However, still our understanding of the ecophysiological nature of the soil algae is based upon the laboratory experiments and observations.

It is observed that typical aquatic and edaphic forms do not exist, albeit no clear demarcation can be made between the two types, as many forms generally occupy the borderline. Forms like *Chroococcus, Microcystis, Anabaena, Oscillatoria, Chlamydomonas, Chlorella, Cladophora*, etc are strict hydrophytes, while *Fritschiella, Vaucheria, Scytonema* and many species of *Calothrix, Nostoc, Haplosiphon* etc grow only on moist and shaded soil surface. *Chlorococcum, Plectonema, Phormidium, Nostoc, Calothrix, Cylindrospermum*, and *Diatoms* occupy an intermediate positions, as they are capable of growing in water as well as on the soil.

Arid soils are probably the most inhospitable of all the habitats where blue green algae grow because, the temperatures are high and water is severely limiting. The algae of arid regions occur in different habitats: algae found in arid soils of America are *Schizothrix, Phormidium, Scytonema* and *Protosiphon*. In India *Microcoleus and Nostoc* are found frequently (Mitra 1951).

In cultivated fields, the algae are found even at 20cm depth because of the turning of soil during ploughing. However, one does not expect them to multiply because of the limitations of light.
Thus the algal activity influences only the top few centimeter layer of the soil, showing pronounced effect on the surface of the soil layer. The texture and the chemical nature of the soil greatly influence the algal distribution. Sandy soils show restricted algal incidence. High moisture content and water holding capacity encourage algal growth. Presence of clay generally favours green algae and tropical conditions encourage blue greens. Likewise low pH accelerates the growth of green algae and at high pH blue greens proliferate. At Alkaline pH the predominance of diatoms and Cyanobacteria is due to increased availability of organic and inorganic nutrients (Lund, 1945 & 1947 and Mitra, 1951). Predominance of green algae at lower pH may be due to the inability of other algae to live at lower levels of nutrient supply. The algae appear to be more abundant in cultivated soils than in uncultivated ones (Tiffany, 1951) and Shtina (1961, 1963, 1964b, 1965a & b) have carried out an extensive studies on the abundance of blue green algae in Russian soil. She found Nostoc and Scytonema were particularly important components of fertile steppe land, and she also observed that the algal flora could be used as an indicator of the soil type and conditions in various habitats. Slight lateral movement in the soil may be brought about by gliding motility, but wind is probably the main agent of algal dispersion over wide areas. Lateral movement in ungrazed prairie soil in Oklahoma was studied by Forest et al (1959). They removed cores, replaced them after sterilization, and then after an interval compared the algal composition of the sterilized area with the unsterilized area surrounding soil. They found that there were no special pioneer forms and that it was dominant species from the surrounding soil, which became most abundant on previously sterilized soil.
Bristol (1927) who did not always distinguish between blue green algae and other algal groups carried out studies on soil algae. In general, the members of blue green algae are extremely variable from habitat to habitat and even within different areas of the same habitat. There are also marked seasonal fluctuations in the flora. The average numbers of blue green algae is 20 to 50 thousand per gram of soil. In Australian arid soils Chan and Beadle (1955) have found low numbers i.e. an average of 1000 to 3000 from soils of tree nursery, Jurgen and Davey (1968) recorded 97,000 nitrogen-fixing algae per gram of top 5mm soil. Singh (1961) calculated 18,000,000 filaments of *Cylindrospermum licheniforme* per gram of soil in maize fields of India.

Vegetation cover in the fields also regulates the occurrence of algal communities. In a rice field, crop canopy encourages the occurrence of forms like *Calothrix*, *Scytonema*, *Tolypothrix*, and *Aulosira*, which flourish well in moist and shaded soil surface. The same field just after transplantation had been seen harbouring green algae like *Hydrodictyon*, *Spirogyra*, *Cladophora* and *Rhizoclonium*, because of shading by crop plants and availability of comparatively combined nitrogen. Cultivation practices also affect the distribution and prevalence of the soil algae, rice field soil due to flooded conditions and shade provided by the crop canopy provides simplified ecosystem which encourage climax communities favouring the growth of only the adapted algal forms. Generally these soils harbour a very rich Cyanobacterial flora and conversely soils from the field where only dry crops are grown, the soil algae show tremendous species diversity and very rarely a particular alga or a group of algae are found to dominate the niche.
Blue green algae are of worldwide distribution and in general, the more inhospitable the habitat, the more likely it is that BGA will be an important component. In Polar regions, species of *Nostoc* are among the important terrestrial algae, others are *Schizothrix, Oscillatoria, Lyngbya, Phormidium* and *Stigonema*. On top of alkaline marble areas on Ross island, Andaman and South Victoria Island, free living *Nostoc* forms an "algal peat", to 10-15 cm deep. *Nostoc* appears in symbiotic state in Antarctic lichens either as primary phycobiant.

Algal growth greatly influences the physical and chemical nature of the soil. Soil algae have high tolerance to extreme cold or heat. Comparatively, temperature as a factor does not signify much with regards to growth. It has been noted that luxuriance of soil algae and total numbers of species is closely related to availability of mineral nutrients. Nutritional independence for carbon in general and for both carbon and nitrogen in the case of nitrogen fixing blue green algae, make algae an important component of the soil microflora. Algae add substantial quantities of organic matter through primary production. Out of the global net production of $2 \times 10^{11}$ tonnes of organic matter, $3.2 \times 10^{10}$ tonnes (amounting to 40%) is accounted by the algae of aquatic and terrestrial habitats. Algal growth not only narrows the carbon / nitrogen ratio, making the soil more fertile, but also increased the humus content of the soil. The enhanced absorption by the soil organic matter has been shown to reduce the effect of the toxicants.

There are reports on the occurrence of other obligate photoautotrophic and chemoautotrophic soil microorganisms, but the sporadic references to these forms indicate that they are probably not important in the soil ecology. However, a number of
facultative photoheterotrophic and chemoheterotrophic algae capable of utilizing simple carbohydrates and organic acids present in the soil substantially, effect the process of nutrient transformation in the soil.

The microbial components of the soil including the soil algae play a very important role in nutrient transformation and mobilization in the soil. The soil microorganisms actually feed the plants through mobilization of various nutrients. Microcoleus, a good soil binder, appears together with various species of Anabaena, Cylindrospermum, Tolypothrix and Fischerella. Aulosira fertilissima, which is perhaps the most important nitrogen fixing species, develops more slowly but by the middle of September, forms an extensive brownish yellow gelatinous growth. This is dominant for about three months and forms a papery layer on the soil surface when the fields dry.

The ecology of the paddy fields has been relatively little studied but the effect of cultivation on the physicochemical conditions, the effect of these on the growth of different species and the inter relations between the various microorganisms and the rice plants are all undoubtedly complex. Knowledge of these would help in making more practical use of BGA. Algae also act as a soil conditioner in paddy field soils.

Many of the investigators have reported that the soils of India are endowed with BGA over other groups. The only difference between temperate and tropical is in comparison with algal flora (Mitra 1951), Dutta and Venkateshwaran (1958), Gonzalves (1959), Pandey (1965), Subba Raju (1968). Mitra (1951) ascertained the preponderance of the chlorophyceae to
Myxophyceae in temperate regions. Subba Raju (1959), indicated that a fair representation of the BGA even in soils that are acidic. On contrary in British soils there is better representation of Chlorophyceae even in alkaline soils (John, 1942). Whereas, Lund (1947) had observed those members of Myxophyceae, Bacillariophyceae will frequently replace Chlorophyceae in alkaline soils, which are not base deficient.

The algal microbial interaction can be symbiotic, antagonistic, synergistic, competition, ammensalism, commensalism, parasitism, neutralism and proto-cooperation. Algae liberate varieties of compounds like amino acids, vitamins, enzymes, carbohydrates, organic acids, polypeptides, antibiotic, and phenolics which generate the above responses (Venkataraman et al, 1974).

The soil ecosystem is our heritage and has limited regeneration capacity. It is a dynamic system. The more we care and cooperate with the living things in it, the more support we will harvest. The ever deteriorating resource accounting and failed to recognize the environment management. Increased use of chemical inputs in agriculture has lead to considerable biodepletion of soils. All these factors have contributed to the stagnated crop yield not to speak of contamination of the ground water and resource depletion. The present day negative nutrient balance in the soil can be corrected only through integrated nutrient management involving careful usage of chemical fertilizer, organic manure and bioinoculents. In addition, soil vitality also has to be preserved which is possible by the use of economic and eco-friendly bioinoculents.
Earlier investigators have oriented principally towards descriptive and taxonomic studies. Later, in the middle of the nineteenth century, much importance was laid from an angle of interrelationship with environment. The present exploratory survey was undertaken to fill the gap of native algal composition and with a view to enumerate the algal flora of Kolar district, Karnataka state, which has not been investigated in detail so far. The emphasis has been laid mainly on cultivated soils of the district.

In the present investigation, soils of different types have been collected from each taluk of Kolar district during 2000. The culture studies were initiated to know the abundance of algal members and the soils were analyzed physico-chemically to assess the correlation between algae and physico-chemical complexes. A large majority of the soils collected are from desiccated areas, while a few are from barren land and irrigated areas to obtain a comparative account.

The main objectives of the present work are as follows:
1. To study the soil characteristics of the region
2. To study the algal floristics in varied soils.
3. To attempt the possible relationship between the abundance of algal species with soil properties.

The thesis is presented in this manner:
1. Algal floristics of the study area
2. Distribution of algae in relation to different physico-chemical factors

Appendices have been provided for floristics occurrence, algal abundance vs physico-chemical parameters and camera Lucida diagrams.