# Nature's Ways of Enriching Soil

by

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Soil is the substrate on which plants grow. It provides plants with a substratum to which they anchor themselves. It is also the reservoir from which plants absorb water and most of their nutrients. Of the elements necessary for plant growth, C, H, & O comes from $CO_2$ and water. Of the other nutrients, the most important ones for plant growth are N, P & K and these come from the soil. In nature, all these nutrients are supplied through cyclic processes. Thus we talk of the Hydrological Cycle, the Carbon Cycle, the $N_2$ Cycle, P. Cycle, etc. This essentially means, that within the biosphere, all nutrients move through land, water and atmosphere in cycles, and the rate at which these cycles operate would essentially determine the growth and continuation of living things. For example, plants fix C from $CO_2$ in the atmosphere through photosynthesis and animals assimilate this carbon either through primary or secondary consumption. Once these plants and animals die, their bodies are decomposed by microorganisms and the $CO_2$ is liberated to the atmosphere. At the same time many other nutrients from their dead bodies are also released to the soil and further converted to re-assimilable forms. If not for the action of these microorganisms, elements essential for life would soon get fixed permanently.

*Of the major nutrients that plants absorb from the soil, nitrogen is frequently the limiting one. This is because nitrogen is easily lost, through leaching, denitrification and $NH_4$ - volatalization. Thus N- is often referred to as the "key" to the realization of yield potential in many crops, and in many cases the nitrogen status of a soil largely determines its fertility. Though it is the growth limiting nutrient in many ecosystems, nitrogen is also the most abundant element in the atmosphere. Seventy eight percent of the air around us is $N_2$ gas. Unfortunately, this gaseous nitrogen or dinitrogen is quite inert and it cannot be used by plants and animals. In its broadest sense, $N_2$- fixation is the combination of dinitrogen with other elements. This takes place abiotically through lightning, volcanic eruptions etc. It is also done industrially in the manufacture of N- fertilizers. In addition, there are certain microorganisms which convert inert dinitrogen directly into a combined form and this is called Biol. $N_2$ - fixation (BNF). This process is confined to certain bacteria and certain cyanobacteria which possess an enzyme called the nitrogenase. On a global scale, of the total amount of $N_2$- fixed, nearly 60 per cent comes through BNF, which is two and a half times that of industrial fixation. Industrial $N_2$-fixation or fertilizer manufacture is a high energy demanding process. It has been estimated that the energy requirement for the worldwide production of $N_2$- fertilizer is equivalent to 2 million barrels of oil per day. It is important to realize that this enormous amount of energy comes from a non-renewable source. On the otherhand,* *energy for BNF comes either directly or indirectly from the sun. It should, therefore, be apparent that crop production in Third World countries like Sri Lanka (which do not have fossil fuel energy) should not depend entirely on industrially produced N-fertilizer. It is imperative that we exploit BNF to the utmost and the research programme on BNF at the Institute of Fundamental Studies is directed towards achieving this objective.*

## *The Organisms that Fix $N_2$*

*BNF is confined to prokaryotic microorganisms, and it is believed that this process evolved a long time ago among primitive organisms. These organisms could be either free living or symbiotic. Among the free-living ones they can be autotrophic or heterotrophic. In the symbiotic ones, the microorganism is always the endosymbiont. The best known symbiotic types are the leguminous plants that produce root nodules, inside which live the N- fixing rhizobia. A lesser known system is the symbiosis between certain non-leguminous plants which form $N_2$-fixing root nodules with Frankia. In both these cases the $N_2$ fixing endosymbiont is heterotrophic and depends on photosynthates from the host for its sustenance. Cyanobacteria which are themselves photosynthetic, also form symbiotic $N_2$ - fixing associations with a number of other groups of plants (Figure 1). A less specific, less intimate and somewhat lesser understood relationship exists in associative $N_2$ - fixation where Azospirillum and certain other* *bacteria fix nitrogen in close association with the roots of certain grasses, including rice. They do not form nodules or any other structures that enable us to recognize such relationships.*

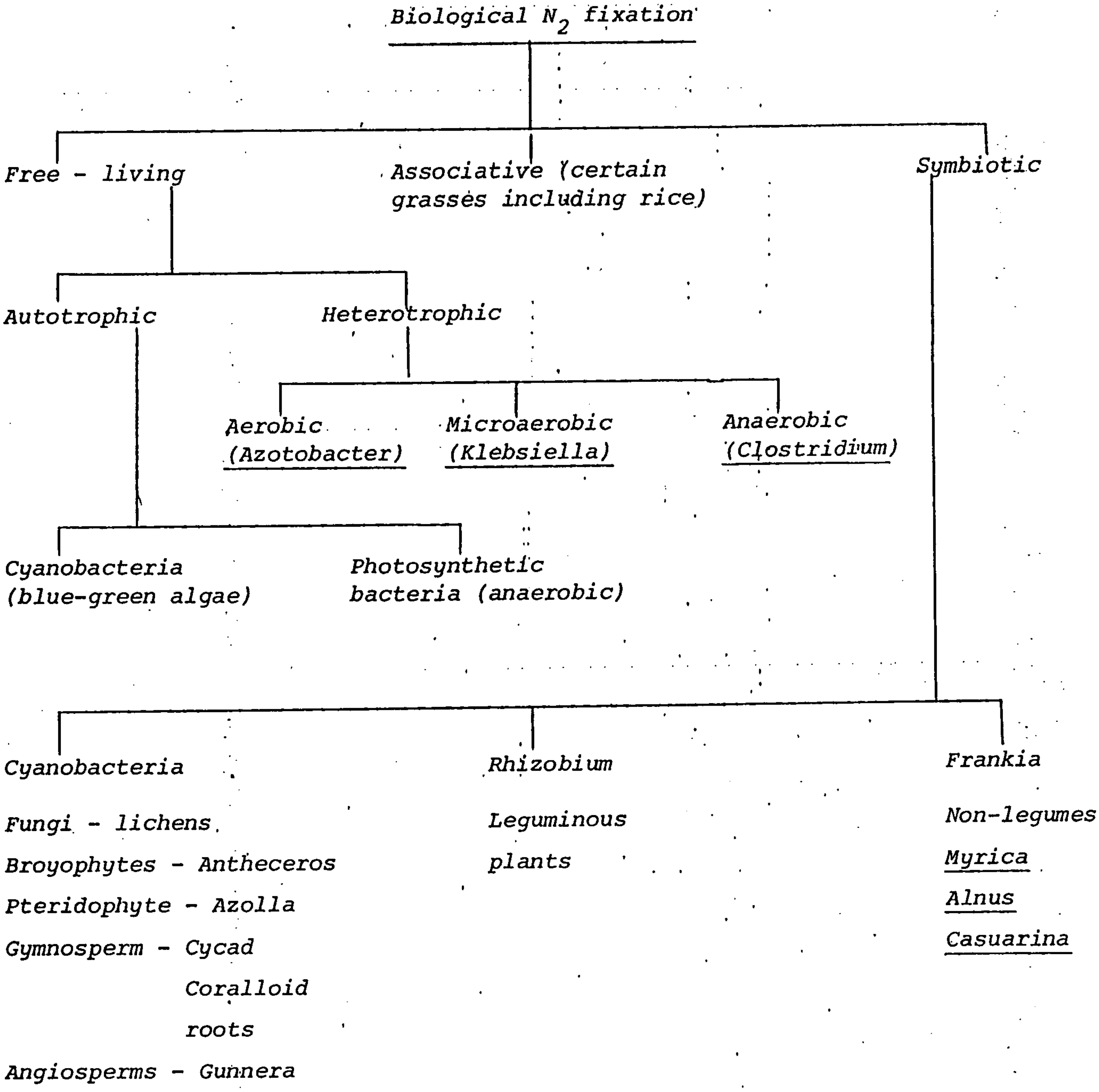

*Figure 1: Organisms and systems that fix nitrogen biologically.*

## The potential of BNF

The best known $N_2$-fixing system the legume - rhizobium system has been used in agriculture by man perhaps since the beginning of civilization. Systematic studies on this association and the development of technologies for its application has resulted in the production of certain food and forage legumes without N-fertilizer application. For example, Brazil produces twelve million metric tons of soya bean annualy without any N-fertilizer applications, and this is estimated to be a saving of a five million tons of urea fertilizer. Of all the developed countries, Australia uses the minimum levels of N-fertilizer which is about one tenth of that used in Europe. Food legumes such as soybean, cowpea, green gram, black gram, peas, dhal, peanuts, winged bean are perhaps the most nutritious of all foods available for human consumption. All these plants fix nitrogen but ironically we in Sri Lanka still add N-fertilizer for their cultivation. This is because we have not yet obtained adequate knowledge to improve and fully utilize the natural $N_2$-fixing potential of these plants. Legumes such as <u>Pureria</u>, <u>Centrocema</u>, <u>Stylosanthus</u> are often used as cover crops in plantations, specially in rubber estates, but hardly any information is available on their $N_2$-fixation. Many of these species not only enrich the soil, but are good forage crops for animals, but pasture production using such plants is virtually non-existent in this country.

We are all aware and very much concerned with the rapid de-forestation that is going on, and everyone is looking for tree species that are suitable for re-forestation and fuel-wood production. The common species that are recommended and widely used are the pines and the eucalypts which grow fast, but often at the expense of the natural vegetation. One wonders why fast growing $N_2$- fixing trees such as Ipil-Ipil (Leucaena leucocephala), Albizzia, Sesbania and Casuarina are not used. Such plants will not only grow on poor eroded soils, but also enrich it and provide the rapid regeneration of the natural vegetation.

Today, Sri Lanka uses around 100,000 metric tons of urea annually for rice production and the government subsidy on this fertilizer alone is about 1000 million rupees. It has been shown that with the proper use of cyanobacteria and Azolla, a rice crop can be provided with one third to half of its fertilizer N-requirements. If these $N_2$-fixing systems can be applied on a large scale it could result in an annual saving of 300 - 500 million rupees.

These few examples amply justify the priority given to research on $N_2$-fixation at our Institute. I hope that I have succeeded in convincing you the necessity to harness your efforts to pursue research on this facinating process, which probably holds the key to low cost food and fuelwood production, which are essential requirements for the development of Third World countries like Sri Lanka.