SYMBIOTIC BACTERIA AND FUNGI

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Keywords: Nitrogen fixation, legumes, Actinorhizal plants, nodulation, *Rhizobium*, *Burkholderia*, *Frankia*, ecto-mycorrhizas (EcM), arbuscular mycorrhizas (AMs), phosphorus, bioremediation

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Summary

Nitrogen (N) and phosphorus (P) are the two most important nutrients for plant growth, but in many environments both are in short supply and/or are unavailable to plants. This is particularly true in tropical forests, where high temperatures and humidity cause mineralisation of organic N, and the very high precipitation results in rapid leaching of the remaining soil N. Therefore, the fixation of atmospheric dinitrogen into ammonia and hence into organic compounds is a crucial part of the N- cycle of these forests. Nitrogenase, the enzyme responsible for biological nitrogen fixation (BNF), has a wide taxonomic distribution in the bacteria and archaea, but is confined to a limited number of species. Among these, soil bacteria called rhizobia, which form symbiotic nodules on the roots of legumes (Fabaceae), are recognised as the main contributors of biologically-fixed nitrogen to pristine environments, most particularly in tropical forests where they are so abundant and diverse, but there are other symbiotic, endophytic, associative and free-living diazotrophs that make a significant contribution, and this chapter describes these as well as the leguminous symbioses.

Similarly, the availability of the second most major essential nutrient for plants, P, is greatly limited by its occurrence and low availability in the soil, most particularly owing to the low solubility of phosphates, and hence plants very early in their evolutionary history developed a symbiotic relationship with fungi called mycorrhizas. There are two

types of mycorrhizas: ecto- and endo- (e.g. arbuscular and ericoid) mycorrhizas, and most plant families (> 95 %) are capable of forming a symbiosis with at least one type. In this chapter we review current knowledge about symbiotic mycorrhizal associations within tropical forests and assess their likely contributions to the P-cycle.

1. Introduction.

Nitrogen and phosphorous are the two main limiting nutrients in both natural and agricultural systems. In agriculture both nutrients are supplied in forms available to plants as fertilisers produced either through chemical processes (eg. the Haber-Bosch process that converts or "fixes" atmospheric nitrogen into ammonia using very high quantities of energy) or from mining mineral deposits (eg. from rock phosphate). Regardless of whether the fertilisers are produced chemically or by mining, the energetic and environmental costs of their production are prodigious. However, in most undisturbed non-agricultural ecosystems (as well as some agricultural ones) soluble nitrogen (ammonium) is made available to plants via a process known as biological nitrogen fixation (BNF), in which bacteria that contain the enzyme complex called nitrogenase (termed "diazotrophs") can fix atmospheric N_2 into ammonia using energy from ATP and reductant (electrons) supplied by respiration (which can be aerobic or anaerobic):

$$N_2 + 8H^+ + 8e^- + 16ATP \rightarrow 2NH_3 + H_2 + 16ADP + 16Pi$$

This ammonia, which is potentially toxic to the organism, is usually then immediately converted into amino acids or amides for use by the diazotrophic bacterium in the production of proteins and peptides to facilitate its growth. The fixed N incorporated into diazotrophic bacteria is then released into the environment when they die, usually in the form of amino acids that then become mineralized and available for uptake by other bacteria and/or by plants. Interestingly, although nitrogenase, the enzyme responsible for nitrogen fixation, has a wide taxonomic distribution in the bacteria and archaea, it is actually confined to a relatively limited number of species (J.P.W. Young in PALACIOS & NEWTON, 2005). Nevertheless, many plants, particularly legumes, but also some other higher plants (eg. *Gunnera*, and "actinorhizal" plants, such as *Alnus*, *Casuarina* and *Myrica*), as well as some cycads and the fern *Azolla*, form mutualistic symbiotic relationships with nitrogen-fixing bacteria. In these systems, soil bacteria located in specialized organs take nitrogen from the atmosphere and convert it to soluble nitrogen that is available for plant growth. Nitrogen-fixing legumes are one of the main sources of nitrogen in both natural environments and many agricultural systems. However, although pathways controlling nitrogen-fixation and the bacterial symbionts involved are well understood in a handful of model and crop legume species, very little is known about the diversity of symbiotic systems in natural environments in terms of the bacteria involved and their host relationships. This is especially so in the tropics where most legume diversity is found.

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Biographical Sketches

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