A common genetic mechanism discovered in nitrogen-fixing plants

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Some soil microorganisms are capable of forging associations with plant roots in the form of symbioses. Certain of these relationships play a highly important ecological and agronomic role. Arbuscular mycorrhizal symbiosis (which links a plant to a fungus) thus gives plants a mechanism for improving their supply of water and mineral nutrition.

This association has been in existence for 400 million years and appears to have accompanied plants in their colonization of the terrestrial environment. At present it involves about 80% of plant species. In a more recent era, about 60 million years B. P., the symbiosis which became established between soil bacteria, Rhizobium species, and leguminous plants doted them with the ability, unique among mass-produced crop plants, to capture nutrient nitrogen from the air.

Rhizobium forms specialized organs, nodules, on the plant roots. These are capable of transforming atmospheric nitrogen into ammonium that can be directly assimilated by the plant. In return, the plant supplies the microorganisms with nutrients in the form of complex carbohydrates.

Scientists have for many years been seeking to unravel the genetic mechanisms that govern such mutually beneficial relationships, on the one hand between plants and bacteria, on the other between plants and fungi. Investigations by a French team in 2000 had shown that some genetic signalling mechanisms operating in the symbiosis between leguminous plants and Rhizobium type bacteria and such plants and mycorrhizal fungi involved a common genetic element named SymRK.

This type of gene was already known to operate in the recognition of Nod factors, signalling substances emitted by the Rhizobium type bacteria which are essential for root nodule formation.

The actinorhizal plants make up another category of plants which have acquired the ability to live symbiotically with a nitrogen fixing bacterium, in this case Frankia. These pioneer plant species, whose host-symbiont mechanisms remain little studied, generally colonize disturbed environments, such as volcanic soils or mining-affected ground, and nitrogen-poor terrains such as moraines or sandy soils. About 260 species of actinorhizal plants exist, spread among 24 genera and classified into eight families of angiosperms, flowering plants.

An IRD team, jointly with a laboratory of the University of Munich, turned particular attention to the tropical tree Casuarina, or Australian pine. The first step employed molecular methods to find the sequence coding for the SymRK gene in the Casuarina genome.

Once isolated, the question was whether or not Casuarina needed this gene to establish its symbiosis with the bacterium Frankia. The team therefore developed transgenic plants in which SymRK gene expression was strongly reduced. Subsequent comparison of these plants' ability to form symbiotic root nodules with that of control plants showed that the plants with lowered SymRK gene expression produced only half as many root nodules as the controls.

The same modified individuals also showed strongly reduced mycorrhization compared with the unaltered Australian pine. The results therefore demonstrated that the weakened SymRK gene expression produced a considerable loss of Casuarina's nitrogen-fixing ability and also a reduction in its aptitude to form mycorrhiza. More generally, these conclusions bring out the fact that, in nitrogen fixing plants, a common genetic factor seems essential for setting-up the three types of symbiotic association involving bacteria (Rhizobium or Frankia) or a mycorrhizal fungus.

Improved understanding of these genetic mechanisms could in the coming years contribute to the development of procedures for performing the transfer of the genetic material necessary for atmospheric nitrogen fixation to plants like cereals, which do not possess this faculty. Although rice, for example, establishes a symbiotic relation with a mycorrhizal fungus, it is incapable of developing nitrogen fixing nodules. Modification of its genome to equip it with this ability could then open the way to considerable reduction of input of nitrogen fertilizers on this crop and thus cut down the resulting soil pollution.

Source: Institut de Recherche Pour le Développement

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