SS AGR 171

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Biological Associations: N_2 Fixation[1]

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There has been considerable advance in biotechnology techniques over the last few decades. We are able to produce genetically engineered crops with increased disease and/or insect resistance, increased nutritional levels, such as higher aminoacids contents. We can splice, hybridize, and multiply DNA and clone entire animals with the existing instrumentation and expertise. A lot of attention is devoted to more sophisticated techniques, whereas simple biological systems that could be better exploited by agriculture, may be overlooked or neglected. Some of these include the utilization and enhancement of symbiotic associations between microorganisms and plants. This report addresses one of these microbial symbioses: N_2 fixation by the legume-rhizobia system.

Most crops are deficient in N or require large inputs for proper growth and development. Yet N is one of the most abundant elements on earth and comprises 78% of the atmosphere. Plants are not capable of utilizing N_2 gas, and require that N be "fixed" in some reduced form in order to assimilate it and use it for aminoacids and, subsequently, protein synthesis, and fruit and seed production.

There are several ways by which N may be fixed: by lightning discharges, industrially (chemically), and through bacteria that can be free-living in association with grass roots (such as sugarcane, corn, forage grasses) or in intimate association with legume roots. Fixation by lightning discharges and precipitation contributes a small fraction of the N fixed, in the range of 3.5-7.5 lb/a per year.

Industrial or chemical fixation is the most often used form. However, as growers have been noticing, N fertilizer prices have risen drastically at all levels of the marketing chain, due mostly to the rapid increase in natural gas prices. Chemical fixation involves a catalytic reaction between atmospheric N_2 and hydrogen derived from natural gas. The process is carried out at high temperatures and pressures to yield ammonia gas. Anhydrous ammonia can be used directly or as the building block for other N fertilizers, such as ammonium nitrate, urea, N solutions, and ammonium phosphates.

Symbiotic N_2 fixation is achieved by the association between specific soil bacteria and the roots of legume plants such as beans, soybeans, peas, cowpeas,

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Aeschynomene, Crotalaria, alfalfa, clovers, vetch, and peanuts, among others. The association results in the production of nodules on the roots and yields a system capable of fixing N_2 gas from the atmosphere into N compounds usable by the plant system. In the mutualistic association, the bacteria obtain their energy in the form of carbohydrates from the host plant, which in turn receives usable N forms produced in the nodules. Efficiency of the symbiosis depends largely on the presence of inoculum but it also depends on soil N levels that are low enough to drastically limit the legume growth in the absence of N_2 fixation.

Thus, if considerable quantities of a N fertilizer are applied to the legume at planting, the association is inhibited and symbiotic fixation is reduced or does not occur. Active N_2-fixing systems are easily recognized by the pink coloration when nodules are cut open; inactive nodules have a green color.

When planting a legume in an area for the first time, inoculation should be done, unless an appropriate efficient *Rhizobium* is already present in the field. If conditions of prolonged drought, high temperatures, acidic or alkaline soils prevail, inoculation may be needed with each planting. Additional information on types of inoculants and on rules for a successful inoculation may be obtained from the IFAS Fact Sheet SS-AGR-154 Inoculation of Agronomic Crop Legumes. Inoculant costs a fraction of the seed costs and are well worth the investment. For example, a 50-lb bag of *Carpon desmodium* costs approximately $190.00, while a package of enough inoculant for the 50 lbs costs $3.60.

The quantity of N_2 fixed by *Rhizobium* bacteria will depend on the N_2-fixing capabilities of the specific legume, of specific *Rhizobium* strain-legume cultivar combinations and on environmental conditions. The literature reports the following values for annual N_2 fixation on a pounds per acre basis: alfalfa, 112-300; red clover, 76-170; pea, 71-135; soybean, 58-105; cowpea, 58-115; and vetch, 80-122. If the crop is incorporated as green manure, the N_2 fixed by the legume may be used by the subsequent crop. In a pasture situation, the use of a legume results in the increased protein content of the forage and a reduction in N fertilizer application.