BIOLOGICAL NITROGEN FIXATION WITH THE SOYBEAN AND COMMON BEAN CROPS IN THE TROPICS

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Brazil's economy is based firmly on agriculture, but the high costs of mostly imported fertilizers has resulted in a major research focus on biological N_2 fixation to enhance crop productivity and agricultural sustainability. One good example is the successful adoption of the soybean (*Glycine max* (L.) Merr.) crop in the country, in large part due to the approach of using biological N_2 fixation as a main component of the crop's production.

Nitrogen Fixation with Soybean and Common Bean in Brazil

The area under cultivation with soybean in Brazil (~22 million hectares) accounts for more than one third of world grain production and the great majority of the soils show populations of *Bradyrhizobium* established by previous inoculations and estimated at 10^3–10^6 cells g^{-1} soil. However, most farmers practice inoculation because the new strains and technologies available today result in grain yield increases averaging at 8%. Furthermore, N-fertilizers do not benefit the crop. Rates of N_2 fixation with the soybean under field conditions can exceed 300 kg of N ha^{-1}, providing up to 94% of total plant N and resulting in an economy to the country estimated at US$3 billion per year. In addition, release of N (~30 kg of N ha^{-1}) to following crops has been reported. Those numbers indicate higher rates of N_2 fixation than in other producing countries, such as U.S.A., Australia, Argentina and China. Explanations for this success in Brazil include: (1) emphasis on selection of both soybean cultivars and rhizobia with higher N_2 fixation capacity; (2) development of technologies aimed at increasing the contribution of the biological process, e.g., studies on compatibility of inoculants with agrochemicals and micronutrients; (3) education of the farmers towards the importance of spending time and money with inoculation; and (4) establishment of a strong legislation controlling both the strains used and the quality of commercial inoculants. The selection programs for superior symbiotic performance have been underway since the late 1960s and still continue, aimed at supplying the increased demands for more productive cultivars.

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Common bean (*Phaseolus vulgaris* L.) represents the most important source of protein for most countries in South America, with Brazil being the largest grower and consumer of the legume worldwide. Among the rhizobial species, *Rhizobium tropici* has proven to be outstanding in terms of genetic stability and tolerance to tropical environmental stresses. Strains very effective in fixing N_2 belonging to this species have been selected and, when used as inoculants, increase nodulation and N_2-fixation rates, allowing plants to produce up to 4,000 kg ha^{-1} without any N-fertilizer.

What About the Future?

Higher rates of N_2 fixation will be needed in future decades because of: (1) the release of more productive cultivars; (2) the use of legumes for biodiesel; (3) the need for recovering degraded areas; and (4) an increased demand for food. New and promising tools and approaches might help to speed the process. The selection of cultivars with a higher capacity of N_2 fixation and adaptability to a variety of environmental conditions might be faster if molecular markers, such as the simple sequence repeat (SSR) markers, are employed. New insights have been gained from genomic and proteomic research on very effective strains, like *Bradyrhizobium japonicum* CPAC 15 and *R. tropici* PRF 81, which are commercially recommended for the soybean and common bean crops, respectively, in Brazil. Comparative genomics, in addition to ecological studies on long-term field experiments, are revealing broad genome plasticity, high rates of horizontal gene transfer from inoculant strains to indigenous bacteria in the Brazilian soils, and significant shifts in microbial community structure subsequent to displacement of natural vegetation. It is also noteworthy that genetic characterization of dozens of bacteria collected from various Brazilian ecosystems are indicating the presence of many new species and may also represent a valuable reservoir of new genes. In the next decade, there will be an increased demand for higher N_2-fixation rates for many legumes and the results obtained in the next few years may be critical in convincing society and its leaders of the importance of the biological process for agricultural sustainability, environmental quality, energy supply, and food security.

Brazil, which is considered the largest reserve of productive land still available in the world, is emerging as a leading grain producer. However, a major challenge will be to devise models – combining basic and applied research – to improve crop yields by bringing degraded soils back to productivity and developing sustainable agricultural systems. N_2 fixation will play a key role in achieving these goals and may benefit large and small landholders, and subsistence and cash legume crops.

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