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Better Crops, Better Environment...through Science

From Scientific Staff of the
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WILL BIOTECHNOLOGY REPLACE NITROGEN FERTILIZER?

Research in molecular biology has put highly desirable and widely adopted traits for herbicide and pest resistance into crop plants. It is expected that the science will soon impact the rate of progress in yield improvement, and that genetically modified plants may show increased stress tolerance and nutrient use efficiency. What is the likelihood of being able to replace N fertilizer altogether?

Plants of the legume family have always been able to make their own N. A complex symbiosis with rhizobial bacteria lets them make the ammonium they need for protein synthesis directly from the N gas abundant in the air. They fix N using the nitrogenase enzyme of the bacteria. It costs the plant something for energy, but perennial species like alfalfa are efficient enough at it that they rarely respond to N fertilizer. Transferring the trait to non-legume crops would be a major challenge. The most important grain crops of the world—the cereals…corn, wheat, and rice—are all non-legumes. They take most, if not all, of their N from the soil. They generally do not produce high yields without N fertilizer.

Research on the genetic control of the legume symbiosis has led to identification of the plant genes that trigger the formation of nodules. A breakthrough was reported in the summer of 2006. Dr. Giles Oldroyd, a scientist working at the John Innes Centre (JIC) in Britain, said: “The fact that we can induce the formation of nodules in the plant in the absence of the bacteria is an important first step in transferring this process to non-legumes…. However, we still have a lot of work before we can generate nodulation in non-legumes.”

Considering that both the plant and the bacteria need to take many more steps after nodulation in order to begin the process of effectively taking N from the air, it is clear that the science behind the transfer of the process to non-legumes is in its infancy. The genome (DNA sequence) of the rhizobial bacteria that fix N in alfalfa was published in 2001. At least 100 scientific studies since then have cited the article—which shows that research is active. However, owing to the complexity of the processes involved, much remains to be discovered.

The Brazilian Agricultural Research Corporation announced in December 2006 that it has finished mapping and sequencing the genome of another bacterium that works as a natural fertilizer. *Gluconacetobacter diazotrophicus* is found in sugarcane, sweet potatoes, and pineapples. As an endophyte—living between the cells of the roots of its host—its association is not as intimate as that of the rhizobia that invade the root cells of a legume to form nodules. However, this organism is responsible for the low N requirements of sugarcane and contributes to the high energy efficiency of the Brazilian ethanol industry.

Genetic improvement has contributed to steady yield gains in North American corn production. Since 1940, yields have been on an increasing trend, growing by about 1.8 bushels per acre each year. Some anticipate that genetic engineering will almost double the rate of yield improvement. The past increase in yields has been accompanied by improved N use efficiency. Biotechnology is reducing the amount of N fertilizer used to grow a bushel of corn, because yields are increasing faster than rates applied.

Sunlight, water, and nutrients remain the major factors limiting crop yields. Biotechnology has potential to improve the efficiency by which plants utilize all three. But growing global demand for food, fuel, fiber, and feed ensures that plant nutrient inputs will continue to play an important role for the foreseeable future.

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Abbreviations in this article: N = nitrogen; DNA = deoxyribonucleic acid.

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