ADVANCES IN NITROGEN FIXATION

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It is widely recognised that the application of soluble nitrogen to crops is probably the single most important method of manipulating plant productivity. In Britain, farmers apply about 1.6m tonnes per annum.

Although fertiliser is increasingly seen as a potential pollutant and health risk, it is accepted that there would be a major decline in crop productivity without it. British scientists believe that one way to reconcile productivity with the environment is to exploit one of nature's more remarkable processes - biological nitrogen fixation by rhizobia bacteria in the root nodules of legumes.

Scientists at the Institute of Grassland and Environmental Research (IGER) are studying this process as part of their remit to develop a cohesive strategy for better management of nitrogen cycling in grassland.

Research is being carried out at the strategic level into the better understanding of the mechanisms which control and regulate the Rhizobium nodules on the roots of legume plants. It is thought that oxygen regulation may eventually provide new insights into ways of manipulating these key processes.

Natural System

At the same time, other areas of inquiry, such as the ecology of Rhizobium, the impact of the legumes on the environment and the measuring of the amounts of nitrogen fixed by this natural system, are yielding information of immediate value to grassland agriculture.

One mechanism controlling nodule activity centres on the layer of cells controlling the oxygen diffusion barrier. The suggestion that these cells are occluded by a glycoprotein which allows the barrier to have a variable resistance has been supported by IGER research in collaboration with scientists from the University of Dundee and the Institute of Plant Science Research.

This was achieved with visual observations of changes in the amount of glycoprotein in soyabean nodules following long term exposure (28 days) to sub- or supra-atmospheric oxygen concentrations (10 or 40%).

However, the normal operation of the diffusion barrier is in response to environmental stress rather than changes in oxygen concentration, and this can start within a few minutes of the imposition of stress and be finished within two or three hours. Using the lupin, changes in the barrier produced by stress have been investigated. Observed changes in the cortical air spaces of lupin nodules represent the first visualisation of the oxygen diffusion barrier during its normal mode of operation.

Model System

It confirms the importance of glycoprotein occlusions in the process and provides researchers with a model system for further studies of this important mechanism. This barrier to gaseous diffusion which protects the production of nitrogenase from oxygen damage may not be the only mechanism to operate in this way at the molecular level.

Work carried out with a scientist from USDA/ARS, Beckley, West Virginia, has confirmed a mechanism which acts rapidly to block nitrogenase function in order to protect this enzyme from oxygen damage.

The study of the population dynamics of strains of Rhizobium which are added to indigenous populations has been made easier by the introduction of a novel marker - the firefly luciferase gene. At IGER, strains have been constructed with the marker gene located on the chromosome or on a broad host range plasmid.

This has provided scientists with an easily visualised marker for use in a wide range of Rhizobium population studies. The modified strains have been tested against the parent types and show no difference in symbiotic effectiveness or stability.

The benefits to soil structure which are achieved by growing nitrogen fixing clover have been demonstrated at IGER in a comparison of soil cores planted with clover, ryegrass or a mixture of the two.

Increased Porosity

Over a four-month period it was found that percolation rates improved markedly under clover, less under mixed species and least under grass. A comparison of the soil moisture characteristic curves of a loam-based compost which had supported clover, grass or a mixture of the two for two years, indicates a similar structuring effect associated with increased porosity where clover was present.

This experiment also examined the ability of the plants to recover fertiliser nitrogen added to the soil. Fertiliser labelled with the heavy isotope of nitrogen 15N added at high and low levels of application, and an estimate was made of the percentage recovered by pure stands of grass, pure stands of clover and by grass clover mixtures.

Recovery of fertiliser by grass showed similar trends in all treatments. Efficiency of recovery ranged from 20 to 34% at the first harvest, increased significantly at the second harvest, but declined progressively thereafter.

On average, the high N treatment was most efficient and the low N least efficient at recovering fertiliser. The trends of nitrogen recovery of clover were in marked contrast to those of grass. While fertiliser recovery by grass generally declined with time, clover showed small but consistent increases.

Fertiliser Recovery

At the first harvest efficiencies ranged from 4 to 16%, rising to between 17 and 47% by the fifth harvest. There was also a much larger difference between treatments than for grass. For example, clover mixed with grass averaged only 11% fertiliser recovery, whilst pure clover averaged 38% and was significantly more efficient at the high N levels.

It was found that mixing grass with clover had little effect on the grass sward's ability to take up fertiliser nitrogen, but it severely curtailed the ability of clover to capture this resource. This indicates that nitrogen fixing clover is a weaker competitor than grass for the nitrogen in the soil provided by fertiliser.

A related experiment investigated the extent to which microbes in the soil compete for nitrogen in the soil mineral N pool. Ryegrass plants grown in vermiculite with a full nutrient solution but no added carbon source, successfully recovered 100% of added nitrogen. However, ryegrass grown in soil with added carbon and inoculated with microflora recovered only 50% of the added nitrogen.

The IGER scientists hope that the continuation of this research into biological nitrogen fixation and nutrient cycling will provide grassland farmers with the practical guidance needed to manage the essential nutrient - nitrogen - more effectively.

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