The invisible hand: managing microbes to promote soil fertility

by Brice Walsh

For ten thousand years man has been "breaking ground" and practising the art of agriculture. In the latter part of this century, with an expanding population and the advent of high yielding varieties of grain crops, modern monoculture agriculture became - and remains - highly dependant on the use of nitrogen fertilizer.

The changing nitrogen cycle since 1945 can be observed in Figure 1. With an abundance of cheap nitrogen fertilizer after the war, plant nutritional needs became increasingly met primarily through industrially-processed nitrogen-fixation.

In these early years, when soils had significant levels of organic matter, synthetic chemical inputs increased crop yields two to three times. As Figure 1. illustrates, however, increased use of chemical fertilizer uncoupled the natural nitrogen cycle by reducing the use of legumes as well as organic matter levels, both important sources of soil nitrogen. Thus, grain yield increases in the forty years following WWII have also been associated with declining soil productivity and increases in environmental contamination.

The use of chemical nitrogen inputs might be justified on the basis that, for plants, protein is protein regardless of whether it comes from a manufactured chemical compound or the soil nitrogen pool. Nitrogen, however, is a "regulator" in an ecological sense, a context where complexity generally promotes stability. Thus, when the complexity of agricultural systems are dismantled, the inherent checks and balances provided by nature no longer function effectively.

Micro option

Given that excess nutrient loading in agriculture systems leads to chemical and biological imbalances, what are the alternatives?

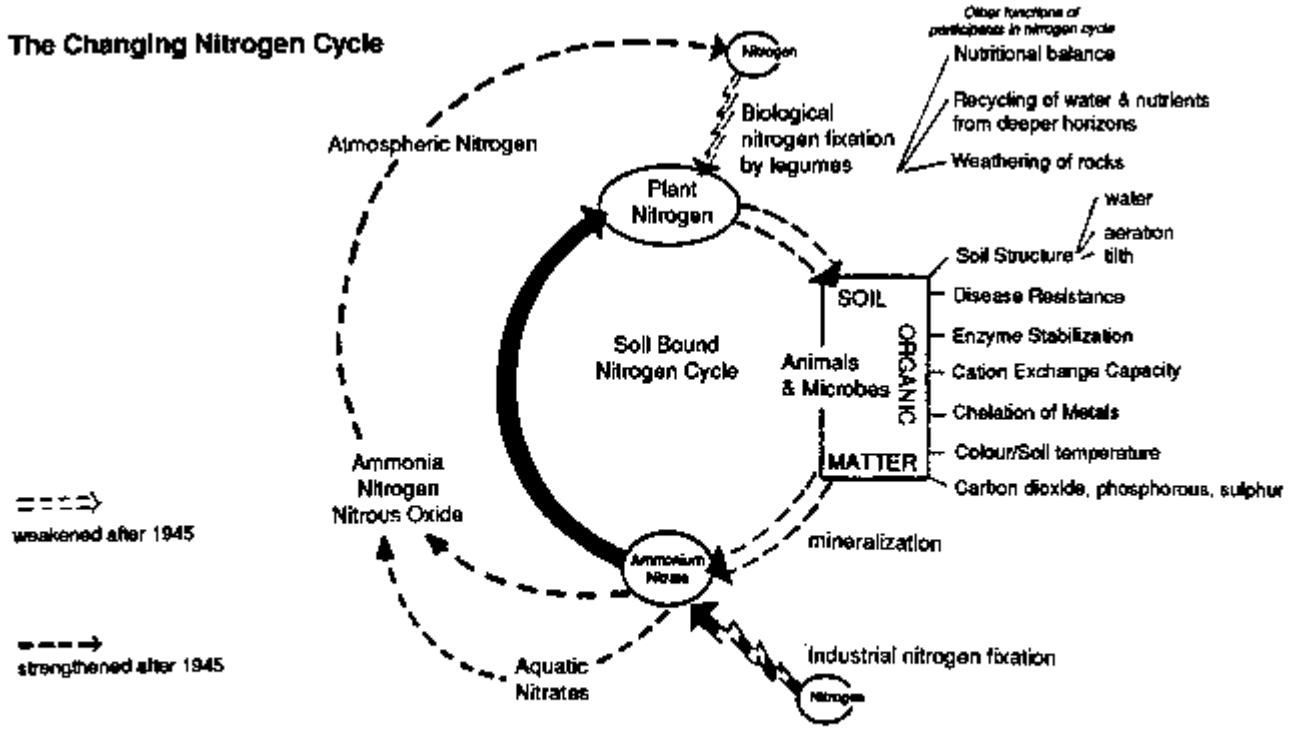
Since the flow of nitrogen is cyclical, if the cycle can be "closed" then soil nitrogen fertility problems could be solved by enhancing natural processes within that closed system. The concept is to maintain soil fertility by cycling and conserving mineral nitrogen, utilizing existing ecological processes.

One of the most effective means of controlling and intensifying natural biological processes is through the soil microbial life. Micro-organisms are "built-in" soil regulators and catalysts,

recycling nutrients bound up in plant and animal residues into available inorganic forms which become the building blocks of future life.

Modern agriculture has tended to ignore microbial processes even though these organisms have had over one billion years to develop highly effective mechanisms to cycle nitrogen in the soil and provide it to plants. A common microbial process is nitrogen-fixation, an important mechanism in that it replenishes nitrogen lost from the soil through crop removal, denitrification and nitrate leaching. It also helps to decrease the dependence of agriculture systems on nitrogen mineralization and fertilizer.

Making use of nitrogen-fixation can be achieved through a crop rotation which includes a legume such as faba beans. As long as the legume crop is used as a green manure rather than being harvested and removed from the land, the nitrogen will enter into the system. In the case of gaseous forms of nitrogen it is important to consider denitrification. If losses of nitrogen (gas) and nitrous oxide are high, then the benefits of nitrogen-fixation are lost. The best way to prevent denitrification is to inhibit the accumulation of nitrate in the soil, which can be accomplished through an ecologically based "closed" nitrogen cycle.



Sources:
- Patriquin, D.G. 1987. Closing the nitrogen cycle. In: Proceedings of the Second R.E.A.P. Conference. Quebec, Canada.
- Patriquin, D.G. 1986. Biological husbandry and the "nitrogen problem". Biol. Agric. Horti. 3: 167 189.

Population control

In a closed nitrogen cycle dependent on microbial processes, managing micro-organism populations is the fundamental factor in regulating the amount of inorganic nitrogen in the system. As Figure 2. indicates, increasing microbial biomass levels, hence potentially mineralizable nitrogen (PMN), are reflected by changes in the opposite direction of nitrate. These data also suggest the importance of microbial mineralization/immobilization processes.

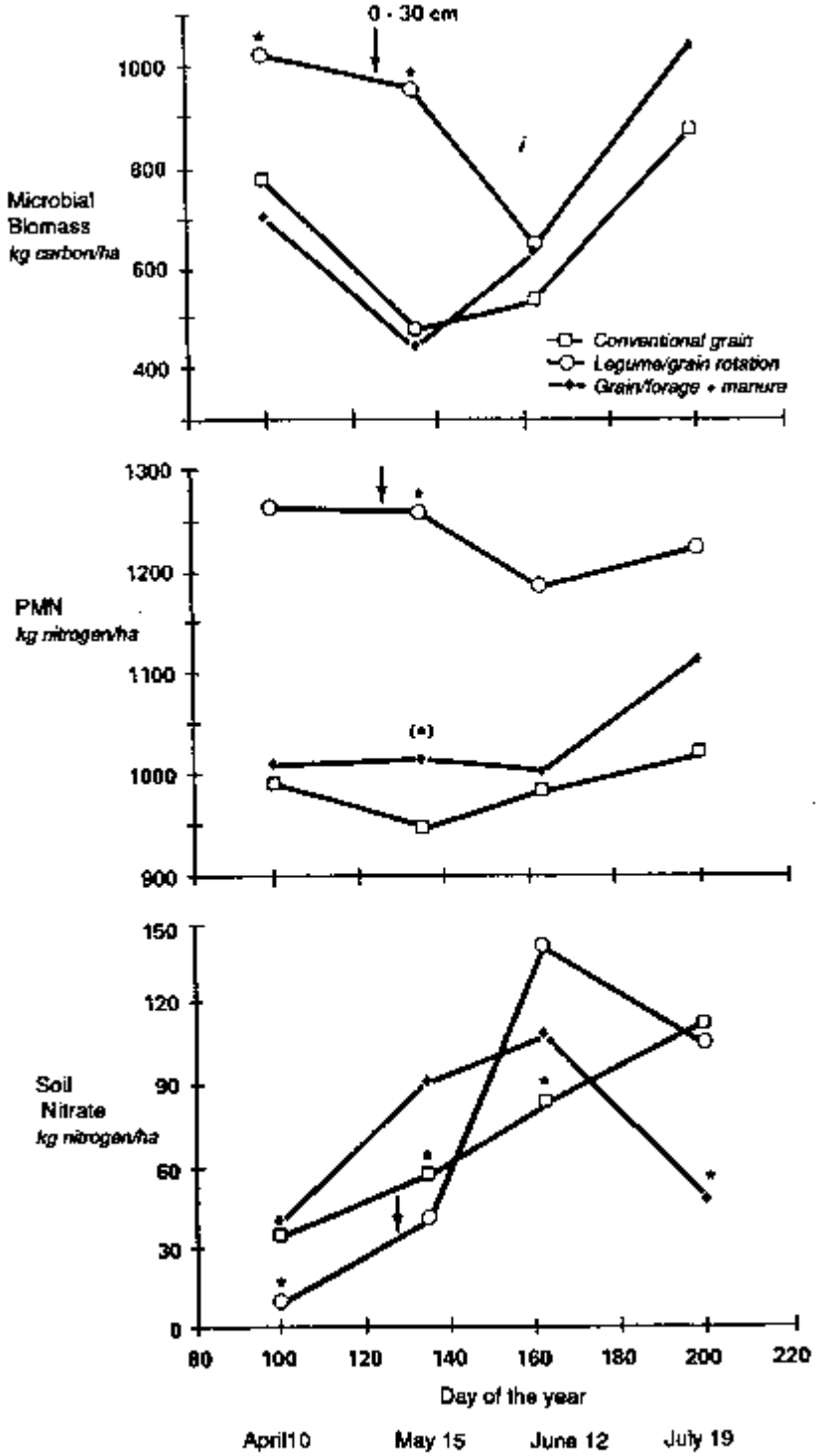
Nitrogen-cycling and conservation can be accomplished through a combination of crop rotations, tillage practices and residue additions which directly regulate microbial populations. With the aim of conserving nitrogen, a residue high in carbon (a microbial food source) such as straw can be incorporated into the soil at the end of the growing season to tie up any free nitrogen (immobilization). In the following spring, and into the growing season when nitrate is required by crops, a material high in nitrogen, such as manure or clover, can be added to the soil (mineralization).

Tillage technology can also be used to control the transformation of nitrogen by micro-organisms. Generally there is decreased microbial biomass as tillage intensity increases. Thus, soil tillage can have a stimulating affect on soil nitrate availability by decreasing microbial food sources (carbon substrates) and hence the amount of PMN in the upper soil horizon.

Intensive long-term tillage, however, can have detrimental effects on the soil's ability to immobilize and conserve nitrogen. The use of winter cover crops and cropping practices such as ridge tillage helps to increase microbial biomass levels, thus reducing soil nitrate levels and the potential for off- season leaching. Therefore, incorporation of high carbon residues with appropriate tillage practices appears to be the most efficient strategy for nitrogen conservation.

The nutrient cycling mechanisms that already exist should be given first consideration for maintaining the soil-plant ecology in agriculture systems. Understanding these efficient mechanisms is the best way for improving the nitrogen economy in crop production with limited chemical inputs. Through evolution, farmers have at their command a hidden resource, an abundant and diverse microbial life which is more than willing to carry out the "invisible" transformation that is a prerequisite for optimal soil fertility.

Soil microbial biomass, potentially mineralizable nitrogen (PMN) and nitrate content in the 0-30 cm soil layer.



Sources:

- Doran, J.W. 1989. Microbial activity and nitrogen-transformations in sustainable systems. Paper presented at conference to Extend Sustainable Systems. Minnesota.
- Doran, J.W., D.G. Fraser, M.N. Culik, and W.C. Liebhardt. 1987. Influence of alternative and conventional agricultural management on soil microbial processes and nitrogen availability. Am. J. Alter. Agric. 2: 99-106.

Management Practices For Regulating Microbial Populations

Increasing Nitrogen & Conservation Strategies

-incorporation of residue with high C/N ratio (e.g. straw)

-reduce tillage operations

-lime soil to neutral pH

- maintain soil moisture and aeration

-growing of perennial forages and cover crops

-application of solid manure or compost

Nitrogen Release & Turnover Strategies

-incorporation of residue with low C/N ratio (e.g. hairy vetch)

-tillage to reduce microbial food sources

Research Literature

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