www.cotswoldseeds.com
Tel: 01608 652552

Cotswold Seeds Ltd
The Cotswold Business Village
Moreton in Marsh,
Gloucestershire GL56 0JQ

Microbes Matter - Soil health is all important

The soil is one of our most precious resources. It is the medium in which we grow our food, and it is home to a multitude of organisms whose activity is vital to crop growth. These organisms, both fungi and bacteria, influence plant growth in many ways and, since many form close physiological associations with plants, they form a vital link between the plant and the soil without which the plant would not thrive. It is crucial that farming practices do not harm these natural associations. Dr John Zarb explores this fascinating subject.

Farming with Fungi
Consider for example the association formed between plant roots and the so-called mycorrhizal fungi (Greek: myco=fungus; rhiza=root). The most common of these microscopic fungi are known as VAM (vesicular arbuscular mycorrhizal) fungi. Within the soil they probably form the largest component of all fungal material. Plants are infected by VAM fungi from spores naturally present in the soil. Infection is initiated by complex chemical interactions between the plant and the fungus and leads to the thread like fungal projections called hyphae penetrating within and between plant root cells. The infection process culminates in the establishment of the mycorrhiza, an entity with distinct structure and function that mediates plant activity in a number of ways, and which is generally beneficial to both plant and fungus. The fungus benefits from this relationship through the acquisition of sugars and other substances produced by the plant. The benefits to the plant are very significant and are described below.

Although the association between plants and mycorrhizal fungi is natural condition and involves by far the majority of plant species on the planet, some plants do not develop the association. These include rapeseed, mustard, kale, cabbage, and swede (Cruciferae); sugarbeet (Chenopodiaciae); and lupin (Leguminosae).

One of the most important ways in which the mycorrhizal benefits the plant is by enhancing its ability to take up water and mineral nutrients, particularly phosphate (P). This is made possible by the fungal hyphae which extend beyond the immediate area of the root to effectively increase the absorptive area. Once taken up by the fungus, the absorbed P is protected from immobilisation in the soil. The practical implications of this are that mycorrhizal plants are more efficient in their use of applied fertiliser, make fuller use of soil mineral reserves and are more tolerant to drought.

Phosphorus itself is required for mycorrhizal infection. In studies of subterranean clover, for example, limiting soil concentrations of P were associated with low levels of mycorrhizal infection. Applying P led to an increase in mycorrhizal colonisation, whilst further increases lead to a decline in infection. Maximum infection occurred at a P level equivalent to six per cent of maximum shoot growth. Declining mycorrhizal infection was related to a concomitant decline in shoot growth. What this means in practical terms is that in intensive farming with high P fertiliser inputs, mycorrhizal infection becomes insubstantial. This has economic implications in that to obtain maximum plant growth, very high fertiliser inputs are necessary. This raises the suggestion that it may be cost effective to reduce fertiliser inputs and utilise natural mycorrhizal acquisition of P to produce crops at, say, 90 per cent of maximum production. Thid would also have high environmental benefits.

Apart from improved uptake of P, mycorrhizal plants are also associated with increased uptake of other soil mineraks including calcium, zinc, potassium, manganese, and boron, the latter being an essential requirement for nitrogen fixation by legumes.

VAM Fungi and Crop Protection
Mycorrhizal fungi are among several species of soil organism to actively protect plants from disease. It is clearly in the interest of a fungus that depends on a healthy plant for survival to sustain that plant. VAM fungi can suppress soil borne plant pathogens by the production of antibiotics, by competing with pathogens for living space on the root, and by stimulating the natural defence mechanisms of the plant. These activities have been studied for many years. Understanding these interactions is important in developing crop and soil management strategies that are not antagonistic to soil organisms. It makes economic and environmental sense to make the most efficient use of natural biological resources present in the soil.

VAM Fungi Interact with Other Soil Organisms
The diversity of life in the soil is vast, but such diversity plays a key role in sustaining an environment suitable for crop growth. Some components of such a wide range of organisms can seem redundant at first because they do not appear to affect crops, but they become vital at other times when they buffer the adverse effects of change such as disease, ploughing, drought, or pollution for example. This is why it is so important not to overlook the role of any micro-organism in the soil.

The concept is exemplified by the various interactions between VAM fungi and other soil organisms. As we have seen VAM fungi and N-fixing bacteria are able to promote plant growth. However, very many other organisms benefit crop growth. Not only do they interact directly with plants, they also interact with each other in ways that benefit plants. The so-called plant growth promoting rhizobacteria (PGPR) can enhance root and shoot growth, nodule formation by Rhizobium, seedling emergence, and mycorrhiza establishment. Furthermore, the microbial antagonists of fungal pathogens can also facilitate the establishment of mycorrhizas with consequent benefits to plant growth and health.

VAM Fungi Facilitate Nitrogen Fixation

It may be of particular interest to growers of forage crops to note that VAM fungi also play a crucial role in grass and legume-based forage production, and nitrogen fixation. Nitrogen fixation is boron-dependent and has a high energy (and thus high P) requirement. VAM fungi are able to alleviate demands for boron and P by facilitating the uptake of both elements. In fact it is well established that mycorrhizal legumes are more efficient N fixers than non-mycorrhizal. Nitrogen fixation can account for around 200kg/ha of soil N (from the natural decay of root nodules) which is significant economic and environmental consideration.

Practical Implications for Soil and Crop Management

But what does all this mean in practical terms to the farmer? The foregoing should support the assertion that it is of paramount importance to maintain a healthy, interactive population of soil organisms in order to sustain crop growth. And obviously, the growth of forage and food crops directly influence animal and human nutrition. Management practices should at least be designed to minimise their impact on the soil environment and, at best, to work in harmony with natural biological processes in order to support sustainable agricultural systems.

Bare fallowing, crop rotation, tillage, pesticide use, fertiliser use, and liming are all integral parts of many agricultural systems. Adverse events such as loss of topsoil, impaired drainage, and reduced aeration are consequences of some agricultural practices. These can harm vital soil processes and lead to significant reductions in crop performance, especially in the long term.

- Extended bare fallows deprive VAM fungi of a suitable host leading to a gradual decline in fungal inoculum. The organism can survive as spores in the soil, but subsequent recolonisation of a crop is generally poorer the longer the fallow.
- Crop rotation is undoubtedly an extremely valuable agricultural practice, but to enable the maximum benefit to be obtained from mycorrhizas in terms of crop nutritionm it is important to consider the following points. A crop of low mycorrhizal dependency should follow a clean fallow, a non-mycorrhizal crop, or any other condition that tends to suppress mycorrhizal inoculum. Alternatively, P could be supplied to a mycorrhizal-dependent crop. If inoculum level is high then the most appropriate VAM-dependent crop that does not violate the rotation can be sown.
- The majority of vital soil organisms are associated with the upper layers of the soil. Preservation of topsoil by retaining cover crops, for example, is a useful practice. Decreased frequency and intensity of tillage should also be considered since severe soil disturbance leads to a temporary decline

in VAM infection.

- With regard to pesticide use, fungicides are generally toxic to VAM whilst insecticides and nematicides are not. Through their ability to facilitate water and nutrient uptake by plants, VAM can increase of residual herbicides to the detriment of the plant.
- Although P fertilisers will suppress VAM, this will be unlikely to adversely affect crop growth directly since the fertiliser will replace the beneficial effect of the fungus. However, the long-term effects of the loss of the fungus are difficult to predict but are likely to be detrimental. Loss of VAM also places more reliance on imported fertilisers which will increase costs. The same can be said of the suppressive effects of N on clover and other leguminous N-fixing crops.
- As soil pH is a major influence on the distribution and survival of VAM fungi and other organisms, liming is bound to affect the overall microbial population which could lead to differences in crop performance.

Summary and Conclusions

The legume-rhizobium symbiosis, the mycorrhizal symbiosis, and the numerous other relationships between plants and micro-organisms have evolved since the time plants first gained a roothold on land. They are naturally occurring phenomena and, in the case of mycorrhizas, they are the rule rather than the exception.

Increased concern about the environmental impact of agrochemicals and high intensity farming, together with examining cost-effective crop production strategies that place less financial reliance on expensive synthetic inputs, have fuelled interest in the practical application of mycorrhizas and legumes in the UK and World agriculture.

The activity of soil organisms is clearly very complex. Whilst it is difficult to predict the precise consequences of agricultural disruption to soil life, it is likely from the available evidence that long term disruption will be environmentally and financially detrimental to crop production. It is universally accepted that soil microbes are crucial in sustaining world agricultural production and our understanding of them is vital if we are to develop sustainable agricultural practices in a world of diminishing resources.

Date Posted: 30th March 2017