Biological Parameters in Soil Mapping

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Roughly, the reactions in soil can be grouped into two main systems: a chemical system and a biological system /JANSSON, 1977/. The chemical system is largely based on equilibrium reactions. The biological system, on the other hand, is based on the microorganisms. A key factor for the biological system is the amount of energy /decomposable organic matter/ which is at the disposal of the microflora.

In Sweden, the mapping system includes only a few parameters. Chiefly, it is worked out to guide the farmers on their decisions on liming and fertilization. The soil is analysed for pH value, the macro-nutrients phosphorus, potassium and magnesium. In some cases - especially on peats and on sandy soils - some trace elements are included /copper and boron/. A rough estimation of the mechanical composition is also performed. All these parameters are mainly controlled by the chemical reaction system.

In the mapping little attention has been paid to parameters which are controlled by the biological system. Only the soil organic matter content has been included. This is a shortcoming because both nutrient supply as well as physical properties are influenced by the microorganisms and thus important information is withheld from the planning of fertilization.

The reason why the biological parameters have not been considered to the same extent as the chemical parameters is that it is difficult to find analytical methods that give a true picture of the relationships between the parameters and the plant reaction.

Soil organic matter content

The organic matter is an important constituent of the soil. It increases the cation exchange capacity /CEC/ and consequently, it is an important parameter when assessing the liming requirement.

Organic matter is also of great importance for the stability of the soil structure. However, it is difficult to quantify the importance in the individual soil because the organic matter interacts with the clay content and the lime status.

The organic matter contains the whole store of nitrogen in the soil and therefore is of the utmost importance for the nitrogen mineralization capacity of the soil nitrogen. However, the relation between soil organic matter and the mineralization capacity is not very good /JANSSON, 1975/. The mineralization power will be discussed in more detail in another section of this report.

In the soil mapping system in Sweden the soil organic matter content is judged in the field simultaneously with the soil sampling. This is an imprecise method and consequently, we are now starting to determine the loss on ignition in the laboratory. However, the loss on ignition must be corrected with a factor, the size of which depends on the clay content. The method is accurate enough for characterizing a soil in soil mapping.

A more accurate method is to determine the soil organic carbon. This can be done by wet or dry combustion. Nowadays automatic analyzers are available. This method is used in field experiments, especially if the aim is to determine organic matter effects as a consequence of different treatments.

Humus quality

Humus can be regarded as substances which are stabile under prevailing conditions. Depending on the circumstances during their formation, humus substances of different kinds can be formed. As an example, the humus quality in a pine forest is quite different from the humus in an arable soil. The humus quality may also differ between different arable soils.

The humus quality has been characterized according to different principles. For many years chemical agents have been used to isolate humus fractions. Very early ODÉN /1919/ isolated fulvic acids, humic acids and a humin fraction. The same method is still used, although in a modified form. WAKSMAN /1939/ introduced a group analysis. As a rule, fractions isolated in such procedures are not biologically uniform /PERSSON, 1968/.

Another possibility is to characterize the organic matter according to the function in the soil. In German literature the following fractions are proposed: "Nährhumus" and "Dauerhumus" /SCHEFFER and SCHACHTSCHABEL, 1956/.

In modern literature the fractions "active", "slow" and "passive" are often used when discussing soil organic matter reactions. They are biologically justified fractions but they cannot be isolated through chemical treatment, like e.g. humic acids. They are especially useful when discussing carbon and nitrogen turnover /PARTON et al., 1983; BJARNASON, 1989/. They will be discussed in greater detail in the next section of the report.

Nitrogen delivery

The soil nitrogen store is almost exclusively found in organic form. Transformations are performed by microorganisms. Their activity is dependent on the energy supply, i.e., decomposable carbon compounds. The microorganisms can use the energy by breaking the energy-rich carbon bonds, which results in carbon dioxide formation. However, the microorganisms also need nutrients and nitrogen is a key nutrient in the protein synthesis. If the energy substrate is poor in nitrogen the microorganisms will immobilize nitrogen. On the other hand, if the substrate is rich in nitrogen, some of it will be mineralized as ammonia.

In a biologically active soil both immobilization and mineralization will occur at the same time. The speed of the reactions and which of them will be the most rapid depends on the decomposability and the nitrogen content of the energy substrate. The processes can result in net mineralization or net immobilization.

The reactions described above are of great importance for the ability of the soil to deliver nitrogen to the crop, i.e., they are important in determining the need for fertilization.

The energy available for the microorganisms can originate from fresh plant residues or from the humus material. As a rule, the plant residues are easily decomposable and give rise to a high biological activity and nitrogen turnover. The plant residues can be poor in nitrogen, e.g. cereal straw. Therefore, they initially cause a net nitrogen immobilization. However, some plant residues are rich in nitrogen, e.g. the tops of sugar beets. They contain more nitrogen than required by the microorganisms. Decomposition of such organic material results in an immediate nitrogen mineralization. The nitrogen effects - positive or negative - as a consequence of decomposing plant residues are, as a rule, rather large but of short duration.

Decomposition of humus substances gives rise to mineralization of nitrogen. It is the "slow" fraction which contributes to the nitrogen mineralization. The turnover time for the "stabile" fraction is so prolonged that the delivery of available nitrogen must be very small.

The nitrogen mineralization capacity which depends on the humus substances is very persistent. As a rule, it undergoes changes very slowly /BJARNASON, 1989/. An exception of that rule is when very drastic changes occur, such as when land is ploughed for the first time, when 30% of the organic matter may be lost in a few decades. This results in a considerable nitrogen mineralization /JENNY, 1933; PERSSON, 1974/.

Types of cropping systems, including the use of animal manure, are very important for the size of the slow humus fraction and the mineralization capacity. However, the difference in mineralization capacity between two cropping systems is often over-shadowed by the short-term nitrogen effects from the plant residues.

It is an urgent task to characterize the capacity of soils to mineralize nitrogen. Unfortunately, there is still no good method available for this.

Soil analysis can hardly be used in determining the effects obtained from fresh plant residues. Those effects must be judged in relation to the decomposability and nitrogen content of the plant material. The lignin content is an important factor. Further, the time for ploughing in the material, as well as the autumn and winter climate, must be taken into consideration. We need a model which describes the decomposition of fresh organic matter during a period of one year.

Different methods have been tested to describe the nitrogen mineralization as a consequence of humus degradation. However, up to now there has been little success. The total nitrogen content of the soil is not a reliable method.

Chemical as well as biological methods have been tested. The chemical methods are considered to extract an active pool of the organic matter. Different extraction agents have been used /STANFORD, 1982; STANFORD and SMITH, 1972/. The EUF-method has also been tested /WIKLICKY and NÉMETH, 1981/. Some authors have reported great success and in Austria the method is in practical use. The method has been tested in Sweden but with rather poor results /LINDÉN, 1985/.

Biological methods are based on the incubation of soil during a certain length of time. The nitrogen mineralized during the incubation time is supposed to relate to the mineralization in the field. STANFORD /1982/ proposed a method where the mineral nitrogen is periodically removed by leaching with $CaCl_2$.

During recent decades the problems involved in predicting the nitrogen situation have been approached in another way. The soil profile is analysed for mineral nitrogen in the spring /BORST and MULDER, 1971; SCHARPF, 1977/ which will provide information on the amount of mineral nitrogen available at the beginning of the growing period. But it does not yield any information about the nitrogen which can be expected to mineralize during the summer.

In the way the method is practised in Sweden, the soil profile is sampled down to 90 cm. The soil core is divided into three sections. In order to avoid ammonium fixation and biological activity the samples must be transported and stored in frozen condition.

The extent to which the nitrogen in the deeper layers is utilized depends on the root penetration. Important factors in that connection are the soil type and the crop. Sugar beets can make use of the deeper nitrogen better than barley.

Nitrogen fixation capacity

There is an increasing interest in cultivation systems without commercial fertilizers. In such systems nitrogen fixation is very important. In the future there may be a need for simple methods to characterize the soils concerning this quality. We know very little about the effects of different cultivation methods on the nitrogen fixation capacity. Diagnostic methods are available, such as the acetylene reduction method /STEWART et al., 1967/ and the isotope dilution method /FRIED and BROESHART, 1975/. However, those methods are hardly suitable for routine analyses.

Soil biomass

During recent years methods for determining microbial carbon and nitrogen have been developed. Most of them are based on the chloroform fumigation incubation method proposed by JENKINSON and POWLSON /1976/. However, it is too early to include the method in practical soil mapping. Interpretation of the results in relation to the requirement of the plant is not yet possible.

Phosphorus delivery

About 50% of the soil phosphorus is found in organic form. However, most of the methods used in soil mapping do not take the organic phosphorus into consideration.

Evaluation of the soil organic phosphorus is a difficult task because phosphorus reacts in the chemical system as well as in the biological system. The two systems meet in the soil water. Mineralized organic phosphorus can immediately react in the chemical reaction system.

Cropping systems including large amounts of organic matter as raw material for humus formation improve the phosphorus availability. The reason may be an increase in phosphorus mineralization. But it may also be an effect of higher solubility of inorganic phosphorus as a consequence of the organic matter. Much work must be done before the soil can be characterized with regard to phosphorus mineralization. Fractionation methods including organic phosphorus have been proposed but there is still much to do before they can be used in soil mapping /TIESSEN et al., 1984/.

Ammonium fixation

Many soils containing clay minerals of the three-layer type have the ability to fix ammonium in a manner whereby it cannot readily be replaced by other cations. It is not a biological reaction but should be mentioned here because microorganisms may be involved in releasing the fixed ammonium. Ammonium fixation is of great importance on some soils and it would be an advantage if the soils were characterized as to their ammonium fixing capacity. This is important when choosing N-fertilizer and when planning K-fertilizing.

The method of determining ammonium fixation is rather simple. A soil sample is supplied with a given amount of ammonium /e.g. 1 me per 100 g of soil/. After that the soil is extracted with 2 *M* KCl solution. Ammonium not extracted is considered as fixed. The fixation capacity will be defined by the method. Biological experiments show that all nitrogen fixed is not equally available to microorganisms and plants /NÖMMIK and VAHTRAS, 1982/. Some of it can be utilized rather soon while most of it is mobilized very slowly.

The microorganisms and the root function

It is quite clear that microorganisms are important not only for the nutrient supply and the structure stabilization but that they also have a direct influence on the roots and the growth of the plant. This is not only the case for root infecting parasites.

A microflora develops in the close vicinity of the roots, which is many times higher than in soil without root influence. This rhizosphere effect is a result of root-exudates which are used as energy source. The composition of this microflora is of importance for the function of the root /GERHARDSSON et al., 1985/.

The rhizosphere effect may be positive or negative. There are some organisms which hamper growth without infecting the plant, whereas others improve the growth. High populations of hampering organisms may be an effect of an unsuitable crop rotation.

At present we have few possibilities to influence the composition of the microflora in a suitable way. Much research must be done first. Therefore today it is not possible to involve characterization of the soil microflora in soil mapping.

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