Fertilizer Recommendations Based on Soil Analysis

L. G. NILSSON

Department of Soil Science, Swedish University of Agricultural Sciences, Uppsala /SWEDEN/

Soil mapping serves as a basis for planning fertilization and liming, and the evaluation of the data of soil analyses presented on the map are mainly based on results of field experiments. As Sweden is a very longish country, the big differences from south to north in climatic conditions must be taken into account and this complicates the interpretation of the values.

Earlier an information of the soil type based on personal estimation was given on the soil map. In the case of repeated soil mapping on the same field a divergence may easily occur, which, in general, may reduce the reliability of the remaining information on the map, so this information is not always given on the maps. When it is not, the evaluation is based on the farmers' knowledge on the soil type. Simple methods of soil type determination are being developed and we hope that in the near future this work will result a possibility to complete the results of chemical soil tests with a reliable information on the soil type.

The chemical analysis consists of the amount of exchangeable potassium and phosphorus according to the AL-method /extraction solution: ammonium lactate; pH = 3.75/, reserves of potassium determined by extraction with HCl and the pH value measured in water. As complementary data the status of magnesium and trace elements can also be received, but nitrogen is not included.

This paper refers to the present application of evaluation which is mainly based on the results of chemical soil analyses mentioned above. An intensive development work, however, is in progress in this field, and as examples we can mention ICP measurement /Inductively Coupled Plasma/ with possibilities of determining several nutrients in soils and plant materials in a rather simple way. The plant analyses can also be used as a basis for correcting by foliar application during the growing season. The dynamics of plant nutrients are also of great importance by evaluating chemical soil tests and for this purpose EUF /Electro Ultra Filtration/ determination has been used. At present we do not have a simple routine method for the quantitative determination of the lime amount needed to reach an aimed pH value. A cooperation between chemical laboratories and our Department is in progress in this field. It can also be noted that the utilization of computers as resources for fertilization recommendations holds a great interest at present in our country. Most of these questions mentioned will be discussed at this Meeting.

When the determination of soil type is carried out ATTERBERG's scale of particle sizes is used /Table 1/. Concerning the quantitative composition of particles the grouping of soil types is made as shown in Table 2. The soils are also divided into groups with regard to their organic matter content /Table 3/ /Statens lantbrukskemiska laboratorium, SLL, 1976/. Parallel with the labour-claiming methods with high accuracy a development work with simple routine methods is in progress and the evaluation of the soil fractions is based on the texture triangle with the assistance of the computer.

When the organic matter content exceeds 20%, the soils are classified as organic soils and their share of arable land in Sweden amounts to about 10%. The fertility of these soils varies considerably depending on their origin. In some of these soils the organic matter decomposition has taken place under anaerobic conditions with the formation of marsh gas and the residual substance called "gyttja", in general, has a high iron sulphide content. When the "gyttja" comes in contact with the oxygen in the air /by tillering for example/ sulphuric acid forms and the pH value drops. This phenomenon, in combination with a high iron content, results in strong phosphorus fixation. For this reason the placement of phosphorus fertilizers is recommended.

Table 1

Soil fractions - particles diameter
/ATTERBERG's scale, SLL, 1976/

Soil fraction	Particle size diameter, mm
Boulders	> 200
Cobbles	200- 20
Gravel	20- 2
Sand	2- 0.2
Fine sand	0.2- 0.06
Silt	0.06- 0.002
Clay	< 0.002

Table 2

Groups of soil types according to clay content
/SLL, 1976/

Clay content %	Soil type
<	Very light clay free soils
< 2	Sandy loam soils
2-5	Slightly clayey soils
5-15	Clayey soils
15-25	Loamy soils
25-40	Clay loam soils
40-60	Heavy clays
> 60	Very heavy clays

Rock phosphate also gives a good response on these acid soils /Statens lantbrukskemiska laboratorium, SLL, 1976/.

The need of liming is based on pH measurements in water in mineral soils and on the "nettokalkmängden" /CaO ton per ha/ in organic soils. The latter method also takes the oxidation of sulphide to sulphate into consideration. This method does not always give proper results and an improved method has a high priority in Swedish agricultural research.

Table 3
Soil classification according to organic matter /SLL, 1976/

Organic matter content weight %	Name of soil*
< 2	Mullfattig
2-3	Något mullfattig
3-6	Måttligt
6-12	Mullrika
12-20	Mycket mullrika
> 20	Mulljord

* Corresponding English words Mull = humus

When the pH value is below 5.5 liming is needed. At pH values about 6 only small amounts are required to maintain the level. At pH values exceeding 6.5, in general, there is no need of liming /Statens lantbrukskemiska laboratorium, 1976/.

The presentation of the analytical results of phosphorus and potassium contents is made on maps with colour marking as dots representing the sampling place on the fields and I think that this form of presentation is the cause of the term soil mapping in Sweden.

Depending on the phosphorus content /AL-P value/ the soils are divided into classes I-V /Table 4/. Perhaps it should be pointed out that in Sweden in 1970 we reported the content of plant nutrients in soil, plant material and fertilizers only in elementary form.

The need of phosphorus fertilization is mainly based on AL-P values /exchangeable phosphorus/. The reserve of phosphorus /HCl-P/ has not shown to give valuable information for fertilization requirement, which means that this analysis is only carried out in special cases.

The general aim is to keep class III and from this class adapt the fertilization to the different crops /Table 4/. A too high value as starting point claims large inputs to maintain and is not judged to be profitable /HAHLIN and ERICSSON, 1981/. There are also studies in progress to investigate how pools built up by heavy fertilization can be utilized by the crops. Results from long-term field experiments indicate that if some of the phosphorus is applied as farmyard manure a better phosphorus status in the soil is received than if all is given as mineral fertilizer /Fig. 1/. The results also confirm that more phosphorus must be applied than is removed by crops to maintain the starting point of AL-P. Concerning the contribute of phosphorus to the crop from the subsoil, it can be noted that the share can amount to 15% /HAAK, 1981/. An effective uptake presumes a favourable start which results in a large root system.

Table 4

Recommendations for fertilization /kg P per ha and year/ according to exchangeable phosphorus content classes of soils /SLL, 1976/

Crop	Exchangeable phosphorus content classes				
	I	II	III	IV	V
	< 2	2–4	4–8	8–16	> 16
	mg AL-P/100 g air-dry soil				
Cereals	25–30	20–25	15–20	0–15	
Oil plants	30–40	20–30	15–20	10–15	
Leys	40–50	30–40	20–30	15–20	
Sugar beets	70–90	50–70	30–50	15–30	
Potatoes	100–120	80–100	60–80	40–60	

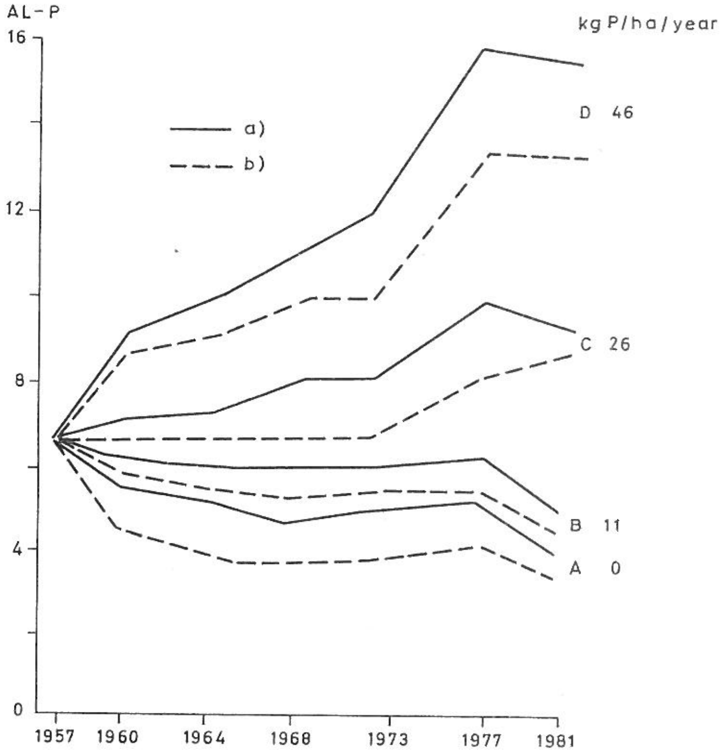

Fig. 1

Relationship between phosphorus fertilization with and without farmyard manure and phosphorus status in the soil. /Average 6 field experiments/.
A: no phosphorus; B: Replacement removed by crops; C: Replacement + 15 kg P per ha; D: Replacement + 30 kg P per ha; a/ with farmyard manure; b/ without farmyard manure. Remark: A with farmyard manure recives some phosphorus

Owing to high prices of this plant nutrient the use in Swedish agriculture has been reduced to half amount during the last years and is now, in average 14 kg P per ha.

Like in the case of phosphorus, the soils are also divided into different classes with regard to their potassium content - AL-K value /Table 5/. In order to evaluate the K requirement of crops it is also important to consider the reserve HCl-P, which in general reveals the clay content of the soils. The recommendation of potassium application largely corresponds to the removement by crops /Table 5/ and a too heavy application - resulting in a luxury consumption - is not desirable. It has also been established that the balance between potassium and magnesium plays an important role in the response of potassium applied /Fig. 2/ /NILSSON, 1987/. Unsatisfactory re-

Table 5

Recommendations for fertilization /kg K per ha and year/ according to exchangeable potassium content classes of soils /SLL, 1976/

	Exchangeable potassium content classes				
	I	II	III	IV	V
	< 4	4-8	8-16	16-32	> 32
	mg AL-K/100 g air-dry soil				
Cereals	60-80	40-60	20-40	0-20	
Oil plants	60-80	40-60	20-40	0-20	
Leys	120-160	100-120	80-100	40-80	
Sugar beets	140-180	100-140	80-100	40-80	
Potatoes	180-240	140-180	100-140	60-100	

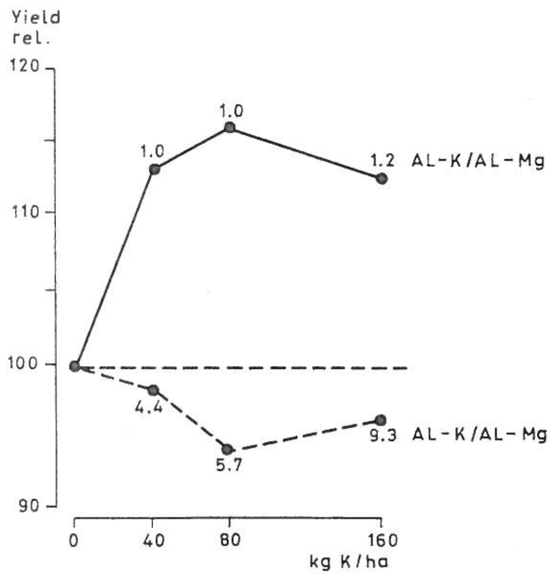

Fig. 2

Effect of K fertilization on yield at the same K status, but at different Mg status in the soil sponse and, in some cases, a negative effect can often be related to the deficiency of magnesium. During a long succession of years potassium has been applied in Swedish agriculture without regarding the magnesium status in the soil. The AL-Mg value is adjusted to the soil type, meaning that lower values can be accepted on sandy soils than on clay soils rich in potassium.

A suitable potassium content in ley hay is 2.0-2.5% in dry matter, which is an optimum condition both from the point of view of yield and feeding. If the content exceeds 3% there are difficulties in receiving a favourable relation between potassium and magnesium by fertilization. The trends in Swedish agriculture in the last decades have been characterized by a change-over from leys rich in clover to grass dominated leys, harvesting and grazing at early stages. Both of these factors contributed to the fact that the Mg question has arisen in feeding /NILSSON, 1987/.

The application of trace elements in our country is mainly restricted to manganese, copper and boron nowadays but probably in the future we will have to take further elements into consideration. The increasing interest in cropping maize for instance may arise an interest in fertilization with zinc. To a limited extent, trace elements, solutions with an allround composition as foliar application are used during the growing season. The reduced supply of farmyard manure has also contributed to an increased interest in the application of microelements.

Nowadays, we do not have a reliable soil testing method for manganese so our recommendations are mainly based upon such factors as soil type, pH value, organic matter, different requirements of crops, etc. /WARLIN, 1981/. Deficiencies of manganese can occur in all the country but are most common on soils rich in lime and on coarse textured soils poor in plant nutrients. About 10% of the arable land is estimated to have a requirement of Mn-application. All fertilization is carried out as foliar application and both manganese sulphate and manganese chelates are used /NILSSON, 1984b/.

With regard to copper, soil tests - extraction with HCl - give a good guidance for fertilization and values above 6-8 mg Cu per kg soil will be found satisfactory. It is estimated that the area of arable land with copper deficiency is about the same as that of manganese /10-15%/, and it particularly occurs in districts with organic soils and sandy soils poor in plant nutrients. Copper deficiency is most common in cereals. From feeding point of view, it is desirable that the copper content in forage does not fall below 4 ppm in dry matter. In the case of leys, when the copper content in the soil is below 3-4 ppm a more positive reaction can be expected of a copper fertilization.

Most of the copper used in Sweden is applied as mineral fertilizers containing this element. It seems to be non-significant if the copper is applied frequently with small rates or is given as a basic fertilization in the crop rotation generally with an interval of 6-7 years. Foliar application might become necessary in order to correct an acute deficiency in growing crops /NILSSON, 1984b/.

Results of soil analyses according to BERGER-TROUG give guidance to boron fertilization. The results are, however, subjected to a great variation which gives rise to uncertainty. In order to study the reason of this variation, an investigation has been carried out resulting in a prolongation of the extraction time from 5 to 15 minutes. After this time the extraction seems to have reached a plateau which gives more stable values /NILSSON and JENISCHE, 1986/. It can also be noted that dry periods during the growing season cause a good response of boron fertilization even at high level of boron in the soil /JOHANSSON and NILSSON, 1973/. This fact also complicates the evaluation of the basis for boron application.

In Sweden, as in many other countries, our crops are divided into three groups: such with a large, with a medium and with a small requirement of boron. To the first group belong sugar beets and oil plants, to the second potatoes, and to the third cereals. When the boron content of the soil is less than 1 ppm there is a deficit for crops with a great requirement; for potatoes an interval between 0.5 to 1.0 may be acceptable and for cerals values below 0.5

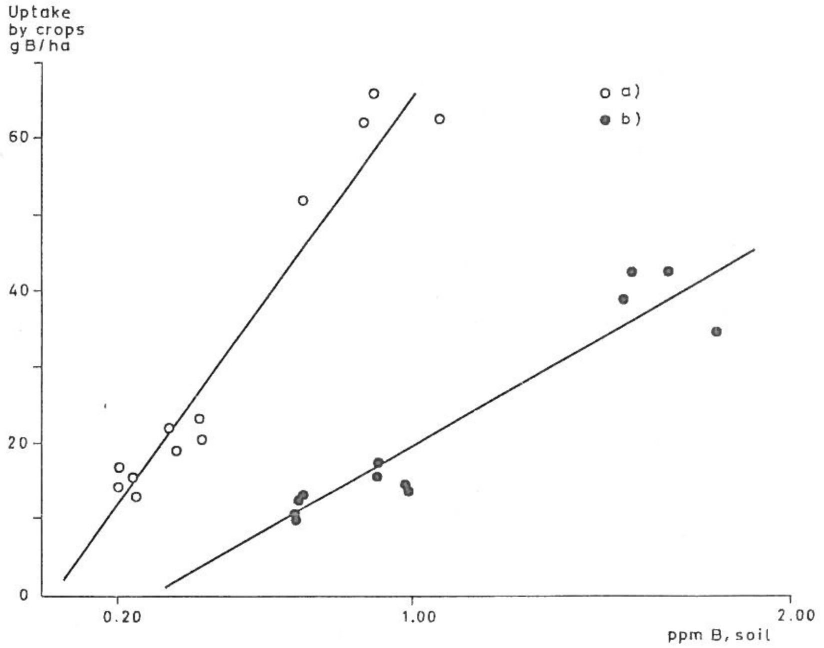

Fig. 3

Relationships between boron taken up by crops grown on sandy soils /a/ and clay soils /b/

are not satisfactory. It has also been established that the boron content in clay soils should be higher than in sandy soils /Fig. 3/ /NILSSON, 1984a/ and that the increasing level of lime reduces the boron uptake by crops /NILSSON, 1987/.

Most of the boron applied in Sweden is with mineral fertilizers containing this element and when a shortage occurs during the growing season Solubor /20%B/ can be used as foliar application.

References

HAAK, E., 1981. Nutrient uptake from subsoil by cereals. Proc. 16th Coll. Int. Potash Institute, Bern.

HAHLIN, M. and ERICSSON, J., 1981. Fosfor och fosforgödsling. Aktuellt från lantbruksuniversitetet 294. Uppsala.

JOHANSSON, O. och NILSSON, L. G., 1973. Borgödsling till höstoljeväxter. Rapp. från avd. för växtnäringslära, nr. 62. Uppsala.

NILSSON, L. G., 1984a. Utvärdering av metod för boranalys i jord. Rapp. från avd. för växtnäringslära, nr. 155. Uppsala.

NILSSON, L. G., 1984b. Mikronäringsämnenas aktualitet inom svenskt jordbruk. K. Skogs-o. Lantbr. akad. tidskr. Suppl. 16. 31-40.

NILSSON, L. G., 1987. Magnesium in grassland production. In: The utilization of secondary and trace elements in agriculture. United Nations.

NILSSON, L. G. and JENNISCHE, P., 1986. Determination of boron in soils and plants. Swedish J. agric. Res. 16. 97-103.

Statens Lantbrukskemiska laboratorium /SLL/ /ed./., 1976. Riktlinjer för kalkning och gödling efter makkarta i södra och mellersta Sverige, nr. 46.

WARLIN, B., 1981. Mangan - ett av våra viktiga mikronäringsämnen. Växtpressen. nr. 3.