# Magnesium-supplying power of some Finnish mineral soils

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**Abstract.** Uptake of magnesium from a sand, fine sand, muddy clay, silty clay and heavy clay soil under exhaustive cropping with perennial rye grass was studied in green house.

An application of 0.5 g Mg as $MgSO_4 \cdot 7\ H_2O$ per the 5-liter pots increased slightly the total yield of rye grass shoots and markedly the amount of Mg harvested in the shoots from the sand and fine sand soils with an initial content of only 14 and 37 ppm exchangeable Mg, respectively. No respond to the application of Mg was detected in the silty clay and heavy clay soils which contained exchangeable Mg 226 and 910 ppm, respectively. The muddy clay soil contained 137 ppm exchangeable Mg, and the application of Mg markedly increased the amount of Mg harvested in the shoots, but brought about a decrease in the yield of shoots.

The amount of Mg harvested in the shoots without the application of Mg was only in the sand and fine sand soils higher than the original content of exchangeable Mg. Yet, in all soils except in the muddy clay, the decrease in the content of exchangeable Mg during the cropping was lower than the amount of Mg harvested. This was taken to indicate that some release of nonexchangeable Mg did occur during this trial. According to a rough estimation this mobilization of Mg varied from 0 to 60 ppm, whereas the corresponding release of nonexchangeable K was 500—1000 ppm, except in the sand soil.

The »exhaustion Mg», or the sum of Mg harvested in the shoots of rye grass and the exchangeable Mg in the soil after cropping, was in all soils of the same order as the amount of Mg extracted by 0.05 N or 0.1 N HC1 from the original soil samples.

Nonexchangeable potassium released mainly from the clay fraction during a growing season may supply a marked part of the K in crops. The release of nonexchangeable Mg seems to be much slower (Michael and Schilling 1957), although under exhaustive cropping the uptake of Mg by plants may be somewhat higher than the corresponding decrease in the content of exchangeable Mg in the soil (Salmon and Arnold 1963, Schroeder et al. 1963, Rice and Kamprath 1968).

Finnish mineral soils are relatively rich in total Mg and also their content of exchangeable Mg is quite high, particularly in clay soils (Kaila 1973). An attempt is made in the present study to estimate to what extent Mg in different kind of our mineral soils may be taken up by plants. A trial on exhaustive cropping in greenhouse with rye grass was carried out with and without an application of Mg and the possible release of nonexchangeable Mg was estimated on the basis of soil analyses.

## *Experimental*

The five soil samples used in the present work were all from the neighbourhood of Helsinki and represented the plough layer of soils of different texture (Table 1). The content of organic C is high in the silty clay and muddy clay samples. The original pH values measured in 0.02 N $CaCl_2$ is typically low in the muddy clay and also in the sand soil. The total content of Mg determined by sodium carbonate fusion does not differ from the average values found for the respective textural groups in a larger material of Finnish soils (Kaila 1973). The content of exchangeable Mg replaced by N $NH_4OAc$ at pH 7 is in the sand and fine sand soils very low in relation to the CEC and other exchangeable cations. In the heavy clay sample, on the other hand, the exchangeable Mg represents a marked part of the CEC, as it is typical of these soils (Kaila 1972).

Table 1. Soil samples

| | 1. Sand | 2. Fine sand | 3. Muddy clay | 4. Silty clay | 5. Heavy clay |
|---|---|---|---|---|---|
| Particle size fractions % | | | | | |
| <2 μm | 3 | 12 | 46 | 30 | 76 |
| 2– 20 μm | 3 | 8 | 31 | 50 | 15 |
| 20– 200 μm | 30 | 68 | 20 | 15 | 7 |
| 200–2000 μm | 64 | 12 | 3 | 5 | 2 |
| Org. C % | 2.1 | 3.7 | 5.3 | 5.9 | 2.8 |
| pH | 4.9 | 5.4 | 4.3 | 5.8 | 5.3 |
| Total Mg % | 0.44 | 0.47 | 0.97 | 1.03 | 1.95 |
| CEC, effective me/100 g | 4.5 | 10.9 | 23.5 | 21.3 | 25.5 |
| CEC at pH 7 » | 9.9 | 20.2 | 42.1 | 29.9 | 36.5 |
| Exchangeable Mg » | 0.1 | 0.3 | 1.1 | 1.9 | 7.6 |
| » Ca » | 3.5 | 9.2 | 16.7 | 18.4 | 16.1 |
| » K » | 0.2 | 0.8 | 1.1 | 0.6 | 1.0 |

The greenhouse trial was performed in 5-liter Mitscherlich pots with 4.8 kg of the air-dry and crushed samples of sand, fine sand and heavy clay, with 4.2 kg of the silty clay and with 3.8 kg of the muddy clay. In addition to these 2.4 kg of the heavy clay sample mixed with an equal weight of washed quartz sand was included.

As the basal dressing all pots received 10 g of a combined Finnish fertilizer ($N : P : K = 8 : 5.7 : 7.5$) and trace elements in solution. During the experimental period N as $NH_4NO_3$ solution was added three times to all pots, and K as KCl, P as $Ca(H_2PO_4)_2 \cdot H_2O$ and trace elements once. The acid muddy clay was limed with 50 g $CaCO_3$ per pot. One half of the pots received 5 g of $MgSO_4 \cdot 7H_2O$. The trial was carried out with four replicates.

The trial was started in the summer 1968 when 40 seeds of perennial rye grass was sown to each pot. The shoots were harvested at unregular intervals until one of the replicates did no more grow. This happened with the sand soil after the fifth harvest, but the growth in the heavy clay was quite vigorous even until the twelfth harvest, when the trial was ended in the spring 1971.

The shoots of each replicate were at each harvest separately analysed for their content of Mg by dry-ashing. The soil from the pots without the application of Mg were at the end of the trial air-dried, and the roots were separated before grinding.

The original soil samples were analysed for their content of Mg soluble in 0.025 N $CaCl_2$, 0.01 N HCl, 0.05 N HCl and 0.1 N HCl at room temperature, and in 0.05 N HCl, 0.1 N HCl 0.5 N HCl and 1.0 N HCl at 50°. The ratio of soil to solution was in all cases 10 to 100. The extraction at room temperature was performed by shaking for one hour, and at the higher temperature by keeping the suspension at 50° C for 18 hours. Mg in the extract was measured by a Perkin Elmer atomic absorption spectrophotometer 290.

## *Results*

The total yields of rye grass shoots (Table 2) were only slightly increased by the application of Mg in the sand and fine sand soils. In the other soils no positive response was found: the total yield in the muddy clay soil was even somewhat decreased by the $MgSO_4$ applied. Yet, the total amount of Mg harvested from the muddy clay was markedly increased by the Mg-application, as it also was the case with the Mg-yields from the sand and fine sand soils. In the silty clay and, particularly, in the heavy clay soil,

Table 2. Total yields of rye grass shoots and of Mg harvested in the shoots

| Soil | Number of harvests | Shoots g/pot* | | Mg in shoots mg/pot* | |
|---|---|---|---|---|---|
| | | without Mg | Mg applied | without Mg | Mg applied |
| 1. Sand .................. | 5 | 74±5 | 89±7 | 75±2 | 307±30 |
| 2. Fine sand ............ | 11 | 183±4 | 196±4 | 244±25 | 557±17 |
| 3. Muddy clay .......... | 11 | 282±14 | 226±6 | 442±10 | 671±11 |
| 4. Silty clay ............. | 10 | 220±13 | 216±11 | 676±17 | 726±39 |
| 5. Heavy clay .......... | 12 | 241±20 | 240±5 | 827±81 | 843±16 |
| 6. Heavy clay + quartz sand .......... | 12 | 230±6 | – | 794±95 | – |

*Mean values with confidence limits at the 95 % level.

the available Mg was so high that no distinct response was detectable. The very good supply of Mg in the heavy clay soil is apparent also in the fact that the growth and the uptake of Mg from the sample diluted with quartz sand were not significantly lower than from the undiluted soil.

Without an application of Mg only five harvests of rye grass shoots could be obtained from the sand soil. The amount of Mg in this material corresponded to 16 ppm of the soil (Table 3) which seems to be somewhat higher than the content of exchangeable Mg in the soil before cropping. Also the amount of Mg in the shoots of eleven harvests from the fine sand soil was higher than the original content of exchangeable Mg. In both these soils, the decrease in the content of exchangeable Mg was markedly lower than the amount of Mg harvested, and this was also the case with the silty clay and heavy clay soils, in spite of their high original content of ecxhangeable Mg. This may be taken to indicate that release of nonexchangeable Mg did occur during the trial. In muddy clay the decrease in the content of exchangeable Mg was enough to support the eleven crops with Mg.

Table 3. Estimation of the Mg-balance in the pot experiment (Expressed as ppm of the soil)

|  | Mg harvested in shoots | Exchangeable Mg in soils |  |  | »Released from nonexchangeable» |  |
|---|---|---|---|---|---|---|
|  |  | original | at the end | difference | Mg | K |
| 1. Sand .......... | 16 | 14 | 9 | 5 | 11 | 10 |
| 2. Fine sand ... | 51 | 37 | 8 | 29 | 22 | 520 |
| 3. Muddy clay . | 116 | 137 | 14 | 123 | 0 | 540 |
| 4. Silty clay .... | 161 | 226 | 122 | 104 | 57 | 990 |
| 5. Heavy clay . | 172 | 910 | 788 | 122 | 50 | 990 |

The release of nonexchangeable K from these soils during cropping was also estimated in the same way and supposing that the K applied as soluble salts was totally taken up by the crops. Except in the sand soil, the release of K appeared to be fairly high and quite of an other order than that of Mg.

In their paper about uptake of Mg over exhaustive cropping Salmon and Arnold (1963) use the term »exhaustion Mg» to mean the sum of the amount of Mg taken up by the plants and the content of easily exchangeable Mg in the soil at the end of the cropping. The »exhaustion Mg» of the present soils (Table 4) ranges from about 0.5 per cent of the total Mg in the sand soil to 5 per cent in the heavy clay soil. It is in all soils only a small fraction of the amount of Mg released by the treatment with N HCl at the higher temperature. It is of the order of the amounts extracted by 0.05 N HCl or 0.1 N HCl at the room temperature.

According to Schachtschabel (1954 and 1956) sandy soils with less than 40 ppm and clay soils with less than 120 ppm of Mg extractable with 0.025 N $CaCl_2$ are deficient in Mg. These test values in Table 4 classify the sand and fine sand soil distinctly deficient in Mg, the silty clay and heavy

Table 4. »Exhaustion Mg» and Mg extracted by various treatments (Mg ppm of soil)

| | 1. Sand | 2. Fine sand | 3. Muddy clay | 4. Silty clay | 5. Heavy clay |
|---|---|---|---|---|---|
| »Exhaustion Mg» ....... | 25 | 59 | 130 | 283 | 960 |
| Mg extracted by | | | | | |
| 0.025 N $CaCl_2$ ...... | 9 | 26 | 100 | 157 | 497 |
| 0.01 N HCl ......... | 12 | 29 | 105 | 134 | 395 |
| 0.05 N HCl ......... | 17 | 41 | 131 | 236 | 876 |
| 0.1 N HCl .......... | 28 | 61 | 175 | 345 | 1400 |
| 0.05 N at 50° C .... | 66 | 145 | 199 | 415 | 1180 |
| 0.1 N HCl » ...... | 212 | 312 | 425 | 835 | 1887 |
| 0.5 N HCl » ...... | 720 | 1060 | 2862 | 3300 | 5980 |
| 1 N HCl » ...... | 970 | 1432 | 5150 | 5410 | 10980 |
| Exchangeable Mg ....... | 14 | 37 | 137 | 226 | 910 |

clay soils to be not in need of Mg fertilizers, and the muddy clay likely to be slightly short of available Mg.

## *Discussion*

There were several weak points in the present study. The growing conditions during the first months were not proper, and the growth during the winter months was scanty. Because difficulties in avoiding contamination with soil, roots were not analysed for their content of Mg. On the other hand, the amount of Mg in the seeds was not taken into account. It is also likely that in this kind of longterm pot trial other factors than the supply of available Mg restricted the growth of rye grass.

Even in spite of the numerous sources of error, it seems that some release of nonexchangeable Mg did occur during cropping in these soils, except in the muddy clay. It is possible that even in this soil some nonexchangeable Mg was released, but because of its rather heavy liming, also conversion of Mg to nonexchangeable forms took place (cf. McLean and Carbonell 1972).

The absolutely low but in relation to the uptake fairly high release of Mg in the sand soil is in accordance with the results reported by Rice and Kamprath 1968). They explain this release on the basis of the low buffer capacity of sand soils which allows the H-ions from the roots to be quite effective in extracting the Mg from nonexchangeable forms. In this trial the end pH of the sand soil was only 4.3.

Schachtschabel (1956) used 0.05 N HCl for the extraction of the available Mg and the easily mobilizeable reserve Mg. In the five soils of the present study the »exhaustion Mg» was equal or somewhat higher than the Mg extracted by 0.05 N HCl. It is obvious that a treatment of soil with N HCl or other acid at a higher temperature will give a far too high estimate of the reserve Mg of soil. In the present study, the »exhaustion K» corresponded in the sand and fine sand soil to about 80 % and in the clay soils to 30—40 % of the K extracted by N HCl at 50° C.

## REFERENCES

Kaila, A. 1972. Basic exchangeable cations in Finnish mineral soils J. Scient. Agric. Soc. Finl. 44: 164—170.

— » — 1973. Calcium, magnesium and potassium in mineral soils of the southern half of Finland. J. Scient. Agric. Soc. Finl. 45: 254—261.

McLean, E. O. & Carbonell, M. D. 1972. Calcium, magnesium, and potassium saturation ratios in two soils and their effects upon yields and nutrient contents of German millet and alfalfa. Soil Sci. Soc. Amer. Proc. 36: 927—930.

Michael, G. & Schilling, G. 1957. Über den Magnesiumversorgungsgrad mitteldeutscher Ackerböden. Z. Pflanzenern. Düng. Bodenk. 79: 31—50.

Rice, H. B. & Kamprath, E. J. 1968. Availability of exchangeable and nonexchangeable Mg in Sandy Coastal Plain Soils. Soil Sci. Soc. Amer. Proc. 32: 386—388.

Salmon, R. C. & Arnold, P. W. 1963. The uptake of magnesium under exhaustive cropping. J. Agric. Sci. 61: 421—425.

Schachtschabel, P. 1954. Das pflanzenverfügbare Magnesium des Bodens und seine Bestimmung. Z. Pflanzenern. Düng. Bodenk. 67: 9—23.

— » — 1956. Der Magnesiumversorgungsgrad nordwestdeutscher Böden und seine Beziehungen zum Auftreten von Mangelsymptomen an Kartoffeln. Z. Pflanzenern. Düng. Bodenk. 74: 202—219.

Schroeder, D., Zahiroleslam, S. & Hoffmann, W. E. 1963. Untersuchungen über die Verfügbarkeit der Magnesiumvorräte des Bodens. Z. Pflanzenern. Düng. Bodenk. 100. 215—224.

## SELOSTUS

# Eräiden kivennäismaiden käyttökelpoisista magnesiumvaroista

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Pitkäaikaista astiakoetta käyttäen tutkittiin raiheinän magnesiumin ottoa hiekasta, hiedasta, liejusavesta, hiesusavesta ja aitosavesta. Magnesiumlannoitus lisäsi jonkin verran raiheinän kokonaissatoa ja runsaasti sadossa korjatun magnesiumin määrää hiekka- ja hietamaassa, mutta ei vaikuttanut merkitsevästi hiesu- tai aitosaven antamiin tuloksiin. Liejusaven antama raiheinäsato aleni hiukan, mutta samalla sadossa korjatun magnesiumin määrä nousi merkittävästi magnesiumlannoituksen ansiosta.

Sadoissa korjatun magnesiumin määrä oli hiekka- ja hietamaassa suurempi kuin maitten alkuperäinen vaihtuvan magnesiumin pitoisuus. Maan vaihtuvan magnesiumin väheneminen kokeen aikana oli kuitenkin liejusavea lukuunottamatta selvästi pienempi kuin sadoissa korjattu magnesiumin määrä. Näin ollen näyttää ilmeiseltä, että kokeen aikana on vapautunut jonkin verran vaihtumatonta magnesiumia. Tämän määrän arvioitiin olevan 0—60 mg/kg maata, kun taas vastaavan kaliumin mobilisoitumisen todettiin hiekkamaata lukuunottamatta olevan 500—1000 mg/kg.

Kasvien ottaman ja kokeen loputtua maassa olevan vaihtuvan magnesiumin summa vastasi alkuperäisistä maista 0.05 tai 0.1 n HCl:lla uutettavissa olevaa magnesiumin määrää.

Huomautus. August Johannes ja Aino Tiuran Maatalouden Tutkimussäätiö myönsi maisteri Ritva Rytille vv. 1968—69 apurahan tutkimustyöhön, johon edellä selostettu astiakoe kuului. Maisteri Rytin kuoleman jälkeen kokeen hoiti itsenäisesti laborantti Kaija Tuominen, joka myös on suorittanut osan analyysityöstä.