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RESEARCH NOTE

Effects of different ammonium nitrate levels on the amounts of exchangeable soil magnesium and applied magnesium in eight mineral soils

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Abstract: Eight mineral soils (pH($CaCl_2$) 4.6—6.1, clay 4—65 %, org. C 1.9—5.7 %) were treated with ammonium nitrate and magnesium sulphate solutions adding 0, 20 or 40 mg mineral N and 0 or 4 mg Mg per 100 g soil. The soils were incubated for seven weeks at a constant temperature of 20 °C and a 25 % moisture level. After incubation, the exchangeable Mg was extracted with 1 M neutral ammonium acetate.

The exchangeable magnesium content seemed to increase in some soils and to decrease in other soils with increasing ammonium nitrate amounts. The applied magnesium was fixed in a non-exchangeable form, especially at the highest ammonium nitrate level, in two clay soils taken from the rapakivi area of south-eastern Finland. In the other soils all applied magnesium was exchangeable irrespective of the amount of ammonium nitrate.

Introduction

A great part of the mineral N in compound N-P-K fertilizers is in the form of NH_4-N. According to several studies (e.g. NOMMIK 1957, SCHACHTSCHABEL 1961, KAILA 1962), the mineral soils have the ability to fix applied NH_4^+ in a non-exchangeable form. The cations Ca^{2+} or Mg^{2+} have no effect on this fixation (NOMMIK 1957).

Only few studies on the effects of different mineral N levels on the exchangeable cation content of the soil are available (SIPPOLA et al. 1973). In laboratory studies on exchangeable cations a common practice is to treat the soil with NH_4^+ acetate or chloride. The NH_4^+-N containing fertilizers may have the same effect, even though the NH_4^+ concentration in the soil remains lower than in laboratory studies.

In a pot experiment, the apparent recovery of fertilizer Mg was low in some clay soils (JOKINEN 1981 a). The antagonism between NH_4^+ and Mg^{2+} in the cation uptake by

Index words: Ammonium nitrate, magnesium sulphate, exchangeable Mg, non-exchangeable Mg, fine sand, finer fine sand, silty clay, sandy clay, heavy clay.

plants was assumed to be the main reason for this. The effects of ammonium nitrate on soil Mg and applied Mg were not studied.

The aim of the present incubation experiment was to study the effects of different ammonium nitrate levels on the exchangeable Mg content of eight mineral soils and on the amounts of exchangeable Mg applied with magnesium sulphate.

Materials and methods

Eight mineral soils were incubated at 20 °C for seven weeks. The soil samples, three non-clay and five clay soils, represented the plough layer of cultivated soil from southern Finland. The same soils were used in an earlier pot experiment (Jokinen 1981 a) and incubation experiment (Jokinen 1981 b). The numbers and characteristics of the soils are given in the latter report. One of the soils, muddy silt (4), was not included in this study because of the too small amount of soil available.

The soils were air-dried and crushed to pass a 2-mm sieve. For the experiment, 100 g soil was weighed into 0.5 litre plastic pots and treated with ammonium nitrate and magnesium sulphate adding the following amounts of N and Mg:

Symbol	Treatment
N_1Mg_0	20 mg N
N_1Mg_1	20 mg N + 4 mg Mg
N_2Mg_0	40 mg N
N_2Mg_1	40 mg N + 4 mg Mg

The treatments without N fertilization (N_0Mg_0 and N_0Mg_1) were common with the incubation experiment on liming and Mg fertilization (Jokinen 1981 b). The fertilizer solutions were thoroughly mixed with the soil. Four replicates were made. Both experiments were incubated at the same time and in the same place. The moisture of the soils was maintained at 25 % of the soil weight, adding de-ionized water as necessary. The pots were covered with perforated plastic film.

After incubation, the soils were air-dried at room temperature and repassed through a 2-mm sieve. The exchangeable Mg was extracted by 1 M neutral ammonium acetate and exchange acidity (Al + H) by 1 M KCl (Kaila 1971). The amount of applied Mg found exchangeable in the soil was calculated as the difference Mg_1-Mg_0. The exchangeable NH_4^+ was extracted with 0.25 M K_2SO_4 (soil : solution = 1 : 10, w/v, 2 h) and determined by destillation. The NO_3^- was determined from the same aliquot of extract after reduction with Devarda's alloy. The amounts of applied mineral N found in the soils were calculated as the differences N_1-N_0 and N_2-N_0.

Results and discussion

After seven weeks of incubation, almost all the mineral N (NH_4^+-N + NO_3^--N) applied was found in the soils extractable in 0.25 M K_2SO_4 at the N_1 level. In finer fine sand (3), sandy clay (6) and silty clay (8), the nitrification of NH_4^+-N seemed to be complete, since the amount of NO_3^--N increased in the same proportion. At the N_2 level, the nitrification of applied NH_4^+ was observed in silty clay (8) only, possibly because of the high amount of mineral N applied.

In finer fine sand (3) and in clays (6—9) without ammonium nitrate, the exchangeable Mg content seemed to be somewhat higher than with N (Table 1). Increased activity of micro-organisms in soils 3, 6 and 8 by N fertilization was concluded on the basis of increased NO_3^--N content during incubation. Some of the exchangeable Mg may be involved in the biological fixation. In fine sand (1) and silty clay (5), the exchangeable Mg content seemed to increase with increasing ammonium nitrate amounts. Some of the non-exchangeable Mg in these soils may become exchangeable without difficulty, e.g. by chemical weathering. This may explain the ability of ryegrass in the pot experiment to take up non-exchangeable Mg from fine sand (1).

Table 1. Exchangeable Mg content, mg/100 g soil, in eight mineral soils after seven weeks of incubation. (Mg_0 = without Mg fertilization. Mg_1 = Mg fertilization 4 mg/100 g soil).

	Mg_0			Mg_1-Mg_0		
	N_0	N_1	N_2	N_0	N_1	N_2
1. Fine sand	1.2[a]	1.5[b]	1.6[b]	4.3[a]	4.3[a]	4.4[a]
2. Fine sand	5.9[a]	6.0[a]	6.1[a]	4.5[b]	3.7[a]	3.6[a]
3. Finer fine sand	16.0[c]	13.6[a]	14.3[b]	3.8[b]	4.0[b]	3.1[a]
5. Silty clay	10.9[a]	11.4[b]	11.5[b]	3.9[a]	4.1[a]	4.1[a]
6. Sandy clay	24.1[a]	23.6[a]	23.9[a]	4.7[b]	3.0[a]	2.4[a]
7. Sandy clay	52.3[a]	48.7[a]	49.2[a]	4.4[a]	4.6[a]	5.1[a]
8. Silty clay	34.5[b]	32.6[a]	33.4[ab]	4.4[a]	4.3[a]	3.6[a]
9. Heavy clay	77.0[a]	75.5[a]	75.5[a]	6.1[a]	4.5[a]	4.5[a]

Results of an individual soil with the same letter do not deviate significantly (P = 5 %). The datas of Mg_0 and Mg_1-Mg_0 were studied separately by Duncan's new multiple range test.

Without ammonium nitrate the applied Mg (4 mg/100 g soil) was found exchangeable in all soils after incubation (Table 1). Considerable amounts of Mg were released from heavy clay (9) in the exchangeable form during incubation.

With ammonium nitrate the applied Mg was partly tied up by fine sand (2) and sandy clay (6) at both N levels and by finer fine sand (3) and silty clay (8) at the N_2 level. The soils 6 and 8 originated from the rapakivi area of south-eastern Finland where, according to Sippola (1974), K-feldspar is more common than elsewhere in Finland. In these soils the fixation of NH_4^+-N into a non-exchangeable form seemed to be low because of the high K content (Scherer 1982). Hence it is possible that applied NH_4^+-N contributed to the formation of non-exchangeable Mg compounds. In finer fine sand (3), the fixation of applied Mg in the non-exchangeable form may be a consequence of the formation of insoluble Al-Mg compounds (Hunsaker and Pratt 1970), since the 1 M KC1 extractable Al^{3+} content of this soil decreased with increasing amounts of ammonium nitrate. The content of H^+ remained constant.

With increasing amounts of ammonium nitrate the reactions against applied Mg deviated in two clays (6 and 7) as well as in two silty clays (5 and 8). From soils 5 and 7 Mg was released in the exchangeable form and in soils 6 and 8 the fixation of Mg in non-exchangeable form occured during incubation.

The apparent recovery of fertilizer Mg by ryegrass (total of 8 cuts) was for the »rapakivi» soils (6 and 8) very low at the N_1 level (1.6 % and 0.4 %), but somewhat higher values were obtained at the N_2 level (13.6 % and 39.7 %) in the pot experiment (Jokinen 1981 a). Ryegrass seemed to be able to take up fixed Mg from these soils during the two growing seasons studied.

From the agricultural point of view the high amount of ammonium nitrate may have positive effects on the exchangeable Mg content of some soils. The applied Mg seemed to be fixed in the non-exchangeable form in some soils and this may contribute to the low recovery of fertilizer Mg. The antagonism between Mg^{2+} and NH_4^+ or K^+ in the cation uptake by plants is the main but not the only reason for the restricted Mg uptake.

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SELOSTUS

Ammoniumnitraatin vaikutus maan magnesiumin ja lannoituksena annetun magnesiumin uuttuvuuteen kahdeksasta kivennäismaasta

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Muhituskokeena tehdyn tutkimuksen maat oli otettu viljeltyjen maiden muokkauskerroksesta eri puolilta Suomea.

Maa n:o	Maalaji	Kunta
1	Karkea hieta	Ruukki
2	Karkea hieta	Mikkeli mlk
3	Hieno hieta	Toholampi
5	Hiesusavi	Laukaa
6	Hietasavi	Anjalankoski
7	Hietasavi	Vantaa
8	Hiesusavi	Anjalankoski
9	Aitosavi	Jokioinen

Laboratoriossa kuivia ja jauhettuja maita lannoitettiin ammoniumnitraatti- ja magnesiumsulfaattiliuoksilla niin, että 100 g kohti maata lisättiin seuraavat määrät typpeä (N) ja magnesiumia (Mg):

N_0Mg_0	Ilman N
N_0Mg_1	Ilman N + 4 mg Mg (n. 80 kg/ha)
N_1Mg_0	20 mg N (n. 400 kg/ha)
N_1Mg_1	20 mg N + 4 mg Mg
N_2Mg_0	40 mg N
N_2Mg_1	40 mg N + 4 mg Mg

Maat kostutettiin (25 % kosteus) ja niitä muhitettiin 20 °C vakiolämpötilassa seitsemän viikkoa.

Ammoniumnitraatin lisääminen aiheutti muutamissa maissa (1, 2 ja 5) lievän vaihtuvan magnesiumin määrän lisääntymisen mahdollisesti kemiallisen rapautumisen seurauksena (Taulukko). Toisissa maissa vaihtuvan magnesiumin määrä näytti vähenevän vilkastuneen pieneliötoiminnan aiheuttaman biologisen pidättymisen vuoksi.

Kaakkois-Suomen rapakivialueelta otetuissa savimaissa (6 ja 8) osa lannoituksena annetusta magnesiumista näytti pidättyvän vaihtumattomaan muotoon. Biologisen pidättymisen lisäksi maassa näyttäisi tapahtuvan kemiallista pidättymistä vaikealiukoisiksi yhdisteiksi. Useimmissa koemaissa lannoituksena lisätty magnesium oli kaikki vaihtuvana, siis kasveille käyttökelpoisena, ammoniumnitraatin määrästä riippumatta.

Aikaisemmin tämän tutkimuksen mailla tehdyssä astiakokeessa raiheinä otti vain pienen osan lannoituksena annetusta magnesiumista juuri niillä mailla, joilla tässä muhituskokeessa todettiin magnesiumin pidättymistä vaihtumattomaksi. Raiheinä kykeni ottamaan vaihtumatontakin magnesiumia.