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Effect of liming and N fertilization on growth, macronutrient content and uptake by mixed stands of three clovers and timothy

RAILI JOKINEN

Department of Agricultural Chemistry, University of Helsinki, SF-00710 HELSINKI, Finland

Abstract. Mixed stands of clovers and timothy grew well in unlimed (Ca_0) acid soil ($pH(CaCl_2)$ 4.8). The highest total yield of red clover-timothy was obtained at a low lime level (Ca_1 = 12 g/pot $CaCO_3$). The yield of red clover alone responded to liming similarly. The reducing effect of N fertilization (2000 mg/pot N as NH_4NO_3) on the yield of clovers was greatest in the first growing season (cuts 1 to 4) without lime, and in the second growing season (cuts 5 to 7) with lime (Ca_1 = 12 g/pot, Ca_2 = 24 g/pot). Liming without N fertilization promoted the growth of timothy only in the two first cuts; N fertilization increased the yield at all lime levels.

Liming increased the Ca content of clovers, but there were no differences between lime levels. Mg and K showed a decreasing trend. N fertilization did not affect the nutrient content of clovers. A good quality of clover yield reguired adequate amounts of other fertilizations than N. In timothy, the Ca content increased slightly at all lime levels; the N and K contents increased by N fertilization.

The N uptake by red clover was highest at the Ca_1 level, by white clover and alsike clover at the Ca_0 level. The proportion of clover was larger than that of timothy of the uptake of N, P, Ca and Mg. When N was applied, the uptake of K showed an opposite direction.

Index words: pot experiment, mineral soil, liming, N fertilization, red clover, white clover, alsike clover, timothy, yield, macronutrient content, macronutrient uptake, $pH(CaCl_2)$, exchange acidity, exchangeable Ca, Mg, K, Ca/Mg.

Introduction

Farming of clovers has aroused great interest in Finland during recent years. According to PULLI and TURTOLA (1983), the problems related to practical farming include poor winter hardiness of these plants and soil acidity. Also the requirement of N fertilization of leys at the start of the growing season must be taken into consideration, since clovers are almost always seeded with timothy.

In previous experiments on the effect of lime and N fertilization on the clover, attention was focused to the yield, N content and N uptake (e.g. MUNNS 1965, MUNNS and Fox

Present address: Department of Agricultural Chemistry and Physics, Agricultural Research Centre, SF-31600 JOKIOINEN, Finland.

1976, MUNNS et al. 1977, RICE et al. 1977, CRAIG et al. 1981, SSALI 1981, AURA and KEMPPAINEN 1983). The contents and uptake of Ca, Mg and K have been studied less (e.g. RAININKO 1968).

The aim of the present pot experiment was to give an account of the effects of three lime levels on the growth, macronutrient content and uptake of clovers (red clover *Trifolium pratense,* white clover *Trifolium repens* or alsike clover *Trifolium hybridum*) in mixed stands with timothy (*Phleum pratense*). The effect of N fertilization was studied at each lime level.

Materials and methods

The study was performed in conventional Mitscherlich pots and in a net-walled greenhouse. The soil, a Litorina fine sand (Table 1), was taken from the plough layer of an agricultural area. Moist soil was crushed to pass a 10-mm sieve. In October 1981, 5 kg of moist soil (4.3 kg air-dry soil) was weighed into each pot and limed with precipitated $CaCO_3$, 0 (Ca_0), 12 (Ca_1) and 24 (Ca_2) g/pot. The total number of pots was 72, i.e. 24 pots per lime level. De-ionized water was added to give a final moisture level of 25 %. The soils were incubated over the winter (October—April) out in the open air, exposed to the hard weather conditions of the Finnish winter.

In May 1982, the soils were fertilized with N (NH_4NO_3). At each lime level, 500 mg/pot N was added to 12 pots, 12 pots being left untreated. All soils were fertilized with 200 mg P and 505 mg K (K_2HPO_4), 200 mg Mg ($MgSO_4 \cdot 7H_2O$), 5 mg B (H_3BO_3), 15 mg Cu ($CuSO_4 \cdot 5H_2O$), 10 mg Mn ($MnSO_4 \cdot 4H_2O$), 10 mg Zn ($ZnSO_4 \cdot 7H_2O$) and 5 mg Mo ($Na_2MoO_4 \cdot 2H_2O$). During the growing season fertilization was repeated after the second cut with the same amounts of N, P and K.

Table 1. Soil characteristics at oneset of the pot experiment.

Particle size distribution	
<2 μm, %	22.4
2—20 μm, %	18.8
20—200 μm, %	57.2
>200 μm, %	1.6
Org. C, %	3.0
$pH(CaCl_2)$	4.8
Exchangeable (pH 7)	
Ca mg/kg	1128
Mg mg/kg	156
K mg/kg	222
Exchange acidity	
Al+H me/kg	8.2

The pots were seeded with a mixture of timothy (*Phleum pratense,* var. Nokka) and red clover (*Trifolium pratense,* var. Venla), white clover (*Trifolium repens,* var. Astra) or alsike clover (*Trifolium hybridum,* var. Högsta). The seeds of clovers were inoculated with *Rhizobium* strain suspension before sowing. The growth was cut four times, June 28, August 3, August 28 and October 7. The fresh yield was sorted out according to the two plant species, dried (60°C until dry + 2 h at 105°C) and weighed. After the 4th cut the covered pots were left in the net-hall over the winter.

In May 1983, fertilization was repeated like in 1982; no lime treatments were applied. Timothy and clovers were reseeded in their own pots and the growth was cut three times, July 11, August 8 and September 23. After the 5th and 6th cuts the pots received N, P and K fertilization, half the amounts given before sowing. Soil samples were taken after the 7th cut, dried at room temperature until air-dry and crushed to pass a 2-mm sieve.

The conditions of the pot experiment were probably unsuitable for alsike clover; it seemed to suffer especially from the short cutting intervals. The pots of the whole experiment were harvested at the same time, and the growth of red clover and timothy pots determined the cutting time. For the inoculation of the seedes, the same strain of *Rhizobium* was used. It is possible that the nodulation of alsike roots was weaker than that of the other clovers.

Seven cuts of all pots were analysed. One gram of plant material was wet combusted with the mixture of three acids, $HClO_4$, H_2SO_4 and HNO_3 (1:2.5:10). The contents of Ca and Mg were determined by AAS (Varian 1000) and the content of K by flame photometry (Corning 400). The total content of N was determined by the Kjeldahl digestion and steam distillation method. The results are given on dry matter basis.

The soil samples were suspended with 0.01 M $CaCl_2$ for 4 h for determination of pH. Exchangeable cations, Ca, Mg and K, were extracted with 1 M neutral ammonium acetate (w/v = 1/20), adding four successive 50 ml aliquots of acetate to 10 g of soil in a centrifuge tube. The contents of Ca and Mg in the extract were determined by AAS and that of K by flame photometry. The exchange acidity (Al + H) was extracted with 1 M KCl and titrated with 0.01 M HCl (KAILA 1971).

Analysis of variance was carried out, considering lime level, N fertilization and interaction between Ca and N the sources of variation. Differences between individual treatments were compared with Duncan's new multiple range test (STEEL and TORRIE 1960).

Results

Soil analyses

The $pH(CaCl_2)$ values of the soils treated in October 1981 with 0 (Ca_0), 12 (Ca_1) and

24 g/pot (Ca_2) of precipitated $CaCO_3$ were in April 1982 4.8, 6.5 and 6.9, respectively. During the first growing season, considerable decreases were observed in pH, the values being 4.4 and 5.6 at Ca_0 and Ca_1 levels, respectively, but a slight decrease to 6.8 only was recorded at the Ca_2 level. By the end of the experiment pH($CaCl_2$) still decreased by about 0.3 units at the Ca_1 and Ca_2 levels (Table 2).

Exchange acidity (Al + H) increased during the experiment in unlimed soils about three-fold when red or white clovers were grown with timothy (Table 2). The contents of 1 M KCl-extractable Al^{3+} and H^+ were in the original soil 2.8 and 5.4 me/kg and in the final unlimed soils 18.4 and 6.4 me/kg, respectively. At the same time, the proportion of Al of the exchange acidity increased from 34 % to 74 %. Alsike clover with timothy has a minor effect on exchange acidity, and still the increase found was concentrated in the Al-content. In limed soils the exchange acidity was mainly attributable to the H^+-content.

The amounts of applied K (total 2000 mg/pot) were too small and therefore the content of exchangeable K was low in all pots at the end of the experiment (Table 2). The amounts of Mg added were adequate since the content of exchangeable Mg in red clover soils decreased only slightly at the Ca_0 level. At the Ca_2 level, some of the exchangeable Mg seemed to become non-exchangeable. The content of exchangeable Ca increased due to liming as expected, and so did the ratio Ca/Mg (me).

Yields

The total yield (7 cuts) of red clover-timothy was highest at the lime level Ca_1 with N fertilization (Table 3). Clover alone

Table 2. Soil characteristics upon termination of the pot experiment.

	Ca_0		Ca_1		Ca_2	
	N_0	N_1	N_0	N_1	N_0	N_1
Red clover and timothy						
pH($CaCl_2$)	4.3^{a}	4.3^{a}	5.1^{b}	5.2^{b}	6.5^{c}	6.5^{c}
Exchangeable						
Ca mg/kg	801^{a}	820^{a}	1635^{b}	1683^{b}	1695^{c}	1695^{c}
Mg mg/kg	144^{b}	142^{b}	137^{b}	127^{a}	130^{a}	121^{a}
K mg/kg	69^{a}	65^{a}	75^{b}	69^{a}	81^{c}	71^{b}
Ca/Mg	3.4^{a}	3.5^{a}	7.3^{b}	8.1^{c}	12.6^{d}	13.6^{e}
Exchange acidity						
(Al + H) me/kg	26.5^{c}	25.4^{c}	5.8^{b}	5.7^{b}	2.3^{a}	2.5^{a}
White clover and timothy						
pH($CaCl_2$)	4.3^{a}	4.3^{a}	5.1^{b}	5.4^{b}	6.6^{c}	6.7^{c}
Exchangeable						
Ca mg/kg	799^{a}	823^{a}	1716^{b}	1769^{b}	2766^{c}	2836^{c}
Mg mg/kg	154^{ab}	161^{b}	164^{b}	166^{b}	156^{ab}	144^{a}
K mg/kg	67^{a}	72^{a}	94^{c}	85^{b}	111^{d}	89^{bc}
Ca/Mg	3.2^{a}	3.1^{a}	6.4^{b}	6.5^{b}	10.8^{c}	12.1^{d}
Exchange acidity						
(Al + H) me/kg	28.3^{c}	26.1^{c}	4.0^{b}	3.9^{b}	2.0^{a}	1.8^{a}
Alsike clover and timothy						
pH($CaCl_2$)	4.5^{a}	4.5^{a}	5.6^{b}	5.6^{b}	6.7^{c}	6.6^{c}
Exchangeable						
Ca mg/kg	938^{a}	923^{a}	1856^{b}	1865^{b}	2805^{c}	2805^{c}
Mg mg/kg	175^{b}	170^{b}	172^{b}	169^{b}	148^{a}	141^{a}
K mg/kg	79^{a}	78^{a}	106^{c}	88^{a}	98^{bc}	84^{ab}
Ca/Mg	3.3^{a}	3.3^{a}	6.6^{b}	6.7^{b}	11.5^{c}	12.1^{d}
Exchange acidity						
(Al + H) me/kg	18.5^{c}	18.9^{c}	3.0^{b}	2.9^{b}	1.6^{a}	2.0^{a}

Table 3. Dry-matter yields (g/pot) of clover and timothy in mixed stands.

	Ca_0		Ca_1		Ca_2	
	N_0	N_1	N_0	N_1	N_0	N_1
			Red clover and timothy			
1st year (4 cuts)						
Clover	49.4^{c}	33.9^{a}	48.9^{c}	43.8^{b}	37.8^{a}	34.4^{a}
Timothy	13.8^{a}	31.6^{cd}	17.6^{b}	29.6^{d}	22.1^{c}	35.0^{d}
Total	63.2^{ab}	65.5^{bc}	66.5^{bc}	73.4^{d}	59.9^{a}	69.4^{cd}
2nd year (3 cuts)						
Clover	38.4^{a}	35.0^{a}	49.5^{b}	38.9^{a}	46.8^{b}	39.7^{a}
Timothy	10.0^{a}	17.7^{b}	10.8^{a}	30.7^{c}	9.6^{a}	29.1^{c}
Total	48.4^{a}	52.7^{ab}	60.3^{c}	69.6^{d}	56.4^{bc}	68.8^{d}
1st + 2nd year (7 cuts)						
Clover	87.8^{b}	68.9^{a}	98.4^{c}	82.7^{b}	84.6^{b}	74.1^{a}
Timothy	23.8^{a}	49.3^{c}	28.4^{a}	60.3^{d}	31.7^{b}	64.1^{d}
Total	111.6^{a}	118.2^{a}	126.8^{b}	143.0^{c}	116.3^{a}	138.2^{c}
			White clover and timothy			
1st year (4 cuts)						
Clover	52.0^{d}	32.1^{b}	43.4^{cd}	29.2^{ab}	37.5^{bc}	22.0^{a}
Timothy	17.3^{a}	36.1^{b}	20.3^{a}	35.2^{b}	21.3^{a}	39.5^{b}
Total	69.3^{b}	68.2^{b}	63.7^{ab}	64.4^{ab}	58.8^{a}	61.5^{ab}
2nd year (3 cuts)						
Clover	36.9^{b}	31.8^{ab}	30.3^{ab}	29.7^{ab}	25.0^{ab}	20.4^{a}
Timothy	7.0^{a}	18.6^{ab}	8.9^{a}	21.8^{ab}	7.6^{a}	29.7^{b}
Total	43.9^{bc}	50.4^{c}	39.2^{ab}	51.5^{c}	32.6^{a}	50.1^{c}
1st + 2nd year (7 cuts)						
Clover	88.9^{c}	63.9^{b}	73.7^{b}	58.9^{b}	62.5^{b}	42.4^{a}
Timothy	24.3^{a}	54.7^{b}	29.2^{a}	57.0^{b}	28.9^{a}	69.2^{b}
Total	113.2^{bc}	118.6^{c}	102.9^{b}	115.9^{c}	91.4^{a}	111.6^{bc}
			Alsike clover and timothy			
1st year (4 cuts)						
Clover	32.7^{c}	20.6^{ab}	30.7^{c}	14.9^{a}	26.0^{bc}	18.7^{a}
Timothy	20.6^{a}	40.9^{c}	22.5^{a}	45.1^{d}	26.7^{b}	48.2^{d}
Total	53.3^{a}	61.5^{b}	53.2^{a}	60.0^{b}	52.7^{a}	66.9^{c}
2nd year (3 cuts)						
Clover	31.4^{a}	22.3^{a}	26.4^{a}	18.8^{a}	27.7^{a}	30.6^{a}
Timothy	4.6^{a}	25.0^{c}	6.6^{a}	30.5^{c}	10.5^{ab}	21.9^{bc}
Total	36.0^{ab}	47.3^{bc}	33.0^{a}	49.3^{c}	38.2^{ab}	52.5^{c}
1st + 2nd year (7 cuts)						
Clover	64.1^{c}	42.9^{ab}	57.1^{bc}	33.7^{a}	53.7^{bc}	49.3^{bc}
Timothy	25.2^{a}	65.9^{b}	29.1^{a}	75.6^{b}	37.2^{a}	70.1^{b}
Total	89.3^{a}	108.8^{b}	86.2^{a}	109.3^{b}	90.9^{a}	119.4^{b}

The results of one plant and one year provided with a common letter do not deviate significantly ($P = 0.05$).

produced the highest yields at the Ca_1 level without N, and the beneficial effect of lime was most obvious in the 4th to 7th cuts (Table 4). In comparison to unlimed treatment, the lime level Ca_2 decreased the growth of red clover at the beginning of the experiment (cuts 2 to 4) and increased it in the second year (cuts 5 to 7).

Nitrogen fertilization depressed the growth of red clover in the first growing season most at the Ca_0 level and seemed to cause a greater decrease than the Ca_2 treatment (Table 3). In the second year, the yield reduction due to N fertilization was significant in limed soils.

Timothy benefited by N fertilization in the first year most without lime and in the second year with lime. Liming without N increased the yield especially in the cuts 1 to 3. In later cuts there were no differences in yield.

White clover-timothy produced the highest yield (7 cuts) without lime, and the yields were as high as those of red clover-timothy (Table 3). Liming decreased the yield of mixed stand mainly because of the restricted growth of white clover. Also N fertilization seemed to decrease the yield of clover.

In the mixed stand of alsike clover-timothy, the total yield remained slightly lower than in the other mixed stands (Table 3). The effects of liming and N fertilization on alsike clover are similar to those on white clover.

The yields of the first cuts consisted mainly of timothy (results are not presented), and the proportion of clover varied between 3 and 19 %. The reseeded yield of the fifth cut contained considerably more clover (11 to 60 %) than the first cut. In general, the proportion of clover in the mixed yield of other cuts increased to about 95 % with advancing growing season. Alsike clover was an exception with decreasing proportions independent of lime level.

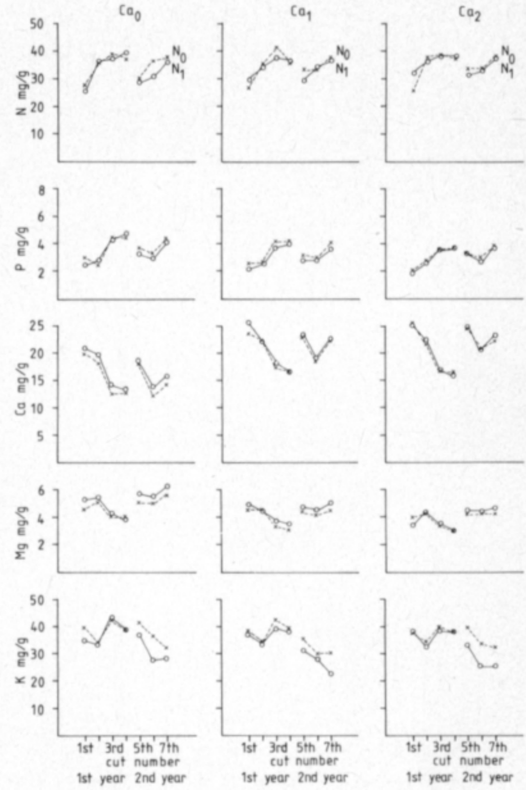

Fig. 1. Macronutrient contents (mg/g dry matter) of red clover (in mixed stad with timothy) at three lime levels without or with N fertilization.

Macronutrient contents of plants

The N, P, Ca, Mg and K contents of the three clovers were similar, therefore the contents of red clover only are presented and discussed. The Na content of white clover was exceptionally high (1—6 mg/g) in comparison to red and alsike clovers (0.1—1 mg/g). Yet, independent of the Na content, the K content of all clovers were similar.

In cuts 5 to 7, the N, P and K contents of red clover seemed to be somewhat higher without N fertilization and lime than with N and lime (Fig. 1). In the Ca and Mg contents the situation was opposite. When Ca was applied, the content of Ca increased, but there were no differences between the Ca_1 and Ca_2 levels. The Mg content of red clover decreased with increasing liming. The contents of N and P were lowest in the first cut of both growing seasons increasing towards the end. The contents of Ca, Mg and K showed different trends.

In the first year, the N, P and K fertilizations were added before sowing and after the second cut, and this was reflected also in the respective contents of timothy (Fig. 2). In the second year, fertilizations were applied for each yield. The small yields obtained without N fertilization exhibited higher contents of N and P than with N. In that year the insufficient supply of K caused only small changes in the K content of timothy. The Ca and Mg contents seemed to increase slightly from cut to cut.

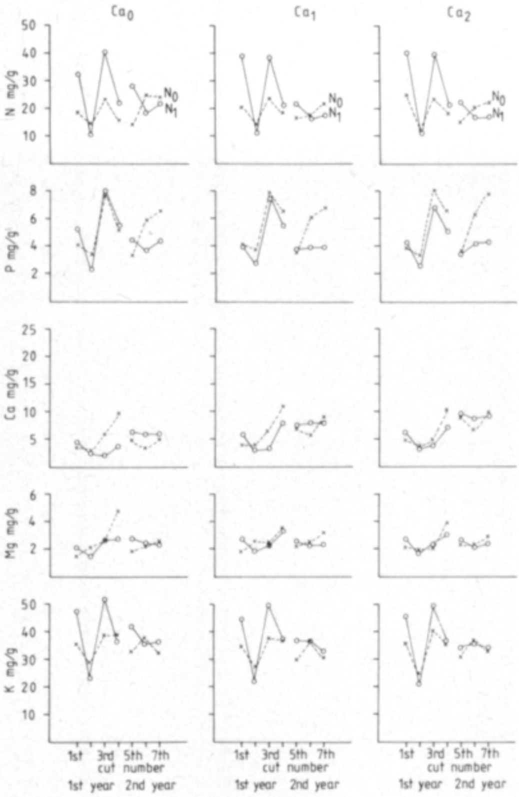

Fig. 2. Macronutrient contents (mg/g dry matter) of timothy (in mixed stand with red clover) at three lime levels without or with N fertilization.

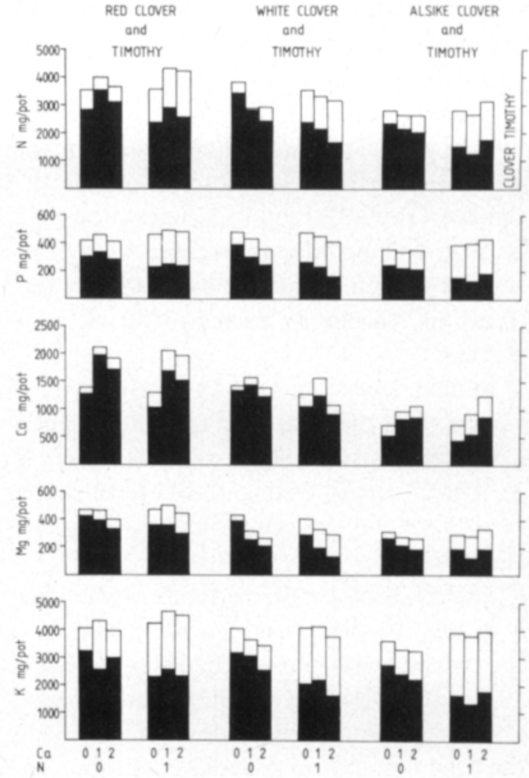

Fig. 3. Macronutrient uptake (mg/pot) of three clovers and timothy in mixed stands at three lime levels without or with N fertilization.

Macronutrient uptake by plants

The amounts of nutrients taken up by mixed stands of clovers and timothy decreased in the sequence red clover > white clover > alsike clover (Fig. 3). Chiefly, the differences in yields reflected the nutrient uptakes. The total uptake of Ca and Mg consisted mainly of the uptake by clovers independent of the N fertilization and lime levels.

In the N-fertilized part of the experiment, the K uptake by timothy was nearly equal to that of red clover and exceeded the uptake by white clover and alsike clover.

The N uptake by clovers was higher without than with N fertilization at all lime levels. The N uptake by white clover and alsike clover decreased with increasing liming. The uptake of N by red clover was lowest at the Ca_0 and highest at the Ca_1 level.

In the 1st cut all clovers took up N most at the Ca_2 level, which may indicate uptake of soil N, mineralized due to liming (Table 4). In the later cuts, the N uptake followed almost always the size of yields. The N uptake by red clover in the 7th cut was highest at the Ca_2 level, which may imply that the negative effect of that lime level turned gradually positive.

Most of all, liming affected the Ca uptake by red clover and alsike clover. An increase was observed in the uptake by red clover between the Ca_0 and Ca_1 levels, whereas a reduction was observed between the Ca_1 and Ca_2 levels. In alsike clover the Ca uptake increased with increasing liming. The Ca uptake

Table 4. Dry-matter yields (g/pot) and N uptake (mg/pot) of red clover in seven cuts without N fertilization at three lime levels.

Cut number	Ca_0	Ca_1	Ca_2
		Yield g/pot	
1	2.1[b]	2.0[b]	1.1[a]
2	18.8[b]	17.8[b]	11.5[a]
3	14.9[b]	25.0[b]	12.8[a]
4	13.5[a]	14.2[a]	12.4[a]
5	7.5[a]	10.1[b]	8.2[ab]
6	14.0[a]	17.9[b]	16.6[b]
7	16.8[a]	21.5[b]	22.0[b]
		N uptake mg/pot	
1	58[b]	52[b]	29[a]
2	660[b]	625[b]	435[a]
3	580[b]	616[b]	496[a]
4	500[a]	506[a]	464[a]
5	226[a]	332[b]	276[a]
6	511[a]	594[b]	555[ab]
7	634[a]	800[ab]	850[b]

The results of individual cut provided with a common letter do not deviate significantly (P = 0.05).

by white clover was nearly independent of the lime levels.

The Mg uptake of all clovers decreased with increasing lime levels, and in this respect white clover was most sensitive. Liming did not affect uptake of P by red clover and alsike clover; P uptake by white clover seemed to decrease.

Discussion

The effects of lime levels (Ca_0 = 0 g, Ca_1 = 12 g, Ca_2 = 24 g $CaCO_3$) and ammonium nitrate rates (N_0 = 0 mg, N_1 = 2000 mg N per 4.3 kg air-dry soil) on red clover, white clover and alsike clover in mixed stands with timothy were studied in a pot experiment during two growing seasons.

All clovers produced high total yields (7 cuts) without lime in spite of the low pH($CaCl_2$) and high Al content of the soil. Before the experiment, the content of exchange acidity in the soil was 8.2 me/kg; Al accounting for about 34 %. At the end of the experiment, the exchange acidity increased to 24.8 me/kg, Al accounting for 74 % the exchange acidity and about 24 % of the effective CEC. According to KAMPRATH (1970) the Al concentration for optimum growth of soybean should not exceed 20 % of the CEC.

Liming of the acid soil decreased the growth of red clover in the first four cuts, and thereafter the yields increased. MUNNS and FOX (1976) reached similar results with some legumes in a pot experiment when oxisol was limed to pH 6. A decrease in clover yields with high lime levels was observed also by SSALI (1981) in a soil with organic matter content exceeding 3 %. The possible reason for the decreased growth may be e.g. the high Ca concentration in the soil (MUNNS and FOX 1976), the inbalance in Ca/Mg (JOKINEN 1981 a), the incapacity to take up non-exchangeable cations (unlike ryegrass) and decrease in nodule number, nodule weight and N fixation (EDWARDS et al. 1981, SSALI 1981). EDWARDS et al. (1981) obtained the highest yield increases of cowpea with 2.5 t/ha lime at pH 4.3; higher lime amounts decreased the yield. According to RICE et al. (1977), red clover was not sensitive to soil acidity in the pH(H_2O) range 4.9—7.2.

As concluded on the basis of the yield and N uptake without N fertilization, white clover and alsike clover were not sensitive to soil acidity and high Al content, since the yields were the highest without lime. For red clover, a suitable pH($CaCl_2$) range seemed to be 5—6, as determined on the basis of yield and N uptake.

In the second growing season with N addition and K shortage, timothy seemed to be stronger than clover in the competition on K, and therefore the K content of clover remained lower than without N. The earlier results of field studies also imply the existence of competition on K between clover and timothy (RAININKO 1968, JOKINEN 1969).

The pH($CaCl_2$) values near 6.5 at the lime level Ca_2 seemed to be too high for the clover, as concluded on the basis of the decreased yield and N uptake in the first growing season. The negative effects of direct liming on clovers may be avoided by liming the field before the establishment of the clover mixed ley. The target pH and amount of lime may vary depending whether high yields or great N uptakes are wanted.

The macronutrient content of clover seemed to be almost unaffected by N fertilization, even the N content. When P, K and Mg are given in adequate amounts the quality (the macronutrient content) of clover will not be dependent on N fertilization. In the case of timothy, nitrogen fertilization increased the nutrient contents.

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SELOSTUS

Kalkituksen ja typpilannoituksen vaikutus apiloiden ja timotein sekakasvustojen satoon ja ravinnepitoisuuksiin

Raili Jokinen

Helsingin yliopisto

Astiakokeessa (maata 4.3 kg/ast, pH($CaCl_2$) 4.8) tutkittiin kolmen kalkkimäärän (Ca = 0 g, Ca_1 = 12 g, Ca_2 = 24 g/ast $CaCO_3$) ja typpilannoituksen (N_0 = 0 mg, N_1 = 2000 mg/ast N, NH_4NO_3:na) vaikutuksia timotein kanssa sekakasvustona viljeltyjen puna-, valko- ja alsikeapilan satoon (yhteensä 7 niittoa) sekä pääravinteiden pitoisuuksiin ja ottoon.

Nykyinen osoite: Maatalouden tutkimuskeskus, maanviljelyskemian ja -fysiikan osasto, 31600 JOKIOINEN

Maat kalkittiin syksyllä 1981 ja pH($CaCl_2$)-arvot mitattiin huhtikuussa 1982 ennen lannoitusta ja kylvöä sekä syyskuussa 1983 sadonkorjuun jälkeen. Tulokset olivat seuraavat:

Kalkitus	pH($CaCl_2$) 1982	1983
Ca_0	4.8	4.3
Ca_1(n. 5 t/ha)	6.5	5.1
Ca_2(n. 10 t/ha)	6.9	6.5

Ilman typpilannoitusta puna-apilan ja timotein sekakasvusto tuotti parhaan sadon pienellä kalkkimäärällä ja valkoapilan sekakasvusto ilman kalkitusta, mutta alsikeapilan sekakasvuston satoon kalkkimäärillä ei ollut merkitsevää vaikutusta. Kalkitus lisäsi timotein satoa vain kahtena ensimmäisenä korjuukertana.

Typpilannoitus vähensi apiloiden satoa ensimmäisenä vuonna kalkkimäärästä riippumatta. Toisena vuonna puna-apilan sato väheni vain kalkituissa astioissa. Typpilannoituksella ei ollut vaikutusta muiden apiloiden satoon. Timotein sato lisääntyi typpilannoituksella jokaisena korjuukertana ja kaikilla kalkkimäärillä. Apiloiden ja timotein sekakasvuston satoon typpilannoituksella oli selvin ja positiivinen vaikutus suuren kalkkimäärän saaneissa astioissa. Runsaimmat sadot saatiin typellä lannoitetuista kasvustoista silloin, kun puna-apilan sekakasvusto sai pienen kalkkimäärän, valkoapilan kasvusto jäi ilman kalkkia ja alsikeapilan kasvusto sai suuren kalkkimäärän.

Sekakasvustojen ottaman typen määrä ei lisääntynyt typpilannoituksella, mutta timotein osuus typen otosta lisääntyi. Eniten typpeä otti puna-apilan sekakasvusto pienen kalkkimäärän tasolla ja muut apilat ilman kalkitusta. Suurella kalkkimäärällä saatiin pienempi puna-apilan kuiva-ainesato mutta suurempi typpisato kuin ilman kalkitusta.

Apiloiden kalsiumpitoisuus kohosi hieman, mutta magnesium- ja kaliumpitoisuus pieneni kalkin määrää lisättäessä. Typpilannoitus ei muuttanut apiloiden typpi-, fosfori-, kalsium- ja magnesiumpitoisuutta. Kaliumlannoituksen niukkuus toisena vuonna vaikeutti apilan kaliumin saantia. Jos apiloille annetaan riittävästi muita ravinteita kuin typpeä, sadon ravinnepitoisuudet pysyvät korkeina. Timotein typpi-, fosfori- ja kaliumpitoisuus muuttui lannoituksen mukaan. Kalkituksen positiivinen vaikutus timotein kalsiumpitoisuuteen oli vähäinen.

Puna-apilaa sisältäville kasvustoille tulisi ehkä käyttää kalkitusaineeksi dolomiittikalkkia jo maan ravinnesuhteen Ca/Mg (me) optimialueen 5—8 alarajalla, sillä apilan magnesiumin otto näytti vähenevän kalkitsemattomaan verrattuna pienelläkin kalkkimäärällä ja Ca/Mg arvoilla 7—8. Apilat eivät ottaneet vaihtumatonta magnesiumia.