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THE EFFECT OF DIFFERENTIATED FIVE-YEAR LONG MINERAL FERTILIZATION ON THE DYNAMICS OF SOIL REACTION AND THE DEPENDENCES BETWEEN THE REACTION AND CALCIUM AND MAGNESIUM CONTENT IN SOIL, MIXED SOD GROWTH AND COCKSFOOT (*DACTYLIS GLOMERATA* L.)

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A b s t r a c t. The five-year long research pertaining to the effect of mineral NPK fertilization on the formation of soil reaction, calcium and magnesium content in soil, mixed sod growth and cocksfoot, was carried out in the localities of Chorzelów and Kraczków in Rzeszów administrative area in the years 1981-1985. The factor deciding about the dynamics of pH_{KCl} of soil was the nitrogen fertilization; the effect of potassium fertilizers was not large and that of phosphorus was almost invisible. The greatest and most quickly preceding decrease of soil reaction was noted in the objects with the dose of 360 and 480 kg N/ha/year. The decrease of pH_{KCl} was accompanied by the decrease in exchangeable calcium content as well as the content of available magnesium in the surface layer of 0-10 cm of grassland and in mixed sod grass. The calcium and magnesium content in cocksfoot underwent slight changes which indicates the dominating effect of the occurring changes of botanic composition of the vegetative cover on the Ca and Mg content in the mixed sod grass. The soils intensively fertilized must be enriched in calcium and magnesium and other elements not introduced with NPK.

K e y w o r d s: mineral fertilization, soil reaction, Ca and Mg content in soil and plant material

INTRODUCTION

The acidification of soils is one of the basic problems connected with the intensification of agriculture.

The mineral fertilization often leads to the quick deterioration of physical, chemical and biological properties of soil. Many authors [1,4,6,11] show that the main cause of this phenomenon is the increasing effect of artificial nitrogen fertilizers. Soil reaction has a great influence on the dynamics in soil and mineral components uptake by the plants. Special role can be ascribed to the basic alkaline elements, i.e., calcium and magnesium. According to Kozłowski *et al.* [8], the acidification is mainly the result of the occurring loss of calcium.

The aim of the research was to determine the dependencies between the mineral NPK fertilization and the reaction, Ca and Mg content in soil and plants of grassland.

MATERIALS

The five-year long research was carried out in the years: 1981-1985 on the permanent meadows in the localities of Chorzelów and Kraczkowa in Rzeszów administrative area. The experiments comprised 12 fertilization objects presented in the tables. Nitrogen fertilizers (34 % ammonium nitrate) were applied in three doses: 1/2 of a year dose under the first outgrowth, and the second and third outgrowth got 1/4 of a year dose of nitrogen each. Phosphorus fertilizers (18 % powder superphosphate) and potassium fertilizers (57 %

chloride potassium salt) were applied in 1981 once under the first outgrowth, since 1982 the potassium fertilizers year dose had been divided and applied 1/3 of a year dose under each outgrowth.

The initial analysis of soils was carried out in spring 1981, before starting of the experiment. Samples were taken from the layers of 0-10 cm and 10-20 cm. The later analyses were carried out only in the layer 0-10 cm twice a year: before the begining of vegetation in the meadows and after harvesting the last swath.

In the soil the following properties were determined:

- the mechanical composition with Prószyński's areometric method,
- pH in 1 mol/dm^3 KCl with potentiometric method,
- available magnesium according to Schachtschabel,
- available phosphorus and potassium according to Egner-Riehm,
- exchangeable calcium with versenate method after the extraction with the solution of 1 mol/dm^3 ammonium acetate.

The soil in Chorzelów the mechanical composition of which corresponded to medium silty clay, was classified as the soil of brown type. The available Mg content ranged from 11.3 to 12.5 mg Mg/100 g of soil, the available potassium - from 30.2 to 32.5 mg K_2O/100 g of soil, the available phosphorus - from 7.2 to 8.4 mg P_2O_5/100 g of soil, the exchangeable calcium from 73.3 to 75.8 mg Ca/100 g of soil. The soil reaction fluctuated on the boundary of slightly acid and acid and ranged from 5.4 to 5.6 pH_{KCl}.

The soil in Kraczkowa had the mechanical composition of silt formations and it was classified as the deluvial soil. It was much poorer. The content of available Mg amounted from 9.3 to 11.7 mg Mg/100 g of soil, the available K from 4.6 to 4.7 mg K_2O/100 g of soil, the available P content from 1.6 to 2.7 mg P_2O_5/100 g of soil, the exchangeable Ca content - from 58.5 to 62.3 mg Ca/100 g. The soil reaction was acid to 5.1 pH_{KCl}.

Each year 3 cuts of hay were harvested. During the harvesting, samples of mixed grass and cocksfoot considered the main crop were taken. The analysis of the chemical composition of cocksfoot allowed to eliminate the effect of changes in the botanic composition of the meadow vegetative cover on the chemical composition of fodder. After drying the samples of plant material to the absolutely dry matter, calcium was determined with the method of flame photometry, and magnesium was determined with the AAS method.

RESULTS

At the beginning of the experiment the soil in Chorzelów, slightly less acidified, had pH_{KCl} 5.4 in the layer 0-10 cm, and 5.6 in the layer of 10-20 cm. pH_{KCl} of the soil in Kraczkowa was 5.1 in the both examined layers. The dynamics of the reaction of the soil in Chorzelów is given in Table 1 and the results of the experiment in Kraczkowa in Table 2.

Soil reaction in both the experiments changed significantly depending on fertilizing as well as along with the passing of time. Mineral fertilization, especially with high doses of nitrogen (360 and 480 kg ha^{-1}year^{-1}) was the cause of quick and very significant decrease in soils reaction; these changes increased as the time passed.

In Chorzelów, depending on objects, each 100 kg N used in the form of ammonium nitrate caused the decrease in soil reaction by 0.06 to 0.09 pH. In Kraczkowa, respectively, these changes amounted to 0.05-0.08 pH.

The effect of the use of potassium fertilizers on the changes of reaction was not large, however, the effect of the applied phosphorus fertilizers was almost invisible. In Chorzelów the initial pH_{KCl} of 5.4 after five years of the experiments decreased to pH 3.8-3.9 in the objects with the dose of 480 kg N. Lower doses of nitrogen caused significantly smaller and slower changes of reaction (Table 1).

In Kraczkowa the soil behaved similarly, however, the negative changes in the reaction were quicker. From the initial pH_{KCl} amounting 5.1 the reaction after five years of the

Table 1. pH_{KCl} dynamics in 0-10 cm soil layer (Chorzelów)

Treatments*	1981	1982		1983		1984		1985		Means for 1982-85
	B	A	B	A	B	A	B	A	B	
No fertilizers	5.4	5.4	5.2	5.4	5.0	5.1	5.5	5:3	5.2	5.30
$N_0 P_{60} K_{90}$	5.4	5.0	5.0	5.4	5.4	5.0	4.8	4.8	4.8	5.00
$N_{120} P_{60} K_0$	5.4	5.1	5.1	4.7	4.7	5.0	5.1	4.7	4.7	4.90
$N_{120} P_{60} K_{90}$	5.3	4.9	5.2	5.4	5.4	5.0	5.0	4.9	5.1	5.10
$N_{240} P_{60} K_{90}$	5.4	5.7	4.9	5.5	5.2	4.6	4.7	4.6	4.7	5.05
$N_{240} P_{60} K_{180}$	5.3	5.0	5.1	5.0	4.7	4.6	4.6	4.8	4.4	4.80
$N_{240} P_{120} K_{180}$	5.3	5.6	4.9	5.3	4.9	4.6	4.6	4.5	4.3	4.85
$N_{360} P_{120} K_{180}$	5.1	5.6	5.4	5.0	4.8	4.6	4.7	44.6	4.3	4.90
$N_{480} P_{120} K_{180}$	5.3	5.5	5.0	5.1	4.9	4.5	4.3	4.2	4.2	4.70
$N_{480} P_{120} K_{270}$	5.2	5.2	5.4	5.2	5.2	4.3	4.1	4.1	3.8	4.65
$N_{480} P_{120} K_{270}$ Cu	5.2	5.3	5.2	5.4	5.2	4.5	4.2	4.0	3.9	4.70
$N_{480} P_{120} K_{270}$ Co	5.2	5.2	5.1	5.2	4.7	4.3	4.2	4.1	4.0	4.60
Mean	5.3	5.3	5.1	5.2	5.0	4.7	4.7	4.6	4.5	4.85
Mean		5.15		5.10		4.70		4.55		

* A - before vegetation; B - after harvest 3rd cut; LSD p = 0.05: for years 0.09, for fertilization 0.13; N - kg N ha^{-1} $year^{-1}$; P - kg P_2O_5 ha^{-1} $year^{-1}$; K - kg K_2O ha^{-1} $year^{-1}$.

Table 2. pH_{KCl} dynamics in 0-10 cm soil layer (Kraczkowa)

Treatments*	1981	1982		1983		1984		1985		Means for 1982-85
	B	A	B	A	B	A	B	A	B	
No fertilizers	5.0	5.3	5.1	5.2	5.1	5.0	4.9	4.9	4.9	5.05
$N_0 P_{60} K_{90}$	5.0	5.0	5.1	5.1	5.1	4.9	5.1	4.8	4.8	5.00
$N_{120} P_{60} K_0$	5.1	5.4	5.1	5.3	5.0	4.8	5.0	4.8	4.8	5.05
$N_{120} P_{60} K_{90}$	5.0	5.3	5.4	5.1	5.0	4.9	5.0	4.8	4.8	5.00
$N_{240} P_{60} K_{90}$	4.9	5.4	5.2	5.0	5.1	5.0	5.1	4.7	4.7	5.00
$N_{240} P_{60} K_{180}$	4.9	5.2	4.9	4.9	5.0	4.6	4.7	4.3	4.2	4.70
$N_{240} P_{120} K_{180}$	4.7	5.2	4.7	4.6	4.6	4.5	4.6	4.4	4.3	4.65
$N_{360} P_{120} K_{180}$	4.9	5.1	5.1	4.8	4.7	4.4	4.3	4.1	3.9	4.55
$N_{480} P_{120} K_{180}$	4.7	4.9	4.5	4.6	4.9	4.3	4.2	4.1	3.8	4.40
$N_{480} P_{120} K_{270}$	4.7	5.1	4.6	4.4	4.4	4.1	4.0	3.8	3.7	4.30
$N_{480} P_{120} K_{270}$ Cu	4.7	5.2	4.3	4.7	4.1	4.1	4.0	3.8	3.7	4.30
$N_{480} P_{120} K_{270}$ Co	4.6	5.1	4.5	4.5	4.2	4.3	4.1	3.9	3.8	4.30
Mean	4.9	5.2	4.9	4.9	4.8	4.6	4.6	4.4	4.3	4.70
Mean		5.05		4.85		4.60		4.35		

* A - before vegetation; B - after harvest 3rd cut; LSD p = 0.05: for years 0.08, for fertilization 0.12; N - kg N ha^{-1} $year^{-1}$; P - kg P_2O_5 ha^{-1} $year^{-1}$; K - kg K_2O ha^{-1} $year^{-1}$.

experiments lowered to pH 3.7-3.8 in some objects with the dose of 480 kg N $ha^{-1}year^{-1}$.

The determination of soil reaction was carried out twice a year: before the beginning of vegetation and after harvesting the last swath. It allowed the determination of changes in, so-called, rest period of the grass rest. The analyses carried out only in spring showed that the soil reaction of the majority of the objects in Kraczkowa did not change in the first year and in Chorzelów even after two years of the experiments. Indeed, the change of reaction occurred, but soil in the period from late autumn to spring was able to neutralize the acidification. In the next years these buffor properties of soil were destroyed by the intensive fertilization.

Some results pertaining to the content of exchangeable calcium in the soils of both experiments are presented in Table 3. The Chorzelów soil had higher content of calcium. In both the localities, the mineral fertilization and other factors had influence on the content of exchangeable calcium in soil. The control objects and objects with lower doses of mineral fertilizers (up to the dose of 360 kg N and proper fertilization with P and K) had the highest content of exchangeable calcium.

The smallest content of calcium was noted in the objects supplied with the dose of 480 kg N, i.e., the most acidified ones (Tables 1, 2, and 3). The distinct drop of Ca content in these objects was noted in 1983, which may be connected with the constant lowering of the soil reaction. However, from that time it should be stressed that also the uptake of calcium from these objects together with the highest crop was the largest. The dependencies between the content of exchangeable calcium and pH_{KCl} of soils are presented by the calculated correlation coefficients. In both the experiments they were statistically significant and positive. For the soil in Chorzelów it was a low dependence, the correlation coefficient was +0.33. For the soil in Kraczkowa this dependence was medium and the correlation coefficient amounted to +0.62.

The content of available magnesium in the soils of both experiments is given in Table 3. The statistically significant differences occurred both between the results from the subsequent objects and between the results from the years of the study.

The influence of the applied mineral fertilizers, especially nitrogen ones, on magnesium content was distinctly negative; the largest and very quickly proceeding deterioration of available magnesium content was noted in the objects with the dose of 480 kg N $ha^{-1}year^{-1}$.

The dynamics of changes in the content of available magnesium was strictly connected with the changes of the soil reaction. The calculated correlation coefficients for available magnesium content and pH_{KCl} of soils were statistically significant, positive and amounted to: +0.42 for Chorzelów (moderate correlation) and +0.75 (high correlation) for Kraczkowa.

The chosen results pertaining to the content of calcium in the mixed grass growth and cocksfoot are presented in Table 4. The content of Ca in the mixed grass was much higher than in the cocksfoot and only mixed grass had the sufficient content from the point of view of feeding norms. The mixed grass in Kraczkowa collected more Ca than the grass in Chorzelów. The noted drop of Ca content in the mixed grass as the result of applied fertilizers, especially nitrogen ones, was mainly the result of the changes of the botanical composition of the grass = *papilionacaous* plants and herbs reaching Ca and the amount of grass increased. The decisive influence of those changes is confirmed by the observations pertaining to the reaction of cocksfoot to NPK fertilization, which not only cause the lowering of Ca content in comparison to control but it was the cause of visible - though statistically insignificant - increase in Ca content in this species.

The content of calcium in the mixed grass and cocksfoot changed significantly over the years which is not reflected by the average values given in Table 4. This phenomenon is probably connected with the proceeding acidification of soils and the decrease in exchangeable calcium content in these soils.

The dynamics of magnesium content in the sod (mixed grass) and cocksfoot was similar to the changes in calcium content. The chosen results are presented in Table 4.

Fertilization - mainly nitrogenous - was the cause of the significant decrease in Mg content in the mixed grass, on the other hand, no such dependence was noted in cocksfoot. These results indicate the dominating effect of the botanic composition on the drop of Mg content in the intensively fertilized grass of the grassland, in the first years at least.

The mixed grass in Kraczkowa had lower Mg content than that in Chorzelów. We may

T a b l e 3. Exchangeable calcium and available magnesium content in 0-10 cm soil layer of meadows

Treatments*	Calcium (mg Ca/100 g of soil)						Magnesium (mg Mg/100 g of soil)					
	Chorzelów			Kraczkowa			Chorzelów			Kraczkowa		
	after 3 cut		mean for 1982-85	after 3 cut		mean for 1982-85 years	after 3 cut		mean for 1982-85 years	after 3 cut		mean for 1982-85
	1981	1985		1981	1985		1981	1985		1981	1985	
No fertilizers	84.1	98.0	93.95	69.2	72.0	67.45	12.4	13.6	12.35	12.2	11.6	13.00
$N_0 P_{60} K_{90}$	59.8	94.7	78.65	52.9	74.0	64.20	12.5	11.3	12.10	14.3	12.4	13.40
$N_{120} P_{60} K_0$	52.1	86.0	83.30	52.6	74.0	66.60	11.4	11.3	11.15	12.8	11.3	11.55
$N_{120} P_{60} K_{90}$	78.2	98.0	86.60	72.1	72.0	69.85	12.0	12.9	12.10	14.5	11.0	12.50
$N_{240} P_{60} K_{90}$	80.2	98.0	77.55	73.3	73.0	70.15	11.9	12.9	11.55	12.3	11.3	12.30
$N_{240} P_{60} K_{180}$	79.0	80.0	75.85	63.8	56.0	56.80	10.5	11.9	11.40	11.9	9.3	11.20
$N_{240} P_{120} K_{180}$	80.7	80.0	75.15	60.6	56.0	57.60	12.1	10.6	11.20	11.2	9.0	9.90
$N_{360} P_{120} K_{180}$	96.6	76.0	84.95	59.3	52.0	55.65	10.9	10.4	11.30	11.3	8.0	10.00
$N_{480} P_{120} K_{180}$	71.7	54.0	67.75	59.0	50.0	52.75	11.6	10.0	10.95	12.6	8.0	10.00
$N_{480} P_{120} K_{270}$	70.4	56.0	62.70	51.5	50.0	50.40	12.3	10.7	11.10	12.2	8.8	10.05
$N_{480} P_{120} K_{270}$ Cu	68.5	64.0	67.45	48.8	53.0	49.45	12.6	9.7	10.90	10.2	8.3	9.00
$N_{480} P_{120} K_{270}$ Co	67.7	63.0	65.10	47.3	53.0	52.60	9.8	10.7	10.70	10.4	7.8	10.55
LSD $p = 0.05$			6.83			3.62			0.75			0.53

* N - kg N ha^{-1} $year^{-1}$; P - kg P_2O_5 ha^{-1} $year^{-1}$; K - kg K_2O ha^{-1} $year^{-1}$.

Table 4. Calcium and magnesium content in meadow sward and cocksfoot-grass (in % of a.d.m.) - means for 1981-1985

Treatments*	Meadow sward				Cocksfoot-grass					
	Chorzelów		Kraczkowa		Chorzelów		Kraczkowa		Chorzelów+Kraczkowa	
	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg	Ca	Mg
No fertilizers	0.89	0.25	0.99	0.40	0.45	0.18	0.54	0.31	0.50	0.25
$N_0 P_{60} K_{90}$	0.90	0.20	0.99	0.30	0.45	0.18	0.63	0.27	0.54	0.23
$N_{120} P_{60} K_0$	0.65	0.20	0.80	0.35	0.46	0.18	0.64	0.31	0.55	0.25
$N_{120} P_{60} K_{90}$	0.71	0.24	0.80	0.39	0.49	0.19	0.60	0.33	0.55	0.26
$N_{240} P_{60} K_{90}$	0.66	0.25	0.74	0.38	0.49	0.21	0.64	0.36	0.57	0.29
$N_{240} P_{60} K_{180}$	0.69	0.23	0.76	0.40	0.48	0.19	0.61	0.33	0.55	0.26
$N_{240} P_{120} K_{180}$	0.67	0.24	0.78	0.38	0.54	0.21	0.56	0.32	0.55	0.27
$N_{360} P_{120} K_{180}$	0.61	0.19	0.76	0.41	0.47	0.17	0.58	0.34	0.53	0.26
$N_{480} P_{120} K_{180}$	0.60	0.18	0.74	0.34	0.49	0.17	0.60	0.30	0.55	0.24
$N_{480} P_{120} K_{270}$	0.64	0.17	0.77	0.32	0.51	0.18	0.59	0.28	0.55	0.23
$N_{480} P_{120} K_{270}$ Cu	0.66	0.17	0.75	0.34	0.48	0.17	0.60	0.31	0.54	0.24
$N_{480} P_{120} K_{270}$ Co	0.63	0.17	0.73	0.34	0.50	0.17	0.57	0.30	0.54	0.24
LSD $p = 0.05$	0.12	0.03	0.08	0.04					n.s.	0.03

* N - kg N ha^{-1} $year^{-1}$; P - kg P_2O_5 ha^{-1} $year^{-1}$; K - kg K_2O ha^{-1} $year^{-1}$.

suspect that the lower content of the elements antagonistic towards magnesium (especially potassium) in soil in Kraczkowa decided about this phenomenon. Not too high doses of NPK did not cause distinct drop in Mg content, only the dose of 480 kg N, independently of the phosphorus and potassium doses, caused significant lowering of Mg content in the mixed grass.

Very high variability of Mg content in the mixed grass in the subsequent years was dependent on the cumulating effect of fertilizing, changes in the botanic composition and changes occurring in soil.

DISCUSSION

The intensification of production in permanent grassland caused a large increase of hay crop, but simultaneously evoked many problems connected with the quality of fodder and soil.

Our own research indicates rapid decrease of the quality of the intensively utilized meadow soils. The application of only some elements as the components of mineral fertilizers must lead to significant changes in the fertility of soils. These changes are dangerous in case of the components not included in the fertilization. Similar opinion is expressed by Gorlach *et al.* [2]. They also turned attention to the great influence of the natural soil fertility on the nutrition of plants.

In the present study the Ca and Mg contents in plants were quite closely connected with the availability of these elements in soil.

The existence of antagonism between potassium content in soil and Ca and Mg uptake by plants was noted. This problem was presented by the author in his earlier work [12]. In these experiments the effect of fertilization - especially high doses of nitrogen - on Ca and Mg content in soil and mixed grass was negative. These results are contradictory to the statement of Panak [10], who writes about the increase in Ca content as the result of mineral NPK fertilization of meadows. Other authors [4,5] report about frequent drop of Ca content caused by the nitrogen fertilization. Gorlach *et al.* [4] add that the quality of hay decreases together with the intensive utilization of a meadow. The author's research fully confirms this view.

Rapid decrease in the pH of meadow soils is a grave problem. The acidification of soil is according to Kozłowski *et al.* [8], mainly the result of calcium elution. Our studies indicate the equally important drop of magnesium content. The range of the acidification, forces us either to the systematic correction of the soil reaction or to giving up high nitrogen doses, because, as the author's research also proved, low nitrogen doses change the soil reaction very slowly. It most frequently stays within the limits of pH 5. Gorlach [3] states that it is doubtfull whether pH 5.5 can be considered the limit at which mineral soils of grasslands should be limed.

The present research indicate the occurrence of changes in soil also in the period of the grass growth. Kopeć [7] also pays attention to this phenomenon.

Mazur *et al.* [9] state that there is the necessity of looking for the ways of appeasement of the soil environment and plant association balance disturbance through the introduction of brakes in the fertilization, liming and the change of the chemical character of fertilizers. One should agree with this statement. The supplementing of the calcium and magnesium losses and simultaneous shaping of the proper soil reaction are the necessity. Much larger attention should be payed to the possibility of applying natural mineral and organic fertilizers rich in the majority of elements. The intensification of production brings the necessity of intensive protection of the grassland and connected with it elements of the environment against degradation.

CONCLUSIONS

1. The main cause of the lowering of meadow soil reaction was the nitrogen fertilization, especially with the doses of 360 and 480 kg N $ha^{-1}year^{-1}$. The dynamics of pH of soils intensively fertilized with nitrogen in the form of ammonium nitrate indicates the intensification

of unfavourable changes with the passing of time.

2. The drop of the reaction of the intensively utilized meadow soils was significant and positively correlated with the changes in exchangeable calcium and magnesium contents.

3. Calcium and magnesium contents in mixed grass decreased significantly with the intensification of NPK fertilization. Nitrogen fertilizers had the decisive influence, especially through the changes of the botanic composition of the vegetative cover.

4. Cocksfoot much less reacted to the mineral fertilization. Even five-year long application of the highest doses of NPK did not cause visible, negative changes in Ca and Mg content in it.

5. The reaction of meadow soils should be systematically controlled, and the fertility of soil should be supplemented by the application of fertilizers containing calcium and magnesium.

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WPŁYW ZRÓŻNICOWANEGO, PIĘCIOLETNIEGO NAWOŻENIA MINERALNEGO NA DYNAMIKĘ ODCZYNU GLEBY ORAZ ZALEŻNOŚCI MIĘDZY ODCZYNEM A ZAWARTOŚCIĄ WAPNIA W GLEBIE, RUNI MIESZANEJ I KUPKÓWCE POSPOLITEJ (*DACTYLIS GLOMERATA* L.)

Pięcioletnie doświadczenia dotyczące wpływu nawożenia mineralnego NPK na kształtowanie się odczynu gleby, zawartość wapnia i magnezu w glebie, runi mieszanej i kupkówce pospolitej wykonano w miejscowościach Chorzelów i Kraczkowa w woj. rzeszowskim w latach 1981-1985. Czynnikiem decydującym o dynamice pH_{KCl} gleby bylo nawożenie azotowe, wpływ nawozów potasowych był niewielki, a fosforowych praktycznie niewidoczny. Największe i najszybciej zachodzące obniżanie się odczynu gleby stwierdzono na obiektach z dawką 360 i 480 kg N $ha^{-1}rok^{-1}$. Obniżaniu się pH_{KCl} towarzyszyło zmniejszanie się zawartości wymiennego wapnia i przyswajalnego magnezu w wierzchniej 0-10 cm warstwie gleb użytków zielonych oraz w runi mieszanej. Zawartość wapnia i magnezu w kupkówce pospolitej ulegała niewielkim zmianom, co wskazuje na dominujący wpływ zachodzących w wyniku nawożenia zmian skladu botanicznego porostu na zawartość Ca i Mg w runi mieszanej. Gleby intensywnie nawożone muszą być wzbogacane w wapń i magnez oraz inne, nie wnoszone wraz z NPK pierwiastki.

S ł o w a k l u c z o w e: nawożenie mineralne, odczyn gleby, zawartość Ca i Mg w glebie i materiale roślinnym.