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IMPACT OF ANTHROPOGENIC FACTORS ON THE CHANGE OF LIMED SOIL PROPERTIES

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Abstract

Field and laboratory trials were carried out in the Vezaiciai Branch of the Lithuanian Institute of Agriculture in 1977-2005. The soil of the trial site was the *Bathihypogleyi - Dystric Albeluvisol* (ABd-gld), texture - morain loam. To evaluate the effect of various combination of liming and fertilization on the change of soil chemical properties was the aim of this investigation. The planned pH levels (factor A) - pH <4.7 (unlimed); 4.7-5.2; 5.2-5.7; 5.7-6.2; 6.2-6.7 and > 6.7 were establihed by primary liming with pulverized limestone in 1976. Pulverized limestone (92.55 % $CaCO_3$) rates were as follows: 1.9; 3.3; 5.8; 14.7 and 49.6 t ha^{-1} respectively.

The object of the investigations was naturally acid soil and the same soil exposed to a long-term (more than 29 years) anthropogenic load. The essential and lasting (r = 0.8–0.9) variation of morain loam soil pH_{KCl} under different anthropogenic load were established. The acidification process had a negative effect on the soil chemical properties. The highest variation of the topsoil pH_{KCl} index to its diminishing (from 6.7 to 4.0) was obtained in the soil annually fertilized with a $N_{135}P_{117}K_{171}$ rate of mineral fertilizers.

It was revealed that the soil acidification process under the effect of intensive mineral fertilization (in both backgrounds with and without manure) was more intensive than in the nonfertilized soil. Systematic long-term manuring had a positive effect on the soil chemical state: decreased the soil acidification process and suspended the increase of mobile aluminium amounts.

Key words

Soil acidification, primary liming, mineral and organic fertilization, pH.

Introduction

Most of Lithuanian albeluvisols and luvisols are acid by nature. The experimental evidence obtained in Lithuania and other countries suggests that the major means for taming these soils are liming, organic and mineral fertilisation (Plesevicius, 1995; Conyers *et al*., 2003). Liming of acid soils resulted in significant changes in soil properties. Natural soil forming (pedogenic) processes are continuously occurring in nature, one of which is soil acidification. This process is promoted in agrosystems by abiotic and anthropogenic factors: acid precipitation, crop and soil management practices, application of physiologically acid mineral fertilisers, Ca, Mg and other elements leaching and removal with yield (Ciuberkienė *et al*., 2000). The level of soil acidification depends mainly on the mother rock, climate and biocenose (Kaczor, 2002). This all results in a continual soil chemical and biological degradation (Douglas, 2000). Acidification rates of these naturally acid and acidifying soils that formed in different territories are significantly increased by anthropogenic activity. The acidification resulting from this activity is to the greatest extent affected by intensive mineral and organic fertilisation, soil tillage and pesticide use (Malhi *et al*., 1998; Ciuberkiene *et al*., 2000; Barak 2000; Conyers *et al*., 2003). Rapid soil acidification after liming is determined by the removal of alkaline compounds (base cations Ca^{+2}, Mg^{+2}) from the ecosystem with plant production, nitrification caused by excess of ammonia nitrogen sources and the accumulation of hydro carbonates, nitrates, chlorides, sulphides, and other soluble salts and NH^{+}; H^{+} ions in the soil. The increasing soil acidification rate is also considerably affected by the excess of organic acids in the soil which occurs due to intensive organic matter accumulation (Helyar, 1991).

The western zone of Lithuania receives a large annual amount of precipitation of 800-850 mm (the national mean is 675 mm). As a result, the area of acid soils is increasing steadily, since topsoil loses 120–200 kg ha^{-1} of calcium annually (Mazvila *et al.*, 2000). Soil liming not only neutralises mobile aluminium, which is one of the most toxic elements for plants, but also causes changes in agrochemical properties, nutrient content and uptake, humus qualitative composition (Svedas, 2000). Summarising the literature data we can affirm that the soil acidification rate depends on the nature of the anthropogenic load and the geochemical state of the soil.

The aim of the research was to evaluate the effect of various combinations of liming and fertilization on the change of soil chemical properties.

Materials and Methods

The long-term trial was established at the Lithuanian Institute of Agriculture Vezaiciai Branch (55°41‘N, 21°30‘E). The experiment was conducted on the the *Bathihypogleyi* - *Dystric Albeluvisol* (ABd-gld), texture - morain loam.. The topsoil before experiment arrangement was very acid pH_{KCl} 4.3–4.4, hydrolytic acidity – 42–51 meq kg^{-1}, base saturation level – 23–26 %, mobile aluminium – 42-70 mg kg^{-1} soil. The soil was low in phosphorus and high in potassium – 72–99 and 232–264 mg kg^{-1} soil, respectively, humus content about 2 %. The planned pH levels (factor A) - < 4,7 (unlimed), 4.7–5.2; 5.2–5.7; 5.7–6.2; 6.2–6.7 and > 6.7 were established by primary liming with pulverized limestone in 1976. Pulverized limestone rates were as follows: 1,9; 3,3; 5,8; 14,7 and 49,6 t ha^{-1} respectively.

The five course crop rotation was as follows: 1) spring rape cv. ‘Sponsor‘ (*Brassica napus annua* L.), 2) spring barley cv.‘Ula‘ (*Hordeum vulgare* L.), 3) red clover cv.‘Liepsna‘ *Trifolium pratense* L .) and timothy grass cv. ‘Gintaras II‘ (*Phleum pratense* L.), 4) winter wheat cv.‘Sirvinta‘ (*Triticum aestivum* Host.), 5) oats cv.**‘**Selma**’** (*Avena savita* L.*).* Mineral fertilizers – ammonium nitrate (NH_4NO_3), superphosphate ($Ca(H_2PO_4)_2$+$2CaSO_4$) and potassium chloride (KCl) in the experimental plots were used according to the following scheme (factor B): without fertilizers, single, double and triple rates of NPK. Single mineral fertiliser rate (N, P_2O_5, K_2O or NPK for short) for spring rape was $N_{70}P_{60}K_{90}$, for spring barley and winter wheat – $N_{45}P_{30}K_{45}$, for perennial grasses first usage year – $P_{45}K_{60}$. Plot size was as follows: 80 m^2 (brutto) and 48 m^2 (netto). The treatments were replicated threefold. Randomised design was used.

The soil samples for chemical analyses were taken from every plot annually after harvesting. from the topsoil (0-20cm). Chemical analyses of soil samples were done using the following methods: pH_{KCl} potentiometrically (ISO 10390:2005), exchangeable (mobile) Al – by the Sokolov method. Experimental findings were processed using correlation–regression analyses.

Results and Discussion

The object of the investigation was naturally acid soil and the same soil exposed to a long-term (more than 29 years) anthropogenic load. The essential and lasting (r = 0.8–0.9) variation of morain loam soil pH_{KCl} under different anthropogenic loads was established. The acidification process had a negative effect on the soil chemical properties. The highest variation of the topsoil pH_{KCl} index to its diminishing (from 6.7 to 4.0) was obtained in the soil annually fertilized with a $N_{135}P_{117}K_{171}$ rate of mineral fertilizers. Primary liming with high chemically active lime rates had the greatest effect on reducing soil acidity. Unlimed and limed soil under natural conditions an 0,2 pH unit acid level in 29 years (figure 1). The rate of soil pH variation of limed soil was highly dependent on the rate of initial liming (figures 1, 2). Acidification in soil limed to pH 5,2-5,7 was more rapid (-0,9 pH unit) and in 29 years pH reached the initial measurments, i.e. soil became very acidic. More intensive acidification was determined when soil was limed to pH 6,2-6,7. Here pH decreased by 1,3 unit after liming, however after 29 years it was about 0,3 unit higher than before liming.

Mineral fertilizers increased soil acidification, especially when fertilizing with high rates ($N_{135}P_{117}K_{171}$) pH changes were diverse in different pH soils. When the soil was very acidic (pH 4,4-4,6) small mineral fertilizer rates decreased pH by 0,2 and high rates ($N_{135}P_{117}K_{171}$) – by 0,7 units.

Acidification in slightly acid soil was more intensive, however the influence of mineral fertilizers was less even when under high rates of fertilization. Mineral fertilizers influence on acidification processes in limed to pH 6,2-6,7 level soil was similar to very acidic soil. Fertilizing with $N_{45}P_{39}K_{57}$ rate decreased pH by 0,2 and fertilizing with $N_{135}P_{117}K_{171}$ – by 1,1 units.

The acidification process was slowed down when manuring (60 t ha^{-1}) every fifth year (Figure 2). Independently of the soil's pH level, manure decreased soil pH by 0-0,2 and by – 0,3-0,4 units on average when fertilizing by $N_{45}P_{39}K_{57}$ and $N_{135}P_{117}K_{171}$ respectively.

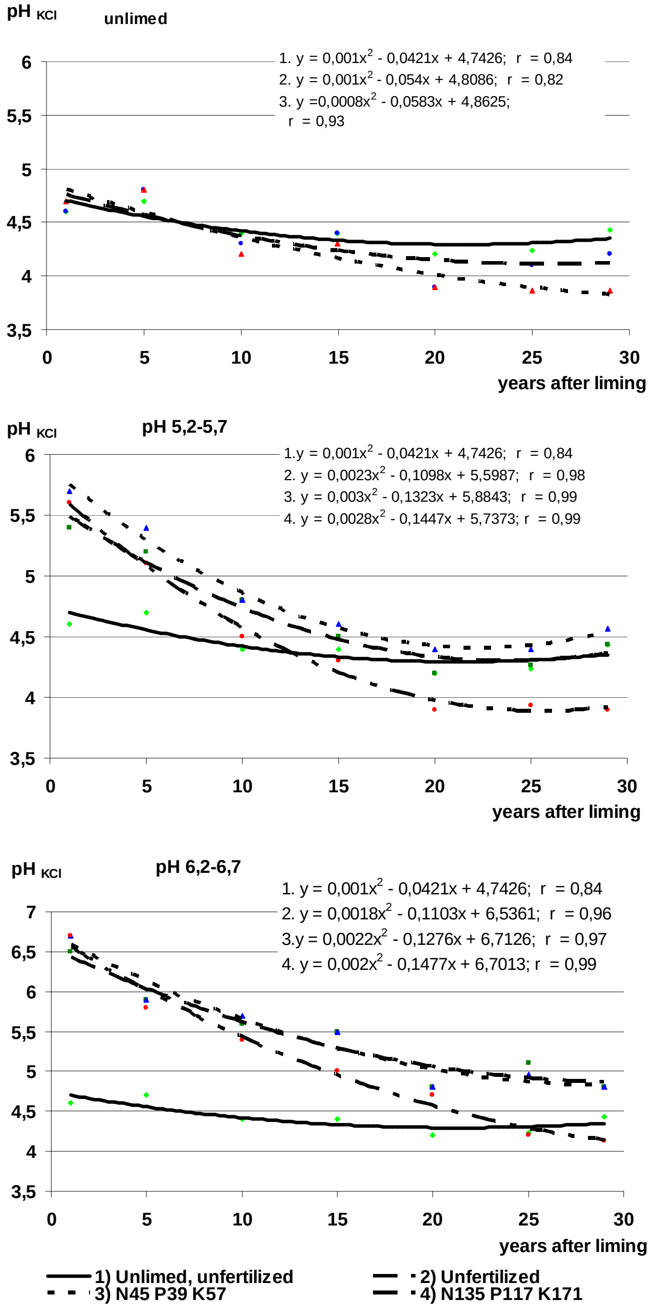

Figure 1. The variation of pH_{KCl} value as affected by various intensity mineral fertilizations, Vezaiciai, 1977 – 2005

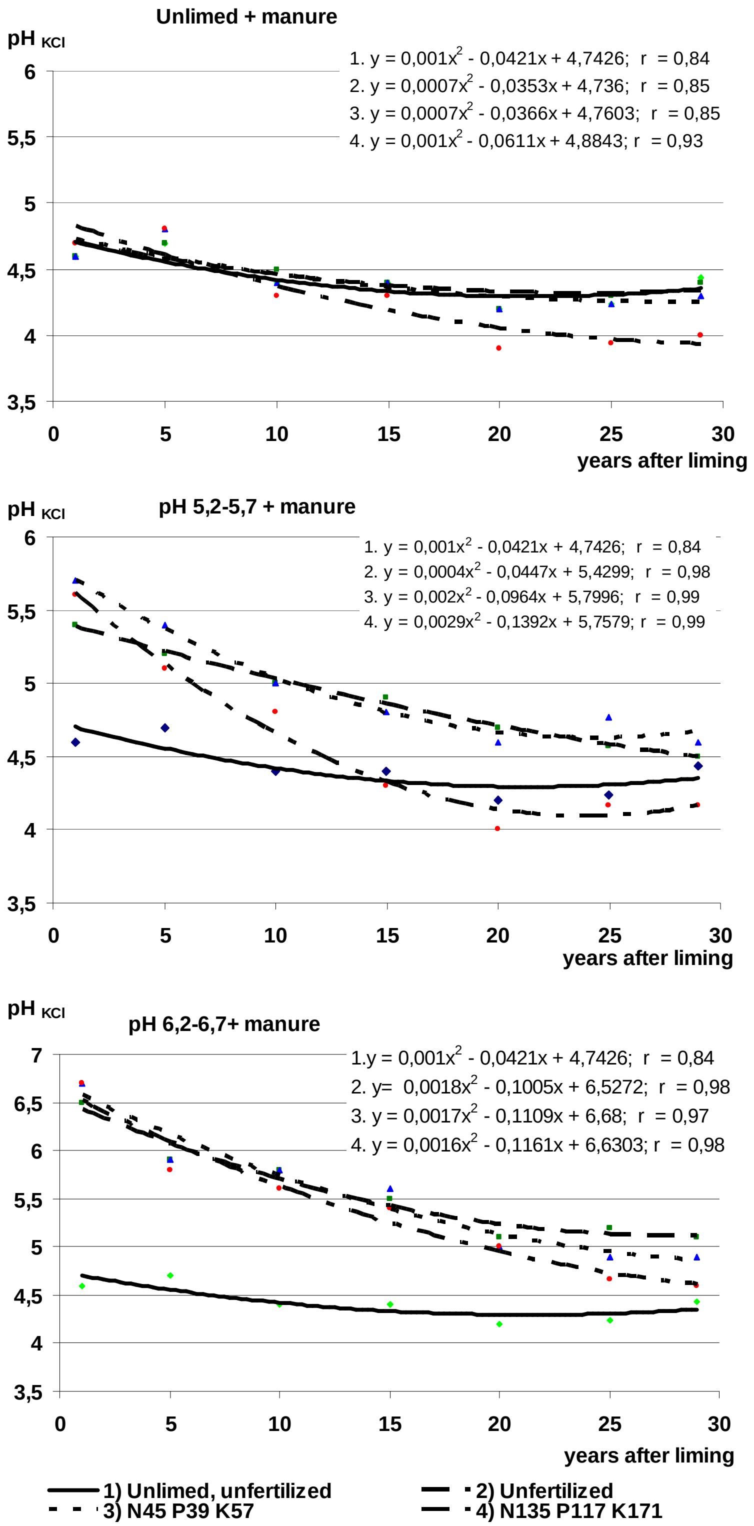

Figure 2. The variation of pH_{KCl} value as affected by various intensity mineral and organic fertilizations, Vezaiciai, 1977 – 2005

The highest amount of mobile aluminium was found in unlimed soil. During the restoration of aluminium compounds mobility was the slowest after main liming. Even after a 29 year period after liming, the amounts of mobile aluminium did not exceed harmful limits when the soil was limed to 5.2-5.7 and 6.2-6.7 pH, and was unfertilized or fertilized with low mineral fertilizer rates ($N_{45}P_{39}K_{57}$). Fertilizing with high rates of physiologically acid mineral fertilizers significantly speeded up acidification processes. Significantly negative changes of all soil acidity indices were determined when fertilizing with $N_{135}P_{117}K_{171}$. At a pH of 5.5 the concentration of Al in the soil solution was quite low. However, as the pH dropped from 5.0 to 4.0, the Al concentration increased markedly.

Manure decreased rapid soil acidification, but could not change the direction of acidification, decalcification and degradation processes. The amounts of basis elements, incorporated with manure were not sufficient to neutralize soil acidity and substitute liming.

Higher yields were obtained when soil was manured, however nutrients were removed. Still, positive manure influence was determined in all research plots, especially when fertilized with $N_{135}P_{117}K_{171}$ mineral fertilizer rate.

Soil acidification in natural biocenoses is a slow process. Acidification rates of these naturally acid and acidifying soils that formed in different territories are significantly increased by anthropogenic activity. Analysis of long-term anthropogenic factors allowed researchers to classify them by the effect on acidification in the following way: 1) stimulating – mineral fertilization → mineral fertilization + intensive liming; 2) stopping – organic fertilization (manuring) (Bernotas et al. 2005).

In the tenth year of fertilization the amount of mobile Al in the soil fertilized with $N_{135}P_{117}K_{171}$ rate was by 30 mg kg^{-1}, and in the 29 years – by 97 mg kg^{-1} higher compared with non-fertilized soil. Having assessed these differences we can substantiate the proposition that fertilization with mineral phosphorus, potassium, and especially nitrogen fertilizers promoted soil acidification. The rate of soil acidification depended on the amounts of fertilizers applied and on the duration of fertilization. Soil acidity was reduced because of the denitrification of nitrogen. The application of ammonium - based nitrogen fertilizers to naturally acid soils at rates in excess of plant requirements resulted in nitrate nitrogen losses, because of leaching.

$2NH_4^+$ (ammonium) + $4O_2 \rightarrow 2NO_3$- (nitrate) + $4H^+$ (acidic hydrogen) + $2H_2O$.

Conclusions

Fertilizing with high rates of physiologically acid mineral fertilizers significantly speeded up acidification processes. The highest change of pH_{KCl} values (over more than a 29 year period) was reduced from 6,7 to 4,0 in the topsoil was which was annually fertilized with $N_{135}P_{117}K_{171}$ mineral fertilizers.

Systematic long-term manuring had a positive effect on the soil chemical state: decrasing the soil acidification process and suspend tinghe increase of mobile aluminium.

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STABILITY OF SOIL ORGANIC MATTER IN AEROBIC AND ANAEROBIC CONDITIONS

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Abstract

The stability of soil organic matter under aerobic and anaerobic conditions was studied. In the four samples of organic and organomineral surface horizons some parameters of organic matter stability were observed. They were expressed by the rate constant of their biochemical oxidation, total biochemical oxygen demand, substrate production of methane and degradability in anaerobic conditions. In analyzed samples no relationship between aerobic and anaerobic stability of their organic matter was found; nor was the expected relationship between total biochemical oxygen demand and "active carbon" C_{hws} was proved.

Key words

Soils, organic matter, stability, aerobic and anaerobic conditions

Introduction

The soil organic matter consists of two main distinct components. Primary organic matter (C_{ox}) which possess negligible ion exchange capacity, but is mineralizable and thus may be the source of energy for soil edaphon. Humic substances with high ion exchange capacity, but an exceptionally slow rate of mineralization. This is why they do not serve as a source of energy for soil microedaphon. Humic substances include fulvoacids ($C_{ox\ FK}$),, humic acids ($C_{ox\ HK}$), hummins and products of their reactions in soil (e.g. with metal ions or soil colloid mineral matter). The importance of the first component is in its ability to maintain the soil microflora and it thus indirectly allows the soil to be inhabitated by macroorganisms. It also influences the mobility of nutrients and the decomposition old organic pollutants in soil. The importance of the second component is mainly in its ability to bind nutrients in the soil by sorption and ion exchange. The importance of both these components is essential and these components cannot be interchanged.

Soil organic matter (SOM) is mostly described only by the value C_{ox} although it is generally known that C_{ox} also expresses primary organic matter of low ion exchange capacity and a high tendency of mineralisation as humified organic matter with just the opposite characteristics (Kolář and Kužel, 1999). Some researchers give other characteristics of soil organic matter: degree of humification $D_H = C_{ox\ HA} + C_{ox\ FA}/C_{ox} \cdot 100$; HA:FA ratio;"active carbon" C_{hws}, C_{cws} /water-soluble C-matters at 20° C/(Kužel *et* al., 2001). Others are using the separation of humic acid fractions by gel chromatography and the expression of percentage proportions of fractions with average relative molecular weight; by the colour quotient $Q_{4/6}$; by the interpretation of IR spectra of humic acids (Capriel *et al.*, 1995).