ISSN 1392-3196 / e-ISSN 2335-8947
Zemdirbyste-Agriculture, vol. 103, No. 2 (2016), p. 129–134
DOI 10.13080/z-a.2016.103.017

The changes of soil acidity in long-term fertilizer experiments

Janis VIGOVSKIS, Aivars JERMUSS, Agrita SVARTA, Daina SARKANBARDE

Research Institute of Agriculture, Latvian University of Agriculture
Zemkopības institūts 7, Skrīveri, Latvia
E-mail: vigovskis@inbox.lv

Abstract

The paper describes the influence of long-term (more than 30 years) fertilizer and lime application on the soil acidity (pH_{Cl}) and identifies the influence of soil acidity on the productivity of crops.

At the Research Institute of Agriculture of Latvian University of Agriculture in Skrīveri, a long-term subsurface drainage field experiment was established in 1981 under the guidance of professor J. Štikāns on the uncultivated gleyic sod-podzolic *Hypostagnic Endogleyic Albeluvisol* (*Hypereutric*, *stw-ng-AB(he)*) loam. Four (slate ash with 80% neutralizing value) lime rates 0 (L0), 2.58 (L1), 5.70 (L2) and 11.40 (L3) t ha^{-1} $CaCO_3$ were used. Primary liming was done in 1981; the maintenance liming was performed in 1994 and in 2014. Four rates of mineral fertilizers: without fertilizers (F0), $N_{45}P_{30}K_{45}$ (F1), $N_{90}P_{60}K_{90}$ (F2) and $N_{135}P_{90}K_{135}$ (F3) were applied annually.

Since 1994, a seven-year crop rotation was created: (1) winter triticale → (2) potatoes → (3) spring wheat → (4) spring oilseed rape → (5) spring barley → (6) and (7) perennial grasses (red clover, timothy), 1st and 2nd year of use.

At the beginning of the experiment, the soil in treatments F0 and F2 was very strongly acid (pH_{KCl} 4.7) but in treatments F1 and F3 – moderately acid (pH_{KCl} 5.6). In limed treatments the soil acidity decreased from pH 4.8 to pH 5.8–6.0. In the following years till 1994, the soil acidity in limed treatments gradually increased (for about 0.4–0.6 pH units). After the first maintenance liming, the soil acidity reached nearly the previous highest level. Within the next twenty years, in the treatments with highest liming rate (11.40 t ha^{-1} $CaCO_3$) the soil acidity increased to pH 5.2. In treatments with low liming rate (2.58 t ha^{-1} $CaCO_3$), the soil acidity increased to pH 4.6, which was even lower than at the beginning of the experiment (pH 4.8). Without maintenance liming, the soil acidity during 20 years increased by 0.7–0.8 pH units. In the unlimed treatments, the soil acidity gradually increased from pH 4.8 to 4.4.

Key words: liming, long term trials, mineral fertilizers, productivity, soil reaction.

Introduction

Soil acidity is one of the most important parameters of soil degradation. Increased soil acidity significantly reduced plant production (Kemmita et al., 2006). The soil pH affects all stages of plant growth, disease resistance, tolerance of low temperature, the lifetime of the crop, forage yield and quality (Su, Evans, 1996). However, soil acidity had little effect on the levels of soil organic C and N stored in the soil. Research results indicated that pH significantly affected a range of properties associated with the soil microbial community (Fernández-Calviño et al., 2011) and its ability to process C and N. In particular, increased soil acidity seems to reduce the intrinsic activity of the microbial community probably by a number of direct and indirect routes including: reducing plant production and the amount of substrate entering the soil, inhibiting certain members of the community (e.g., nitrifiers), and increasing Al in the soil, which reduces substrate bioavailability and induces toxicity (Kemmita et al., 2006). In addition to the lack of calcium, acid soils are characterized by a high prevalence of easily mobile forms of Al, Fe and Mn, and low contents of available P, K and Mo (Su, Evans, 1996). The results of researches in Austria show that soil pH increased with soil depth, but different tillage systems (mouldboard ploughing, no-tillage, deep conservation tillage and shallow conservation tillage) for seven years had no effect on soil pH (Neugschwandtner et al., 2014).

Satisfactory yields of crops on acid soils can be achieved if the repair is carried out by lime fertilizers (Grewal, Williams, 2003; Repšienė, Skuodienė, 2010). The main task of soil liming is to ensure favourable conditions for plant nutrition. Liming increases soil organic matter in mineral soils due to higher C inputs and productivity (Paradelo et al., 2015). Long-term experiments in Lithuania show that systematic periodical liming over 56 years (by 0.5 rates every 7 years and 2.0 rates every 3–4 years) on the background of minimal organic fertilizing and conventional tillage, has a positive effect on the structure of moraine loam soil (*Bathygleyic Dystric Glossic Retisol*). The largest amount (68.4–72.1%) of water stable aggregates (>0.25 mm) occurred in intensively limed soil. Systematic periodical liming decreased the soil organic carbon amount in the soil. Soil organic carbon amount was approximately by 0.11–0.18 percentage points lower compared to the unlimed plots (1.44%). Periodical soil liming resulted in lower dissolved organic carbon content due to the decrease in biologically toxic Al at higher pH. Periodical liming significantly decreased the content of humic and fulvic acids. Fulvic acids were dominant in the soil in all treatments as a consequence of the low carbon content and slow humification processes in the soil (Karčauskienė et al., 2015). Other researches show that liming had little effect on soil structure variables but increased microbial activity in soil (Stenberg et al., 2000; Fuentes et al., 2006; Čepulienė et al., 2013), soil microbial biomass C and N by improving the soil environment for micro-organisms (Soon, Arshad, 2005). The benefits of liming include increased nutrient availability. A reduction of soil acidity to close to neutral soil pH values (pH_{KCl} 6.7) improved the rate of phosphorus supply in the soil and enhanced the ability of plants to absorb phosphorus (Jokubauskaitė et al., 2015). This agrees with the results obtained by Wheeler (1998).

The aim of the present paper is to analyse the influence of long term (more than 30 years) fertilizer and lime application on the changes of soil acidity (pH_{Cl}) and to identify the influence of soil acidity on the productivity of crops.

Materials and methods

Site and soil description. The research was carried out at the Research Institute of Agriculture of Latvian University of Agriculture in the long-term subsurface drainage field experiment "Sidrabiņi" established in Skrīveri in 1981 under the guidance of professor Juris Štikāns. The paper presents the experimental data from the 1981–2015 period. The long-term drainage field experiment was established on the uncultivated gleyic sod-podzolic *Hypostagnic Endogleyic Albeluvisol* (*Hypereutric*, *stw-ng-AB(he)*) loam that had not been used in agriculture for 20 years before. At the beginning of the experiment (1981), the soil properties (at 0–22 cm depth) were pH (KCl) 4.7–5.6, hydrolytic soil acidity 32–34 mequiv kg^{-1}, available phosphorus (DL-method) 10–20 mg kg^{-1} P_2O_5, exchangeable potassium (DL-method) 40–60 mg kg^{-1} K_2O and soil organic matter 19–21 g kg^{-1} (Tyurin method).

Experimental design. The four rates of mineral fertilizers: F0 – without fertilizers, F1 – $N_{45}P_{30}K_{45}$, F2 – $N_{90}P_{60}K_{90}$ and F3 – $N_{135}P_{90}K_{135}$ calculated in form of P_2O_5 and K_2O were used together with four rates of liming: L0 – without liming, L1 – 2.58 t ha^{-1} $CaCO_3$, L2 – 5.70 and L3 – 11.40 t ha^{-1} $CaCO_3$ (slate ash with 80% neutralizing value) (Fig. 1). Primary liming was done in 1981 (Estonian oil shale ashes with 415.4 g kg^{-1} CaO, 44 g kg^{-1} MgO, 21 g kg^{-1} K_2O, 2.1 g kg^{-1} P_2O_5 and 76 g kg^{-1} SO_3), the maintenance liming was performed in 1994 (dolomitic limestone with 97.0% neutralizing ability, 188 g kg^{-1} Ca, 120 g kg^{-1} Mg, humidity content ≤0.2%, amount of particles smaller than 1 mm – 99.5%) and 2014 (BALTKALK with 97.6% neutralizing ability, 333 g kg^{-1} Ca, 6.9 g kg^{-1} Mg, humidity content 8–16%, amount of particles smaller than 1 mm – 88.8%). The total area (1.6 ha) of the experimental field was divided into 16 plots (15 × 50 m).

Agronomic practices. Since 1994, a seven-year crop rotation was created: (1) winter triticale → (2) potato, → (3) spring wheat → (4) spring oilseed rape → (5) spring barley undersown with perennial grasses → (6) perennial grasses, 1st year of use, and → (7) perennial grasses, 2nd year of use. In the sowing year, mixtures of herb species were sown under barley. In the first rotations the components of mixtures were *Phleum pratense* and *Trifolium pratense*, but in 2012 a mixture of *Trifolium pratense*, *Festuca pratensis*, *Phleum pratense* and *Festulolium* was made.

$N_0P_0K_0$	F0L0 0 t ha^{-1} $CaCo_3$	$N_{90}P_{60}K_{90}$	F2L0 0 t ha^{-1} $CaCo_3$
$N_0P_0K_0$	F0L3 11.4 t ha^{-1} $CaCo_3$	$N_{90}P_{60}K_{90}$	F2L1 2.85 t ha^{-1} $CaCo_3$
$N_0P_0K_0$	F0L2 5.7 t ha^{-1} $CaCo_3$	$N_{90}P_{60}K_{90}$	F2L2 5.7 t ha^{-1} $CaCo_3$
$N_0P_0K_0$	F0L1 2.85 t ha^{-1} $CaCo_3$	$N_{90}P_{60}K_{90}$	F2L3 11.4 t ha^{-1} $CaCo_3$
$N_{45}P_{30}K_{45}$	F1L0 0 t ha^{-1} $CaCo_3$	$N_{135}P_{90}K_{135}$	F3L0 0 t ha^{-1} $CaCo_3$
$N_{45}P_{30}K_{45}$	F1L3 11.4 t ha^{-1} $CaCo_3$	$N_{135}P_{90}K_{135}$	F3L1 2.85 t ha^{-1} $CaCo_3$
$N_{45}P_{30}K_{45}$	F1L2 5.7 t ha^{-1} $CaCo_3$	$N_{135}P_{90}K_{135}$	F3L2 5.7 t ha^{-1} $CaCo_3$
$N_{45}P_{30}K_{45}$	F1L1 2.85 t ha^{-1} $CaCo_3$	$N_{135}P_{90}K_{135}$	F3L3 11.4 t ha^{-1} $CaCo_3$

Figure 1. The design of the long-term subsurface drainage field experiment "Sidrabiņi"

Traditional soil tillage was used including mouldboard ploughing (for winter crops – in the previous autumn and for spring crops – after harvest of previous crops, cultivation and rototilling before sowing. Mineral fertilizers were applied according to the anticipated rates of plant nutrient elements annually during the pre-sowing cultivation of soil. For winter crops the phosphorus as single superphosphate and potassium as potassium chloride were applied before the sowing in autumn and nitrogen in the form of ammonium nitrate was applied the next spring at the beginning of vegetation and at the tillering stage. During the growing season all the required common soil and crop management practices were applied – treatment with herbicides, fungicides and insecticides.

Experimental methods and assessments. The soil for agrochemical analyses was sampled from 0–20 cm depth annually after harvesting. Soil samples were taken in each plot using a 12 mm diameter steel auger, and the samples from each plot were mixed, dried and sieved. After maintenance liming in 2014, the soil samples for assessment of liming efficacy were taken in two depths: 0–10 and 11–20 cm in spring. Soil acidity (pH_{Cl}) was determined according to the standard LVS ISO 10390:2006 Soil quality – Determination of pH. Calcium (Ca) and magnesium (Mg) in yield was determined according to the standard LVS EN ISO 6869:2002 Animal feeding stuffs – Determination of the contents of calcium, copper, iron, magnesium, manganese, potassium, sodium and zinc (by atomic absorption spectrometry). The yields were determined from 25.38 m^2 (for cereals and oilseed rape), 39.20 m^2 (for potatoes) and 27.55 m^2 (for perennial grasses) in four replications.

Statistical analyses. The data of soil chemical properties and crop yield were processed using a two-factor *ANOVA* with replication, correlation and regression analysis methods. All data were evaluated according to Fisher criteria (*F*) and $LSD_{0.05}$. The symbols used in the article * denote statistically significant at 95% significance level.

Meteorological conditions. The long-term experiment is located in the central part of Latvia (latitude N 56°38′, longitude E 25°08′). The annual precipitation amount is normally 670 mm. The annual air temperature is +5.7ºC. The winter average air temperature is −4.3ºC. The duration of the growing season is 180–210 days.

Results and discussion

The data of the long-term experiment show that during 34 years soil parameters showed significantly different soil acidity related to the different level of fertilizer application and liming rates. At the beginning (1981) of the experiment the soil in treatments F0 and F2 was very strongly acid (pH_{KCl} 4.7) but in treatments F1 and F3 it was moderately acid (pH_{KCl} 5.6).

In unlimed treatments, the changes of soil acidity depended on the rate of mineral fertilizers. During 34 years in unfertilized treatment (F0) the soil acidity increased slightly by 0.3 pH units (Fig. 2). In this treatment very low crop yields were obtained, thereby the removal of Ca and Mg by yield was significantly lower than in the treatments with fertilization, small amount of plant residues for decomposition and not used physiologically acidic synthetic fertilizers. The removal of calcium by yield for spring oilseed rape in this treatment was as low as 0.22 kg ha^{-1}, whereas in unlimed treatments at F1 – 2.66 kg ha^{-1}, at F2 – 3.83 kg ha^{-1} and at F3 – 7.27 kg ha^{-1} ($LSD_{0.05}$ = 1.23 kg ha^{-1}, r = 0.99). The removal of magnesium by yield in unlimed and unfertilized treatment was only 0.17 kg ha^{-1}, whereas in unlimed treatments at F1 – 1.77 kg ha^{-1}, at F2 – 2.61 kg ha^{-1} and at F3 – 5.06 kg ha^{-1} ($LSD_{0.05}$ = 0.76 kg ha^{-1}, r = 0.99). Similar effect was observed also for other crops in the 3rd crop rotation. Lowering of soil pH in the unfertilized treatment was also documented by Vašak et al. (2015). In a long-term experiment in Czech Republic after 14-years, the decrease of pH was 0.11–0.63 units depending on the experimental sites. The biggest decrease was ascertained in lighter soils with lower sorption capacity. The decrease in pH is likely to have been caused by leaching of basic ions and removal of basic ions by plants. For Ca and Mg leaching the annual rainfall is important (Vašak et al., 2015).

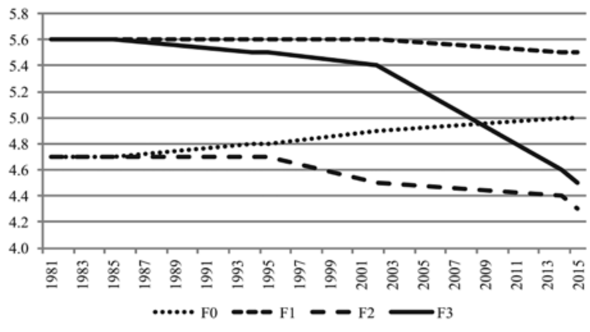

Figure 2. Changes of pH_{KCl} without liming, during 1981–2015

In treatment with low rate of mineral fertilizers (F1), the changes of soil acidity were not significant, the value of soil pH even increased by 0.1 units. In treatment F2, the processes of soil acidification were faster than in treatment F1 and the value of soil pH decreased by 0.4 units. The biggest changes of soil acidity were ascertained in treatment F3 with the highest rate of mineral fertilizers ($N_{135}P_{90}K_{135}$). During 34 years the soil acidity decreased by 1.1 pH units. The similar results were documented in Lithuania (Bakšienė et al., 2014). During 10 years in conventional-chemical farming system where physiologically acidic synthetic fertilizers are used the soil pH and exchangeable bases showed clear tendency towards decrease from 6.0 to 5.5 and from 8.2 to 6.3 mequiv kg^{-1}. The soil acidification after the application of NPK agrees with the results in Czech Republic (Vašak et al., 2015). The results obtained in the long-term field experiment in Slovenia show that conventional tillage and application of crop residues together with NPK fertilizers increased pH by 0.06 and 0.03 units per year, respectively, which means that the pH in the soil increased by14% and 8%, correspondingly, between 1994 and 2011 (Šimanský, Kováčik, 2015).

Four years after the primary liming the soil acidity in all limed treatments decreased significantly and soil pH reached 6.0–6.4 units, which corresponded to moderately acid and slightly acid soils. The changes of soil acidity in treatments with the highest rate of lime (L3) depending on the rate of mineral fertilizers are shown in Figure 3. The next nine years in treatments F0, F1 and F3 the soil acidity changed only by 0.1 pH units but in treatment F2 the soil acidification was faster – by 0.5 pH units. After maintenance liming in 1994, the soil acidity decreased by 0.1–0.3 pH units. During the next twenty years (1994–2014) the maintenance liming was not done. During 20 years, the soil acidity in all fertilized treatments exceeded the level detected at the time of setting up the experiment only by 0.2–0.4 pH units. In unfertilized treatment, the soil pH decreased by 0.6 units but was 0.9 pH units higher than before the experiment.

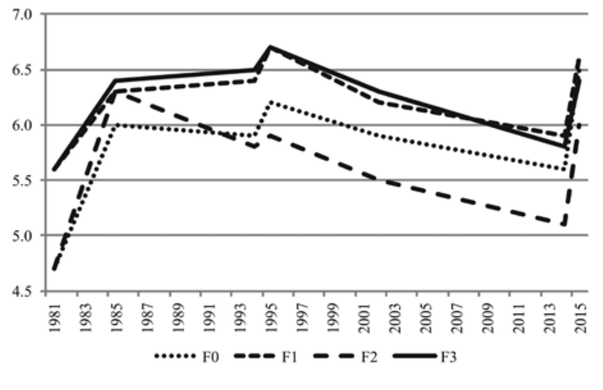

Figure 3. Changes of soil pH in variant with liming rate 11.40 t ha^{-1} $CaCO_3$, during 1981–2015

The results in other long-term experiments show that only a long-term regular combined application of organic (Repšienė, Skuodienė, 2010) and mineral fertilizers together with liming once in crop rotation made it possible to maintain the soil pH value at initial level. The regular application of lime resulted in a successive, 1999 through 2008, increase in soil pH value in all fertilization treatments by 1.7–2.7 units (Jaskulska et al., 2014). Changes in the periodically limed soil pH, hydrolytic acidity and mobile Al were more intense and their restoration to previous levels is slower compared to primary limed soils. In such soils even after 14–23 years since the last lime application the productivity of crop rotation is still higher than in unlimed soils (Marcinkonis, Tripolskaja, 2008).

The maintenance liming in 2014 was done with 6.0 t ha^{-1} $CaCO_3$ before sowing in the 0–10 cm soil layer. After liming, soil acidity in soil layer 0–10 cm decreased by 0.5–0.9 pH units but in the deeper layers the changes of soil acidity were minor (Table 1).

Table 1. Changes of soil pH_{KCl} after maintenance liming (soil layer 0–10 cm)

Variants	Before liming 2014	After liming 2015
F0L0	5.0	5.0
F0L1	5.2	6.1*
F0L2	5.3	6.2*
F0L3	5.6	6.5*
F1L0	5.5	5.5
F1L1	5.9*	6.5*
F1L2	5.9*	6.5*
F1L3	5.9*	6.6*
F2L0	4.4	4.3
F2L1	4.9	5.7*
F2L2	5.0	5.9*
F2L3	5.1	6.0*
F3L0	4.6	4.5
F3L1	5.0	5.7*
F3L2	5.7*	6.2*
F3L3	5.8*	6.4*
$LSD_{0.05}$	0.64	0.56

Long-term fertilization and periodical liming affected the productivity of crops. The yields of crops in the 3rd rotation are presented in Table 2.

Triticale is very suitable for growing in Latvian agroclimatic conditions. Such traits as high yield potential, good nutrient efficiency, resistance to diseases are advantages for growing triticale in Latvian organic and conventional fields (Kronberga, 2008). Triticale is grown in moderately acid and slightly acid soils (pH_{Cl} 5.6–6.5) which was the case in our long-term experiment. Triticale is a pH tolerant species and had the least response to soil pH (Liu et al., 2004). The grain yield varied from 0.74 to 5.46 t ha^{-1} and depended on the rate of fertilizers ($p < 0.05$, $r = 0.91$) and rate of lime ($p < 0.05$). If soils are more acid, the experiments show that in order to raise the fertility of acid soils and increase the yield of cultivated plants, it is necessary to use a combination of NPK, lime and organic fertilizers, as well as to apply NPK fertilizers with increased dose of phosphorous (Biberdžić et al., 2012).

Potato grows in strongly acid and moderately acid soils with pH 5.0–6.0 The yield of potato varied from 10.08 to 39.10 t ha^{-1} and depended on the rate of mineral fertilizers ($p < 0.05$, $r = 0.99$). There was not found significant influence of rates of liming.

Spring wheat and barley are sensitive to soil acidity. Barley had the largest yield response to soil pH in comparison with wheat and triticale (Liu et al., 2004). There was found a significant positive relationship

Table 2. Yields (t ha^{-1}) of crops in 3rd rotation (2008–2014)

Variants	Triticale	Potato	Spring wheat	Spring oilseed rape	Spring barley undersown with perennial grasses	Perennial grasses, 1st year of using (dry matter)	Perennial grasses, 2nd year of using (dry matter)
F0L0	0.74	10.19	1.28	0.07	0.44	0.18	0.90
F0L1	0.74	10.08	1.35	0.25	0.99*	0.28*	1.21
F0L2	0.78	10.14	1.48	0.15	0.85	0.21*	1.27
F0L3	0.79	11.13	1.12	0.11	0.66	0.22	1.07
F1L0	3.45*	20.56*	2.44*	0.59*	2.43*	2.80*	6.12*
F1L1	3.27*	20.82*	2.20*	0.78*	3.05*	3.52*	6.55*
F1L2	3.11*	21.48*	2.44*	0.68*	2.68*	2.54*	5.31*
F1L3	3.23*	19.44*	2.53*	0.66*	2.65*	2.78*	6.17*
F2L0	4.18*	30.63*	2.32*	0.87*	3.09*	4.02*	4.32*
F2L1	4.53*	31.23*	2.46*	0.82*	2.95*	4.31*	4.71*
F2L2	4.69*	31.83*	2.90*	0.90*	3.21*	4.58*	5.30*
F2L3	4.89*	31.67*	2.79*	1.05*	3.34*	5.58*	5.59*
F3L0	4.73*	35.66*	2.78*	1.58*	3.41*	6.62*	6.85*
F3L1	5.46*	35.78*	2.90*	1.76*	4.23*	6.50*	6.56*
F3L2	4.52*	35.46*	2.85*	1.73*	4.36*	5.73*	6.48*
F3L3	3.69*	39.10*	2.75*	1.86*	5.26*	4.39*	5.93*
$LSD_{0.05}$	0.43	6.28	0.21	0.31	0.50	0.41	0.57

between top soil (0–10 cm) pH and yield of wheat, and top and subsoil (11–20 cm) pH and yield of barley (Flower, Crabtreec, 2011). The optimal soils for growing of these cereals are slightly acid or neutral soils (pH_{KCl} 6.0–7.0). The yields of spring wheat were very low and varied from 1.12 to 2.90 t ha^{-1} and depended on the rate of fertilizers ($p < 0.05$, $r = 0.88$) and rate of lime ($p < 0.05$). Similar effect of fertilizing ($p < 0.05$, $r = 0.93$) and liming ($p < 0.05$) was observed on spring barley productivity (Fig. 4). The yields of barley varied from 0.44 to 5.26 t ha^{-1} Oilseed rape is very sensitive to soil acidity. The optimal soil reaction for oilseed rape is pH_{KCl} 6.2–7.5. The yields of oilseed rape were very low and varied from 0.07 to 1.86 t ha^{-1}. Both mineral fertilizers ($p < 0.05$, $r = 0.96$) and liming ($p < 0.05$) had significant effect on the productivity of oilseed rape (Fig. 4).

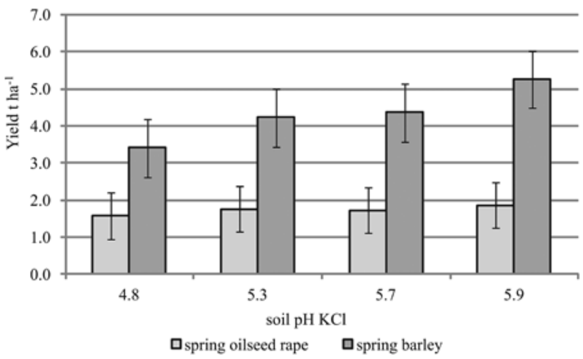

Figure 4. The yields of crops (spring oilseed rape and barley) sensitive to soil acidity under different soil pH

The mixture of perennial grasses was made from grasses bred at Research Institute of Agriculture in Skriveri and is suitable for growing in moderately acid to slightly acid soils (pH_{KCl} 5.6–6.5). The dry matter yields of perennial grasses in the 1st year of use varied from 1.99 to 9.44 t ha^{-1}, in the 2nd year – 0.90–6.85 t ha^{-1}. The main factor that influenced productivity was rate of fertilizers ($p < 0.05$, $r = 0.94$). It significantly influenced the botanical composition of swards, too (Table 3).

Table 3. The botanical composition of swards, 1st year of use, 2013

Variants	Botanical composition %			
	Trifolium pratense	*Festuca pratensis*	*Phleum pratense*	*Festulolium*
F0L0	10	33	5	52
F0L1	20	22	10	49
F0L2	16	37	5	42
F0L3	13	33	7	47
F1L0	53	7	8	33
F1L1	50	9	6	36
F1L2	42	7	19	31
F1L3	43	8	16	33
F2L0	13	1	13	72
F2L1	14	2	11	73
F2L2	17	1	11	72
F2L3	15	1	11	73
F3L0	0	16	5	80
F3L1	0	14	4	81
F3L2	0	14	6	80
F3L3	0	13	6	81

In Slovenia, the liming significantly affected the increase of green forage and hay yield. In the mixture with red clover and Italian ryegrass, the red clover proportion in total hay yield decreased as a result of the application of liming to increase the share of Italian ryegrass (Tomic et al., 2012).

Conclusions

1. During 34 years, in the unlimed treatments the changes of soil acidity depended on the rate of mineral fertilizers. In the unfertilized treatment, the soil acidity increased slightly – by 0.3 pH units. In the treatment with low rate of mineral fertilizers ($N_{45}P_{30}K_{45}$), the value of soil pH increased by 0.1 units. In the treatment $F_{90}P_{60}K_{45}$, the value of soil pH decreased by 0.4 units. The largest changes of soil acidity were ascertained in the treatment with the highest rate of mineral fertilizers ($N_{135}P_{90}K_{135}$) – the soil acidity decreased by 1.1 pH units.

2. Nine years after the primary liming, the soil acidity in all limed treatments decreased from pH_{KCL} 5.6 to 6.7 and from pH_{KCL} 4.7 to 6.2. After maintenance liming in 1994, the soil acidity decreased by 0.1–0.3 pH units. During 20 years, the soil acidity in all fertilized treatments exceeded the level determined at the time of setting up the experiment only by 0.2–0.4 pH units. In unfertilized treatment, the soil pH decreased by 0.6 units and was 0.9 pH units higher than before the experiment.

3. Long-term fertilization and periodical liming affected the productivity of crops. The grain yield of cereals (triticale, spring barley and spring wheat) and spring oilseed rape depended on the rate of fertilizers and rate of liming while the main factor which influenced the productivity of perennial grasses was rate of fertilizers. It significantly influenced the botanical composition of swards.

Acknowledgements

This work was supported by the European Regional Development Fund within the project Development of Technology of Reduction of Environmental Pollution Using Mineral Fertilizers (No. 2010/0232/2DP/2.1.1.1.0/10/APIA/VIAA/097).

Received 23 11 2015
Accepted 06 04 2016

References

Bakšienė E., Ražukas A., Repečkienė J., Titova J. 2014. Influence of different farming systems on the stability of low productivity soil in Southeast Lithuania. Zemdirbyste-Agriculture, 101 (2): 115–124 http://dx.doi.org/10.13080/z-a.2014.101.015

Biberdžić M., Maksimović G., Barać S., Jovov Z. 2012. Economic effects of triticale production on acid soils. Economics of Agriculture, 3: 579–587

Čepulienė R., Marcinkevičienė A., Velička R., Kosteckas R., Pupalienė R. 2013. Effect of spring oilseed rape crop density on plant root biomass and soil enzymes activity. Estonian Journal of Ecology, 62 (1): 70–78 http://dx.doi.org/10.3176/eco.2013.1.06

Fernández-Calviño D., Rousk J., Brookes P. C., Bååth E. 2011. Bacterial pH-optima for growth track soil pH, but are higher than expected at low pH. Soil Biology and Biochemistry, 43: 1569–1575 http://dx.doi.org/10.1016/j.soilbio.2011.04.007

Flower K. C., Crabtreec W. L. 2011. Soil pH change after surface application of lime related to the levels of soil disturbance caused by no-tillage seeding machinery. Field Crops Research, 121: 75–87 http://dx.doi.org/10.1016/j.fcr.2010.11.014

Fuentes J. P., Bezdicek M. F., Albrecht S., Smith J. 2006. Microbial activity affected by lime in a long-term no-till soil. Soil and Tillage Research, 88: 123–131 http://dx.doi.org/10.1016/j.still.2005.05.001

Grewal H. S., Williams R. 2003. Liming and cultivars affect root growth, nodulation, leaf to stem ratio, herbage yield, and elemental composition of alfalfa on an acid soil. Journal of Plant Nutrition, 26 (8): 1683–1696 http://dx.doi.org/10.1081/PLN-120022381

Jaskulska I., Jaskulski D., Kobierski M. 2014. Effect of liming on the change of some agrochemical soil properties in a long-term fertilization experiment. Plant, Soil and Environment, 60 (4): 146–150

Jokubauskaitė I., Karčauskienė D., Antanaitis Š., Mažvila J., Šlepetienė A., Končius D., Piaulokaitė-Motuzienė L. 2015. The distribution of phosphorus forms and fractions in retisol under different soil liming management. Zemdirbyste-Agriculture, 102 (3): 251–256 http://dx.doi.org/10.13080/z-a.2015.102.032

Karčauskienė D., Jokubauskaitė I., Repšienė R., Ambrazaitienė D., Šlepetienė A. 2015. Effect of liming on the dynamics of water-stable aggregates and organic carbon in moraine loam soil. NJF 25th Congress. Rīga, Latvia, p. 195–200

Kemmitta S. J., Wrighta D., Gouldingb K. W. T., Jonesa D. L. 2006. pH regulation of carbon and nitrogen dynamics in two agricultural soils. Soil Biology and Biochemistry, 38: 898–911 http://dx.doi.org/10.1016/j.soilbio.2005.08.006

Kronberga A. 2008. Selection criteria in triticale breeding for organic farming. Latvian Journal of Agronomy, 11: 89–94

Liu D. L., Helyar K. R., Conyers M. K., Fisher R., Poile G. J. 2004. Response of wheat, triticale and barley to lime application in semi-arid soils. Field Crops Research, 90: 287–301 http://dx.doi.org/10.1016/j.fcr.2004.03.008

Marcinkonis S., Tripolskaja L. 2008. The soil acidity parameters of soils with stopped liming. Latvian Journal of Agronomy, 11: 250–256

Neugschwandtner R. W., Liebhard P., Kaul H. P., Wagentrist H. 2014. Soil chemical properties as affected by tillage and crop rotation in a long-term field experiment. Plant, Soil and Environment, 60 (2): 57–62

Paradelo R., Virto I., Chenu C. 2015. Net effect of liming on soil organic carbon stocks: a review. Agriculture, Ecosystems and Environment, 202: 98–107 http://dx.doi.org/10.1016/j.agee.2015.01.005

Repšienė R., Skuodienė R. 2010. The influence of liming and organic fertilisation of the changes of some agrochemical indicators and their relationship with crop weed incidence. Zemdirbyste-Agriculture, 97 (4): 3–14

Soon Y. K., Arshad M. A. 2005. Tillage and liming effects on crop and labile soil nitrogen in an acid soil. Soil and Tillage Research, 80: 23–33 http://dx.doi.org/10.1016/j.still.2004.02.017

Stenberg M., Stenberg B., Rydberg T. 2000. Effects of reduced tillage and liming on microbial activity and soil properties in a weakly-structured soil. Applied Soil Ecology, 14 (2): 135–145 http://dx.doi.org/10.1016/S0929-1393(00)00043-3

Su C., Ewans L. J. 1996. Soil: solution chemistry and alfalfa response to $CaCO_3$ and $MgCO_3$ on an acid *Gleysol*. Canadian Journal of Soil Science, 76: 41–47 http://dx.doi.org/10.4141/cjss96-007

Šimanský V., Kováčik P. 2015. Long-term effects of tillage and fertilization on pH and sorption parameters of haplic *Luvisol*. Journal of Elementology, 20 (4): 1033–1040

Tomic D., Stevovic V., Durovic D., Lazarevic D. 2012. The impact of soil liming on the productivity of grass-legume mixture of red clover (*Trifolium pratense* L.) and Italian ryegrass (*Lolium italicum* L.) Acta Agriculturae Serbica, 17 (33): 21–29

Vašak F., Černy J., Buranova Š., Kulhanek M., Balik J. 2015. Soil pH changes in long-term field eksperiments with different fertilizing systems. Soil and Water Research, 10: 19–23 http://dx.doi.org/10.17221/7/2014-SWR

Wheeler D. 1998. Investigation into the mechanisms causing lime responses in a grass-clover pasture on a clay loam soil. New Zealand Journal of Agricultural Research, 41: 497–515 http://dx.doi.org/10.1080/00288233.1998.9513333

ISSN 1392-3196 / e-ISSN 2335-8947
Zemdirbyste-Agriculture, vol. 103, No. 2 (2016), p. 129–134
DOI 10.13080/z-a.2016.103.017

Dirvožemio rūgštumo pokyčiai ilgalaikiame tręšimo eksperimente

J. Vigovskis, A. Jermuss, A. Svarta, D. Sarkanbarde

Latvijos žemės ūkio universiteto Žemės ūkio tyrimų institutas

Santrauka

Straipsnyje aprašoma ilgalaikio, daugiau nei 30 metų, tręšimo ir kalkinimo įtaka dirvožemio rūgštumui (pH_{Cl}) bei augalų produktyvumui.

Latvijos žemės ūkio universiteto Žemės ūkio tyrimų institute 1981 m. *Hypostagnic Endogleyic Albeluvisol* (*Hypereutric*, *stw-ng-AB(he)*) priemolio dirvožemyje buvo įrengtas paviršinis drenažas ir vykdytas ilgalaikis lauko eksperimentas. Naudotos keturios normos kalkių (skalūnų pelenų): 0 (L0), 2,58 (L1), 5,70 (L2) ir 11,40 (L3) t ha^{-1} $CaCO_3$. Pirminis kalkinimas atliktas 1981 m., palaikomasis – 1994 ir 2014 m. Kasmet tręšta keturiomis normomis mineralinių trąšų: be trąšų (F0), $N_{45}P_{30}K_{45}$ (F1), $N_{90}P_{60}K_{90}$ (F2) ir $N_{135}P_{90}K_{135}$ (F3).

Nuo 1994 m. taikyta septynių laukų sėjomaina: (1) žieminiai kvietrugiai → (2) bulvės → (3) vasariniai kviečiai → (4) vasariniai rapsai → (5) vasariniai miežiai su įsėliu → (6) ir (7) daugiametės žolės (raudonieji dobilai ir motiejukai).

Eksperimento pradžioje F0 ir F2 variantų dirvožemis buvo labai rūgštus (pH_{KCl} 4,7), o F1 ir F3 variantų – vidutiniškai rūgštus (pH_{KCl} 5,6). Kalkintų variantų dirvožemio pH padidėjo nuo 4,8 iki 5,8–6,0. Kitais metais iki 1994-ųjų kalkintų variantų dirvožemio rūgštumas palaipsniui didėjo (apytiksliai 0,4–0,6 pH vieneto). Po pirmojo palaikomojo kalkinimo dirvožemio rūgštumas beveik pasiekė prieš tai buvusį aukščiausią lygį. Per kitus 20 metų variantuose, kalkintuose didžiausia norma kalkių (11,40 t ha^{-1} $CaCO_3$), dirvožemio rūgštumas padidėjo iki pH 5,2. Variantų, kalkintuose maža norma kalkių (2,58 t ha^{-1} $CaCO_3$), dirvožemio rūgštumas padidėjo iki pH 4,6 ir buvo netgi mažesnis nei bandymo pradžioje (pH 4,8). Be palaikomojo kalkinimo, dirvožemio rūgštumas per 20 metų padidėjo 0,7–0,8 pH vieneto. Nekalkintų variantų dirvožemio rūgštumas palaipsniui padidėjo nuo pH 4,8 iki 4,4.

Reikšminiai žodžiai: dirvožemio rūgštumas, ilgalaikiai eksperimentai, kalkinimas, mineralinės trąšos, produktyvumas.

Please use the following format when citing the article:
J. Vigovskis, A. Jermuss, A. Svarta, D.Sarkanbarde. 2016. The changes of soil acidity in long-term fertilizer experiments. Zemdirbyste-Agriculture, 103 (2): 129–134 DOI 10.13080/z-a.2016.103.017