Impact of Anthropogenical Activity on the Chemical Degradation Process of Soils

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Abstract: Liming of acid soils is the basic means of increasing of soil fertility. It was established that intensive liming speeding-up the leaching of nutritious matter in the sub-soil. Acidification process of soils without liming occurred more intensive with comparison with non-liming soils.

Results of the field experiments carried out in Lithuanian Institute of agriculture during 1988 to 1998 showed that in the absence of liming the soil acidification occurred at the rate of decrease in 0.1 pH units during every year. As the results of this process there was an increase in the contents of elements such as Al, Zn and Cu and decrease in the amount of bases in the soil. It was established that 10 years after liming the soil pH decreased from 5.4 to 4.4 with concomitant increase in soil acidity. Acidification of soil in the first five year was not so intensive, the pH decrease by about 0.2 units. Acidification was more intensive during the last five years period and the pH decreased by 0.4 to 0.6 units. Correlation relation between soil reaction and amount of nutritious mater was strong in most cases.

Keywords: acid soils, nutritious matter, fertilising

1 Introduction

The Lithuanian Centre of Agrochemistry was established in 1985 with the objective of working mainly on acid soils.. The soils with pH 5.5 or less occupies an area of around 80% in the East and Southeast Lithuania and around 50% in Western Lithuania (Mazvila, 1998). The plants growing on acid soils experience deficiencies of many elements. In acid soils the micro-biological activity as well as mineralising of nutrients are affected. Aluminium and manganese may become harmful to the plants. The yield of wheat, barley, clover and beet has been reported to be low in these soils as compared to normal soils. In Vezaiciai it has been established that after liming of soils the pH increased from 4.4 to 6.5, the yield of barley increased from 0.46 to 4.44 $t \cdot ha^{-1}$ (Ciuberkiene, 1998). Decrease in acidity due to liming depends upon dose, kind and course of lime, physical properties of soil, amount of precipitation, amount and nature of mineral fertilisers (Ezerinskas, 1998). Soil acidification was fixed after the second year of liming (Ciuberkiene, 1998, Veitiene, 1996). Liming of the soil is recommended after every 5 to 7 years. The dose of repeating lime depends upon the time of previous liming. The acidification of soil is one of the reasons for soil degradation. The soil acidification and related changes in chemical indices were termed as Chemical Time Bombs (Blake, Goulding, Johnson, 1984, 1987). In addition to aluminium soil acidification also affects the zinc, manganese and some other elements. In acid soils therefore exits a danger of accumulation of these elements to the toxic levels in soils and plants (Veitiene, 1998). The process of acidification can be restricted by liming as well as with avoiding the use of acid producing fertilisers and addition of optimum amounts of organic matter to the soil.

2 Materials and methods

Soil characteristic. The field trials were carried out in 1988 on the gleyic sod podzolic light loam soil (JP_1^v). The top soil chemical characteristics are presented in Table 1.

The composition of the soil showed that original non-limed soil was more acidic. It contain less amount of bases. Amount of Al was near toxic limits. The soil have average amount of phosphorus and very high amounts of potassium. It contains low amounts of micro-elements. The acidity of soil as well as aluminium content decreased after first year of liming. Amount of hydrolytic soil acidity decreased and that of bases increased after liming

Table 1 Chemical characteristics of soil

Agrochemical indices	1988	1989
pH_{KCl}	4.05 — 4.60	5.2 — 5.4
Hydrolytic soil acidity, mmol $H^+ \cdot kg^{-1}$	41.6 — 55.0	24.0 — 35.1
Amount of bases, mmol (+)$\cdot$ kg^{-1}	28.7 — 44.5	71.3 — 93.7
Exchangeable soil acidity, mmol $H^+ \cdot kg^{-1}$	3.6 — 8.7	0.3 — 0.7
Mobile aluminium, $mg \cdot kg^{-1}$	29.0 — 75.9	0.2 — 2.2
P_2O_5, $mg \cdot kg^{-1}$	105.0 — 125.0	127.0 — 152.0
K_2O, $mg \cdot kg^{-1}$	238.0 — 262.0	268.0 — 297.0
Total N, $g \cdot kg^{-1}$	1.2 — 1.4	0.10 — 0.13
Humus, $g \cdot kg^{-1}$	8.5 — 28.9	—
Ca, $mg \cdot kg^{-1}$	505 — 649	—
B, $mg \cdot kg^{-1}$	0.25 — 0.44	0.25 — 0.44
Cu, $mg \cdot kg^{-1}$	1.16 — 1.47	0.97 — 1.17
Zn, $mg \cdot kg^{-1}$	0.54 — 1.07	1.10 — 1.79

Methods of analyses. Soil pH was estimated by electrometer with glass electrode; hydrolytic soil acidity according to Kappen; exchangeable soil acidity and mobile aluminium according to Sokolov; amount of bases according to Kappen-Hilcovic; mobile potassium and phosphorus according to AI, total nitrogen by Kjeldal method; boron was extracted in hot water and estimated colorimetrically; copper in 1 mol HCl $\cdot$ dm^{-3} extract; zinc in 1 mol KCl $\cdot$ dm^{-3} extract; calcium in ammonium acetate extract were estimated on atomic absorption spectrophotometer; humus was estimated according to Turin.

3 Results and discussion

The chemical analysis of soil showed that pH of the soil which was in the range of 5.2 to 5.4 after the liming of the soil in1989 decreased to 4.5 to 4.7 after the period of ten years in 1998. The average decrease in pH was observed to be 0.1 units per year (Table 2).

Table 2 Changes in soil reaction (pH_{KCl}) at Vezaiciai, over the period of time

Treatments	$x \pm Sx$		
	1989	1994	1998
Without micro-elements	5.4 ± 0.13	5.2 ± 0.08	4.6 ± 0.13
B once during rotation into soil	5.3 ± 0.20	5.1 ± 0.12	4.6 ± 0.16
B every year onto plants	5.4 ± 0.19	5.1 ± 0.10	4.6 ± 0.11
B every year into soil and onto plants	5.3 ± 0.19	5.1 ± 0.12	4.6 ± 0.16
Cu once during rotation into soil	5.2 ± 0.09	5.1 ± 0.04	4.4 ± 0.11
Cu every year onto plants	5.4 ± 0.09	5.2 ± 0.14	4.7 ± 0.18
Cu every year into soil and onto plants	5.3 ± 0.25	5.0 ± 0.14	4.6 ± 0.14
Zn once during rotation into soil	5.2 ± 0.20	5.0 ± 0.18	4.6 ± 0.19
Zn every year onto plants	5.2 ± 0.13	5.2 ± 0.10	4.6 ± 0.12
Zn every year into soil and onto plants	5.4 ± 0.13	5.2 ± 0.13	4.6 ± 0.13
Mo every year onto plants	5.3 ± 0.20	5.1 ± 0.15	4.6± 0.15
Mo every year into soil and onto plants	5.2 ± 0.16	5.0 ± 0.12	4.5 ± 0.14

x — average data; *Sx* — standard divination

Acidification of soil in the first five year was not so intensive. The pH decreased by about 0.2 units during 1989 to 1994. Acidification was more intensive during the last five-year period from 1994 to 1998 when the pH decreased by 0.4 to 0.6 units. This may probably be due to effectiveness of lime for the first four years and leaching down of the $CaCO_3$ as $Ca(HCO_3)_2$ into subsoil at later period when acidification of soil were noticeable again. The reaction of the soil seems to be sufficiently stable. The deviation of ±0.12 —0.16 $pH_{KCl.}$ from the average data showed the diversity of field trial in respect of soil acidity is low.

Amount of mobile aluminium in the soil has a direct relation with the soil reaction (Table 3).

Table 3 Impact of soil acidification on the amount of mobile aluminium, mg·kg^{-1}

Treatments	x ± Sx		
	1989	1994	1998
Without micro-elements	0.9 ± 0.4	1.6 ± 0.6	15.9 ± 6.1
B once during rotation into soil	0.3 ± 0.7	8.9 ± 7.4	22.1 ± 10.1
B every year onto plants	0.3 ± 0.2	6.4 ± 3.7	19.9 ± 7.6
B every year into soil and onto plants	1.9 ± 1.8	5.1 ± 3.2	21.3 ± 10.1
Cu once during rotation into soil	1.4 ± 0.5	4.2 ± 1.6	33.8 ± 7.2
Cu every year onto plants	0.3 ± 0.2	4.9 ± 2.0	15.7 ± 7.8
Cu every year into soil and onto plants	1.4 ± 1.3	6.4 ± 2.5	17.2 ± 8.2
Zn once during rotation into soil	2.2 ± 0.8	12.0 ± 4.9	20.6 ± 9.9
Zn every year onto plants	0.8 ± 0.2	4.7 ± 2.1	25.8 ± 6.7
Zn every year into soil and onto plants	0.5 ± 0.2	3.3 ± 1.0	13.9 ± 6.2
Mo every year onto plants	1.0 ± 0.7	7.6 ± 2.3	18.8 ± 7.2
Mo every year into soil and onto plants	1.7 ± 1.0	5.5 ± 3.0	18.3 ± 8.0

x — average data; *Sx* — standard deviation

As reported in the preceding section the Al content of non-limed soil varied from 29 — 76 mgAl • kg^{-1}, which was decreased to 0.3 — 2.2 mgAl • kg^{-1} after liming the soil. However over the period of 10 years as the acidity of soil increased it was also increased to 14 — 34 mgAl • kg^{-1}. A wide variation in deviation from average showed that aluminium was not a stable element.

Amount of available phosphorus decreased with soil acidification over a period of time after liming the soil (Table 4). In spite of fertilisation of crop every year, the average decrease of 20% over the period from 1989 to 1998 showed that the soil acidification degraded the soil with respect to the available phosphorus. The deviations from average data were not large. It indicates that phosphorus is rather a stable element.

Table 4 Impact of soil acidification on the amount of mobile phosphorus, mg·kg^{-1}

Treatments	x ± Sx		
	1989	1994	1998
Without micro-elements	152 ± 11	123 ± 12	105 ± 10
B once during rotation into soil	147 ± 10	127 ± 10	111 ± 6
B every year onto plants	137 ± 9	123 ± 3	112 ± 10
B every year into soil and onto plants	145 ± 7	122 ± 3	117 ± 8
Cu once during rotation into soil	129 ± 9	116 ± 5	110 ± 9
Cu every year onto plants	137 ± 11	129 ± 6	118 ± 6
Cu every year into soil and onto plants	140 ± 8	138 ± 2	106 ± 10
Zn once during rotation into soil	145 ± 12	126 ± 5	111 ± 9
Zn every year onto plants	130 ± 2	126 ± 8	112 ± 3
Zn every year into soil and onto plants	142 ± 6	126 ± 4	114 ± 9
Mo every year onto plants	145 ± 10	121 ± 5	116 ± 7
Mo every year into soil and onto plants	127 ± 6	132± 10	113 ± 8

x — average data; *Sx* — standard deviation

Amount of mobile potassium, contrary to phosphorus, increased by soil acidification over the period of time. The average increase was to the extent of 15% (Table 5). In contrast to other chemical indices, the increase of potassium was quite noticeable after five years. After this period although the K content increased but the increase was not significant.

Table 5 Impact of soil acidification on the amount of potassium, mg • kg^{-1}

Treatments	$x \pm Sx$		
	1989	1994	1998
Without micro-elements	296 ± 12	331 ± 16	343 ± 17
B once during rotation into soil	297 ± 22	326 ± 12	320 ± 7
B every year onto plants	286 ± 19	327 ± 5	319 ± 19
B every year into soil and onto plants	293 ± 12	334 ± 2	326 ± 8
Cu once during rotation into soil	270 ± 6	297 ± 10	323 ± 10
Cu every year onto plants	273 ± 15	361 ± 21	345 ± 8
Cu every year into soil and onto plants	278 ± 19	308 ± 21	341 ± 25
Zn once during rotation into soil	278 ± 14	335 ± 4	314 ± 5
Zn every year onto plants	279 ± 10	338 ± 10	312 ± 10
Zn every year into soil and onto plants	287 ± 16	349 ± 10	317 ± 20
Mo every year onto plants	268 ± 11	331 ± 10	342 ± 25
Mo every year into soil and onto plants	285± 14	363 ± 24	344 ± 15

x — average data; *Sx* — standard deviation

Change of soil reaction not influenced the amount of boron in the soil and variation of data was not considerable (Table 6).The data showed that boron availability is not sensitive to the soil reaction. These results are at variance from the results reported by some other workers [Ezerinskas, 1998, Veitiene,1987].

Amount of calcium contrary to boron, has rather wide data variation. It is directly related to soil reaction. Migration of calcium to sub soils due to soil acidification is rather fast.

Table 6 Impact of soil acidification on the amount of boron and calcium, mg • kg^{-1}

Treatments	$x \pm Sx$		
	boron		calcium
	1989	1994	1997
Without micro-elements	0.25 ± 0.02	0.19 ± 0.01	562 ± 72
B once during rotation into soil	0.25 ± 0.03	0.26 ± 0.01	569 ± 107
B every year onto plants	0.25 ± 0.04	0.25 ± 0.03	597 ± 58
B every year into soil and onto plants	0.31 ± 0.03	0.24 ± 0.04	508 ± 89
Cu once during rotation into soil	0.32 ± 0.05	0.18 ± 0.02	497 ± 72
Cu every year onto plants	0.27 ± 0.04	0.21 ± 0.01	555 ± 38
Cu every year into soil and onto plants	0.31 ± 0.01	0.20 ± 0.01	577 ± 61
Zn once during rotation into soil	0.42 ± 0.05	0.25 ± 0.02	566 ± 99
Zn every year onto plants	0.44± 0.05	0.23 ± 0.04	520 ± 77
Zn every year into soil and onto plants	0.38 ± 0.04	0.26 ± 0.04	606 ± 39
Mo every year onto plants	0.32 ± 0.06	0.26 ± 0.02	585 ± 67
Mo every year into soil and onto plants	0.28 ± 0.05	0.26 ± 0.03	558 ± 69

x — average data; *Sx* — standard deviation

Zinc is considered to be active in the acid soil. There is quite a large variation in the content of zinc in soils Acidification of soil over the period of 10 years after liming decreased the zinc content by 50%. The decrease in mobile zinc in the acid soils is contradictory to earliest studies (Veitiene, 1987). The decrease in content of zinc in the present study may due to its removal by crops as the higher crop yields were obtained after liming of the soil.

Amount of copper in the acid soil increased by about 27% over the period of time and data variation in the acid soil was quite large as compared to limed soils (Table 7).

Table 7 Impact of soil acidification on the amount of copper and zinc, $mg \cdot kg^{-1}$

Treatments	$x \pm Sx$			
	copper			zinc
	1989	1996	1989	1996
Without micro-elements	1.07 ± 0.11	1.27 ± 0.24	1.10 ± 0.08	1.00 ± 0.20
B once during rotation into soil	1.17 ± 0.08	1.77 ± 0.30	1.56 ± 0.04	0.80 ± 0.14
B every year onto plants	1.07 ± 0.08	1.47 ± 0.08	1.44 ± 0.17	1.12 ± 0.22
B every year into soil and onto plants	1.12 ± 0.07	1.67 ± 0.20	1.61 ± 0.10	0.70 ± 0.13
Cu once during rotation into soil	0.97 ± 0.02	1.40 ± 0.27	1.79 ± 0.41	0.65 ± 0.13
Cu every year onto plants	1.12 ± 0.11	1.37 ± 0.19	1.42 ± 0.27	0.65 ± 0.14
Cu every year into soil and onto plants	1.10 ± 0.20	1.50 ± 0.22	1.36 ± 0.16	0.67 ± 0.14
Zn once during rotation into soil	1.02 ± 0.08	1.57 ± 0.32	1.64 ± 0.10	0.55 ± 0.12
Zn every year onto plants	1.05 ± 0.05	1.35 ± 0.20	1.42 ± 0.22	0.90 ± 0.33
Zn every year into soil and onto plants	1.05 ± 0.05	1.50 ± 0.24	1.19 ± 0.19	0.77 ± 0.11
Mo every year onto plants	1.02 ± 0.02	1.40 ± 0.10	1.28 ± 0.07	0.60 ± 0.17
Mo every year into soil and onto plants	1.12 ± 0.13	1.12 ± 0.14	1.37 ± 0.21	0.67 ± 0.18

x — average data; Sx — standard deviation

Acidification of soil is one reason of chemical degradation of soils. The chemical soil degradation decreased the productivity of crop rotation due to increasing in contents of elements such as Al, Zn, and Cu in the soil. Soil acidification also causes irreversible chemical process.

The aim to increase soil productivity either due to liming or due to mineral fertilisers is through decreasing the process of acidification and increasing the mineralising of organic matter containing nutrients. This aim therefore can easily be achieved by paying more attention to the marginally affected soils as compared to totally degraded soils.

Results of researches corroborated the data of literature, that activity of chemical elements by soil acidification varies in the order of: K > Ca > Al > P > Zn > Cu > B. This arrangement of nutrients is not against the metals activity rules. Soil acidification is a natural process governed by inherent chemical laws. However it should not be allowed to proceed to extreme ends. On the marginal fields cultivation of the plants, which are tolerant to acidic soils reaction is recommended. Productivity from acid soil can be ensured by liming the soil, use of non-acid producing fertilisers and abundant use of organic matter, which increases the amount of humus in the soil.

4 Conclusions

(1) Acidity of soil in period of 10 years after primary liming increased about 1.0 pH_{KCl}. Soil acidity increased from 5.2—5.4 to 5.0—5.1 in first five years and from 5.0—5.1 to 4.5—4.7 in second five years.

(2) Chemical degradation of soils due to acidification decreased soil fertility and increased a possibility for accumulation of toxic elements (Al, Zn, Cu) in soil and plants.

References

Antanaitis A., Mazvila J., (1984).Amount of mobile magnesium and other micro-elements and it’s dependence from soil characteristic. In: research and using of micro-elements in agriculture. p. 29-30. (In Lithuanian).

Blake L., Johnston A. E., at all., (1984). Mobilisation of aluminium in soil by acid deposition and its uptake by grass cut for hay a Chemical Time Bomb. Soil Use and Management, 10: 51-55.

Ciuberkiene D., (1998). The dependence of barley yield and it’s quality at the soil reaction. In: The present and future at crop science and bee keeping. p. 124-130.

Ezerinskas V., (1998). Live powder efficiency and rates on the acid soils. In: The present and future of crop science and bee keeping. p. 149-154.

Goulding K.W.T., Blake L., (1997). Soil acidification and the mobilisation of toxic metals caused by acid deposition and fertilisers application. Natural and anthropogenic causes and effects of soil acidification. p. 15-20.

Mazvila J., (1998).Agrochemical properties of soil and it’s changing. p.195.(In Lithuanian).

Veitiene R., (1987). Dynamics of micro-elements in different loam soils. In: Short summary of scientific conference. p.47-51.(In Lithuanian)

Veitiene R., (1998). Micro-elements in crop rotation. In: The present and future of crop science and bee keeping. p.475-480.

Veitiene R., (1996). Usage of micro-elements in crop rotation. Agriculture. Scientific Articles of the Lithuanian institute of agriculture. 56: 43-53.