LITHUANIAN RESEARCH CENTRE FOR AGRICULTURE AND FORESTRY

VĖŽAIČIAI BRANCH

Agreement No 2/2012-04-16

ASSESSMENT OF EFFECT OF KALKTRĄŠĖ IN ACID SOILS OF WESTERN LITHUANIA

REPORT
of precise field trials and lab analyses performed in 2012

Vėžaičiai, 2012

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CONTENTS

INTRODUCTION

Growing soil acidity is one of the forms of its chemical degradation associated with growing hydrogen and aluminium ions concentration in soil solution, natural calcium leaching under heavy precipitation, pollution and use of physiologically acid fertilizers, taking with the yield. Acidification process affects most western Lithuania, because the soils of this region are distinguished from the others due to the fact that their calcaric layer is deeper than 1.5-3 m, and the subsoil due to the intense leaching before liming was very or moderately acidic. These soils contain much mobile aluminium, toxic to the plants, toxicity of which is often associated with high Fe and Mn and low Ca and Mg concentrations in plant tissue. Soils with a pH of 5.5 are named relatively acidic, and are suitable for most agricultural plant growth, because they contain no harmful mobile aluminium. In order to maintain pH_{KCl} indicator at such and higher rate the plough layer soil has to be limed. It is known that duration of the effects of lime on soil acidity indicators improvement depends mainly on chemical activity of liming substance, particle size, method, time and quantity of insertion. Moreover, duration of effect of liming substances on agroecosystem is extended by their coordination with divalent cations (Ca and Mg) leaching hindering measures being organic fertilizers, covering plants, perennial grasses or boardless tillage. Long-term liming study in Vėžaičiai branch found that single-time liming with large limestone dust rates has the highest neutralizing effect in the first year after liming and remains effective for more than two decades, while neutralizing effect of coarse dolomite meal is slower, but longer. But there is still no scientifically based answer of what is the level and duration of neutralizing effect of currently manufactured in Lithuania granulated liming substance Kalktrašė on the soil acidity parameters and crop productivity.

The aim of the study is to assess the effectiveness of granulated liming substance Kalktrąšė on the soil and red clover (perennial grasses) harvest, while growing them in the following rotation chain: spring barley → winter wheat → red clover (perennial grasses).

Tasks:

1. To evaluate effect of granulated liming substance on soil chemical properties three years after liming
2. To find out effect of granular lime substance effect on clover dry matter yield
3. To base scientifically effectiveness of granular lime substance Kalktrąšė when using them for the main liming.

Research data in the report:

The report contains effect of liming substances on soil chemical properties in dynamics. Soil reaction change data is presented in figures (3, 4, 5, 6, 7) after setting the trial and three years after (2009 - 2012). Also, during evaluation of the effectiveness of liming substance on acidity parameters in the arable layer it is necessary to emphasize the fact that the crops grown in rotation (spring barley, winter wheat, perennial grasses) received ploughless tillage. During such tillage the liming substances remained embedded in the upper (0-15 cm) arable layer.

The cultivated crop yield is given for the year 2012. Yields of other plants - spring barley, winter wheat – are given in interim reports of 2010 and 2011.

1. REVIEW OF LITERATURE

Recently declining country's soil pH_{KCl} after intense and systematic liming in 1964 - 1994 is seen somewhat differently than before liming, when the soil pH_{KCl} was 5.0 and less and the plants sensitive to soil acidity - red clover, wheat, barley - poorly fruited. In currently becoming acidic and having reached similar pH_{KCl} value soils very high harmful effect on crop yield is still not felt, they still give (having fertilized the plants with NPK fertilizer) substantial yield. It was influenced by previous liming with relatively high rates of pure $CaCO_3$ (in Western Lithuania even 6-15 t ha^{-1}). Such liming both increased pH_{KCl} and also significantly reduced the amount of mobile aluminium, in a few decades significantly shifted the subsoil's pH_{KCl} and other agrochemical characteristics (Mažvila, 2010). In the Western region of Lithuania after the previous intensive liming mobile aluminium has been found in only 0.42 to 1.76 mekv kg^{-1}. This amount is non-toxic to plants, but due to the constant leaching of exchange cations into the deeper layers, their loss with the yield, physiological acid fertilizer effect, recovery of mobile aluminium is gaining momentum. Therefore, to avoid an even greater soil acidification and mobile aluminium recovery, for the time being acidic soils (pH_{KCl} to 5.0) are necessary to lime though in lower rates (2-4 t ha^{-1}) of liming substances (Mažvila, 2010, Scott et al., 1999). The need in liming is further actualized by knowledge that in acidic soils the main yield-limiting phosphorus is not available for the plants. Liming substances increase levels of phosphorus in soil available and active for the plants (Szymanska et al, 2008). Limed soil has higher electrical conductivity and more intense nitrogen fixation (Moreira, Fager, 2010). American scientists found that for improvement of acid soils highly effective is dusty dolomite powder, applying it at the rates of 1-2 t ha^{-1} every 3-4 years (Ossom, Rhykerd, 2008). The long-term studies of liming performed in the middle latitudes regions have found that plant yield and organic matter content substantially increase only when liming is a continuous long-term process. Such liming is aimed to maintain soil pH_{H2O} at about 6.0 (Haynes, Naidu, 1998).

Liming efficiency depends on the lime particle coarseness. Neutralization effect of lime, depending on the size of the particles, is differentiated as follows: particle size <0.3 mm (neutralizing efficiency is 100 per cent), particle size from 0.3 to 0.85 mm (neutralizing efficiency is 60 %) and particle size > 0.85 mm (neutralizing efficiency is 0.1 %) (Stone et al. al., 1998). Liming substances according to particle size are divided into dusty, granular and crushed. This is the same calcareous substance just being in different forms and with different neutralizing effect. According to it granular liming substances occupy the intermediate position between the dust and crushed matter. Dust lime has the fastest effect, only its placing compared with granulated is more complicated because of the need in special equipment. Granular lime reacts longer with the soil, compared with the dust, so it should be placed at least a couple of months before placing the other fertilizers (Ossom and Rhykerd, 2008).

In the European countries, for annual maintenance liming of soils granular lime substances are widely used (Pierce, Warncke, 2000). In Czech Republic product Fertdolomite - 4 % CaO + 16 % MgO, 3 % N, 2.5 % P_2O_5 and 3.0 % K_2O (10 t ha^{-1} once every 7 years) is used for main liming lime (Kovacevic et al., 2010). In Canada granular lime substance Calcipril - CaO 51 % or Magpril - CaO 46% and MgO 15% for maintenance liming is used (500 kg ha^{-1}) (Lalande et al., 2009). Liming substance grain size determines the neutralization reaction rate in the soil and calcareous substance volume. The most efficient and fastest to neutralize acidic soil is finely grained calcareous material due to the higher surface area and better contact with the soil (Murdock, 2009). Another study found that the liming efficiency depends mainly on existing soil pH (Valzano et al., 2010). These authors argue that the combination of lime 2.5 t ha^{-1} and plaster 1t ha^{-1} best improved soil properties and crop yield applying using no-tillage cultivation.

2. RESEARCH METHODOLOGY

2.1. Study location and object

Study location: the study was carried out in 2009 - 2012 in the Lithuanian Agriculture and Forest Science Centre (LRCAF) Vėžaičiai branch rotation field (Western Lithuania, Coastal lowland eastern edge 55° 43'N, 21° 27'E).

Study object: granulated different fraction (0.01-2 mm and 2-4 mm diameter) calcareous substances Kalktrąšė, whose chemical composition is as follows: CaO 36.50 %, MgO 2.70 %, Fe_2O_3 1.90 %, K_2O 3.30 %, SO_3 3.90 %.

2.2. Study conditions

Study conditions. The trial was installed in 2009. Soil is Dystric Albeluvisol (*Dystric Albeluvisols* (Jin)). The soil texture is moraine clay. The soil is very acidic (4.42 ± 0.03 pH_{KCl}), high (42.3 ± 2.76 mg kg^{-1}) in mobile Al which is toxic for plants. The study is continuous, carried out the rotation chain: spring barley → winter wheat → perennial grasses (2012). Two different fractions of granular lime substance Kalktrąšė with a grain size of 0.01 to 2.0 mm (fine fraction) and 2,0 - 4.0 mm (coarse fraction) in diameter was applied. 0.5 and 1.0 rates according to hydrolytic soil acidity were used for liming. Rate 0.5 of kalktrąšė included 3.5 t ha^{-1} of pure $CaCO_3$, in total physical weight was 4.5 t ha^{-1}. Rate 1.0 included 7.0 t ha^{-1} of pure $CaCO_3$, natural weight was 9.0 t ha^{-1} of lime substances.

Kalktrąšė was placed in the fall of 2009 and inserted into 7-11 cm depth. In the spring of 2010 after fertilization with mineral fertilizers and inserting them with the means of germinator, barley was sown. After removing the spring barley crop, winter wheat was sown. In the spring (2011), when winter wheat vegetation renewed, undercrop of red clover was sown. In 2012 red clover grew. Background mineral fertilization was done to all crops in the rotation according to the physiological needs of the plants. Soil samples for chemical analysis were taken twice a year in spring and autumn every six months.

Soil. The trials were installed in at an average cultivated soil, Dystric Albeluvisol. Soil arable layer is 20 - 28 cm thick, silty dusty, light and medium loam (clay fraction < 0.002 mm makes 14-15 %). Stable aggregates made only 48 – 51 % of the total aggregate content. Such soil does not ensure good aeration and moisture conditions for the plants. In the event of extreme natural conditions (rain or drought) soil becomes too viscous or too compacted, forms a crust on the soil surface, making it difficult for the aeration of the soil and plant roots oxygenation.

Soil chemical characteristics prior to the trial is given in the Table 1.

Table 1. Soil chemical characteristics prior to the installation of the test (2009).

Agrochemical indicator	$\bar{x} \pm S\bar{x}$	Coefficient of variation (V %)
Mobile P_2O_5, mg kg^{-1}	139 ± 3,50	3,57
Mobile K_2O, mg kg^{-1}	204 ± 4,0	2,77
Summary N, %	0,14 ± 0,001	0,10
Organic C %	1,29 ± 0,04	4,39
pH_{KCl}	4,46 ± 0,02	1,19
Mobile Al, mg kg^{-1}	63,87 ± 4,41	21,81
Hydrolytic acidity, mekv. kg^{-1}	59,6 ± 1,18	6,25
Exchange Ca, mg kg^{-1}	654 ± 37,5	18,15
Exchange Mg, mg kg^{-1}	160 ± 2,75	5,44

Note. $\bar{x}$ is mean; $\pm S\bar{x}$ is deviation from the mean.

Study soil is average in phosphorus (P_2O_5 is 139 ± 3,50 mg kg^{-1}), high in potassium (204 ± 4,0 mg kg^{-1}), average in nitrogen (summary N is 0,14 ± 0,001 %), having average content of organic carbon 1,29 %, low in exchange Ca which is 654 ± 37,5 mg kg^{-1} and in exchange Mg which is 160 ± 2,75 mg kg^{-1} (table 1). Soil is very acid (pH_{KCl} 4,46 ± 0,02) having much toxic-for-plants mobile Al (63,87 ± 4,41 mg kg^{-1}), high hydrolytic acidity (59,6 ± 1,18 mekv. kg^{-1}). Based on these chemical properties the trial soil is heterogeneous, because coefficient of variation varies in a broad range from 0,10 to 21,81.

Agro climatic conditions. In September, October 2011 average temperature was close to the multi-annual standard (table 2). Precipitation was slightly higher than the average multi-annual standard: in September it reached 116 % or the standard, in October 123 per cent of the standard. In November precipitation was as little as 47,7 mm (half of the standard), and monthly average air temperature was 4,7 ºC (1,8 ºC higher that the standard). Plant vegetation period completed on 15 November. In December warm autumn-like weather prevailed. Average monthly air temperature in December was 2,3 °C (1,5° higher than the average multi-annual). Precipitation of the month was 219,8 mm (2,6 times higher than the standard).
Warm weather remained till the middle of January 2012, the highest air temperature was up to plus 4,7 °C. After that air temperature started gradually lowering. The end of January was especially cold, when the lowest temperature dropped down to -13 °C. Average monthly air temperature was -1,61 °C (1,4° higher that average multi-annual). Monthly precipitation was 1,6 times of the standard. The cold winter-like weather, having started in the end of January, continued till the end of the second decade of February. From then on weather started warming, there were thaws. Average monthly temperature in February was -7,79 °C (4,79° lower than the standard). Monthly precipitation was 83,8 mm (179 % of the standard).

Table 2. Meteorological data of Vėžaičiai ordinary climate station 2011-2012.

	Average air temperature ºC					Precipitation, mm				
	Decades					Decades				
Months	I	II	III	Monthly average	Average multi-annual air temperature 1947-2010	I	II	III	Sum per month	Average multi-annual precipitation standard 1947-2010
2011										
September	13,8	13,6	12,6	13,3	12,4	50,1	52,9	6,2	109,2	94,1
October	11,6	7,0	6,8	8,5	7,8	45,1	56,9	11,2	117,2	95,6
November	5,3	3,7	5,2	4,7	2,9	0,0	10,0	37,7	47,7	91,4
December	2,8	2,7	1,4	2,3	-0,8	107,7	82,8	29,3	219,8	82,8
2012										
January	1,74	0,68	-7,05	-1,61	-3,0	45,8	47,3	11,9	105,0	66,8
February	-16,8	-6,35	0,6	-7,8	-3,0	9,5	34,8	39,5	83,8	46,7
March	-1,1	2,1	3,9	1,7	-0,2	7,3	7,7	5,3	20,3	46,9

April	1,3	6,7	11,6	6,5	5,7	18,5	1,7	7,9	28,1	41,3
May	10,5	11,0	14,5	12,1	11,2	10,4	22,2	7,0	39,6	44,3
June	11,7	15,3	14,8	14,0	14,8	14,3	13,1	50,3	77,7	63,6
July	19,3	15,6	19,3	18,1	17,0	20,5	37,7	7,0	65,2	90,4
August	17,7	16,0	15,0	16,2	16,5	59,8	0,8	21,2	81,8	95,1

March weather was changeable. Average air temperature was 1,7 °C (1,9 ºC higher than the average multi-annual). Precipitation was 20,3 mm or 43 per cent of the standard.
Weather in April 2012 was full of contrasts. Average monthly air temperature in April was 6,5 °C (1,4 ºC higher than the average multi-annual). Larger part of precipitation fell in the first decade, later dry weather prevailed. As little as 28,1 mm or 68 per cent of the standard fell during the month. On 24 April active plant vegetation started. This is in line with the average multi-annual dates.
May weather was changeable: from the warm ones to sudden cooling. Monthly average temperature was 12,1 °C (0,8 ºC higher than the average multi-annual). Precipitation during the month was 39,6 mm or 89 per cent of the standard.
June was at an average warm, precipitation distributed unevenly. Average air temperature was 14,0 °C (0,8 ºC lower than the average multi-annual air temperature). Precipitation was 77,7 mm, half of it during two days (25 and 26).
July's weather was extremely changeable, cool weather changed the warm ones. Monthly precipitation was 65,2 mm (65,2 % or the standard), its larger part (58,2 mm) fell during the first and the second decades. Clover growth conditions were favourable.
In the beginning of August warmer, later average warm weather prevailed. August's precipitation was 81,8 mm (86,0 % of the standard), its larger part (59,8 mm) fell during the first decade.

Research scheme

1. Unlimed
2. Limed with granulated (Ø 0,01 - 2,0 mm) Kalktrąšė 0,5 rate according to hydrolytic soil acidity (4,5 t ha^{-1})
3. Limed with granulated (Ø 0,01 - 2,0 mm) Kalktrąšė 1,0 rate according to hydrolytic soil acidity (9,0 t ha^{-1})
4. Limed with granulated (Ø 2,0 - 4,0 mm) Kalktrąšė 0,5 rate according to hydrolytic soil acidity (4,5 t ha^{-1})
5. Limed with granulated (Ø 2,0 - 4,0 mm) Kalktrąšė 1,0 rate according to hydrolytic soil acidity (9,0 t ha^{-1}).

Red clover *Nike* was grown. Red clover grew after winter wheat. In spring before clover vegetation renewal it was fertilized with P60K60. Mineral fertilizer applied: granulated superphosphate and potassium chloride.

Field trial parameters. Trial fields were allocated in two rows randomly, with four repetitions (fig.1.). Size of primary field was 36 m^2, size of accounted field was 16,8 m^2.

Repetition 3					Repetition 4				
5	3	1	4	2	1	5	3	4	2
Repetition 2					Repetition 1				
4	2	5	3	1	5	1	2	3	4

Figure 1. Field trial plan

Schedule of the works performed and clover growing and development stages:

1. Soil samples taken for chemical analysis - 2012.04.10
2. Perennial grasses were fertilized with phosphorus and potassium fertilizers (P60K60) - 2012.04.11.
3. Clover in rosette stage - 2012.04.30.
4. Test fields separations were performed - 2012.05.08
5. Clover in branching stage - 2012.05.14.
6. Clover in budding stage - 2012.05.22.
7. Clover buds begin get red - 2012.06.04.
8. Clover flowering start - 2012.06.11.
9. Clover grass I harvest was done - 2012.06.14.
10. Clover begins to regenerate - 2012.06.25.
11. Clover atoll flowering time - 2012.07.16 .
12. Clover grass II harvest was done - 2012.07.26.
13. Soil samples taken for chemical analysis – 2012.08.21.
14. Clover prepared for the winter (grass cut and removed) - 2012.10.22.
15. Throughout clover vegetation soil samples to determine moisture were taken every 7 days.

2.3. The research methods

The study was conducted through precise field tests and laboratory analytical methods.
Soil sampling in the experimental field. During the test soil samples of each field's arable 0 - 20 cm layer from at least 10 places were taken for chemical analysis. For the first time samples were taken before placing the Kalktrąšė in 2009. For the second time soil samples were taken in the spring of 2010 before sowing barley, i.e. within half a year after liming. For the third time samples were taken after the harvesting barley, i.e. one year after liming. For the fourth time samples were taken in 2011 after resumption of winter wheat vegetative growth, i.e. one and a half year after liming. For the fifth time samples were taken in autumn after winter wheat harvesting, that is two years after liming. For the sixth time the samples were taken in the spring of 2012 when red clover renewed vegetation, for the seventh time the samples were taken in the fall, in the end of the vegetative growth of clover. Chemical analysis was carried out with all soil samples collected in order to evaluate the impact of Kalktrąšė.

In 2012 during red clover growing season (every 7-8 days) soil samples were taken (from 0-10 cm and 10-20 cm) for moisture analysis. During each harvest grass samples were taken from each test field to find out dry matter content.

Laboratory analysis methods:

pH_{KCl} , P_2O_5 and K_2O: Egner - Riehm - Domingo (A-L)
Mobile Al: Sokolov
Hydrolytic acidity: Kappen;
Exchange Ca and Mg: Egner - Riehm - Domingo (A-L)
Total N - Kjeldahl
Dry matter: weight.
Soil chemical analyzes were conducted through standardized methods in LMMC Agrochemical research laboratory.
In order to evaluate research data statistics statistical package ANOVA (Tarakanovas, Raudonius, 2003) was used. The smallest limit R_{05} of significant difference between the options was presented.

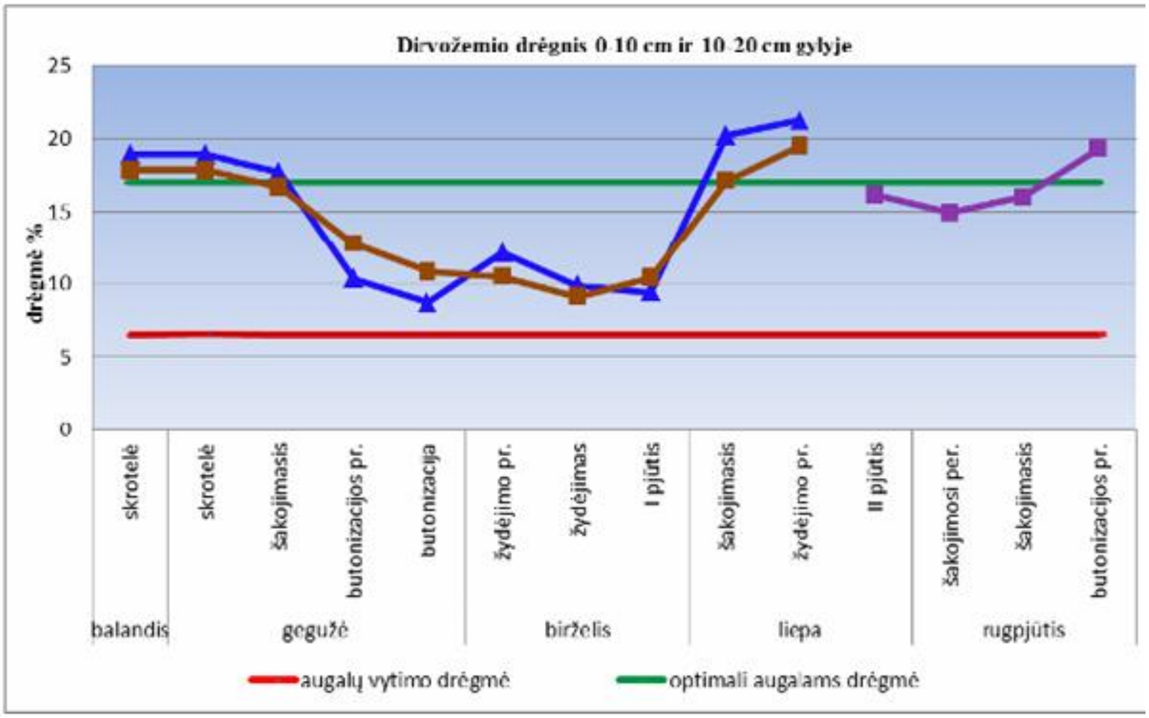
3. SURVEY RESULTS

3.1. Soil moisture during the plant vegetation period

Soil moisture has a significant impact on the development of plants. Also, when there is sufficient moisture content in the soil, favourable conditions for the liming materials and mineral fertilizers to move to the soil sorbed complex are created. For barley, winter triticale to grow optimal is medium loam arable soil moisture 17-18 per cent (Dirsė et al., 1984). Other authors think that the optimum moisture content in the medium loam soil is 19-23 per cent (excess humidity > 29 per cent, wet 24-28 %, optimal 13-18 per cent, arid 7-12 %, very dry < 7 %) (Кулаковская et al., 1984). During red clover vegetation soil moisture in the arable layer ranged in quite a wide range from 8.7 to 21,3 per cent in 0-10 cm depth (Fig. 2).

Soil moisture at 0-10 cm and 10-20 cm depth

Moisture



Rosette rosette branching start of butonisation butonisation start of blossoming blossoming 1st harvesting branching start of blossomimg 2nd blossoming branching br. Branching start of butonisation

April May June July August

Plant withering moisture Optimum moisture for plants

Fig. 2. Soil moisture during red clover vegetation
Vėžaičiai, 2012

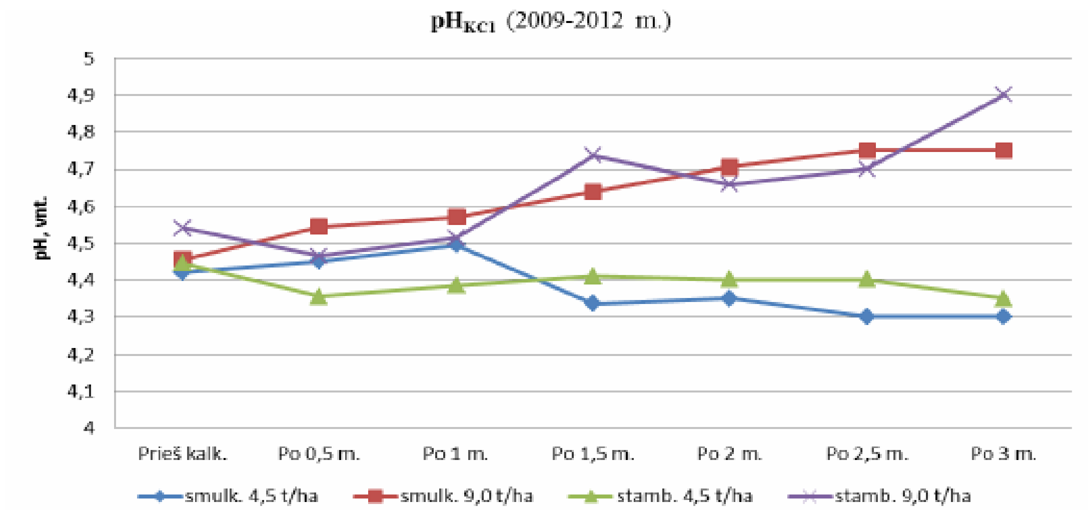
During red clover intense growth period there was enough moisture, in the rosette and branching stages soil moisture in the 0-20 cm layer was 16.7 to 17.8 %. Red clover lacked moisture most from mid-May, at the beginning of their budding up to flowering. Soil moisture content at 0-20 cm depth was reduced to 9.11-10.5, i.e. below the optimal rate. However, such a decrease in soil moisture did not have a negative effect on the first clover yield. Soil moisture conditions have been favourable for clover atolls to grow and liming materials go into the soil sorbed complex. Soil moisture at 0-20 cm depth was optimal from 16.2 to 19.5 %. Clover yield data is presented in 3.5 section.

3.2. Change of phosphorus and potassium in the soil

Before installing the outdoor test, soil contained 139 ± 3,50 mg kg^{-1} of mobile P_2O_5, 204 ± 4,0 mg kg^{-1} of mobile K_2O. During the three-year period of production of agricultural crops being spring barley, winter wheat, red clover in the crop rotation and fertilizing them in optimum mineral fertilizer rates, mobile P_2O_5 increased to 233 ± 72.03 mg kg $^{-1}$, or from mid to high amount of phosphorus. Volume of mobile K_2O 212 ± 6.29 mg kg $^{-1}$ in the soil remained similar – the soil is high in potassium .

3.3. Effect of Kalktrąšė on soil pH_{KCl} , mobile aluminium and hydrolytic acidity

Six months after insertion of Kalktrąšė, pH_{KCl} increased slightly by 0.03-0.09. (Fig. 3). One year after liming increase in pH_{KCl} was by 0.1 in the soil limed with fine fraction both lower (4.5 t ha $^{-1}$) and higher (9.0 t ha $^{-1}$) rate. Two years after liming pH_{KCl} largest increased thanks to the larger Kalktrąšė rate of both small and coarse fractions, pH_{KCl} change was from 4.5 to 4.7. Three years later thanks to the both fraction larger rates of Kalktrąšė pH_{KCl} increased up to 4.8-4.9 and thanks to small rates pH_{KCl} did not change further, remaining at the same level 4.3 to 4.4.



Before liming 0,5 years after 1 year after 1,5 years after 2 years after 2,5 years after 3 years after

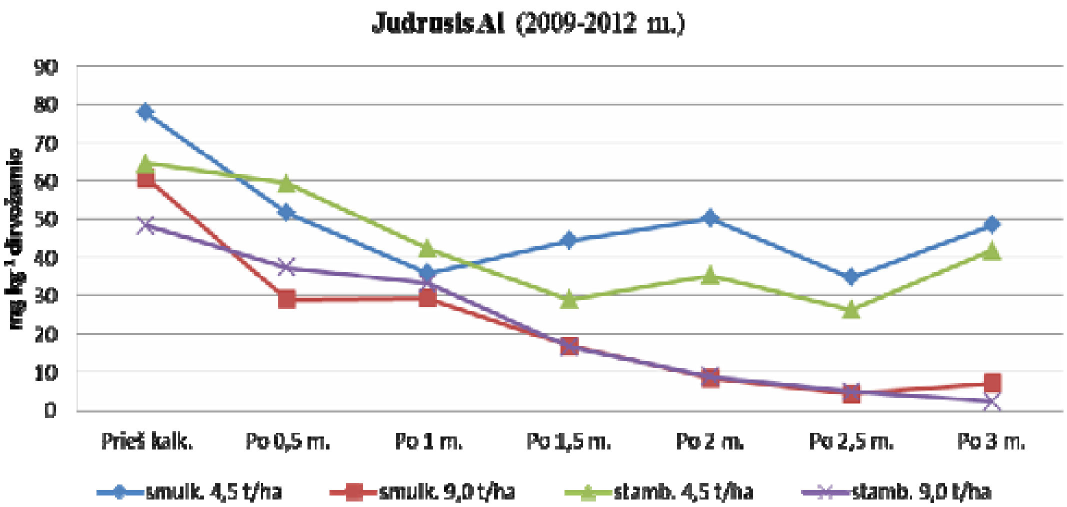
Fine fine coarse coarse

Fig. 3. Effect of Kalktrąšė on pH_{KCl} change in the soil
Vėžaičiai, 2009-2012

Mobile aluminium content in the soil most rapidly decreased after inserting the fine fraction smaller and larger Kalktrąšė rates (Figure 4). Six months after liming mobile Al in the soil decreased respectively from 77.7 to 51.6mg kg $^{-1}$ and from 60.7to28.9mg kg $^{-1}$. One year after liming reduction of mobile Al was found thanks to the both rates of coarse fraction of Kalktrąšė. After two years it was found that the soil limed with both larger (9 t ha $^{-1}$) Kalktrąšė rate and small (0.01 to 2.0 mm), both coarse (2.0-4.0 mm) fraction, mobile Al reached plants-friendly level of 8.5 and 8.9 mg kg $^{-1}$. After liming with smaller rates of the both fractions, mobile Al remains at the harmful for plants levels - 50.1 and 35.2 mg kg $^{-1}$. After three years thanks to larger rates mobile aluminium fell to 2.3 to 7.0 mg kg $^{-1}$, and thanks to the small rates it remains at the same level from 48.3 to 41.8 mg kg $^{-1}$.

Mobile Al

mg kg $^{-1}$ of the soil



Before liming 0,5 years after 1 year after 1,5 years after 2 years after 2,5 years after 3 years after

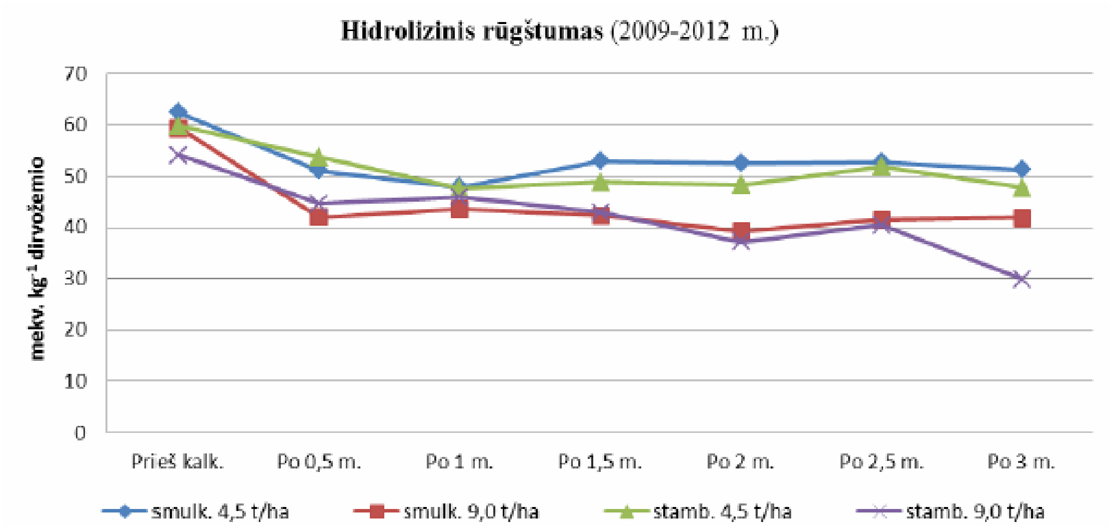
Fine fine coarse coarse

Fig. 4. Effect of Kalktrąšė on mobile Al change in the soil
Vėžaičiai, 2009-2012

Soil hydrolytic acidity decreased similarly to the mobile aluminium (Fig. 5). Two years after liming with the lower rate of both fine and coarse fractions of Kalktrąšė, hydrolytic acidity decreased from 59.4 to 62.4 mekv. kg $^{-1}$ to 48.3-52.5 mekv. kg $^{-1}$. Due to the larger rate of both fractions hydrolytic acidity further decreased to 37.1-39.2 mekv. kg $^{-1}$. After three years thanks to larger Kalktrąšė rate hydrolytic acidity decreased due to fine fraction small groups down to 41.9 mekv. kg $^{-1}$, and due to coarse down to 29.9mekv.kg $^{-1}$. Hydrolytic acidity due to the small rate of the fine fraction decreased to 51.3 mekv. kg $^{-1}$, from coarse to 47.8 mekv. kg $^{-1}$.
Using the lime improves soil structure, since calcium binds soil particles into stable structural aggregates. It also improves the water mode, activates the activity of beneficial microorganisms.

Hydrolytic acidity (2009-2012

Mekv.kg $^{-1}$ of the soil



Before liming 0,5 years after 1 year after 1,5 years after 2 years after 2,5 years after 3 years after

Fine fine coarse coarse

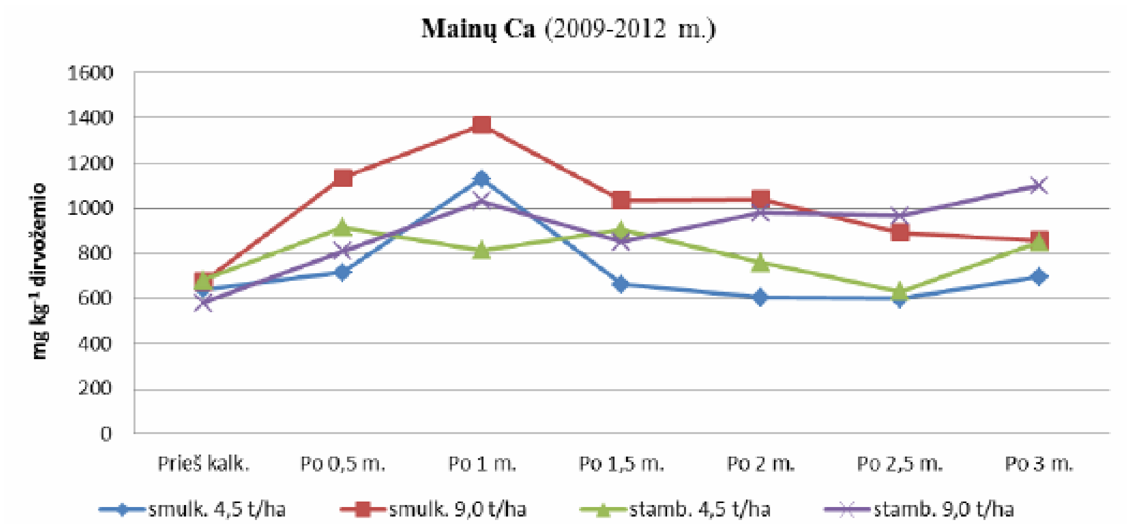
Fig. 5. Effect of Kalktrąšė on hydrolytic acidity change in the soil
Vėžaičiai, 2009-2012

3.4. Kalktrąšė's influence on exchange calcium and exchange magnesium

Exchange calcium in the soil mostly increased thanks to Kalktrąšė fine fraction large (9.0 t ha^{-1}) rate (Figure 6). Six months after insertion of Kalktrąšė exchange Ca in the soil increased to 1133.5 mg kg^{-1}, after one more year its level was even higher:1367.5mg kg^{-1}. And two years after liming exchange Ca in the soil stabilized and highest level (979.5 to 1039.5 mg kg^{-1}), was found where the two fractions at the larger rates were inserted.
After three years exchange Ca in the soil increased the most (up to 1101 mg kg^{-1}) thanks to Kalktrąšė larger rate (9.0 t ha^{-1}) coarse fraction, thanks to the same rate of fine fraction exchange Ca in the soil is less: 857 mg kg^{-1}. Similar trends persist, when the lower (4.5 t ha^{-1}) Kalktrąšė rate was applied

Exchange Ca

Mg kg^{-1} of the soil



Before liming 0,5 years after 1 year after 1,5 years after 2 years after 2,5 years after 3 years after

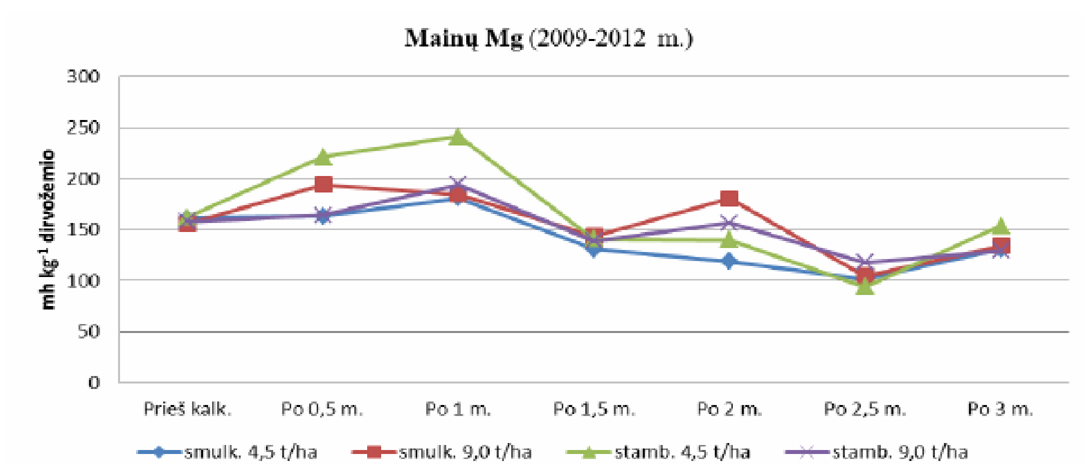
Fine fine coarse coarse

Fig. 6. Effect of Kalktrąšė on exchange Ca change in the soil
Vėžaičiai, 2009-2012

Kalktrąšė also demonstrated effect on exchange magnesium (Fig. 7). Exchange Mg due to both (4.5 and 9.0 t ha^{-1}) rates and different fractions (0.01-2 and 2.0-4.0 mm) in soil increased similarly to the exchange Ca both after one and two years. After three years thanks to Kalktrąšė both rates and both fractions exchange Mg levels in the soil were similar: 131-154 mg kg^{-1}.

Exchange Mg

mg kg^{-1} of the soil



Before liming 0,5 years after 1 year after 1,5 years after 2 years after 2,5 years after 3 years after

Fine fine coarse coarse

Fig. 7. Effect of Kalktrąšė on exchange Mg change in the soil
Vėžaičiai, 2009-2012

3.5. Effect of Kalktrąšė on red clover yield

Cultural plants tolerate differently the soil acidity. Depending on the acidity of the soil and plant sensitivity to acid soil reaction, thanks to the lime substances crop yield could double or increase even more (Legere et al., 1994).
In the limed soil with different fractions both Kalktrąšė rates both the first and second harvest yields were significantly higher compared with the unlimed soil (Table 3). The second yield showed the trend that Kalktrąšė's fine fraction gave higher clover dry matter yield compared with the more coarse lime substance fraction (Figure 8-12)..

Table 3. Effect of Kalktrąšė on red clover yield
Vežaičiai 2012

Option	Red clover dry matter yield, t ha^{-1}		
	1st harvest	2nd harvest	Annual
1. Unlimed	2.44	1.08	3.52
2. Kalktrąšė 0.5 n. (4.5 t ha^{-1}) fine fraction	6,06**	3,63**	9,69**
3. Kalktrąšė 1.0 n. (9.0 t ha^{-1}) fine fraction	5,73**	4,14**	9,87**
4. Kalktrąšė 0.5 n. (4.5 t ha^{-1}) coarse fraction	5,24**	3,47**	8,71**
5. Kalktrąšė 1.0 n. (9.0 t ha^{-1}) coarse fraction	6,08**	3,51**	9,59**
R_{05}	1,262	0,394	0,902

Note: ** – statistically significant at 99 % probability level.

According to studies, in the limed soil annual yield of red clover dry matter was 2.5 - 2.8 times higher compared with the unlimed.

CONCLUSIONS

After having evaluated the prevailing in western Lithuania naturally acidic (pH_{KCl} 4.42, 640 mg exchange Ca, hydrolytic acidity 62.4 mekv. kg^{-1}, mobile Al 77.7 mg kg^{-1}) moraine loam Dystric Albeluvisol chemical property changes due to granular lime Kalktrąšė different fractions (fine Ø 0.01 to 2.0 mm and coarse Ø 2.0-4.0 mm) level [(0.5 and 1.0 rates according to hydrolytic soil acidity (physical weight respectively 4.5 t ha^{-1} and 9.0 t ha^{-1})] three years after liming, the following conclusions can be drawn:

1. The fastest (six months after insertion) to neutralize the soil was both rates of Kalktrąšė fine fraction (0.5 and 1.0). Mobile Al dropped (from 77.7-60.7 mg kg^{-1} to 51.6-28.9 mg kg^{-1}) and hydrolytic acidity also dropped (from 59.4-62.4 mekv. kg^{-1} to 48.3-52.5 mekv.

kg^{-1}). After that, the soil reaction rate stabilized and soil neutralization went on independently from the Kalktrąšė fraction size.

2. Soil neutralizing effect depended on inserted content of Kalktrąšė. A year and a half after liming with the rate of 1.0 (9.0 t ha^{-1}) in both fractions soil acidity showed a down-trend. The highest soil neutralizing effect was observed at three years. Exchange Ca in the soil increased to 1101 mg kg^{-1}, pH_{KCl} to 4.9 and hydrolytic acidity decreased down to 29.9-41.9 mekv. kg^{-1}, and mobile aluminium remained at small and non-toxic level for the plants (2.3 to 7.1 mg kg^{-1}) .

3. Kalktrąšė rate of 0.5 (4.5 t ha^{-1}) was too small, because three years after liming the soil remained acidic pH_{KCl} was 4.4, hydrolytic acidity was 47.8-51.2 mekv. kg^{-1} , with a lot of mobile Al toxic for the plants 41.8-48.3 mg kg^{-1} and a few exchange Ca 697-850 mg kg^{-1}.

4. After having limed with Kalktrąšė two fractions 0.5 and 1.0 rates, annual yield of red clover dry matter was 2.5-2.8 times higher compared with the unlimed. Limed soil with Kalktrąšė 0.5 rate while remaining sour, created more favourable conditions for the red clover to grow and uptake the fertilizer.

Fig 8. Unlimed soil (ill-weeds prevail in the red clover) 2012
Fig. 9. Red clover in limed soil (Kalktrąšė 0,5 rate Ø 0,1-2,0 mm) 2012
Fig. 10. Red clover in limed soil (Kalktrąšė 0,5 rate Ø 2,0-4,0 mm) 2012
Fig. 11. Red clover in limed soil (Kalktrąšė 1,0 rate Ø 2,0-4,0 mm) 2012
Fig. 12. General Picture of the trial "Assessment of effect of Kalktrąšė in acid soils", 2012

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