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The influence of liming and organic fertilisation on the changes of some agrochemical indicators and their relationship with crop weed incidence

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Abstract

The current paper presents the results of experiments carried out at the Lithuanian Institute of Agriculture's Vėžaičiai Branch during the period 2005–2009 on a *Dystric Albeluvisol* (*ABd*). We explored the effects of farmyard manure, alternative organic and lime fertilisers on soil agrochemical indicators and their relationship with weed incidence in a crop rotation (winter wheat → lupine-oats mixture → winter oilseed rape → spring barley undersown with perennial grasses). Unlimed and farmyard manure – unfertilised soil was very acid, with a pH_{KCl} of 4.0–4.3, hydrolytic acidity of 56.32–68.11 mequiv kg^{-1} and mobile Al of 77.8–143.7 mg kg^{-1}. In unlimed soil applied with 40 and 60 t ha^{-1} rates of farmyard manure hydrolytic acidity declined to 56.78–40.52 mequiv kg^{-1}, the content of mobile Al dramatically declined to 39.3–8.5 mg kg^{-1}, pH_{KCl} increased to 4.3–4.6. Unlimed and farmyard manure-unfertilised soil contained 678–777.3 mg kg^{-1} of exchangeable Ca and 157.7–163.3 mg kg^{-1} of exchangeable Mg. In the soil fertilised with farmyard manure the content of exchangeable Ca increased by 1.4–2.8 times and that of exchangeable Mg by 1.0–1.5 times.

In limed soil, the acidity was most markedly reduced by lime fertilisers, only traces (1.0–0.9 mg kg^{-1}) of mobile Al were identified, a significant reduction in hydrolytic acidity occurred and pH_{KCl} increased. Through the application of all organic fertilisers hydrolytic acidity declined by 17–18%, pH_{KCl} value increased by 6–7%, compared with the limed soil. The highest increase (1.3–1.5 times) in exchangeable Ca content resulted from lime fertilisers, while exchangeable Mg content increased by up to 1.5 times. In limed and organically fertilised soil the highest contents of exchangeable Ca and Mg (2917.3–1949.0 mg kg^{-1} and 322.7–243.0 mg kg^{-1}) were recorded in the treatments applied with 60 t ha^{-1} of farmyard manure. Alternative organic fertilisers were not more effective than farmyard manure in reducing soil acidity.

The effects of the agricultural practices applied on the crop weed incidence manifested themselves in all experimental years. In the first year of organic fertiliser effect (in the winter wheat crop), strong correlations were established between soil agrochemical indicators and weed number and mass. In the second year of effect, due to the adverse weather conditions and poorer weed suppression capacity of lupine, the relationship between the number of weeds, their mass and individual agrochemical indicators was insignificant, except for that between weed mass and mobile Al content. Strong correlations were established in the third and fourth years of effect for winter oilseed rape and barley crops, respectively.

Key words: soil agrochemical indicators, liming, organic fertilisers, weed incidence indicators, correlation.

Introduction

Soil and climate conditions are major factors determining crop productivity. Liming of acid soils is one of the key practices that can conserve or even increase their productivity (Plesevičius, 1995; Mao et al., 2008; Lukjanova, Mandre, 2009). Lime fertilisers alter the mobility and build-up of some biogenic elements in the soil. In acid soil, fertiliser phosphorus is converted into alumo-phosphates, which are plant unavailable compounds. Liming renders less readily plant available phosphorus compounds into more readily available ones (Небольсин и др., 1998). High concentration of hydrogen ions present in the soil exerts a negative effect on the physical and chemical state of root cell protoplasm by inhibiting metabolism in it, which deteriorates plant nutrition conditions. Aluminium present in acid soil forms soluble compounds which have even more harmful impact not only on plant root system but also on the growth of the entire plant (Knašys, 1985; Небольсин, Небольсина, 1997).

To maintain soil potential productivity and produce a stable yield, one has to regularly replenish soil reserves with organic matter and control the intensity of their synthesis and destruction processes (Chalk, 1998). Farmyard manure (FYM) is the main fertiliser maintaining soil potential fertility since with its application the soil receives biogenic elements that are removed with grown produce. It takes a long time for the influence of FYM to stand out in the processes of soil fertility restoration.

In acid soils, the main chemical characteristics exerting significant effect on crop productivity are pH, hydrolytic acidity, and mobile Al content. The effect of FYM on the variation of these indicators mostly depends on its rates and application periodicity. At low soil acidity (pH 5.5), the effect of FYM on the mobile Al content and hydrolytic acidity is inappreciable. Application of 42–84 t ha^{-1} of FYM once or twice per rotation during a 12-year period did not cause any change in the soil pH value (Tripolskaja, 2005). FYM efficacy is especially evident in acid soils which are very high in mobile Al. A reduction in soil acidity values was established after a 21-year regular application (every 3–4 years) of 40 and 60 t ha^{-1} FYM. However, during that period, liming proved to be a more effective ameliorative practice for very acid *Dystric Albeluvisol* compared with FYM application. Only after 28 years, fertilisation at 40 and 60 t ha^{-1} FYM had the greatest effect on the reduction of hydrolytic acidity and mobile Al in the soil. After 47 years of regular FYM application it was found that 60 t ha^{-1} rate gave the greatest soil neutralisation effect: hydrolytic acidity declined to 55 ± 1.9 mequiv kg^{-1}, mobile Al to 13 ± 1.3 mg kg^{-1} (Plesevičienė et al., 1997; Repšienė et al., 2005).

FYM can be replaced by other organic fertilisers: green manure, straw or other plant residues that are left after crop harvesting. Comprehensive experimental evidence has been accrued in Lithuania on straw, green manure application for various purposes, such as to improve soil structure, increase soil productivity, reduce soil erosion, manage plant diseases and pests (Janušienė, 2000; Velička et al., 2000; Arlauskienė, Maikštėnienė, 2001).

Weed incidence in a field crop is determined by crop alternation, soil nutrient status and crop rotation structure. It is important to create adequate conditions for crop rotation plants. With diminishing soil acidity resulting from liming, the number of acidophilus weeds consistently declined (Čiuberkis, 2009), and the total number of weeds significantly (r = 0.84**–0.96**) depended on mobile Al content in the soil (Skuodienė, Repšienė, 2009). All organic fertilisers designed to ameliorate the soil were found to increase crop weed incidence; however, farmyard manure was responsible for a greater increase in weed incidence compared with legume biomass incorporated as green manure (Arlauskienė, Maikštėnienė, 2005).

The present study was aimed to establish the effects of farmyard manure, alternative organic and lime fertilisers on soil agrochemical indicators as well as the relationship between these indicators and crop weed incidence.

Materials and methods

Experimental site, soil, design. Experiments were conducted at the Lithuanian Institute of Agriculture's Vėžaičiai Branch during the period 2005–2009. The soil of the experimental site is *Dystric Albeluvisol* (*ABd*) with a texture of till. The trial was set up having reconstructed the long-term research (started in 1959) on FYM rates, having replaced the seven-course crop rotation (winter wheat, spring barley, oats, fodder beet, spring barley + undersown crops, perennial grasses of the 1st year of use, perennial grasses of the 2nd year of use) by the five-course crop rotation. The experimental design is presented in Table 1.

Perennial grasses (clover/timothy mixture) were sown in the spring of the year of trial reconstruction (2005) and winter wheat was sown in the autumn of the same year. The five-course crop rotation consisted of winter wheat (2006), lupine and oats mixture for green manure (2007), winter rape (2008), spring barley undersown with perennial grasses (2009), perennial grasses (red clover 90%, timothy mixture 10%) (2010). The total plot size amounted to 25.5 m^2 (4.25 × 6) and harvested area to 13.8 m^2 (2.3 × 6). The trial was replicated four times.

Table 1. Trial design

Treatment No.	Before reconstruction	After reconstruction	Treatment abbreviation
1	Unlimed and without FYM	Unlimed and without organic fertilisers	U
2	Limed and without FYM	Limed and without organic fertilisers	L
3	Unlimed and applied with 80 t ha^{-1} FYM	Unlimed and applied with 40 t ha^{-1} FYM	U-40
4	Limed and applied with 80 t ha^{-1} FYM	Limed and applied with 40 t ha^{-1} FYM	L-40
5	Limed and applied with 80 t ha^{-1} FYM	Limed and applied with alternative organic fertilisers	L-O1
6	Unlimed and applied with 120 t ha^{-1} FYM	Unlimed and applied with 60 t ha^{-1} FYM	U-60
7	Limed and applied with 120 t ha^{-1} FYM	Limed and applied with 60 t ha^{-1} FYM	L-60
8	Limed and applied with 120 t ha^{-1} FYM	Limed and applied with alternative organic fertilisers	L-O2

During the primary fertilisation back in 1959 when the trial was set up, 80 and 120 t ha^{-1} of FYM were applied in two applications divided into equal parts for the seven-course crop rotation (for winter wheat and fodder beet). After the reconstruction of the trial in 2005 (i.e. after six seven-course rotations), 40 and 60 t ha^{-1} FYM were incorporated in a single application (for winter wheat) in the five-course crop. Solid cattle manure was used. The following alternative organic fertilisers were employed: aftermath of perennial grasses (disked in and ploughed in at 15–20 cm depth in 2005), winter wheat straw (after wheat harvesting the straw was chopped and ploughed in at 10–15 cm depth in 2006), lupine and oats fresh mass (disked in and ploughed in at 15–20 cm after lupine pods had reached milk maturity in 2007), oilseed rape stubble and straw (after harvesting oilseed rape stubble and straw were chopped and incorporated by a cultivator and ploughed in at 15–20 cm depth in 2008).

On limed background, after each rotation (also after reconstruction) liming was applied repeatedly using powder limestone at one rate chosen according to the hydrolytic acidity.

Analyses and analytical methods employed. Soil analyses were done using the following techniques: mobile Al by Sokolov, hydrolytic acidity by Kappen, exchangeable Ca and Mg (A-L), pH_{KCl} potentiometrically. The soil for agrochemical analyses was sampled from 0–20 cm depth annually after harvesting. Soil agrochemical characteristics since the year 2005 are presented in Table 2.

Table 2. Agrochemical soil characteristics before the reconstruction of the trial in 2005

Treatment	Hydrolytic soil acidity mequiv kg^{-1}	pH_{KCl}	Mobile Al mg kg^{-1}	Exchangeable Ca mg kg^{-1}	Exchangeable Mg mg kg^{-1}
U	67.85	4.0	169.7	701.3	140.3
L	30.71	6.0	3.9	1560.0	224.0
U-40	58.62	4.1	93.3	933.3	142.7
L-40	10.97	6.0	0.6	3168.7	281.0
U-60	48.51	4.4	28.8	1186.7	170.3
L-60	14.86	6.0	2.4	2621.3	250.3

In solid FYM, Ca and Mg contents (1.25% and 0.59%, respectively) were determined trilonometrically.

Weed counts were carried out in 0.25 m^2 – sized sites in four places per each plot. Weed incidence in winter wheat plots was determined before harvesting at BBCH 79 (late milk maturity), in lupine-oats mixture when lupine pods had reached milk maturity and in winter wheat plots at BBCH 89 (complete maturity), in spring barley plots at BBCH 87–89 (hard and complete maturity). The weeds were pulled and weighed and species composition was determined.

Weather conditions. During the experimental period, the weather conditions were diverse (Figure). In 2006, vegetation was resumed on April 25.

The amount of precipitation during the growing season made up 56.9% of the long-term mean, and the mean air temperature was by 1.3ºC higher than the long-term mean. With dry weather prevailing and reducing moisture reserves in the soil, the conditions for winter wheat and weed emergence and growth were adverse.

In 2007, vegetation was resumed on March 26. Warm and wet weather prevailed during the growing season. The amount of precipitation that fell during the growing season amounted to 148.4% or 629.5 mm. Lupine and oats growth and development were adversely affected by the elemental hail that occurred on May 15 and the downpour on July 7–8. In terms of rainfall and temperature, September and October were similar to the long-term mean. Agro-meteorological conditions for winter oilseed rape and weed emergence and growth were favourable.

In 2008, vegetation was resumed on April 3, and according to temperature and precipitation it was similar to the long-term mean (mean temperature 13.4ºC, amount of precipitation 90.1%).

In 2009, vegetation was resumed on April 11. The amount of precipitation that fell during the growing season was 460.2 mm, which amounted to 108.5% of the long-term mean. The conditions for barley and weed growth were favourable.

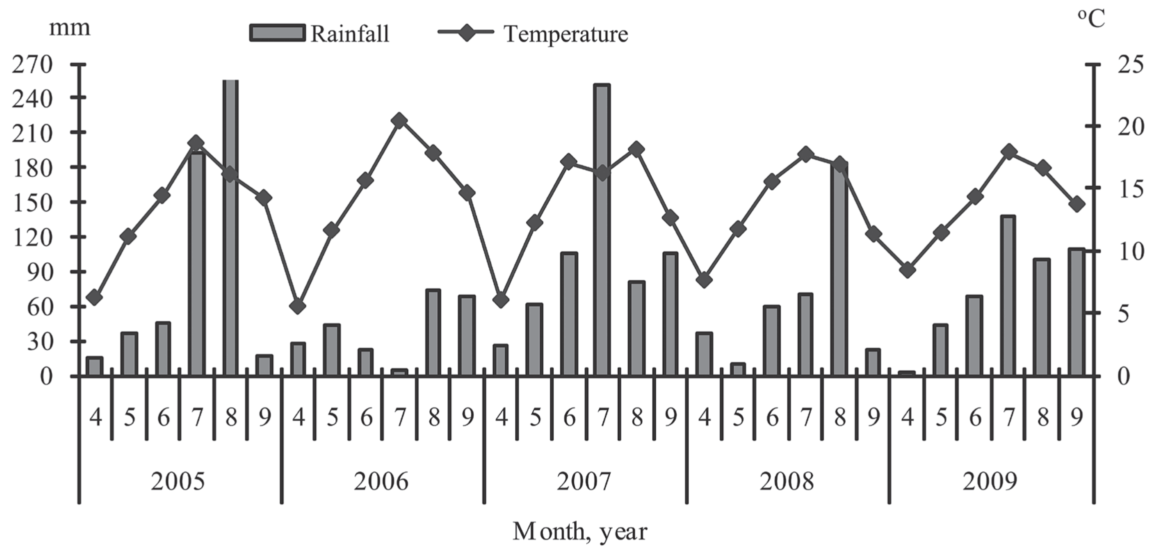

Figure. The amount of precipitation (mm) and mean air temperature (ºC) during the growing season (data from the Vėžaičiai Weather Station)

Statistical data analysis. The data were processed using the software package *Selekcija*. The soil pH (negative logarithm of hydrogen ion concentration) data were antilog-transformed from an *Anova* model then log-transformed again. The data of agrochemical indicators and weed incidence were estimated by the analysis of variance and correlation and regression analysis methods using the software *Anova* and *Stat-Eng*. Before analysis, the data of weed number and mass were transformed according to the formula $\sqrt{x+0.5}$ (Tarakanovas, Raudonius, 2003). The symbols used in the article * and ** denote statistically significant at 95% and 99% significance level, V % coefficient of variation, l – linear correlation, n – curvilinear correlation.

Results and discussion

The data from all rotation's annual tests (2005–2009) suggest that in unlimed and FYM-untreated soil hydrolytic acidity was the highest and in separate years varied from 56.32 to 68.30 mequiv kg^{-1}. The variation of this indicator per entire rotation was not high (V = 10.83%) (Table 3). Comparison of unlimed and FYM-untreated soil with limed soil revealed a significant reduction in hydrolytic acidity in all experimental years. Also, a significant reduction of this indicator was established in unlimed soil treated with 40 and 60 t ha^{-1} FYM compared with unlimed and FYM-untreated soil. In limed and FYM and organic fertiliser-applied soil a reduction of hydrolytic acidity was established, however, it was not significant, except for the year 2008. In limed and FYM and alternative fertiliser-applied soil the variation of hydrolytic acidity (2006–2009) was found to be high (V = 24.12–30.58%).

Table 3. Agrochemical soil indicators 2006–2009

Treatment	2006	2007	2008	2009	V %
Hydrolytic soil acidity mequiv kg^{-1}					
U	56.32	68.30	67.27	68.11	10.83
L	16.95	28.75	23.04	22.13	25.78
U-40	47.70	56.78	52.76	51.74	10.16
L-40	13.22	25.27	15.24	15.42	30.58
L-O1	12.93	25.04	16.48	15.65	29.20
U-60	40.52	55.08	51.41	50.08	12.03
L-60	15.23	22.54	14.75	13.87	24.45
L-O2	14.37	25.39	17.49	17.94	24.12
LSD_{05}	6.261	7.654	5.410	5.517	
Mobile Al mg kg^{-1}					
U	134.4	79.6	143.7	77.8	33.7
L	0.9	0.0	1.0	0.0	180.0
U-40	39.3	17.4	32.0	15.0	42.8
L-40	0.3	0.0	0.5	0.0	182.3
L-O1	0.3	0.0	0.0	0.0	341.9
U-60	20.1	8.5	23.6	13.8	66.4
L-60	0.0	0.0	0.0	0.0	26.6
L-O2	0.3	0.0	0.1	0.0	286.2
LSD_{05}	16.243	15.079	14.381	12.506	
Exchangeable Ca mg kg^{-1}					
U	758.0	777.3	678.0	732.7	12.5
L	2089.7	2126.3	1681.7	1631.7	14.1
U-40	1242.0	1185.0	1922.3	1045.0	12.0
L-40	2565.7	2481.0	1983.7	1927.7	15.4
L-O1	2561.3	2667.3	1940.3	1900.0	18.2
U-60	1528.7	1366.3	1231.0	1022.3	21.6
L-60	2917.3	2797.3	2239.3	1949.0	17.8
L-O2	2435.3	2405.3	1932.3	1655.0	17.4
LSD_{05}	338.320	319.504	197.128	249.760	
Exchangeable Mg mg kg^{-1}					
U	162.3	163.3	163.3	157.7	11.2
L	229.0	240.7	207.0	209.7	12.4
U-40	202.0	205.7	159.0	181.3	14.7
L-40	313.7	276.3	236.3	245.7	13.3
L-O1	291.0	299.3	236.7	261.7	11.7
U-60	219.7	228.0	187.7	173.7	16.5
L-60	322.7	310.3	256.0	243.0	16.9
L-O2	279.3	283.3	227.0	210.0	17.5
LSD_{05}	49.35	39.30	29.897	49.570	

In all experimental years, mobile Al analysed were made using the same Sokolov method, but ranking the data showed a marked (V = 33.7%) Al content variation both in unlimed and unfertilised treatments and in the other treatments. In unlimed soil, the contents of mobile Al were very high 134.4–77.8 mg kg^{-1}, in limed soil Al was found only at trace levels 1.0–0.9 mg kg^{-1}, or zero level (bound). In unlimed soil, fertilised with 40 and 60 t ha^{-1} FYM, the content of mobile Al declined to 39.3 and 8.5 mg kg^{-1}. In limed soil, both FYM and alternative organic fertilisers practically did not have any effect on mobile Al. Mobile Al is much more toxic to plants than hydrogen (Gallego, Benito, 1997). In acid soil, liming eliminates mobile Al in the topsoil layer and long-term regular application of only FYM markedly improves plant growing conditions since Ca and Mg present in the soil bind mobile Al (Минеев, Ремре, 1990; Fuentes et al., 2006).

Soil acidity has the greatest impact on calcium in the soil. Acidic soils are low in calcium, while in neutral or slightly neutral soils calcium occurs at higher concentrations. Plants need calcium since the very emergence. It is vital for normal growth of roots and above-ground plant organs. If there is a shortage of calcium, roots are deprived of the ability to elongate because of which plants cannot utilise nutrients from deeper soil layers (Čermak, Klement, 2005). Experimental evidence suggests that exchangeable Ca variation was moderate, the coefficient of variation (V) varied from 11.98% to 21.60%. In unlimed and unfertilised soil, exchangeable Ca amounted to 678.0–777.3 mg kg^{-1}. In limed soil, the content of Ca increased by 2.2–2.76 times compared with that in unlimed soil. In unlimed soil fertilised with 40 and 60 t ha^{-1} FYM, exchangeable Ca status was by 1.4–2.8 times higher, compared with unlimed and FYM-untreated soil. In separate years, in limed and fertilised with 40 t ha^{-1} FYM and alternative (O1) fertilisers soil calcium contents were similar. In limed and fertilised with 60 t ha^{-1} FYM soil, exchangeable Ca contents were the highest 2917.3–1949.0 mg kg^{-1}, and compared with the soil applied with alternative fertilisers calcium contents were lower 2435.3–1655.0 mg kg^{-1}. Annual incorporation of alternative fertilisers did not replenish the soil with calcium as much as single FYM application.

Magnesium is a vital element in plant photosynthesis, since it is a constituent of chlorophyll. Plants take up magnesium from the soil, and when acid soils are limed they take magnesium from lime fertilisers or from magnesium-containing fertilisers. Very acid and moderately acid soils contain the lowest levels of Mg, while slightly neutral (pH 6.1–6.5) and close to neutral and alkaline (pH 6.6 and more) soils contain much higher concentrations of Mg (Lietuvos dirvožemių…, 1998). Experimental findings indicate that Mg variation was moderate (V = 11.2–17.5%). In unlimed and FYM-unfertilised soil, exchangeable Mg content amounted to 157.7–163.3 mg kg^{-1}. In limed and unfertilised soil, exchangeable Mg content was 1.3–1.5 times higher compared with that in unlimed and unfertilised soil. In unlimed and fertilised with 40 and 60 t ha^{-1} FYM soil, exchangeable Mg content was 1.0 and 1.5 times higher compared with unfertilised soil. In limed and FYM (40 and 60 t ha^{-1}) and alternative-fertiliser applied (O1, O2) soil exchangeable Mg varied in a similar patter to that of exchangeable Ca.

Experimental data evidenced that long-term and regular FYM application on unlimed soil tended to reduce soil acidity, which was also found to decline in limed soil fertilised with 40 and 60 t ha^{-1} FYM. No significant differences between FYM rates (40 and 60 t ha^{-1}) and alternative fertilisers (O1 and O2 treatments) in terms of their effects on acidity indicators (pH, mobile Al, hydrolytic acidity) and exchangeable Ca and Mg were observed.

According to pH_{KCl} indicator, unlimed and FYM-unapplied soil was very acid (pH 4.2–4.0). In unlimed and FYM-applied soil, pH_{KCl} was 4.6–4.3 (Table 4).

Table 4. Soil pH_{KCl} during 2006–2009

Treatment	2006	2007	2008	2009
U	4.2	4.1	4.0	4.2
L	6.1**	5.7**	5.5**	5.5**
U-40	4.4**	4.5**	4.3**	4.5**
L-40	6.3**	6.0**	6.0**	6.0**
L-O1	6.3**	6.0**	6.0**	6.0**
U-60	4.6**	4.5**	4.4**	4.5**
L-60	6.3**	6.0**	6.0**	6.0**
L-O2	6.2**	6.0**	6.0**	5.9**

Limed and organic fertiliser-unapplied soil in separate years varied from slightly neutral (pH_{KCl} 6.1) to slightly acid (pH_{KCl} 5.5). In limed and FYM and alternative organic fertiliser-applied soil pH_{KCl} totalled 6.3–5.9.

To neutralise soil acidity, annual alternative organic fertiliser incorporation was not superior to a single FYM application in the crop rotation. The effects of the practices applied on the crop rotation weed incidence manifested themselves in all experimental years. The data of FYM rates research done at the LIA's Vėžaičiai Branch suggest that before the trial reconstruction, i.e. in the fourth and fifth rotation (1981–1995), with increasing FYM rate, weed number and mass in the rotation crops on acid soil tended to decline, while in limed soil they tended to increase and weed botanical composition tended to change (Plesevičienė et al., 1997). However, in the seventh rotation, where duration of the rotation and plants had been changed and various organic fertilisers had been used, other trends were also observed. The highest total average weed number and mass (185.8 weeds m^{-2} and 152.9 g m^{-2}) were established in unlimed, organic fertiliser-unapplied plot. A reduction in the mobile Al content in the soil and changes in other soil indicators resulting from liming gave 46.6% reduction in the total weed number in the crops and 56.8% reduction in weed mass. Having fertilised limed plots with FYM and alternative organic fertilisers, crop growing conditions improved, which resulted in a higher competitive power of crops and caused a reduction of the total weed incidence: weed number declined by 18.1% and 6.7%, however, weed dry matter mass increased by 10.2% and 5.8% respectively, compared with limed and organic fertiliser-unapplied plot. Having applied FYM on unlimed plots weed number and mass declined by 40.5% and 31.1%, compared with unlimed and organic fertiliser-unapplied treatment (Skuodienė, Repšienė, 2009).

Short-lived weeds prevailed in the rotation crops. They accounted for on average 89.1% of the total weed number. Of the short-lived weeds the most prevalent ones in all experimental years were *Viola arvensis* (Murray) and *Capsella bursa-pastoris* (L.) Med.

Analysis of the individual crops' weed incidence showed that in the winter wheat crop significantly lower (70.6–74.0% or 61.0–69.0 weeds m^{-2}) weed counts were identified in limed and organic fertiliser-applied plots, compared with unlimed and organic fertiliser-unapplied plot (Table 5).

Table 5. The effect of organic fertilisers and liming on the weed incidence in the crop rotation during 2006–2009

Treatment	Weeds							
	Winter wheat		Lupine-oats mixture		Winter rape		Spring barley	
	number m^{-2}	DM mass g m^{-2}	number m^{-2}	DM mass g m^{-2}	number m^{-2}	DM mass g m^{-2}	number m^{-2}	DM mass g m^{-2}
U	234.5	262.5	257.0	68.4	69.0	100.0	182.7	180.8**
L	88.2**	128.3**	153.3*	35.8*	29.5**	59.4	126.3	40.3**
U-40	176.0*	239.6	160.5	55.4	25.0**	97.0	135.3	43.5**
L-40	62.5**	188.8**	126.1**	53.8	25.0**	55.4	100.7**	31.5**
L-O1	69.0**	173.7**	186.5	68.7	28.0**	27.4	90.0**	24.5**
U-60	138.6**	206.4**	136.5*	50.3	33.5**	119.9	91.3**	30.3**
L-60	65.0**	133.3**	148.0*	65.2	22.0**	25.4*	101.3**	28.5**
L-O2	61.0**	136.4**	177.0	63.4	25.5**	36.3	121.3*	29.0**

Significantly lowest (128.3 g m^{-2}) total weed mass was recorded in limed organic fertiliser-unapplied plot, where nutrition conditions were poorer for cultivated crop also. The highest weed mass (262.5 g m^{-2}) was determined in unlimed, organic fertiliser-unapplied plot, where acidophilus weeds *Scleranthus annus* L. and *Spergula arvensis* L. accounted for 65.3% of the total weed mass.

The correlation regression analysis shows that in the first year of organic fertiliser effect, i.e. in the winter wheat crop, weed number strongly correlated with the soil agrochemical parameters tested: mobile Al, hydrolytic acidity, Ca and Mg contents, and H_{KCl}. With reducing Al content and hydrolytic soil acidity and increasing pH_{KCl} indicator, Ca and Mg contents, the number of weeds tended to decline. In all the cases, the correlation was significant at 99% significance level. Weed dry matter mass was also influenced by soil agrochemical properties, except for Mg content in the soil. The correlations were significant at 95% and 99% significance level. These relationships are reflected by the equations of linear regression (Table 6). It is evident from the equations of regression that with an increase in pH_{KCl} indicator by 1 unit the weed number declined by 64.7 weeds m^{-2}, and weed mass by 46.0 g m^{-2}.

Lupine-oats mixture was the most heavily weed-infested crop rotation stand (on average 173.7 weeds m^{-2}). It is maintained that lupine germination period is long and leaves cover soil surface later, as a result of which weed smothering power of lupine is weaker (Weik et al., 2002). The findings of weed number and mass in the mixture were inconsistent. Significantly fewer weeds were established in a limed plot applied with 40 t ha^{-1} FYM. A trend was noted that in limed soil the effect of alternative organic fertilisers on the spread of weeds was lesser than that of FYM. Averaged data suggest that alternative organic fertiliser, i.e. winter wheat straw insignificantly (by 33.8%) increased weed number compared with FYM.

Table 6. The relationship of soil agrochemical indicators with weed incidence indicators during 2006–2009

Weed incidence indicators (y)	Soil agrochemical indicators (x)	Parameters of equation y = a + bx		*r*
		a	b	
Winter wheat				
Number of weeds m^{-2}	Mobile Al mg kg^{-1}	80.407	1.28	0.919**l
	Hydrolytic soil acidity mequiv kg^{-1}	5.073	2.869	0.993**l
	pH_{KCl}	469.924	−64.693	−0.955**l
	Exchangeable Ca mg kg^{-1}	278.707	−0.083	−0.967**l
	Exchangeable Mg mg kg^{-1}	372.619	−1.033	−0.916**l
Dry matter mass of weeds g m^{-2}	Mobile Al mg kg^{-1}	162.31	0.868	0.801*l
	Hydrolytic soil acidity mequiv kg^{-1}	109.385	1.995	0.888**l
	pH_{KCl}	438.384	−46.027	−0.874**l
	Exchangeable Ca mg kg^{-1}	296.675	−0.056	−0.843**l
	Exchangeable Mg mg kg^{-1}	338.838	0.615	−0.701 n
Lupine-oats mixture				
Number of weeds m^{-2}	Mobile Al mg kg^{-1}	147.981	1.285	0.861**l
	Hydrolytic soil acidity mequiv kg^{-1}	119.336	1.212	0.545 n
	pH_{KCl}	287.34	−22.395	−0.482 n
	Exchangeable Ca mg kg^{-1}	220.763	−0.028	−0.516 n
	Exchangeable Mg mg kg^{-1}	281.207	−0.46	−0.568 n
Dry matter mass of weeds g m^{-2}	Mobile Al mg kg^{-1}	55.786	0.132	0.323 n
	Hydrolytic soil acidity mequiv kg^{-1}	56.385	0.032	0.053 n
	pH_{KCl}	57.374	0.046	0.004 n
	Exchangeable Ca mg kg^{-1}	55.45	0.001	0.075 n
	Exchangeable Mg mg kg^{-1}	48.88	0.035	0.157 n
Winter oilseed rape				
Number of weeds m^{-2}	Mobile Al mg kg^{-1}	24.804	0.29	0.959**l
	Hydrolytic soil acidity mequiv kg^{-1}	15.469	0.514	0.73*l
	pH_{KCl}	89.773	−10.886	−0.651 n
	Exchangeable Ca mg kg^{-1}	64.175	−0.02	−0.741*l
	Exchangeable Mg mg kg^{-1}	83.027	−0.244	−0.587 n
Dry matter mass of weeds g m^{-2}	Mobile Al mg kg^{-1}	54.412	0.426	0.582 n
	Hydrolytic soil acidity mequiv kg^{-1}	15.464	1.537	0.901**l
	pH_{KCl}	265.895	−37.886	−0.936**l
	Exchangeable Ca mg kg^{-1}	157.649	−0.058	−0.882**l
	Exchangeable Mg mg kg^{-1}	250.041	−0.884	−0.879**l
Spring barley				
Number of weeds m^{-2}	Mobile Al mg kg^{-1}	24.885	0.539	0.966**l
	Hydrolytic soil acidity mequiv kg^{-1}	15.369	0.524	0.748*l
	pH_{KCl}	101.794	−13.139	−0.672 n
	Exchangeable Ca mg kg^{-1}	64.955	−0.022	−0.71*l
	Exchangeable Mg mg kg^{-1}	85.743	−0.255	−0.641 n
Dry matter mass of weeds g m^{-2}	Mobile Al mg kg^{-1}	54.646	0.783	0.58 n
	Hydrolytic soil acidity mequiv kg^{-1}	16.735	1.518	0.894**l
	pH_{KCl}	299.022	−44.084	0.932**l
	Exchangeable Ca mg kg^{-1}	166.333	−0.068	−0.903**l
	Exchangeable Mg mg kg^{-1}	241.983	−0.841	−0.873**l

Significantly lowest (35.8 g m^{-2}) total weed mass, like in the winter wheat crop, was recorded in a limed plot not applied with organic fertilisers. Averaged data showed that it was the highest in unlimed and organic fertiliser-unapplied plot and in limed and alternative organic fertiliser-applied (K-A1) plots where acidophilus weeds accounted for the largest share of the total mass: 59.1% *Scleranthus annus* L. and *Scleranthus annus* L. and 38.7% *Chenopodium album* L.

Statistical analysis of weed number and mass relationship with individual agrochemical indicators in the lupine-oats mixture shows that the correlation was insignificant, except for that between weed mass and mobile Al content. This relationship is statistically significantly reflected by the linear regression equation (Table 6), which suggests that with an increase in mobile Al in the soil by one mg kg^{-1}, weed number increases by 1.3 m^{-2}.

A clear effect of the practices investigated was noted in the third and fourth years of effect, i.e. after ploughing down lupine-oats mixture.

Winter oilseed rape was the least weed-infested (on average 34.4 weeds m^{-2}) crop in the rotation sequence. The lower weed number in the winter oilseed rape crop resulted from the fact that by filling in the ecological niche, due to its biological characteristics it exhibits higher competitive power (Velička, Trečiokas, 2002). The total weed number changed only inappreciably through the application of various soil improvement measures. Significantly lowest total weed number and mass (22.0 weeds m^{-2} and 25.4 g m^{-2}) were established when winter oilseed rape had been grown in limed and 60 t ha^{-1} FYM-applied soil where winter oilseed rape growing conditions were the best. The differences in weed dry matter mass between limed and unlimed plots were distinct, but not significant. The highest weed mass was recorded in unlimed and FYM-applied plots, where weed mass was determined by the acidophilus weed *Scleranthus annus* L. (43.5–62.0%).

Correlation regression analysis indicates that in the winter oilseed rape crop weed number significantly correlated with soil mobile Al, hydrolytic acidity and Ca content, and weed mass correlated with hydrolytic acidity, Ca and Mg content and pH_{KCl} indicator. The correlations were significant at 95 and 99% significance level.

Tripleurospermum perforatum (Merat.) M. Lainz. became widespread in the winter oilseed rape crop. If at the beginning of rotation in winter wheat and lupine-oats crop *Tripleurospermum perforatum* (Merat.) M. Lainz. amount and mass made up 9.0% and 12.5% and 4.8% and 4.5%, respectively, in oilseed rape crop this made up 18.7% and 42.0%. Some researchers have reported that one of the negative traits of the crop rotation with a large winter oilseed rape area is the spread of *Tripleurospermum perforatum* (Merat.) M. Lainz. (Velička, Trečiokas, 2002).

In the spring barley crop, the number of weeds was several times higher than that in winter oilseed rape. Significantly lowest total weed number and mass (90 weeds m^{-2} and 24.5 g m^{-2}) was in the limed and alternative fertiliser-applied plot. Soil application with various organic fertilisers and liming significantly improved spring barley growth conditions, therefore cereals were able to better compete with weeds.

The correlation regression analysis showed that in the fourth year of effect, like in the third year, weed number and mass significantly correlated with the same agrochemical soil indicators.

While estimating correlation regression analysis of crop rotation weed incidence and agrochemical indicators it must be noted that in all experimental years, except for the second year of effect, weed number and mass was significantly influenced by hydrolytic soil acidity and exchangeable Ca content in the soil. The correlation of weed incidence indicators with hydrolytic soil acidity was established to be strong and positive and with exchangeable Ca content the correlation was strong and negative. This means, that with increasing soil hydrolytic acidity more weeds emerge and their mass is higher, and with increasing exchangeable Ca content in the soil, fewer weeds emerge and their mass tends to be lower.

Conclusions

1. Unlimed and FYM-unapplied soil was very acid pH_{KCl} 4.0–4.3, with a very high hydrolytic acidity of 56.32–68.11 mequiv kg^{-1} and mobile Al content of 77.8–143.7 mg kg^{-1}. In unlimed and applied with 40 and 60 t ha FYM soil, hydrolytic acidity declined to 56.78–40.52 mequiv kg^{-1}, a dramatic reduction occurred in aluminium content to 39.3–8.5 mg kg^{-1}, and pH_{KCl} increased to 4.3–4.6. In unlimed and FYM-unapplied soil, exchangeable Ca amounted to 678–777.3 mg kg^{-1}, exchangeable Mg to 157.7–163.3 mg kg^{-1}. In the soil fertilised with FYM, exchangeable Ca content increased by 1.4–2.8 times and that of exchangeable Mg by 1.0–1.5 times.

2. In limed soil, lime fertilisers were responsible for the greatest reduction in soil acidity; only traces (1.0–0.9 mg kg^{-1}) of mobile Al were found, hydrolytic acidity significantly declined and pH_{KC} increased. All organic fertilisers applied gave a reduction of hydrolytic acidity of 17–18%, and an increase of pH_{KCl} of 0.2–0.4 units compared with limed soil. Exchangeable Ca content increased most (1.3–1.5 times) through lime fertilisers and that of exchangeable Mg by up to 1.5 times compared with unlimed soil. In limed and organic fertiliser-applied soil the highest contents of exchangeable Ca and Mg (2917.3–1949.0 mg kg^{-1} and 322.7–243.0 mg kg^{-1}) were found in the treatments applied with 60 t ha^{-1} FYM. Alternative organic fertilisers were not more effective than manure in reducing soil acidity.

3. Statistically significant correlations were established between the soil agrochemical indicators tested and weed number and mass in grain cereal and winter oilseed rape crops. Strong (r = 0.801*–0.993**) correlations at 99% significance level were established in the first year of organic fertiliser effect (FYM and green manure) in the winter wheat crop. In the second year of effect, due to unfavourable weather conditions and lupine weaker competitive power against weeds, the relationship between individual agrochemical indicators and weed number and mass was not significant for the lupine-oats mixture, except for the relationship between weed mass and mobile Al content. In the third and fourth years of effect, strong correlations (r = 0.71**–0.966**) at 95% and 99% significance level were established for winter oilseed rape and spring barley respectively, except for the relationships between weed number and pH_{KCl} value, exchangeable Mg content and weed mass and mobile Al content.

4. Hydrolytic soil acidity and exchangeable Ca content in the soil exerted a significant effect on the number and mass of weeds in the rotation crops in all experimental years, except for the second year of effect. Crop weed incidence parameters strongly and positively correlated with hydrolytic soil acidity (r = 0.73*–0.993**) at 95% and 99% significance level, and strongly negatively with exchangeable Ca content (r = −0.71*–−0.967**) at 95% and 99% significance level.

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Kalkinimo bei organinių trąšų įtaka dirvožemio agrocheminių rodiklių pokyčiams ir jų ryšys su pasėlių piktžolėtumu

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Santrauka

Straipsnyje pateikti tyrimai atlikti Lietuvos žemdirbystės instituto Vėžaičių filiale 2005–2009 m. moreninės kilmės lengvo priemolio nepasotintajame balkšvažemyje (JIn), *Dystric Albeluvisol* (*ABd*). Tirta mėšlo, alternatyvių organinių bei kalkinių trąšų įtaka dirvožemio agrocheminiams rodikliams ir šių rodiklių ryšys su pasėlių piktžolėtumu sėjomainoje (žieminiai kviečiai → lubinų ir avižų mišinys → žieminiai rapsai → vasariniai miežiai su daugiamečių žolių įsėliu). Nekalkintas ir netręštas mėšlu dirvožemis buvo labai rūgštus – pH_{KCl} 4,0–4,3, hidrolizinis rūgštumas – 56,32–68,11 mekv. kg^{-1}, judrusis Al – 77,8–143,7 mg kg^{-1}. Nekalkintame ir patręštame 40 bei 60 t ha^{-1} mėšlo dirvožemyje hidrolizinis rūgštumas sumažėjo iki 56,78–40,52 mekv. kg^{-1}. Ypač sumažėjo judriojo Al kiekis – iki 39,3–8,5 mg kg^{-1}, pH_{KCl} padidėjo iki 4,3–4,6. Nekalkintame ir netręštame mėšlu dirvožemyje mainų Ca nustatyta 678–777,3 mg kg^{-1}, mainų Mg – 157,7–163,3 mg kg^{-1}. Tręštame mėšlu dirvožemyje mainų Ca (1,4–2,8 karto) ir mainų Mg (1,0–1,5 karto) kiekis padidėjo.

Kalkintame dirvožemyje rūgštumą labiausiai mažino kalkinės trąšos, judriojo Al liko tik pėdsakai – 1,0–0,9 mg kg^{-1}, iš esmės sumažėjo hidrolizinis rūgštumas ir padidėjo pH_{KCl}. Nuo visų naudotų organinių trąšų hidrolizinis rūgštumas sumažėjo 17–18 %, pH_{KCl} rodiklis padidėjo 6–7 %, palyginti su kalkintu dirvožemiu. Nuo kalkinių trąšų labiausiai padidėjo mainų Ca (1,3–1,5 karto) kiekis, mainų Mg – iki 1,5 karto. Kalkintame ir tręštame organinėmis trąšomis dirvožemyje mainų Ca ir Mg daugiausia (2917,3–1949,0 mg kg^{-1} ir 322,7–243,0 mg kg^{-1}) buvo panaudojus 60 t ha^{-1} mėšlo. Alternatyvios organinės trąšos nebuvo veiksmingesnės už mėšlą dirvožemio rūgštumui sumažinti.

Sėjomainoje taikytų priemonių įtaka pasėlių piktžolėtumui pasireiškė visais tyrimų metais. Pirmaisiais organinių trąšų poveikio metais (žieminių kviečių pasėlyje) tarp tirtų dirvožemio agrocheminių rodiklių ir piktžolių skaičiaus bei jų masės nustatyti stiprūs koreliaciniai ryšiai. Antraisiais poveikio metais dėl nepalankių meteorologinių sąlygų ir lubinų silpnesnio piktžolių stelbimo piktžolių skaičius ir jų masės priklausomumas nuo kai kurių agrocheminių rodiklių buvo neesminis, išskyrus tarp piktžolių masės ir judriojo Al kiekio. Trečiaisiais ir ketvirtaisiais poveikio metais (atitinkamai žieminių rapsų ir vasarinių miežių pasėliuose) nustatyti stiprūs koreliaciniai ryšiai.

Reikšminiai žodžiai: dirvožemio agrocheminiai rodikliai, kalkinimas, organinės trąšos, piktžolėtumo rodikliai, koreliacinis ryšys.