NARDI FUNDULEA, ROMANIA ROMANIAN AGRICULTURAL RESEARCH, NO. 34, 2017
www.incda-fundulea.ro Print ISSN 1222-4227; Online ISSN 2067-5720

ORGANIC FERTILIZERS EFFECT ON CROP WEEDINESS IN ACID AND LIMED SOILS

Regina Skuodienė[*], Regina Repšienė, Danutė Karčauskienė

Vėžaičiai Branch, Lithuanian Research Centre for Agriculture and Forestry
Gargždų 29, Vėžaičiai, Klaipėda distr., Lithuania
[*]Corresponding author. E-mail: regina.skuodiene@vezaiciai.lzi.lt

ABSTRACT

Field experiments on crop weediness were carried out at Vėžaičiai Branch of Lithuanian Research Centre for Agriculture and Forestry during the period 2010-2014. The study was conducted in the long-term naturally acid and limed *Bathygleyic Distric Glossic Retisol* formed on medium-moraine loam. The study was aimed to determine the weed variation tendencies in acid soils after liming and fertilizing with different organic fertilizers.

A long-term fertilization with farmyard manure and organic fertilizers unequally affected the amount of weeds and their mass in crops of the rotation.

During the stage of shooting, weed germination was more intense and the number of weeds was greater by 15% than in the stage of maturity. After liming, the amount of mobile Al decreased and the weed number decreased by 17%. Significant impact of liming on the weed number was determined in stands of winter wheat and spring barley. In the stage of shooting, organic fertilization did not have significant influence on weediness indicators (weed number and number of weed species).

Due to unequal nutrition and growth conditions of weeds in limed soil in the stage of crop maturity, the weed number and their mass decreased, respectively by 30.7% and 58.7% compared to unlimed soil. Organic fertilizers differently affected the weediness of crops of the rotation. The most significant effect of organic fertilizers was in the second year of use and in the fourth year the differences were insignificant. In the treatments fertilized with farmyard manure the weed number and mass were lower for the first two years. The use of the green manure on the background of different farmyard manure rates increased weed number in crops of the rotation.

Key words: soil acidity, organic fertilizers, crop rotation, weed number and mass.

INTRODUCTION

Lithuania has recently been subject to traditional crops, as winter oilseed rape and cereals, and perennials dropped. Soil degradation is observed especially in the western part of Lithuania.

Ecologically sensitive automorphic moderately podzolized sod-podzolic soil on moraine loam (till) are prevailing in the Western Lithuania. This soil is very acid (pH_{KCl} 3.9-4.2) in whole profile to the 160 cm depth and amount of toxic mobile aluminium is very large both in the topsoil and subsoil (respectively 100-300 mg kg^{-1}). The deficiency in clay (<0.002 mm), cations of Ca, Mg and organic colloids is the main factor that influences the stability of structure in the soil (Motuzas et al., 2009).

All these reasons hamper the formation of food, water and warmth regime for the best usage of genotype potential in the soil. The improvement and conservation of this soil fertility are the strategic directions of research (Ozeraitiene, 2002). It is important to keep nutrient reserves in the soil with organic matter. Acid soil liming is one of the most important factors that can conserve and even increase soil fertility (Kristek et al., 2015). Harmful effect of soil acidity on agricultural plants can be avoided by using organic fertilizers. Together with farmyard manure various macro- and microelements, microorganisms and physiologically active matters are incorporated into the soil. Therefore, organic fertilizers have the impact on all characteristics of the soil - agrochemical, physical, microbiological, humidity and air regime (Repšienė and Skuodienė, 2010).

Weeds are both harmful for crop production and important for biodiversity,

Received 27 April 2016; accepted 7 February 2017. First online: April, 2017. DII 2067-5720 RAR 2017-67

while herbicides can pollute the environment (Colbach et al., 2014). In an agricultural system, the aim is to produce the highest yield achievable whilst minimising costs. In comparison with pests and diseases, weeds have the potential to incur the greatest yield loss, through competition with the crop and decreasing yield quality, and can, therefore, incur high costs of control (Oerke, 2006).

Changes of weed specific composition (biodiversity) are influenced by crop rotation, fertilization with organic and mineral fertilizers, technologies, agrotechniques and the use of herbicides (Ulbert et al., 2009; Repšienė and Skuodienė, 2010; Andreasen and Streibig, 2011; Harasim et al., 2014). Multispecies crop rotations, intercrops and cover crops may reduce opportunities for weed growth and regeneration through resource competition and niche disruption (Liebman and Davis, 2000).

Direct (physical) weed control can only be successful where preventive and cultural weed management is applied to reduce weed emergence (e.g. through appropriate choice of crop sequence, tillage, smother/cover crops) and improve crop competitive ability (e.g. through appropriate choice of crop genotype, sowing/planting pattern and fertilization strategy) (Bàrberi, 2002). Weeds tend to aggregate in patches within fields, and there is evidence that this is partly due to variation in soil properties (Metcalfe et al., 2016).

Acid soil liming and fertilization with organic fertilizers change soil characteristics as well as plant growth conditions (Skuodienė and Repšienė, 2009). The research conducted on a *Bathygleyic Distric Glossic Retisol* showed that in the first year of organic fertilizer 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 content 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. 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} (Repšienė and Skuodienė, 2010).

The aim of the study was to determine the weed variation tendencies in acid soils after liming and fertilizing with different organic fertilizers.

MATERIAL AND METHODS

Site and soil description

The soil of the experimental site is *Bathygleyic Distric Glossic Retisol* (WRB 2014) formed on medium-moraine loam. The trial was established in 2010 in a long-term experimental trial (since 1959) of farmyard manure rates. The five-course crop rotation consisted of swards (2010), winter wheat var. ʻŠirvintaʼ (2011), lupine var. ʻDerliaiʼ and oats var. ʻBelindaʼ mixture (2012), spring rape var. ʻAcherasʼ (2013), spring barley var. ʻLuokėʼ with undersown swards (2014), swards (red clover var. ʻSadūnaiʻ and timothy var. ʻŽolisʻ (2015). The total plot size was 8.5 m×3 m=25.5 m^2. The harvested area amounted to 15 m^2 (6 m×2.5 m). The trial was replicated four times. Treatments in the replications were randomised.

Trial factors and treatments

Factor A – Soil acidity: 1) unlimed soil, 2) limed soil.

Factor B – Organic fertilizers: 1) without organic fertilizers (control treatment), 2) green manure or plant residues, 3) farmyard manure 40 t ha^{-1}, 4) green manure (on the background of 40 t ha^{-1} farmyard manure (bkgd of FYM 40)), 5) farmyard manure 60 t ha^{-1}, 6) green manure (on the background of 60 t ha^{-1} farmyard manure (bkgd of FYM 60)).

In a long-term experimental trial of farmyard manure rates starting from 1959 to 2005, 80 and 120 t ha^{-1} of farmyard manure were incorporated 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, 40 and 60 t ha^{-1} of farmyard manure were incorporated in a single application (for winter wheat) in the five-course crop whereas in the fourth and sixth treatments the manure was not applied. Solid cattle manure was used containing 14.53% of dry matter, 17.83 of organic matter, 0.42% of total nitrogen N, 0.27% P_2O_5, 0.67% K_2O, 2668 mg kg^{-1} Ca, 692 mg kg^{-1} Mg, pH_{KCl} 8.5.

The following alternative organic fertilizers were employed: in 2010 the aftermath of swards was disked in at 15 cm and ploughed in at 20 cm depth. In 2011, after wheat harvesting the straw was chopped, incorporated at 15 cm and ploughed in at 20 cm depth. In 2012, the green mass of lupine and oats was disked in at 15 cm and ploughed in at 20 cm depth after lupine pods had reached milk maturity. In 2013, after rape harvesting the stubble and straw were chopped and incorporated by a cultivator at 15 cm and ploughed in at 20 cm depth.

On limed background, in 2010 liming was applied repeatedly using powder limestone at one rate chosen according to the hydrolytic acidity.

All treatments were equally fertilized with mineral fertilizers (background fertilization). The rate of fertilizer $N_{60}P_{60}K_{60}$ have been applied for winter wheat and spring barley stands, $N_{30}P_{60}K_{60}$ – for lupine-oats mixture, $N_{60}P_{90}K_{120}$ – for winter rape stand. Fungicides and insecticides were used in case of necessity; herbicides were not used at all. Conventional soil tillage was applied. Soil agrochemical characteristics of plots without organic fertilizers before trial establishment are presented in Table 1.

Table 1. Soil agrochemical characteristics at experiment established in 2010

Variable	Unlimed soil	Limed soil
pH_{KCl}	4.00	5.52
Mobile Al mg kg^{-1}	117.5	0.4
Mobile P_2O_5 mg kg^{-1}	205.0	139.7
Mobile K_2O mg kg^{-1}	216.0	145.3
N_{Total}	0.125	0.137

Methods of analysis

Weed record was performed in stationary areas of 0.25 m^{-2} in size in four positions of every plot during crop shooting and maturity stage. During the first record, weed specific composition was determined, during the second record, the weeds were eradicated and their specific composition and dry matter mass were determined. Weed number was recalculated unit per m^{-2} and mass - g m^{-1}. Due to poor conditions for germination and growth of spring rape stand (2013), ecological niches formed and conditions for weed spread were the most favourable. Therefore, the weediness data of the second record (maturity stage) are not presented.

Soil pH_{KCl} was estimated using potentiometric method, N_{tot} – using Kjeldahl method, mobile P_2O_5 and K_2O – using Egner-Riehm-Domingo (A-L) method, mobile Al – using Sokolov method.

Agrometeorological conditions

The spring in 2010 was late. In April, not cold and dry weather prevailed, and in May it was warm and rainy. Adequate soil moisture and warm weather had a positive influence on the growth of perennial grasses. The rainy weather of June was replaced by a heat wave in July. The compacted soil dried off and cracked. The moisture content at a depth of seedbed on July 12 was 5.9-7.5%, which is below the plant wilting humidity. Although the amount of rainfall that fell during the summer was 43% higher than the long-term mean, its distribution was very uneven.

The spring in 2011, the prevailing weather was dry (in March the precipitation was 40%, in April 93% and in May 85% of the long-term mean). The average air temperature of spring period was close to the long-term mean.

The spring in 2012 was warm and dry. The average temperature in April and May exceeded the long-term mean respectively by 0.7°C and 1.9°C while the amount of rainfall was 21% less than the long-term mean. In spring time, the temperature and the amount of rainfall were close to the long-term means. However, the rainfall distribution was very uneven. The autumn was warm and wet. Humid and warm weather conditions during the period of vegetation in 2013 were favourable for the growth of spring rape. The spring in 2014 was warm and dry. During the intensive plant growth period in May and June, it was dry and cool, and especially dry was the month of July. The amount of rainfall was only 33.8 mm or 38% of norm. Dry weather lasted until the 11th of August. In the second decade of August after the abundant rainfall, conditions for swards growth and development improved.

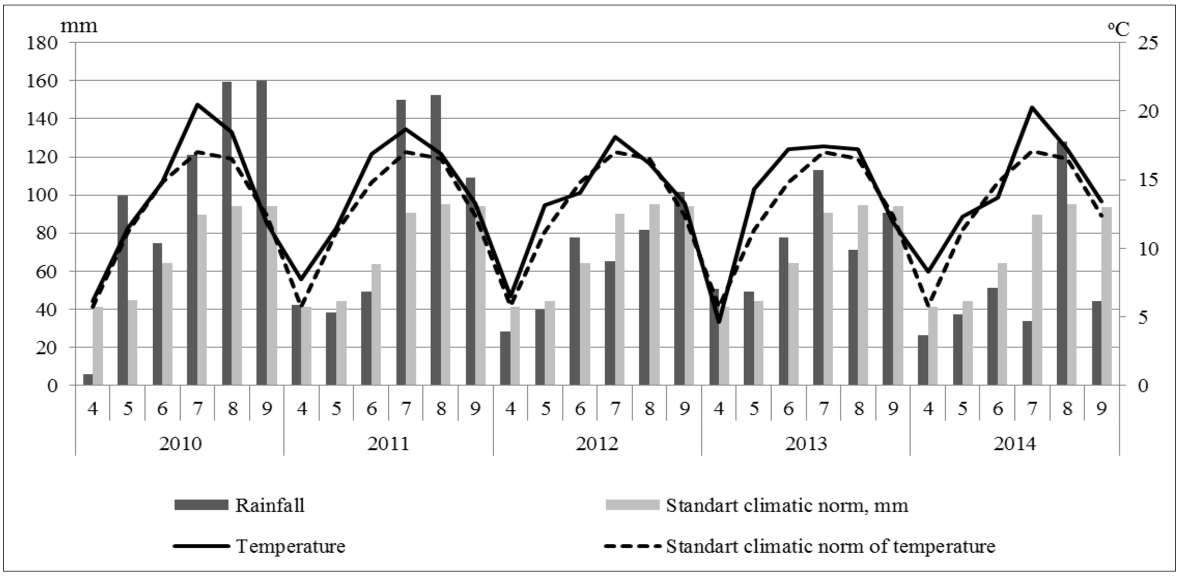

Figure 1. The amount of rainfall (mm) and mean air temperature (°C).
Data from the Vėžaičiai Meteorological Station

The experimental data were analysed by a two-factor analysis of variance recommended in agronomy science. Significance of the differences between the means was determined according to the least significant difference (LSD) at 0.05 probability level. The data were processed using software *ANOVA* (Clewer and Scarisbrick, 200). Data of weed density and biomass were transformed, according to Y = Sqr (x + 1); however, means on the original scales are reported (Onofri et al., 2010). Correlation-regression analysis was also performed.

RESULTS AND DISCUSSION

The amount of mobile Al in the soil

Soil acidity is a major factor that affects the growth of many crops throughout the world (Rengel, 2015).

The greatest amount of mobile Al (122.36-133.33 mg kg^{-1}) was determined in unlimed soil without organic fertilization (Table 2). Systematically inserting farmyard manure (40 and 60 t ha^{-1}) to unlimed soil, the amount of mobile Al significantly decreased in all experimental year compared to the soil without manure.

Table 2. The amount of mobile aluminium in the soil mg kg^{-1}

Treatment	Unlimed soil		Limed soil	
	2011	2013	2011	2013
Without organic fertilizers	122.36	133.33	0.00**	0.00**
Green manure or plant residues	122.36	93.67**	0.00**	0.00**
Farmyard manure 40 t ha^{-1}	17.51**	43.67**	0.00**	0.00**
Green manure (bkgd of FYM 40)	22.32**	27.50**	0.00**	0.00**
Farmyard manure 60 t ha^{-1}	4.64**	16.53**	0.00**	0.00**
Green manure (bkgd of FYM 60)	18.14**	37.03**	0.00**	0.00**
$LSD_{05\,(2011)}$ 9.029, $LSD_{05\,(2013)}$ 26.695				

In limed soil mobile Al was not determined at all. Liming eliminates mobile Al from the top layer of the soil. Plant growth conditions can be improved systematically applying only the farmyard manure as well as there are Ca and Mg in the manure, which link the mobile Al (Fuentes et al., 2006).

The yield of swards

Swards were grown to maintain soil fertility and crop productivity in crop rotation (2010).

In the first year of growth, a long-term systematic liming and fertilization with farmyard manure had the impact on their growth and development (Table 3). The greatest dry matter yield (7.19 t ha^{-1}) of swards was in limed soil, fertilized with 60 t ha^{-1} farmyard manure. In unlimed soil without organic fertilizers the yield of swards was 27% lower. In limed soil the amount of clover dry matter yield was determined greater (64.1-66.6%) compared to unlimed soil. Other researchers indicate a positive liming influence on dry matter yield of swards as well (Šiaudinis et al., 2014).

Table 3. Dry matter yield of swards (DM t ha^{-1}) and botanical composition of swards %

Treatment	Unlimed soil		Limed soil	
	DM yield (t ha^{-1})	Clover (%)	DM yield (t ha^{-1})	Clover (%)
Without organic fertilizers	5.26	52.1	6.35**	64.1
Farmyard manure 40 t ha^{-1}	6.35**	60.1	6.78**	66.3*
Farmyard manure 60 t ha^{-1}	6.59**	58.9	7.19**	66.6*

* and ** - the least significant at p< 0.05 and p< 0.01, respectively

Significance of the effect of soil acidity and organic fertilization for weediness according to F-test

Consistent patterns of associations are typical for crops. Intra and interspecific competition shows up in them. In a *Bathygleyic Distric Glossic Retisol* a long-term fertilization with farmyard manure and fertilization with organic fertilizers unequally affected weed number and mass in stands of crop rotation. Data of the analysis show that soil acidity (factor A) and organic fertilizers (factor B) as well as their interaction according to F-test (weed number, mass and number of species) had the significant influence on crop weediness during the stage of maturity (Table 4).

Table 4. Significance of the effect of liming and organic fertilizers on weed infestation parameters according to *F*-test

Investigation period	Indicators of weed incidence	Year	Actions and interactions		
			A	B	A × B
1	2	3	4	5	6
Shooting	Weed number	2011	37.94**	ns	ns
		2012	ns	ns	ns
		2013	ns	ns	ns
		2014	5.27*	ns	ns
Maturity	Weed number	2011	26.81**	3.85*	ns
		2012	23.05**	6.93**	4.85**
		2014	ns	ns	ns
Maturity	DM mass	2011	77.59**	8.11**	5.37**
		2012	13.91**	4.15**	6.4**
		2014	160.42**	6.37**	6.23**
Shooting	Number of species	2011	ns	ns	ns
		2012	ns	ns	ns
		2013	ns	ns	ns
		2014	ns	ns	ns
Maturity	Number of species	2011	ns	ns	ns
		2012	14.12**	10.37**	ns
		2014	22.88**	ns	ns

* and ** - the least significant at p< 0.05 and p< 0.01, respectively; ns - not significant.

Soil acidity and organic fertilization impact on weed germination

During the shooting stage crops are still developing so they cannot compete with weeds (Romaneckienė et al., 2008). According to the average data, in the first year of agro-measures application winter wheat stand was the least weedy in limed as well as in unlimed soil, respectively: 92.7 and 177.6 unit m^{-2} weeds. In unlimed soil, during the shooting stage in winter wheat (2011) and in spring barley stands (2014) (when germination of weeds is the most intensive) the weed number was significantly greater compared to crops in limed soil, respectively: by 91.6 and 12.2% (Table 5).

Table 5. The effect of soil acidity and organic fertilizers on the weeds emergence (weeds m^2)

Treatment	Winter wheat 2011	Lupine-oats mixture 2012	Spring rape 2013	Spring barley 2014
Soil acidity (factor A)				
Unlimed soil	177.6	204.3	184.0	370.2
Limed soil	92.7**	180.3	169.6	330.0*
Organic fertilizers (factor B)				
Without organic fertilizers	139.3	198.0	163.7	345.7
Green manure or plant residues	155.0	219.3	183.0	399.3
Farmyard manure 40 t ha^{-1}	113.7	205.7	180.0	325.7
Green manure (bkgd of FYM 40)	136.3	170.3	203.3*	313.0
Farmyard manure 60 t ha^{-1}	120.7	164.7	179.3	353.0
Green manure (bkgd of FYM 60)	145.7	196.0	151.3	364.0
Interaction of factors A × B				
A1 × B1	194.7	234.7	194.0	375.3
A1 × B2	210.7	266.0	193.3	407.3
A1 × B3	144.0	193.3	172.7	338.7
A1 × B4	153.3	171.3	208.7	330.7
A1 × B5	148.0	139.3*	192.7	371.3
A1 × B6	214.7	221.3	142.7*	398.0
A2 × B1	84.0**	161.3	133.3*	316.0
A2 × B2	99.3*	172.7	172.7	391.3
A2 × B3	83.3**	218.0	187.3	312.7
A2 × B4	119.3	169.3	198.0	295.3
A2 × B5	93.3*	190.0	166.0	334.7
A2 × B6	76.7**	170.7	160.0	330.0

* - significant at $p \leq 0.05$, ** - significant at $p \leq 0.01$.

In unlimed soil, lupine-oats mixture (2012) and spring rape stands (2013) were weedier as well, respectively: by 13.3 and 8.5%. It should be noted that spring barley with undersown red clover and timothy mixture generally forms a good competitive ability and has positive tendency to reduce crop weediness (Skuodienė et al., 2016). However, the investigation accomplished in 2014 showed that in the first part of plant vegetation period spring barley with undersown clover and timothy mixture was the weediest (on the average 350.1 unit m^{-2}). That could be determined by late sowing of spring rape which formed sparse crop due to unfavourable meteorological conditions in 2013. References indicate that after germination spring rape stand develops slowly. Differently from winter rape, the stage of rosette of spring rape lasts up to 40 days, therefore the competitive ability of spring rape stand is decreased (Velička and Trečiokas, 2002). Due to unfavourable conditions for germination, ecological niches form in stands of cultural plants, consequently the conditions for weed spread are the most favourable (Benvenuti, 2004).

Paying a lot of attention to reduce the environment pollution it is very important to apply soil fertility conditioning measures, i.e. to use organic fertilizers. Analysing only the impact of organic fertilization it can be observed that organic fertilization did not have a significant impact on weediness indicators in the stage of shooting (Table 5). The obtained differences were within the error limits. According to the average data, the application of red clover - timothy mixture or other plant residues for the green manure had a tendency to increase the weed number in crop stands for three in four years of investigation. In the treatments fertilized with farmyard manure and in those applied with green manure on the background of different farmyard manure rates (40 and 60 t ha^{-1}), the weed number data were less consistent. The obtained differences were within the error limits.

The effect of examined factors interaction on weed number significantly showed up in the first year of agro-measures application in the stand of winter wheat. Independently from the organic fertilization that was applied, the weed number was 22.2-64.3% lower in many ways in limed compared to unlimed soil.

Weed number and their dry mass at crop maturity stage

The intensity of weed germination was changing during the warm season of the year. Crop weediness data before harvesting showed that conditions of different years determined the impact of examined means on the weed number and mass. During the period of vegetation, starting from crop shooting untill the maturity, the weed number in stand of winter wheat (the second part of vegetation in 2011 was warm and wet) remained similar (Table 6). Lupine-oats mixture (2012) in the stage of maturity was the weediest (moderately 291.3 unit m^{-2}) culture of the rotation sequence. It is stated that lupine grass germinate a long time, therefore the leaves later cover the surface of the soil and their competitive ability is weaker (Weik et al., 2002). In 2014, when the weather was warm and dry and competitive ability of spring barley with undersown red clover and timothy mixture was better, the weed number decreased 2.9 times in limed and 3.3 times in unlimed soil.

The effect of soil acidity on the weed infestation in crops remained during the stage of maturity as well. In unlimed soil in winter triticale stand (2011) the weed number before harvesting was greater by 79.8%, in lupine-oats mixture (2012) - by 35.7%, in spring barley stand (2014) - by 29.1% compared to limed soil (Table 6). A similar tendency was observed analysing the data of the weed dry matter mass. In unlimed soil in winter wheat stand the weed mass was greater 3.2 times, in lupine-oats mixture - 1.7 times and in spring barley stand - 8.4 times compared to limed soil.

Analysing only the impact of organic fertilization on crop weediness it can be observed that fertilization with farmyard manure reduced weed number and mass for the first two years. Green manure application on the background of different farmyard manure rates increased the weed number in crops of the rotation.

Organic fertilizers had the greatest effect on the second member of the rotation (lupine-oats mixture (2012)). The greatest weed number (356.7 unit m^{-2}) and mass (122.7 g m^{-2}) were estimated in the mixture without organic fertilizers. The weed number and mass in the mixture were moderately 1.3 and 1.9 times less in the soil fertilized with organic fertilizers.

Due to the interaction of the investigative factors, the growing conditions of plants of the rotation improved in limed soil fertilized with organic fertilizers. Better competitive ability of crops of the rotation determined weediness decrease. The weed number in a square metre and their dry matter mass were significantly lower in many ways compared to unlimed plots without organic fertilization.

Organic fertilization reduced crop weediness in unlimed soil as well, especially in the mixture of lupine-oats. The weaker effect of organic fertilization was in stands of winter wheat where the green manure was inserted on the background of different farmyard manure rates. In these plots the weed number was significantly greater. However, in the plots fertilised with farmyard manure the weed number decrease was noticed. Other authors indicate the opposite data about the impact of manure on crop weediness (Arlauskienė and Maikštėnienė, 2004). Fertilization with farmyard manure did not have the effect on the weed number in stand of spring barley. The obtained differences were within the error limits. Fertilizing with different rates of farmyard manure or using the green manure on the background of different farmyard manure rates the data of weed mass were less consistent.

Table 6. The effect of soil acidity and organic fertilizers on the weed infestation in the crops of the rotation during the maturity stage

Treatment	Winter triticale 2011		Lupine-oats mixture 2012		Spring barley 2014	
	number/ m^{-2}	mass of DM ($g\ m^{-2}$)	number/ m^{-2}	mass of DM ($g\ m^{-2}$)	number/ m^{-2}	mass of DM ($g\ m^{-2}$)
Soil acidity (factor A)						
Unlimed soil	182.1	101.6	335.4	96.6	127.3	71.4
Limed soil	101.3**	32.0**	247.2**	57.9**	98.6	8.54*
Organic fertilizers (factor B)						
Without organic fertilizers	137.3	83.1	356.7	122.7	98.0	38.5
Green manure or plant residues	128.7	90.5	348.3	97.1	123.7	62.2
Farmyard manure 40 t ha^{-1}	92.7*	35.6**	256.7**	70.1*	112.0	28.9
Green manure (bkgd of FYM 40)	177.7	42.1**	243.3**	45.3**	110.3	27.7
Farmyard manure 60 t ha^{-1}	116.3	41.4**	222.7**	63.7*	105.3	14.8*
Green manure (bkgd of FYM 60)	197.7	108.0	320.2	64.5**	128.3	68.8
Interaction of factors A × B						
A1 × B1	152.0	117.1	460.7	192.2	99.3	65.6
A1 × B2	153.3	154.7	434.0	144.1	166.7	115.4*
A1 × B3	107.3	46.3**	257.3**	76.9**	107.3	49.2
A1 × B4	249.3*	56.3**	267.3**	56.0**	128.7	45.5
A1 × B5	136.0	53.7**	204.7**	66.6**	126.7	23.6**
A1 × B6	294.7*	181.8*	388.7	43.4**	135.3	129.2**
A2 × B1	122.7	49.0**	252.7**	53.2**	96.7	11.4**
A2 × B2	104.0	26.4**	262.7**	50.0**	80.7	6.93**
A2 × B3	78.0*	25.0**	256.0**	53.2**	116.7	8.55**
A2 × B4	106.0	28.0**	219.3**	34.6**	92.0	9.89**
A2 × B5	96.7	29.0**	240.7**	60.7**	84.0	6.03**
A2 × B6	100.7	34.3**	251.7**	85.6**	121.3	8.43**

*- significant at $p \leq 0.05$, ** - significant at $p \leq 0.01$

Weed number variety in crops of the rotation during the period of plant vegetation

The results of the investigation showed that soil acidity and organic fertilization changed the variety of weed species (Table 7). The greatest number of weed species (7-10 species) was estimated in lupine-oats mixture and the lowest number (4 species) - in stand of winter wheat. Due to better nutrition and plant growth conditions in limed soil the insignificant tendency of weed species increase was noticed except for the spring barley stand in the stage of maturity when the amount of precipitation during vegetation period was less than standard climate norm.

In the crops of all experimental years the annual weeds dominated (96.4%). In limed plots there were slightly more annual weeds than in unlimed plots, respectively by 97.6 and 95.8%. Also, a variation of weed population was noticed during the plant vegetation period. In the first part of vegetation, independently from soil acidity, there were more annual weeds compared to the stage of crop maturity, respectively by 98.7 and 93.2%.

Crop weediness depended not only on soil acidity, crop management measures application but also on the other factors (biological characteristics of plant species, the weediness of precrop, meteorological conditions). The significant indicator of meteorological conditions is the amount of precipitation during the plant vegetation period (Harasim et al., 2014; Skuodienė et al., 2016). Statistical analysis of the investigation results showed that linear correlation between the amount of precipitation in the stage of shooting (x) and number of weeds or number of species (y) was strong (r=0.87* and 0.94**), and in the stage of maturity it was strong negative (r=-0.91* and -0.96**). During all vegetation period in 2012, the weeds spread more abundantly due to favourable meteorological conditions.

Table 7. Number of weeds species, units

Treatment	Winter triticale 2011		Lupine-oats mixture 2012		Spring barley 2014	
	Shooting	Maturity	Shooting	Maturity	Shooting	Maturity
Soil acidity (factor A)						
Unlimed soil	4.2	6.2	7.2	10.1	7.7	6.0
Limed soil	4.4	6.9	7.8	11.2**	7.7	4.2**
Organic fertilizers (factor B)						
Without organic fertilizers	3.8	6.8	6.9	9.9	7.0	5.3
Green manure or plant residues	3.7	5.9	7.8	10.5	7.4	5.2
Farmyard manure 40 t ha^{-1}	4.8	6.1	7.5	10.0	7.9	4.8
Green manure (bkgd of FYM 40)	4.1	7.0	7.8	10.3	8.1	5.1
Farmyard manure 60 t ha^{-1}	4.9	6.4	7.4	10.0	8.1	4.5
Green manure (bkgd of FYM 60)	4.6	6.8	7.4	13.0**	7.8	5.9
Interaction of factors A × B						
A1 × B1	4.0	6.0	6.5	10.0	6.5	6.0
A1 × B2	3.0	5.0	7.2	9.3	6.7	6.0
A1 × B3	5.0	6.3	7.2	9.8	8.3	5.5
A1 × B4	3.7	6.7	6.8	9.3	8.8*	6.3
A1 × B5	4.7	6.0	7.7	9.3	8.5*	5.3
A1 × B6	4.7	7.0	8.0	12.7**	7.5	7.0
A2 × B1	3.7	7.7	7.3	9,8	7,5	4,7
A2 × B2	4.3	6.8	8.5*	11,7*	8,2	4,3
A2 × B3	4.5	5.8	7.8	10,2	7,5	4,2
A2 × B4	4.5	7.3	8.8**	11,3	7,3	3,8*
A2 × B5	5.2	6.8	7.2	10,7	7,7	3,7*
A2 × B6	4.5	6.7	6.8	13,3**	8,0	4,8

*- significant at p≤0.05, ** - significant at p≤0.01.

Soil acidity and applied organic fertilizers had the impact on the weed specific composition. *Spergula arvensis* L. dominated in winter wheat stand during the shooting stage (2011) and in lupine-oats mixture (2012) in unlimed soil without farmyard manure and *Viola arvensis* Murray dominated in unlimed soil fertilized with farmyard manure or the other organic fertilizers (on the background of different farmyard manure rates) as well as in limed soil. Similarly in 2011 and 2012, *Poa annua* L. was abundantly found in limed soil and in 2012 - *Capsella bursa-pastoris* (L.) Medik. as well. In spring rape stand (2013) due to unfavourable development conditions for agricultural plants, acidophilic weeds *Spergula arvensis* L., *Scleranthus annuus* L. dominated in unlimed soil and *Chenopodium album* L., *Capsella bursa-pastoris* (L.) Medik. - the weeds fond of soil full of nutrients - dominated in limed soil. Similar tendency persisted in 2014. Acidophilic weeds *Spergula arvensis* L. dominated in unlimed soil and *Chenopodium album* L., *Erophila verna* (L.) Besser. dominated in limed soil where nutrient supply for plants is better.

In the later part of vegetation period i.e. plant maturity, a similar tendency persisted as during the shooting stage. In all experimental year, acidophilic weeds *Spergula arvensis* L. or *Scleranthus annuus* L. dominated in limed soil without farmyard manure. In unlimed soil fertilized with farmyard manure or other organic fertilizers (on the background of different farmyard manure rates) as well as in limed soil in 2011 *Viola arvensis* Murray dominated, in 2012 - *Tripleurospermum perforatum* (Merat.) M. Lainz. and in 2014 - *Chenopodium album* L.

CONCLUSIONS

The influence of the crop management measures applied in crop rotation was significant in all experimental years. Liming and fertilizing with organic fertilizers changed soil characteristic as well as the plant growth conditions.

A long-term fertilization with farmyard manure and organic fertilizers in a *Bathygleyic Distric Glossic Retisol* formed on medium-moraine loam unequally affected weed quantity and mass in stands of crop rotation.

During the shooting stage the weeds were germinating more intensively, their number was 15% greater than during the stage of crop maturity. After liming, the amount of mobile aluminium decreased and the number of weeds decreased by 17%. The main influence of liming on the weed number was determined in stands of winter wheat and spring barley. Organic fertilization did not have significant influence on the weediness indicators (number of weeds and their species) during the shooting stage.

Due to unequal weed nutrition and growth conditions during the crop maturity stage in limed soil the weed number decreased by 30.7% and their mass by 58.7%, compared to unlimed soil. Different organic fertilizers had unequal influence on the weediness of crops of the rotation. The greatest effect of organic fertilizers showed up in the second year of treatment and in the fourth year the differences were not significant. Fertilization with farmyard manure reduced weed number and mass for the first two years. Green manure application on the background of different farmyard manure rates increased weed number in crops of the rotation.

Acknowledgments

The paper presents research findings, obtained through the long-term research programme "Productivity and sustainability of agricultural and forest soils" implemented by Lithuanian Research Centre for Agriculture and Forestry.

REFERENCES

Andreasen, C., Streibig, J.C., 2011. *Evaluation of changes in weed flora in arable fields of Nordic countries - based on danish long-term surveys*. Weed Research, 51(3): 214-226.

Arlauskienė, A., Maikštėnienė, S., 2004. *The effects of preceding crops and organic fertilizers on the occurrence of short-lived weeds in different agrosystems*. Zemdirbyste-Agriculture, 88: 102-116.

Bàrberi, P., 2002. *Weed management in organic agriculture: are we addressing the right issues?* Weed Research, 42(3): 177-193.

Benvenuti, S., 2004. *Weed Dynamics in the Mediterranean Urban Ecosystem: Ecology, Biodiversity and management*. Weed research, 44: 341-354.

Clewer, A. G., Scarisbrick, D. H., 2001. *Practical statistics and experimental design for plant and crop science*. New York, USA, 346 p.

Colbach, N., Biju-Duval, L., Gardarin, A., Granger, S., Guyot, S.H.M., Eziere, D.M., Munier-Jolain, N.M., Petit, S., 2014. *The role of models for multicriteria evaluation and multiobjective design of cropping systems for managing weeds*. Weed Research, 54: 541-555.

Fuentes, J. P., Bezdicek, D. F., Flury, M., Albrecht, S., Smith, J.L., 2006. *Microbial activity affected by lime in a long-term no-till soil.* Soil and Tillage Research, 88(1-2): 123-131.

Harasim, E., Wesołowski, M., Kwiatkowski, C., 2014. *The effect of reduced growth retardant rates on weed infestation of a winter wheat* (*Triticum aestivum* L.) *crop*. Romanian Agricultural Research, 31: 271-281.

Kristek, S., Jović, J., Rašić, S., Kraljičak, Ž., Antinac, I., 2015. *The influence of liming and organic fertilization on microbial activity in the soil*. Proceedings of the 9th International Symposium on Plant-Soil Interactions at Low pH. 18-23.10.2015., Dubrovnik, Croatia: 16-17.

Liebman, M., Davis, A.S., 2000. *Integration of soil, crop and weed management in low-external-input farming systems.* Weed Research, 40(1): 27-47.

Metcalfe, H., Milne, A.E., Webster, R., Lark, R.M., Murdoch, A.J., Storkey, J., 2016. *Designing a sampling scheme to reveal correlations between weeds and soil properties at multiple spatial scales*. Weed Research, 56: 1-13.

Motuzas, A.J., Buivydaitė, V., Vaisvalavilčius, R., Šleinys, R., 2009. *Dirvotyra.* Enciklopedija. Vilnius.

Oerke, E.C., 2006. *Crop losses to pests*. Journal of Agricultural Science, 144(1): 31-43

Onofri, A., Carbonell, E.A., Piepho, H.P., Mortimer, A.M., Cousens, R.D., 2010. *Current statistical issues in Weed Research*. Weed Research, 50: 5-24.

Ozeraitienė, D., 2002. *Possibility of optimal reaction and stable structure conservation in ecologically sensitive soils*. Proceedings of the third International Congress Man and soil at the Third Millennium, Logrono: 727-735.

Rengel, Z., 2015. *Acid soils, climate change and greenhouse gas emissions*. Proceedings of the 9th International Symposium on Plant-Soil Interactions at Low pH: 2-3.

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

Romaneckienė, R., Pilipavičius, V., Romaneckas, K., 2008. *Weed emergence and death in the crop of spring barely of different competitive ability*. Agricultural Sciences, 15(1):17-24.

Šiaudinis, G., Karčauskienė, D., Šlepetienė, A., 2014. *The impact of lime and nitrogen fertilization on cocksfoot and reed canary grass productivity in Albeluvisol and energy evaluation of their cultivation technology.* Zemdirbyste-Agriculture, 101(4): 403-410.

Skuodienė, R., Karčauskienė, D., Repšienė, R., 2016. *Influence of soil tillage and their combinations with deep loosening and organic fertilizers on crop weediness*. Zemdirbyste-Agriculture, 103(2): 135-142.

Skuodienė, R., Repšienė, R., 2009. *The effects of organic fertilizers and liming on segetal flora in a sustainable crop rotation on acid soil*. Zemdirbyste-Agriculture, 96(4): 154-169.

Ulber L., Steinmann H.H., Klimek S., Isselstein J., 2009. *An on-farm approach to investigate the impact of diversified crop rotations on weed species richness and composition in winter wheat*. Weed Research, 49: 534-543.

Velička, R., Trečiokas, K., 2002. *Influence of winter and summer rape on crop weediness in different rotations*. Vagos, 53(6): 31-40.

Weik L., Kaul H. P., Kübler E., 2002. *Grain yields of perennial grain crops in pure and mixed stands*. Journal of Agronomy and Crop Science, 188: 342-349.