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MANURING EFFECT ON THE SOIL PROPERTIES AND CROP ROTATION YIELD

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Abstract

The paper summarizes the data of the long-term field trials and laboratory analyses done at the Vėžaičiai Branch of the Lithuanian Institute Agriculture during 1999-2002. The soil of the experimental site is *Dystric Albeluvisol* with a morain loam texture. The data of the sixth rotation in the seven-field rotation system show that the acidity of unlimed morain loam soil decreased under the effect of all manure rates: 20, 40, 80, 120 t ha^{-1}. In limed soil manure had almost no effect on soil acidity parameters. A significant increase in mobile P_2O_5 and K_2O in unlimed soil was obtained from the highest manure rates (80 and 120 t ha^{-1}), whereas in limed soil the amount of nutrients increased from all manure rates. The long-term manuring had a positive effect on the physical state of both acid and limed morain loam soil. The best aeration and moisture conditions in the soil-plant system were obtained when liming and manuring by the highest rates (80 and 120 t ha^{-1}) had been applied. Incorporation of all manure rates per rotation had a positive effect on the crop rotation yield in limed soil, while in unlimed soil the yield of the crop rotation was increasing under the effect of the highest manure rates (80 and 120 t ha^{-1}). In terms of crop yield, similar effectiveness of systematic manuring by the highest manure rates (80 and 120 t ha^{-1}) and liming was observed in the sixth crop rotation.

Key words: manure rates, soil properties, crop rotation yield.

Introduction

The type of soils predominant in West Lithuania – unsaturated – *Dystric Albeluvisol* have acid reaction, contain a lot of mobile Al that is toxic for plants, and a low content of absorbed bases. By liming such soils, the potential and exchange acidities are neutralised, the quantities of mobile aluminium toxic to the plants decrease, the quantities of absorbed bases, mobile phosphorus, potassium, nitrogen, some micro-elements increase, the activities of micro-organisms improve, mineral fertilizers have stronger effect /Nebolsin, Nebolsina, 1997; Šilnikov et al., 1997; Chriznikova, 1998; Mažvila et al., 2003/. Long-term and systematic manuring decreases the soil acidity and increases absorption capacity. In the course of manuring various macro- and micro-elements, physiologically active substances, micro-organisms are introduced into the soil together with organic substance /Plesevičienė et al., 1997; Tripolskaja, 1999/. Therefore manure has some impact on almost all properties of soil – agrochemical, physical, microbiological, humidity and air conditions /Poulton, 1995; Tripolskaja, 1999; Čiuber-kienė, Ežerinskas, 2000; Simanavičienė et al., 2001/. Manure contains all main nutrients, however their quantities are not sufficient to satisfy the needs of plants in the optimal way. In order to ensure the most favourable plant nutrition mode, the soil requires mineral fertilizing /Mineev, Rempe, 1990/. The data obtained by foreign and Lithuanian researchers show that when applying the organic – mineral fertilization to rotation plants, the highest and sustainable crop yields are ensured, steady quantities of humus in the soil are sustained /Kurniševa et al., 1996; Vaneka et al., 1997; Žukov, Sorokina, 1998; Greimas, 2000/. When applying the mixed fertilizing system, not only agrochemical but also biological and physical properties of soils improve /Plesevičienė et al., 1997; Bagdonienė et al., 1998; Simanavičienė et al., 2001/.

The paper provides the data on long-term manuring effect on chemical and physical soil properties and on rotation plants.

Materials and methods

The tests were carried out in West Lithuania, on the eastern part of the sea-coast lowland with moderately warm, humid climate. The soil of the experimental site is *Dystric-Epihypogleyic Albeluvisol* with a morain loam texture (clay 13-15 %). To evaluate the effects of different manure rates 20 t ha^{-1}, 40 t ha^{-1}, 80 t ha^{-1}, 120 t ha^{-1} on the physical properties of acid and limed soil and crop rotation yield was the aim of this investigation. The trials were conducted in a 7-field rotation: 1) winter wheat (*Triticum* L.) 2) spring barley (*Hordeum* L.), 3) oats (*Avena sativa* L.), 4) fodder beet (*Beta vulgaris* L.), 5) barley with undercrop, 6) perennial grasses (mixture of timothy and red clover *Phleum pratense* L. and *Trifolium pratense* L.) of the 1st year of use, 7) perennial grasses of the 2nd year of use. Two soil backgrounds: acid and limed were used for the manure rates incorporation. Every year after harvesting the soil was limed at 1.0 rate by hydrolytic soil acidity. The amount of manure (shown in the scheme) was applied at equal portions twice per crop rotation for winter wheat and fodder beet. The type of organic fertilizer – solid cattle manure. Manure chemical composition was as follows: dry matter 21.3-36.4 %, total nitrogen 0.20-0.41 %, P_2O_5 0.18 % - 0.23 %, K_2O 1.10 % - 1.22 %. The mineral fertilization for both acid and limed soils was the same: $N_{60}P_{60}K_{60}$ for cereals, $N_{120}P_{90}K_{150}$ for fodder beet, $N_{40}P_{60}K_{60}$ for barley with undercrop, $P_{60}K_{90}$ for perennial grasses 1st usage year, $N_{60}P_{60}K_{90}$ for perennial grasses 2nd usage year. The data of acid and limed soil (without manure) chemical characteristics are presented in Table 1. The soil samples for chemical and physical analyses were taken from the topsoil after harvesting. Samples for soil structure analyses were taken in the topsoil layer 0-20 cm depth, bulk density was estimated every 5.0 cm.

Chemical analyses of the soil samples were done using the following methods: potentiometric for pH_{KCl}, Kappen for hydrolytic soil acidity, Sokolov for mobile aluminium, Kappen-Hilkovic for total absorbed bases, mobile P_2O_5 and K_2O using the method by Egner-Riem-Domingo (A-L) and Kjeldahl for total nitrogen. Physical analyses of the soil samples were done using the following methods: Savinov for soil structure and its water stability, cylinder-auger of Kachinski for soil bulk density /Vadiunina and Korcagina, 1986/. Analysis of variance and correlation analyses for soil properties characteristics and crop rotation yield determination were used /Dospehov, 1985; Tarakanovas, 1999/.

Table 1. Agrochemical characteristics of acid and limed soil
1 lentelė. *Rūgštaus ir pakalkinto dirvožemio agrocheminė charakteristika*
Vėžaičiai, 1995 m.

Soil agrochemical indices *Dirvožemio cheminiai rodikliai*	Unlimed soil *Nekalkintas dirvožemis*	Soil limed by 1 rate *Dirvožemis pakalkintas 1 norma*
Soil acidity (pH_{KCl}) / *Dirvožemio rūgštumas (pH_{KCl})*	4.2	5.6
Mobile Al mg kg^{-1} / *Judrusis Al mg kg^{-1}*	115	2.4
Total absorbed bases meq kg^{-1} *Sorbuotų bazių suma mekv. kg^{-1}*	15	84
Available P_2O_5 mg kg^{-1} / *Judrusis P_2O_5 mg kg^{-1}*	152	146
Available K_2O mg kg^{-1} / *Judrusis K_2O mg kg^{-1}*	195	184
Humus % / *Humusas %*	1.62	1.82

Arbitrary symbols used in the article: significant * at the 0.05 and ** at the 0.01 levels.

Results and discussion

Agrochemical soil properties. When manuring with increasing manure rates, pH_{KCl} index in unlimed soil was increasing from 4.1 to 4.2 - 4.4, while in limed soil it was increasing from 5.8 to 5.9 - 6.1 (Table 2). In unlimed soil 80 and 120 t ha^{-1} manure rates resulted in an increase in the total absorbed bases from 35.3 to 44.3 meq kg^{-1}. In limed soil lime fertilizers resulted in 90.4 meq kg^{-1} average quantity of absorbed bases. In limed soil 80 and 120 t ha^{-1} manure rates increased the total absorbed bases by 16 and 24 %, respectively.

Manuring in acid soils significantly improves the conditions of plants growth, as Ca and Mg contained in manure, bond exchangeable aluminium /Mineev, Rempe, 1990/. In unlimed soils unfertilized with manure the soil contained 117.8 mg kg^{-1} of mobile Al, while having applied 120 t ha^{-1} manure rate the quantities decreased to 26.8 mg kg^{-1}. In limed soils the quantities of mobile Al were very low – only 1.5 mg kg^{-1}. In unlimed soils humus, actually was increasing only from 80 and 120 t ha^{-1} manure rates. In limed soil humus was significantly increasing from all manure rates, except for 20 t ha^{-1}. The data of correlation – regression analysis showed that soil agrochemical indicators were under the impact of annual manure rates (2.9, 5.7, 11.4 and 17.1 t ha^{-1}). In unlimed soils a strong correlation $\eta = 0.89^{**}$ between manure rates and mobile Al was observed (Table 3). Linear relationship $r = 0.60^{**}$ was revealed between the manure rates and the total absorbed bases. In limed soils moderate correlation $\eta = 0.47^{**}$ was established only between the manure rates and the total absorbed bases.

Table 2. The effect of manure on topsoil agrochemical properties
2 lentelė. *Mėšlo poveikis dirvožemio agrocheminėms savybėms*
Vėžaičiai, 1996-2002

Manure rates $t\ ha^{-1}$ per rotation *Mėšlo normos $t\ ha^{-1}$ per rotaciją*	Soil acidity pH_{KCl} *Dirvožemio rūgštumas pH_{KCl}*	Mobile Al $mg\ kg^{-1}$ *Judrusis Al $mg\ kg^{-1}$*	Total absorbed bases $meq\ kg^{-1}$ *Sorbuotų bazių suma mekv. kg^{-1}*	Mobile P_2O_5 $mg\ kg^{-1}$ *Judrusis P_2O_5 $mg\ kg^{-1}$*	Mobile K_2O $mg\ kg^{-1}$ *Judrusis K_2O $mg\ kg^{-1}$*	Humus % *Humusas %*
Unlimed soil / *Nekalkintas dirvožemis*						
0	4.1	117.8	25.5	163	245	1.79
20	4.2**	91.2**	27.7	169	249	1.86
40	4.2**	69.2**	25.2	166	252	1.96
80	4.3**	48.3**	35.3*	188**	276**	2.12*
120	4.4**	26.8**	44.3**	211**	299**	2.26**
LSD_{05} / R_{05}	0.09	16.58	7.58	10.4	18.2	0.289
Soil limed by 1 rate / *Dirvožemis pakalkintas 1 norma*						
0	5.8	1.5	90.4	150	196	1.87
20	5.9	1.7	93.7	160	216*	1.87
40	5.9	1.8	91.2	193**	251**	2.10**
80	6.0**	1.3	105**	227**	294**	2.28**
120	6.1**	1.0	112**	239**	319**	2.33**
LSD_{05} / R_{05}	0.13	0.98	8.21	11.3	17.4	0.14

Table 3. Soil agrochemical indicators (y) in relation to the rates of manure (x)
3 lentelė. *Dirvožemio cheminių rodiklių* (y) *priklausomumas nuo mėšlo normų (x)*
Vėžaičiai, 1996-2002

Soil agrochemical indices *Dirvožemio cheminis rodiklis*	Equations of regression *Regresijos lygtis*	r or η probability % *r ir η tikimybės lygis %*
1	2	3
Unlimed soil / *Nekalkintas dirvožemis*		
Soil acidity pH_{KCl} *Dirvožemio rūgštumas pH_{KCl}*	$y = 4.0961 + 0.0194x$	0.45**
Mobile Al $mg\ kg^{-1}$ *Judrusis aliuminis $mg\ kg^{-1}$*	$y = 115.88 - 8.7282x + 0.211x^2$	0.89**
Total absorbed bases $meq\ kg^{-1}$ *Sorbuotų bazių suma mekv. kg^{-1}*	$y = 23.24 + 1.1267x$	0.60**
Mobile P_2O_5 $mg\ kg^{-1}$ *Judrusis P_2O_5 $mg\ kg^{-1}$*	$y = 162.22 + 2.539x$	0.47**
Mobile K_2O $mg\ kg^{-1}$ *Judrusis K_2O $mg\ kg^{-1}$*	$y = 244.34 + 1.213x + 0.119x^2$	0.65**
Humus % / *Humusas %*	$y = 1.9113 + 0.0181x$	0.24 (76 %)

Table 3continued
3 lentelės tęsinys

1	2	3
Soil limed by 1 rate / *Dirvožemis pakalkintas 1 norma*		
Soil acidity pH_{KCl} *Dirvožemio rūgštumas* pH_{KCl}	y = 5.791 + 0.01973x	0.37*
Mobile Al mg kg^{-1} *Judrusis aliuminis mg* kg^{-1}	y = 90.146 + 0.5832x + 0.0439x^2	0.47**
Total absorbed bases meq kg^{-1} *Sorbuotų bazių suma mekv.* kg^{-1}	y = 1.7062 - 0.0343x	0.13 (57 %)
Mobile P_2O_5 mg kg^{-1} *Judrusis* P_2O_5 *mg* kg^{-1}	y = 147.42 + 9.246x - 0.2223x^2	0.84**
Available K_2O mg kg^{-1} *Judrusis* K_2O *mg* kg^{-1}	y = 191.87 + 11.263x - 0.2206x^2	0.88**
Humus % / *Humusas %*	y = 1.8666 + 0.03x	0.49**

A significant increase in mobile P_2O_5 in unlimed soils was established from 80 and 120 t ha^{-1} manure rates, and in limed soils – from all manure rates, only except for 20 t ha^{-1}. In limed soils manure had a stronger effect on the increase in mobile P_2O_5 in the soil – $\eta = 0.84$**. In unlimed soils the effect was weaker – r = 0.47**. The quantities of mobile potassium significantly increased in unlimed soils from 80 and 120 t ha^{-1} manure rates and in limed soils – from all rates. In limed soils manure had a stronger effect on the increase in mobile potassium in the soil $\eta = 0.88$**. In unlimed soils the effect was moderate $\eta = 0.65$**. Humus quantities, depending on the manure rates applied, changed according to linear relationship, weak correlation r = 0.49** was observed in limed soils and very weak correlation r = 0.24 in unlimed soils, at 76 % probability level.

Soil physical properties. Aeration and moisture conditions in the plant – soil system are closely dependent on the soil structure. The most favourable air and moisture regime in *Dystric Albeluvisol* was recorded when the water stable aggregates > 0.25 mm made up 70-80 % /Levin, 1972/. The investigations done in Lithuania showed that it is impossible to reach optimal soil conditions for plant growth by using intensive liming only. It is necessary to combine proper liming and organic fertilizer application /Plesevičienė et al., 1997; Ožeraitienė, 2001/. The data of our investigations agree with this inference. The long-term manuring had a positive effect on both acid and limed morain loam soil structure (Tables 4, 5).

Agronomically valuable structural mesoaggregates (0.25-5 mm) prevailed (61-65 %) and the other valuable fractions (>5 and < 0.25 mm) made up from 19-25 % and 14-16 % in acid and limed soil. The tendency of an increase in agronomically valuable mesoaggregates was already observed in the acid and limed soil when the largest manure rates of 80 and 120 t ha^{-1} had been used. The largest (65-66 %) amount of valuable aggregates (0.25-5mm) was identified in the soil limed and fertilized with the highest (120 t ha^{-1}) manure rate. The analysis of soil structural qualities suggests that the combination of liming and manuring is the best way to improve the structure of morain loam soil.

Table 4. The effect of manure rates on topsoil aggregate composition
4 lentelė. *Mėšlo normų įtaka dirvožemio agregatinei sudėčiai*
Vėžaičiai, 2005

Manure rate t ha^{-1} per rotation *Mėšlo normos per rotaciją t ha^{-1}*	Size of aggregates mm / *Agregatų dydis mm*		
	Macroaggregates *Makroagregatai* > 5 mm	Mesoaggregates *Mezoagregatai* 5-0.25 mm	Microaggregates *Mikroagregatai* < 0.25 mm
Unlimed soil / *Nekalkintas dirvožemis*			
1. 0	25.03	60.75	15.52
2. 20	24.13	61.68	14.04
3. 40	24.44	61.34	14.21
4. 80	22.17	63.26	14.58
5. 120	22.13	62.03	15.85
LSD_{05} / R_{05}	4.57	3.35	3.59
Soil limed by 1 rate / *Dirvožemis pakalkintas 1 norma*			
1. 0	20.10	64.00	15.90
2. 20	21.46	63.02	15.53
3. 40	20.66	63.99	15.35
4. 80	19.94	64.80	14.26
5. 120	19.48	66.15	14.54
LSD_{05} / R_{05}	1.86	4.52	3.31

Table 5. The effect of manure rates on topsoil structure stability
5 lentelė. *Mėšlo normų įtaka dirvožemio struktūros patvarumui*
Vėžaičiai, 2005

Manure rate t ha^{-1} per rotation *Mėšlo normos per rotaciją*	Unlimed soil *Nekalkintas dirvožemis*		Soil limed by 1 rate *Dirvožemis pakalkintas 1 norma*	
	Size of aggregates mm / *Agregatų dydis mm*			
	>1.0	> 0.25	>1.0	> 0.25
1. 0	10.69	44.71	11.09	45.26
2. 20	10.83	48.53	10.40	47.59
3. 40	11.24	49.75	12.43	47.88
4. 80	11.74	52.17	13.34	56.28**
5. 120	13.11	51.07	14.87*	59.40**
LSD_{05} / R_{05}	5.24	5.64	3.05	5.03

The greatest (65-66 %) amount of water stable aggregates > 0.25 mm was found in the limed and fertilized with the highest manure rates of 80 and 120 t ha^{-1} soil (Table 5). The best aeration and moisture regime was identified in this soil: the lowest bulk density (1.25 Mg m^{-3}) and the highest moisture content (20 %) (Table 6).

Table 6. The effect of manure rates on topsoil bulk density and moisture
6 lentelė. *Mėšlo normų įtaka dirvožemio tankiui ir drėgniui*

Vėžaičiai, 2005

Manure rate t ha^{-1} per rotation *Mėšlo normos t ha^{-1} per rotaciją*	Unlimed soil *Nekalkintas dirvožemis*		Soil limed by 1 rate *Dirvožemis pakalkintas 1 norma*	
	Soil indicators / *Dirvožemio rodikliai*			
	Bulk density Mg m^{-3} *Tankis Mg m^{-3}*	Moisture % *Drėgnis %*	Bulk density Mg m^{-3} *Tankis Mg m^{-3}*	Moisture % *Drėgnis %*
1. 0	1.33	17.41	1.33	17.78
2. 20	1.36	17.45	1.42	17.67
3. 40	1.29	18.70	1.31	18.39
4. 80	1.32	18.64	1.34	18.79
5. 120	1.31	19.35	1.25	19.89*
LSD_{05} / R_{05}	0.14	2.08	0.11	1.51

Yield of rotation plants. The paper provides the data on the main crop yields of rotation plants (Table 7). Winter wheat was sensitive to soil acidity, especially to mobile Al. In unlimed soils manuring decreased the content of mobile Al, therefore the yield of wheat was increasing. The highest yields 3.89 and 4.21 t ha^{-1} of wheat crop were obtained in the soils fertilized with 80 and 120 t ha^{-1} of manure per rotation, respectively. In limed soils even unfertilized with manure the crop yields were by 0.32 t ha^{-1} higher compared to the crop yield when the highest manure rate (120 t ha^{-1}) had been applied in unlimed soils. Like wheat, barley was found to be sensitive to mobile Al. The tendency of changes in barley crop yield remained the same as that of wheat. In unlimed soils the highest barley crop yields of 2.44 and 2.74 t ha^{-1} were obtained having manured with 80 and 120 t ha^{-1} per rotation. In limed soils the barley crop yield increased by 1.53 t ha^{-1} only due to the lime fertilizers. When increasing manure rates to 80 and 120 t ha^{-1} per rotation, the highest crop yields of 3.10 and 3.69 t ha^{-1} were obtained. In unlimed soils the highest manure rates of 80 and 120 t ha^{-1} per rotation for barley crops yield were similar to the lowest manure rates of 20 and 40 t ha^{-1} per rotation in limed soils. Oats were not sensitive to soil acidity and absorbed nutrients from the soil and fertilizers well. In unlimed soils the manure increased the oats crop yield by 11- 40 % and in limed soils by 8-45 %. In unlimed soils the highest crop yield (3.69 and 3.52 t ha^{-1}) was obtained having applied 40 and 80 t ha^{-1} manure rates per rotation. In limed soils the highest yield of oats 5.0 t ha^{-1} was obtained having applied 120 t ha^{-1} manure rate per rotation.

Fodder beets were sensitive to soil reaction, therefore they positively responded to neutralisation of soil acidity with manure. Significant increase in the yield of fodder beet roots was observed in acid soil from 40, 80, 120 t ha^{-1} manure rates. Soil liming had a positive effect on the yielding capacity of fodder beets. In limed soil even unfertilized with manure, the root yield was by 0.54 t ha^{-1} higher, compared to the yield obtained applying 120 t ha^{-1} manure rate in unlimed soils. In unlimed soils the major barley crop increase was obtained from the highest manure rates, in limed soils from 40, 80 and 120 t ha^{-1} per rotation. In unlimed soils all manure rates resulted in significant increases in

Table 7. The effect of manure rates on the yield of the main production of the crop rotation plants t ha^{-1}

7 lentelė. *Mėšlo įtaka sėjomainos augalų pagrindinės produkcijos derliui t ha^{-1}*

Vėžaičiai, 1996-2002

Manure rates t ha^{-1} per rotation *Mėšlo normos t ha^{-1} per rotaciją*	Years and yield of crop rotation plants / *Metai ir sėjomainos augalų derlius*						
	1996	1997	1998	1999	2000	2001	2002
	Winter wheat *Žieminiai kviečiai*	Spring barley *Vasariniai miežiai*	Oats *Avižos*	Fodder beet *Pašariniai runkeliai*	Spring barley *Vasariniai miežiai*	Dry matter yield of perennial grasses *Daugiamečių žolių sausųjų medžiagų derlius*	
	Grain *Grūdai*			Tubers *Šaknia-vaisiai*	Grain *Grūdai*	1st year of use *I n.m.*	2nd year of use *II n.m.*
Unlimed soil / *Nekalkintas dirvožemis*							
1. 0	1.06	0.82	2.63	3.30	0.71	2.49	1.58
2. 20	1.44	0.84	2.93	3.30	0.88	3.68*	2.09
3. 40	2.13	1.10	3.69*	12.19*	1.18	4.49**	2.32*
4. 80	3.89**	2.44**	3.52*	25.71**	1.66**	5.08**	2.32*
5. 120	4.21*	2.74**	3.30	34.91**	1.58**	5.13**	2.30*
LSD_{05} / R_{05}	1.18	0.49	0.87	7.43	0.57	1.15	0.59
Soil limed by 1 rate / *Dirvožemis pakalkintas 1 norma*							
1. 0	4.53	2.35	3.44	35.45	1.21	4.30	2.08
2. 20	5.53*	2.67	3.72	44.11**	1.79	4.84	2.45
3. 40	5.34	2.88*	4.52*	53.79**	2.35**	5.05	2.35
4. 80	5.54*	3.10**	4.72*	56.74**	2.29**	5.33*	2.62*
5. 120	5.57*	3.69**	5.00**	64.07**	2.66**	5.89**	2.63**
LSD_{05} / R_{05}	0.89	0.45	1.09	5.40	0.67	0.99	0.39

perennial grass yield. In limed soils the yield of perennial grass dry mater was increasing, but not significantly from all manure rates. In unlimed soils although timothy grass dominated 27-71 %, weeds in some of the samples made up to 56.3 %. In limed soils red clover dominated 89.7-92.7 %, and weeds made up 0.1 – 0.6 %. The average amount of metabolisable energy increased in both acid and limed soil, from 4.8 to 26.3 GJ ha^{-1} and from 10.1 to 21.6 GJ ha^{-1} respectively, when the manure rates were being increased from 20 t ha^{-1} to 120 t ha^{-1} /Repšienė et al., 2005/.

Conclusions

1. Long-term and systematic manuring at 80 and 120 t ha^{-1} rates per rotation had a major impact on the changes in the chemical indicators of unlimed soils. The amount of mobile Al decreased from 117.8 to 48.3-26.8 mg kg^{-1}. The total absorbed bases increased from 25.5 to 35.3-44.3 meq kg^{-1}, pH_{KCl} from 4.1 to 4.3-4.4. In limed soils

manuring had no effect on the amount of mobile Al. The total absorbed bases increased from 90.4 to 105-112 meq kg^{-1}, pH_{KCl} indicators increased from 5.8 to 6.0-6.1.

2. In unlimed soils significant increases in mobile P_2O_5 and K_2O and humus were observed from 80 and 120 t ha^{-1} manure rates, and in limed soils from all manure rates, except for 20 t ha^{-1} rate. In limed soils manure had a strong effect on the increase of mobile P_2O_5 $\eta = 0.84$, K_2O $\eta = 0.88$ and moderate effect $r = 0.49$ on the increase of humus in the soil. In unlimed soils the correlation was weaker – P_2O_5 $\eta = 0.47$, K_2O $\eta = 0.65$.

3. The long-term manuring had a positive effect on both acid and limed morain loam soil physical state. The greatest amount of water stable aggregates (65-66 %) >0.25 mm, the lowest bulk density (1.25 Mg m^{-3}) and the highest moisture content (20 %) were identified in the limed and with the highest manure rates 80 and 120 t ha^{-1} fertilized soil.

4. While manuring the soil with 20 to 120 t ha^{-1} manure rates per rotation, the yielding capacity of the rotation plants was increasing in limed soils. In unlimed soils the crop yield of the rotation plants was increasing to the highest extent from 80 and 120 t ha^{-1} manure rates. In terms of crop yield, similar effectiveness of systematic manuring by the highest manure rates (80 and 120 t ha^{-1}) and liming was observed in the sixth crop rotation.

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MĖŠLO ĮTAKA DIRVOŽEMIO SAVYBĖMS IR ROTACIJOS AUGALŲ DERLIUI

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Santrauka

Straipsnyje apibendrinti ilgamečio lauko bandymo ir laboratorinių analizių duomenys, gauti LŽI Vėžaičių filiale 1996-2002 metų laikotarpiu. Dirvožemis – *nepasotintasis balkšvažemis*, granuliometrinė sudėtis – moreninis priemolis. Nustatyta, kad nuo visų mėšlo normų: 20, 40, 80, 120 t ha^{-1} mažėjo nekalkinto dirvožemio rūgštumas, kai tuo tarpu pakalkintame dirvožemyje mėšlas rūgštumo rodikliams įtakos beveik neturėjo. Judriųjų P_2O_5 ir K_2O esminis padidėjimas nekalkintame dirvožemyje gautas nuo didžiųjų mėšlo 80 ir 120 t ha^{-1} normų, o kalkintame – beveik nuo visų normų. Palankiausios aeracinės ir drėgmės sąlygos sistemoje dirvožemis - augalas buvo pakalkintame ir daugiausiai mėšlu patręštame (80 ir 120 t ha^{-1}) dirvožemyje. Pakalkintame dirvožemyje sėjomainos augalų derlingumas didėjo nuo visų mėšlo normų, o nekalkintame – tik nuo didžiausių: 80 ir 120 t ha^{-1}. Sėjomainos augalų derlingumui sistemingas tręšimas 80 ir 120 t ha^{-1} mėšlo normomis veikė panašiai kaip kalkinimas.

Reikšminiai žodžiai: mėšlo normos, dirvožemio savybės, sėjomainos derlius.