Effects of lake sediments on changes in sandy loam cambisol properties and on crop productivity

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Abstract. The feasibility of using lake sediments as fertilisers has been studied at the Voke Branch of the Lithuanian Institute of Agriculture since 1994. The experiments were carried out on a sandy loam cambisol on two backgrounds (without mineral fertilisers and with minimal rates of mineral fertilisers) in the crop rotation (maize, barley with under-crop, perennial grasses of the 1st and 2nd years of use, winter rye) with the application of calcareous (25 t ha^{-1}), organic (10, 40 t ha^{-1}) and siliceous (25, 100 t ha^{-1}) lake sediments and their mixtures with manure and limestone. Organic fertilisers were applied only to the first crop (maize) in the rotation.

Experimental evidence suggests that calcareous sediment and limestone declined soil acidity, whereas organic and siliceous sediments had no effect on soil acidity. Only the higher rate of organic (40 t ha^{-1}) and siliceous (100 t ha^{-1}) sediments increased the content of total nitrogen in soil by 0.002–0.021 and that of humus by 0.53 percentage units. Fertilisation with mineral fertilisers compensated for the amount of mobile phosphorus and potassium necessary for crop growth.

The application of lake sediments had a positive impact on the quality of sandy loam cambisol physical properties. Organic and siliceous sediments increased the soil moisture content and porosity and declined the soil bulk density to a higher degree than calcareous sediment. Calcareous sediment improved the afore-mentioned soil physical characteristics to a greater extent compared with limestone. All rates of organic sediment gave a crop yield increase of 4–20%, 10 t ha^{-1} of sediment with 25 t ha^{-1} of manure gave a yield increase of 22–25%, and 50 and 100 t ha^{-1} rates of siliceous sediment a yield increase of 8–30%.

Key words: sediments, manure, soil, properties, yield

INTRODUCTION

It is vital to conserve organic matter of light textured soils. When extensive cropping system is employed, conservation of soil organic matter is possible provided the soil is regularly replenished with organic fertilisers. One of the sources of organic fertilisers in Lithuania are lake sediments that are available in large quantities in the regions characterised by unproductive soils. Research carried out in various countries on the effects of lake sediment suggests that its efficacy depends on the chemical composition. All sediments are subdivided into organic (50–90% of organic mater), calcareous (30–60% of calcium carbonate), siliceous (25–45% of silicon dioxide), and mixed. All kinds of sediments are used to fertilise infertile soils. They have a positive effect on soil agrochemical and physical characteristics and increase crop productivity (Kronbergs & Viduzs, 1993; Tsekhanovich et al., 1993).

Calcareous sediment is more suited for soil liming, whereas organic and siliceous sediments are used as a source of nutrients (Kirdun, 1981; Grishina & Kurmisheva, 1990; Orlov & Sadovnikova, 1996; Chochlova, 1997).

The efficacy of calcareous sediments has been studied relatively extensively in Lithuania. The rates of 50, 100, 150, and 200 t ha^{-1} (of dry matter) of calcareous sediment from Lake Ilgutis (Vilnius distr.) were studied on a sandy loam and sandy haplic luvisol in the crop rotation fields. Various rates of the sediment served as a long-term measure intended to improve chemical and physical characteristics of the soil. After fertilisation with the lake sediment the acidity of the soil decreased, the content of humus increased, the qualitative composition improved. All rates of the lake sediment improved soil texture and moisture regime. However, various rates of calcareous sediments had no positive effect on the productivity of crop rotation. The research evidence showed that the application of sediments on a sandy loam soil (pH 6.0) in the 1st season of the crop rotation increased the yield of crop plants by 2–5%. Barley was found to be the most productive crop. Only after the application of the highest rate (200 t ha^{-1}) of dry lake sediment the productivity increased by 7% during the 2nd season of the crop rotation. This suggests that sediments containing a higher content of organic matter are more effective for the yield of crop plants (Bakšienė, 1996, 1998).

According to Russian scientists, organic lake sediment is most effective. Their research findings indicate that organic sediment was not less efficient than peat-manure compost on a sod-podzolic sandy loam soil, in some cases it was even superior. The rate of 60–80 t ha^{-1} of sediment gave a yield increase of 0.34–1.61 t ha^{-1} for barley, while the same rate of peat-manure compost gave a yield increase of 0.28–1.06 t ha^{-1} (Grigorov & Ovchinnikov, 1994).

Experiments to study the feasibility of using lake sediments for fertilisation and to compare their efficacy with other fertilisers (manure, limestone) have been conducted at the Vokė Branch of the Lithuanian Institute of Agriculture since 1994.

MATERIALS AND METHODS

Field experiments. Experimental plots for the study of calcareous, organic and siliceous lake sediments (chemical composition presented in Table 1) were established in a field crop rotation (maize, maize (*Zea mays* L.), barley (*Hordeum* L.), with under-crop, perennial grasses (*Trifolium pratense* L. and *Pheleum pratense* L.) of the 1st and 2nd year of use, winter rye (*Secale cereale* L.) on a sandy loam cambisol (54º49′N, 25º10′E) with a pH value of 6.0, P_2O_5 130–230, and K_2O 150–210 mg kg^{-1} of soil, humus content 1.7–2.05%.

Changes in agrochemical and physical soil properties and the yield of crops fertilised with sediments were studied according to the following experimental design and treatments: 1) control; 2) 10 t ha^{-1} limestone ($CaCO_3$); 3) 25 t ha^{-1} calcareous sediment (**CS**); 4) 10 t ha^{-1} organic sediment (**OS**); 5) 40 t ha^{-1} organic sediment (**OS**); 6) 25 t ha^{-1} siliceous sediment (**SS**); 7) 100 t ha^{-1} siliceous sediment (**SS**); 8) 25 t ha^{-1} calcareous sediment (**CS**) + 25 t ha^{-1} manure; 9) 10 t ha^{-1} organic sediment (**OS**) + 25 t ha^{-1} manure; 10) 25 t ha^{-1} siliceous sediment (**SS**) + 25 t ha^{-1} manure; 11) 65 t ha^{-1} manure (**M**).

Table 1. Chemical composition of lake sediment and manure.Vokė, 1994.

Substance	% dry matter				
	N	P	K	Ca	Mg
Calcareous lake sediment	0.62	0.02	0.03	13.2	0.52
Organic lake sediment	3.29	0.04	0.16	1.48	0.22
Siliceous lake sediment	1.11	0.02	0.55	1.01	0.78
Manure	1.62	0.41	1.54	0.24	0.17

All fertilisers, except for the mineral fertilisers, were applied at the beginning of the rotation, before sowing. During the following years, the after-effect was observed. All rates of sediment were calculated for dry mass. Minimum rates of mineral fertilisers ($N_{30\text{-}60}P_{30\text{-}40}K_{50\text{-}60}$) were applied annually before sowing.

Soil sampling. To identify changes in agrochemical soil properties, samples were taken before the establishment of the experimental plots (in 1994) and after the first season of the crop rotation. Soil bulk density, moisture, total and aeration porosity were measured annually after sowing in spring (I) and after harvesting in autumn (II).

Analytical methods. Basic soil properties were estimated, using the following methods: pH_{KCl} potentiometrically (GOST 26483-85, 1986), exchange bases – 0.1 M $BaCl_2$ (1:10) extract (ISO 11260, 1994), mobile P and K extracted with lactate-acetate-ammonium mixture – spectrophotometrically (GOST 26208-91, 1993), total nitrogen – by Kjeldahl instrument (GOST 26107-84, 1985, ISO 11261, 1995). Individual humus substances were dissolved in different solvents: 0.1 M NaOH, 0.1 M NaOH after soil decalcification with 0.05 M H_2SO_4 and after that in 0.02 M NaOH.

Soil bulk density, moisture, total and aeration porosity were estimated by the weighing method.

Statistics. The data of soil chemical characteristics and crop yield were processed using the software ANOVA. The data were treated by employing the Fisher's criteria (F) and LSD_{05} (Little & Hills, 1978; Tarakanovas & Raudonius, 2003).

RESULTS AND DISCUSSION

Our research findings indicate that the use of all kinds of sediments for fertilisation had a positive impact on the agrochemical properties of sandy loam cambisol (Fig. 1).

Calcareous sediment (treatment 3) such as limestone (treatment 2) declined soil acidity. All rates and mixtures of organic and siliceous sediments had no effect on soil pH. The contents of nitrogen and humus changed inappreciably. The total exchangeable bases increased by 11.8 – 48.0 mequiv kg^{-1} of soil.

Fertilisation of soil with calcareous lake sediment, its mixtures and manure slightly affected the content of total nitrogen and humus. However, after fertilisation with 40 t ha^{-1} organic and 100 t ha^{-1} siliceous sediments, the content of total nitrogen increased by 0.002–0.021 and that of humus by 0.53 percentage units.

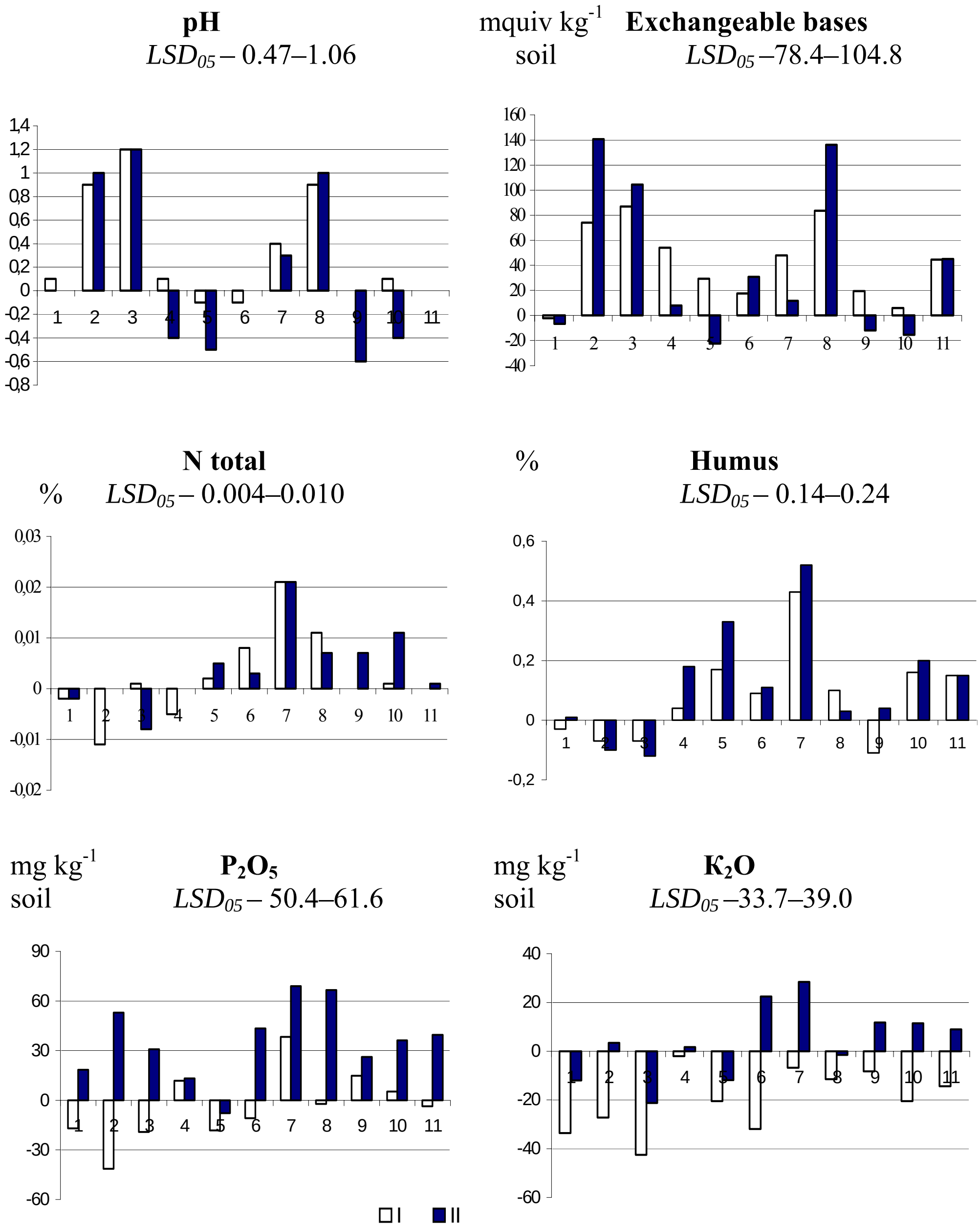

Fig. 1. Changes in agrochemical indicators after fertilisation of sandy loam cambisols with sediments and their mixture with other fertilisers (I – indicators on the background without mineral fertilisers; II – indicators on the background of minimum rates of mineral NPK fertilisers; 1-11 – treatments of trials).

A small content of phosphorus (0.02–0.04%) was identified in various kinds of lake sediments. Fertilisation with mineral (non-organic) fertilisers had a greater effect on the variation in mobile phosphorus. In almost all treatments, the content of phosphorus (except for treatment 7 with 100 t ha^{-1} siliceous sediment) was, on the background without mineral fertilisers, lower by 2.2–19.2 mg kg^{-1} compared to its amount before the establishment of the experimental plots; while on the background with mineral fertilisers in almost all treatments it was by 13.2–68.9 mg kg^{-1} soil higher.

Similarly, the content of potassium in lake sediments was rather low, too. Consequently, due to various fertilisation treatments, the content of mobile potassium in the soil changed similarly to that of phosphorus. On the background without mineral fertilisers (when organic fertilisers were applied), the content of potassium (2.0–42.5 mg kg^{-1} of soil) was lower almost in all treatments compared with its content before the establishment of the experimental plots. However, on the background with mineral fertilisers, it was higher (1.7–28.5 mg $kg^{-1}$of soil) almost in all treatments. Different fertilisation with organic fertilisers did not have any effect on the content of potassium in soil.

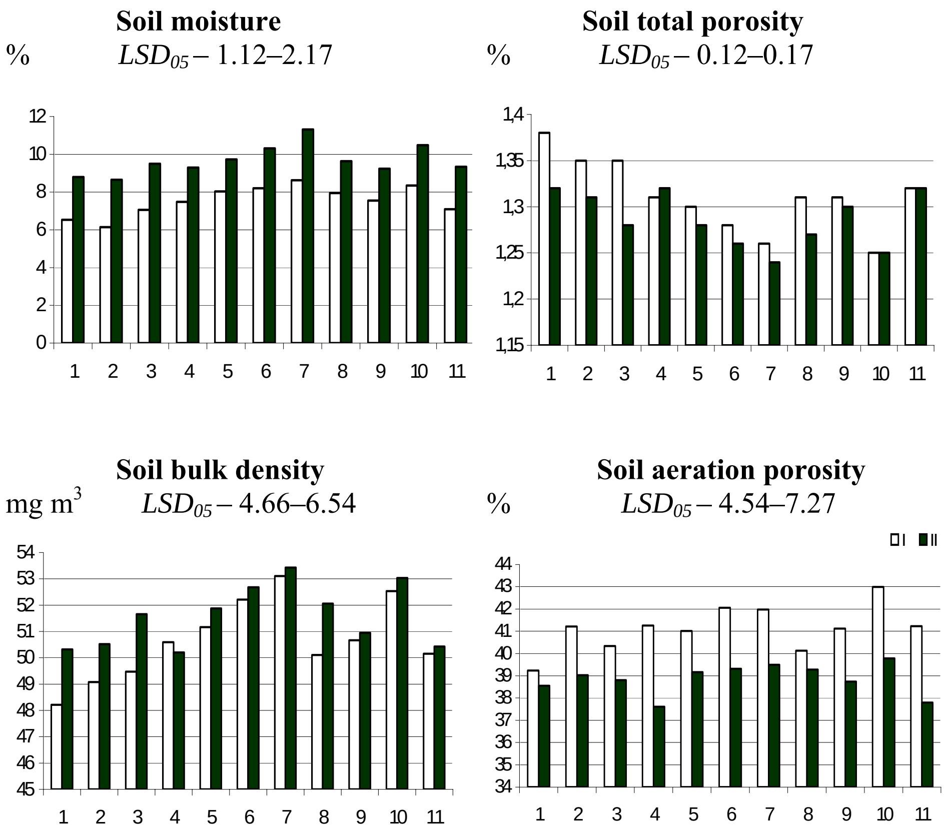

Fig. 2. Effect of lake sediments on humidity, density, total porosity and aeration porosity of sandy loam cambisol (I – spring, after sowing; II – autumn, after harvesting; 1-11 – treatments of trials).

Table 2. Effect of organic sediments on feed unit yield of the crop rotation.

Treatment	Feed unit yield						Total feed units	
	maize	maize	barley	perennial grasses	perennial grasses	winter rye	over rotation	%
Background without mineral fertilisers								
1) control	2223	1528	1981	3183	3421	2512	14848	100
2) 10 t ha^{-1} $CaCO_3$	2818	1514	1892	2774	2801	1505	13304	90
3) 25 t ha^{-1} **CS**	3100	1468	2780	3499	3633	2226	16706	113
4) 10 t ha^{-1} **OS**	2188	1416	1943	4416	3111	1977	15051	101
5) 40 t ha^{-1} **OS**	3255	1386	2120	5357	3550	2113	17781	120
6) 25 t ha^{-1} **SS**	2730	1237	2770	4264	2462	2874	16337	110
7) 100 t ha^{-1} **SS**	3115	1649	3614	4739	2808	5818	21743	146
8) 25 t ha^{-1} **CS**+25 t ha^{-1} **M**	2888	1640	2490	3646	3314	2414	16392	110
9) 10 t ha^{-1} **OS**+25 t ha^{-1} **M**	3885	1582	2040	4908	3503	2394	18312	123
10) 25 t ha^{-1} **CS**+25 t ha^{-1} **M**	4043	1663	3007	4569	2643	2567	18492	125
11) 65 t ha^{-1} **M**	3255	1489	1920	4496	3202	2102	16464	111
LSD_{05}	686	956	1494	1272	730	994	2599	
Background of minimum rates of mineral fertilisers								
1) control	2993	1549	3072	3211	3291	1674	15790	100
2) 10 t ha^{-1} $CaCO_3$	2853	1493	3295	2504	2953	1964	15062	95
3) 25 t ha^{-1} **CS**	3885	1204	3803	3365	3682	2574	18513	117
4) 10 t ha^{-1} **OS**	2695	1439	3728	5423	3755	2436	19476	123
5) 40 t ha^{-1} **OS**	3028	1736	4021	5865	4063	2508	21221	134
6) 25 t ha^{-1} **SS**	3518	1787	3790	4406	2515	2886	18902	120
7) 100 t ha^{-1} **SS**	3430	2107	4802	4097	2471	3567	20474	130
8) 25 t ha^{-1} **CS**+25 t ha^{-1} **M**	4585	1482	3926	2629	3483	2534	18637	118
9) 10 t ha^{-1} **OS**+25 t ha^{-1} **M**	4113	1946	4071	5379	4061	2667	22237	141
10) 25 t ha^{-1} **CS**+25 t ha^{-1} **M**	3115	1892	3991	4132	2174	2332	17636	112
11) 65 t ha^{-1} **M**	3098	1925	3945	4928	3791	2341	20028	127
LSD_{05}	1029	973	944	926	759	749	2212	

The application of lake sediment had a positive impact on the quality of physical properties of sandy loam cambisol (Fig. 2).

While analysing the impact of sediments on soil moisture it was found to be lower in spring and higher in autumn. In this experiment a stronger effect was observed when fertilising with sediments and sediment-manure mixture. Compared with the impact of manure, the rate of 40 t ha^{-1} of organic and 25, 100 t ha^{-1} siliceous lake sediments increased the soil moisture by 0.93–1.50 and 1.52–2.52 percentage units. The effect of manure equalled the smaller rate of organic sediment (10 t ha^{-1}). Soil bulk density did not depend on moisture. The data indicate a tendency towards a decrease of this parameter only after application of 40 t ha^{-1} organic, 25, 100 t ha^{-1} siliceous sediments and sediment-manure mixture. Soil bulk density varied from 1.24 to 1.38 Mg m^3 only in certain periods, and only in autumn it was slightly lower.

Total soil porosity directly depended on the soil bulk density. With the decrease of density, the porosity increased. It was evidently proved by the research results. Total soil porosity was lower in spring, after soil cultivation, and it increased in autumn after harvesting. However, soil aeration porosity was higher in spring, and decreased in autumn. The highest (51.16–53.43%) total and (39.16–42.99%) aeration porosity was identified in the soil applied with 40 t ha^{-1} organic, 25, 100 t ha^{-1} siliceous sediments and their mixtures with manure sediment almost during the whole experimental period.

Summarised results of long-term experiments showed that fertilising with all kinds of lake sediments improved the soil. Organic and siliceous sediments increased soil moisture and porosity, and decreased bulk density to a greater extent than calcareous sediment. Calcareous sediment improved the afore-mentioned soil physical indicators more than limestone.

Norwegian and Canadian scientists (Sveistrup et al., 1995; Zebarth et. al., 1999) have reported the positive effects of lake sediments on soil physical properties. Application of sediments increased soil porosity and moisture retention capacity, improved soil texture and quality.

The application of different rates of sediments on a sandy loam soil had a marked effect on the increase in the productivity of crop rotation plants (Table 2).

On the background without mineral fertilisers, the greatest efficacy was recorded when sandy loam soil had been applied with 100 t ha^{-1} siliceous sediment. In this treatment the yield of crop rotation increased by 3,464 feed units (46%). The efficacy of the 9th and 10th treatments (10 t ha^{-1} **OS** + 25 t ha^{-1} **M** and 25 t ha^{-1} **SS** + 25 t ha^{-1} **M**) was practically identical, the yield increase amounted to 23 and 25%, compared with the control. Soil fertilisation with 40 t ha^{-1} of organic sediment increased the crop rotation productivity by 2,933 (20%) feed units. The application of manure was equivalent to the application of 25t ha^{-1} calcareous and siliceous sediments.

On the background of minimum rates of mineral fertilisers, the application of 10 t ha^{-1} organic sediment was more effective, increasing the crop rotation productivity by 6,447 (41%) feed units. The application of 40 t ha^{-1} organic and 100 t ha^{-1} siliceous sediments increased the crop rotation productivity by 4,684 and 5,431 feed units (30 and 34%). The efficacy of these treatments was equal to the treatment with manure. The application of 65 t ha^{-1} manure secured an increase in the crop rotation productivity by 4,238 feed units or 27% per rotation.

Data analysis of the crop rotation productivity as affected by the application of calcareous sediment and limestone suggests that in most cases (except for maize in 1995) fertilisation with lake sediment was more effective than the application of limestone. Consequently, calcareous sediment can be used not only as calcareous substance but also as a source of nutrients for plants.

Research findings from other countries indicate that organic and siliceous sediment influences agricultural crops much more effectively (Grigorov & Ovchinnikov, 1994). However, the experimental data in this article show that in most cases calcareous sediment gave an increase in the crop productivity, too.

CONCLUSIONS

1. Calcareous lake sediment and limestone decreased soil acidity. Organic and siliceous sediments had no effect on soil acidity. Only the higher rate of organic (40 t ha^{-1}) and siliceous (100 t ha^{-1}) lake sediments increased total nitrogen and humus content in the soil. Fertilisation with mineral fertilisers compensated for the content of mobile phosphorus and potassium required by plants for growth.

2. The application of lake sediment had a positive effect on the quality of physical properties of sandy loam cambisol. Organic and siliceous lake sediments increased soil moisture and porosity, and decreased bulk density more than calcareous lake sediment. Calcareous lake sediment improved the soil physical characteristics more than limestone.

3. Calcareous lake sediment and manure mixtures increased the crop rotation productivity more than limestone and manure mixtures. All rates of organic sediment increased the crop yield by 4–20%. The rate of 10 t ha^{-1} sediment with 25 t ha^{-1} of manure increased the crop yield by 22–25% and the rates of 50 and 100 t ha^{-1} siliceous sediment increased the crop yield by 18–30%.

REFERENCES

Bakšienė, E. 1996. Efficiency of Calcareous Sapropel in Soddy–podzolic Sandy Loam Soil. *Agricultural Sciences* **4**, 3–8 (in Lithuanian).

Bakšienė, E., Janušienė, V., Lugauskas, A., Šliaužienė, D. & Salina, O. 1996. The Efficiency of Organic–silicon Sapropel on the Field Crop Rotation on Soddy-gley Light Loamy Soil. *Agriculture,* Dotnuva-Akademija, **53**, pp. 197–210.

Bakšienė, E. The efficiency of calcareous sapropel in crop rotation. 1998. *Agriculture*, Dotnuva-Akademija, **64**, pp. 29–42.

Chochlova, O. B., 1997. Sapropel - ameliorants and fertilizer of long action. *The Author's thesis of agricultural sciences.* Moscow, 20 pp. (in Russian).

Grigorov, M.S. & Ovchinnikov, A.S. 1994. Utilization of Volga-Akhtuba flooplain sapropel. *Pochvovedenie* 0(5), pp. 62–66.

Grishina, L.A., Kurmisheva, N.A., Kazakova, S. V. & Moroz, O.R. 1990. The effect of overwashing of sapropel fertilizers on agrochemical properties and humus status of soddy-gley soil . *Moscow University soil science bulletin* **45**(2), 62–69.

Kirdun, E.A., 1981. Efficiency of sapropelic fertilizers on soddy podsolic soils. *Problems of use of sapropels in a national economy* (in Russian). Minsk, pp. 112–114.

Kronbergs, A. & Viduzs, A. 1993. The value of organic fertilizers and sapropel. *Raziba* **8**, 24–27.

Little, T.M. & Hills, F.J. 1978. *Agricultural experimentation: Design and analysis.* John Wiley & Sons, New York.

Orlov, D.S. & Sadovnikova, L.K., 1996. Nontraditional ameliorants and organic fertilizer. *Euroasian soil science* **29**(4), 474–479.

Sveistrup, T., Marcelino, V. & Stopps, G. 1995. Effects of slurry application on the microstructure of the surface layers of soils from northern Norway. *Norwegian Journal of Agricultural Sciences* **1(**2), 1–13.

Tarakanovas, P., & Raudonius, S. 2003. The statistical analysis of data of agricultural researches applying computers programs ANOVA, STAT, SPLIT-PLOT from a package SELECTION and IRRISTAT. Academy, **57** p. (in Lithuanian).

Tsekhanovich, Yu. U., Susha, A. U. & Svaiba, V. F 1993. Effects of different sapropels on crop yield as a function of their doses and moisture. *Vyestsi Akademii Ahrarnykh Navuk Byelarusi* **0(**1**),** 11–14.

Zebarth, B.J., Neilsen, G.H., Hogue, E. & Neilsen, D., 1999. Influence of organic waste amendments on selected soil physical and chemical properties. *Canadian Journal of Soil Science* **79**(3), 501–504.