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Effect of sapropel fertilizer on the quality of the yield of some field crops

L. Zarina[1,2,*], S. Cerina[1] and L. Proskina[3]

[1]Institute of Agricultural Resources and Economics, Crop Management Department, Zinatnes 2, LV-4126 Priekuli, Latvia
[2]Latvia University of Life Sciences and Technologies, Faculty of Agriculture, Liela 2, LV-3001 Jelgava, Latvia
[3]Latvia University of Life Sciences and Technologies, Faculty of Economics and Social Development, Liela 2, LV-3001 Jelgava, Latvia
[*]Correspondence: livija.zarina@arei.lv

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Abstract. Sapropel is specific water body sediments containing a high level of organic matter formed from remains of water biota mixed with mineral components. One of the most promising utilisation ways of sapropel is agriculture where it can be used as soil amendment to improve soil physical properties and thus obtain economically viable and high quality yield of field crops. For three years the experiments were conducted at Priekuli Research Centre of the Institute of Agricultural Resources and Economics. Dehydrated sapropel mass from Lake Bizas was studied as soil biological fertilizer to determine its suitability for use in field crop production. Researches were carried out in organic crop rotation, in the fields of potato, winter rye and field bean. Three different doses of sapropel fertilizer were applied. During the three-year period (2020–2022), the yield indicators of the plant species included in the study were evaluated, and the quality of the yield of these species was assessed. The results of research confirm the positive effect of sapropel on yield quality indicators - protein (field beans), starch (potatoes) falling number and 1,000 seed mass (winter rye).

Key words: faba bean, sapropel, organic fertilizer, potato, winter rye.

INTRODUCTION

In Agriculture Lake sapropel is used as a fertilizer. The use of it as a fertilizer improves the mechanical structure of soil, shows its moisture absorbing and water-retaining capacity, improves aeration, increases the amount of humus in soil, and activates soil processes. Sapropel fertilizer facilitates the mobilization of the soil components, leading to self-cleaning of harmful plants, fungi, and microorganisms (Didukh et al., 2016). Considering this, sapropel nowadays becomes a popular natural organic-mineral fertilizer and soil conditioner (Stankevica et al., 2019). The environmental aspect is also important. The use of sapropel deposits for soil fertilization provides the formation of a closed ecological cycle with the support of a rational cycle of substances within a specific ecological system. This approach creates the conditions for the transition to a more advanced biogeocenotic basis of nature management (Tsiz et al., (2021). The importance of sapropel's, as organic fertilizer, use, in particular, increase in connection with the tasks set for the European Green Deal (Agriculture and the…, 2020), which envisages, inter alia, placing emphasis on the rational use of local resources.

The composition and properties of sapropel in different deposits are very various (Kurzo et al., 2017; Vincevica-Gaile & Stankevica, 2018; Strakhovenko et al., 2021; Khilchevskyi et al., 2022); it is determined by the productivity of the specific water body, physiographic conditions, hydrological regime, surface runoff and lakebed characteristics, as well as climatic conditions. Therefore, it is important to be aware of the composition of sapropel obtained in a particular deposit before its practical application. In addition, it should be kept in mind that sapropel in its natural state is not a full-fledged fertilizer; it is only raw materials for its production (Morozov et al., 2020).

In Latvia sapropel is one of the important national natural resources of the country. The volume of sapropel the lakes of Latvia is estimated at approximately 500 million tons (with 60% moisture). However, complete research of sapropel was carried out only in a few Latvian lakes (Stankevica, 2020) and this is one of the reasons why it is relatively little used in agriculture.

Effectiveness of sapropel usage in agriculture is proved by a number of investigations conducted in various countries and generally its positive effect on soil properties and forming of yield was found (Blecic et al., 2014; Zarina, 2016). Information is available on the positive effects of sapropel on vegetables such as tomatoes (Naumova et al., 2017), lettuce (Grantina-Ievina et al., 2014), however there is very little research on how the use of sapropel affects the quality of crop yields. The aim of this study was to find out effect of sapropel as fertilizer on the quality of the yield of faba bean (*Vicia faba* L.), potato (*Solanum tuberosum* L) and winter rye (*Secale cereale* L.). There are processing industries for these species in Latvia, so information about the quality of their harvest is especially important.

This paper provides an insight into whether and how the use of sapropel as an organic fertilizer affects the quality of concrete field crops and what dose would be the most economically effective.

MATERIALS AND METHODS

Experiments were conducted at the Priekuli Research Centre of the institute of Agricultural Resources and Economics during the period 2020–2022. The effect of sapropel as fertilizer (NPK 2.8–0.11–0.37) on the quality of the yield of faba bean, potato and winter rye in sandy loamy soddy podzolic soil - *Luvisol (WRB, 2014*) was tested in three organically managed, certified from 2004, fields of organic crop rotation. Soil agrochemical characteristics in the beginning of experiment are shown in Table 1.

Table 1. Soil characteristics of experimental fields in the beginning of studies

Field number	Crop	Pre-crop	pH_{KCl}	Organic matter content (mg kg^{-1})	Mobile P (mg kg^{-1})	Mobile K (mg kg^{-1})
1	Faba bean	Spring cereals	5.8	21	157	65
2	Potato	Winter rye	5.2	28	141	95
3	Winter rye	Green manure (buckwheat)	5.7	28	103	117

Soil samples and analyzes were carried out in accordance with the procedure approved by the Cabinet of Ministers: Soil agrochemical research and procedure for evaluating results (Soil agrochemical…, 2022). Soil samples were taken from the 0–20 cm depth before sowing in spring – for potato and faba bean and accordingly in autumn - for winter rye. The preparation of the field for sowing/planting and crop management was carried out according to the generally accepted technology for organic farming. Meteorological data were obtained from the Priekuli meteorological station 0.8–1.0 km from the experimental site. Weather data at the study site are in Figs 1, 2.

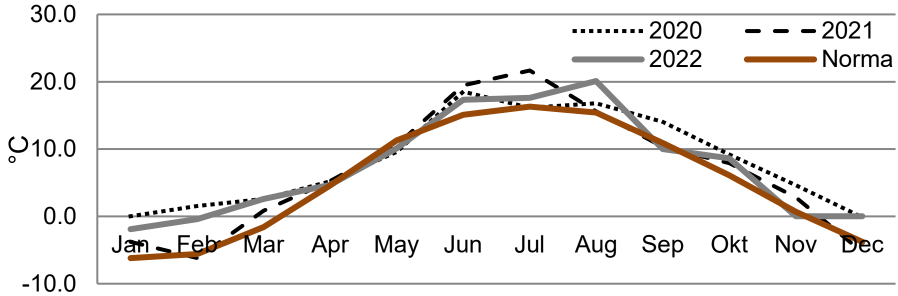

Figure 1. The air temperature during the crop growing season (Priekuli Meteorological Station, Latvia).

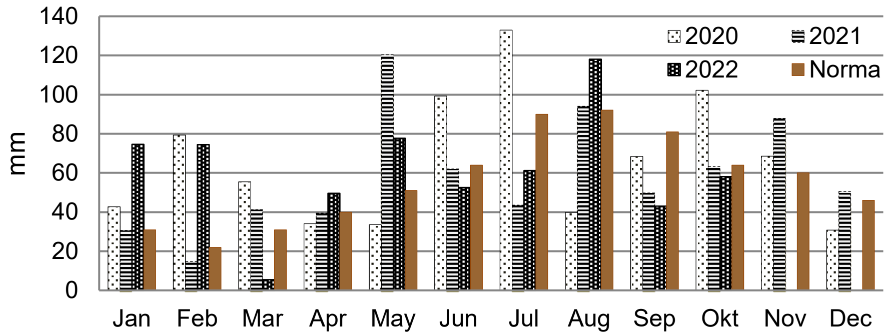

Figure 2. The amount of rainfall during the crop growing season (Priekuli Meteorological Station, Latvia).

The vegetative periods were quite different in terms of temperature and precipitation. In 2020, the weather was colder than the long-term average in April and May, and was rich with precipitation in June and July. In 2021 was hot in the middle of summer, and this period the precipitation rates were lower than the average. In 2022 was also hot and dry period in summer. Due to such vegetative conditions, the germination and development of crops (and also weeds) was different every year, and this to a large extent affected the performance time of crop management works.

Experiment Design

There were four different treatments with rates of sapropel; 0, 20, 40 and 60 t ha^{-1}. Sapropel was spread before sowing, in the period between the first and second soil cultivation. Sapropel is used, which is extracted as a mineral from Biža Lake, Andrupene parish, Krāslava County. Sapropel chemical composition is reflected in Table 2.

Table 2. Chemical composition of sapropel of Lake Biza

Indicator*	Content	Methods of determination
Dry matter content, %	24.40	ISO 6496:1999
Total nitrogen, %	2.82	LVS EN ISO 5983-2:2009
Calcium (Ca) %	1.01	LVS EN ISO 6869:2002
Phosphorus (P) %	0.11	ISO 6491:1998
Magnesium (Mg) %	0.31	LVS EN ISO 6869:2002
Potassium (K) %	0.37	LVS EN ISO 6869:2002
Sodium (Na) %	0.02	LVS EN ISO 6869:2002
Cinc (Zn), mg kg^{-1}	136.93	LVS EN ISO 6869:2002
Copper (Cu)), mg kg^{-1}	6.19	LVS EN ISO 6869:2002
Manganese (Mn)), mg kg^{-1}	202.15	LVS EN ISO 6869:2002
Iron (Fe), mg kg^{-1}	11,227.55	LVS EN ISO 6869:2002

*The content of elements is given in dry matter.

Trials were set up in three fields, and they were planed for each species separately. The arrangement scheme of variants was the same for all species. A randomised plot design with four replicates was used (Fig. 3). The size of each experimental plot was 12 m^2 (1.2×10 m) for faba bean and winter rye and 28 m^2 (2.8 m × 10 m) for potato. Basic soil treatment - ploughing was carried out in autumn, for winter rye - in early September, for potatoes and field beans - in October, 20–23 cm deep. The agrotechnical operations applied in the experiment are shown in Table 3.

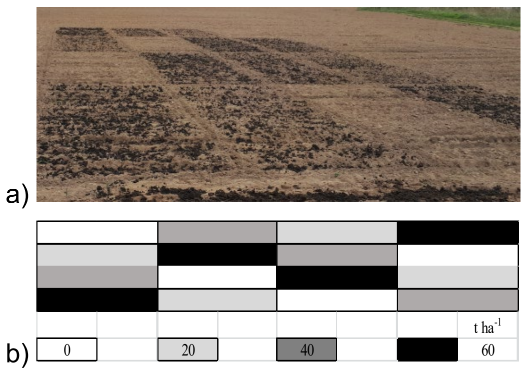

Figure 3. Design of experimental fields (a – before 2nd cultivation; b – scheme of plots).

Table 3. The agrotechnical operations of the experiment

Agrotechnical operation	Timing
Pre-sowing soil tillage (cultivation)	End of April, at the time of soil physical maturity
Sowing: (55 seeds m^2 for faba bean, 200 kg ha^{-1} for winter rye, distance between seeded potato - 27 cm)	Right after pre–sowing soil tillage
Inter-row loosening for potato (OKN-8-2138)	2 times till germination, 2–3 times after germination with and without harrowing
Harrowing for faba bean	1–2 times
Harvesting	August (winter rye and potato), September (faba bean)

Sampling and determination of yield quality

Each plot was harvested at maturity using a combine harvester *ZURN 110* for faba bean and winter rye and 1-ROW harwester for potato. The yield of each plot was weighed. A sample was taken from the harvest of each plot - 1 kg for beans and rye, 5 kg for potatoes for quality evaluation. Samples of winter rye and field bean grains were dried to a constant (14%) moisture content in a platform dryer, cleaned of impurities and small grains. The dry matter content of all plant samples was determined after oven drying at 130 °C for 2 h (ISO 712:2009). Grain quality determined using *Infratec Nova*. The falling number (FN) was determined by the ICC standard method 107/1. The starch content was determined as soon as possible after harvest for all variants samples at same time using underwater weight.

Data analyses

The experimental data were statistically processed by applying two-factor analysis of variance (ANOVA). Significant differences among the studied treatments were determined by calculating the least significant difference at the 95% and 99% level of significance ($p < 0.05$ and $p < 0.01$). A dispersion analysis was performed, using Fisher's *LSD* test to identify significant differences between the means.

RESULTS AND DISCUSSION

The average values of quality parameters of faba bean, potato and winter rye measures are summarized in Fig. 4. Although the differences seem small when variants are compared, we were able to detect some general tendencies and also statistically significant effects when interaction with year was taken into account.

Variant	Year			
	2020	2021	2022	Average
S-0	28.4	29.6	32.0	30.0
S-20	27.7	29.9	30.5	29.4
S-40	29.0	30.0	31.0	30.0
S-60	28.8	30.6	31.8	30.4

Faba bean protein content, %

Variant	Year			
	2020	2021	2022	Average
S-0	104.5	110.3	111.0	108.6
S-20	115.9	111.4	112.6	113.3
S-40	109.7	111.8	109.5	110.3
S-60	107.9	119.8	115.8	114.5

Winter rye falling number

Variant	Year			
	2020	2021	2022	Average
S-0	19.4	18.4	19.0	18.9
S-20	19.8	18.5	18.4	18.9
S-40	19.8	18.7	18.7	19.1
S-60	19.7	17.4	18.3	18.8

Potato starch content, %

Variant	Year			
	2020	2021	2022	Average
S-0	33.2	29.6	32.0	31.5
S-20	35.1	29.9	30.5	32.5
S-40	35.3	30.0	31.0	32.1
S-60	35.4	30.6	31.8	32.5

Winter rye 1,000 kernel weight, g

Figure 4. The average values of quality parameters of the yield of faba bean, potato and winter rye.

The two-way ANOVA indicated interaction between the year and the variant for all yield measures except for faba bean protein content. The plots of estimated marginal means of protein content are presented in Fig. 5. In this case there were no interaction effects, but both the year and the sapropel variant indicated to have significant effect on protein content ($p < .001$ and $p = 0.098$ accordingly). The Fisher's LSD post-hoc test showed that all years mutually differ from each other (p-values < .001) and there was a significant difference between S-20 and S-60 variants (p = .016). The average values in all years are highest for the variant S-60 and the lowest for variant S-20. The exception is control which had highest content in the year 2022 and lowest in 2021 when compared to experimental variants. This might point to higher contrasts in control settings. The variation of protein due to the climatic year was from 27.7% in 2020 to 32% in 2022. Apparently, the year 2022 was more favorable for plants, when photosynthesis could take place more intensively. The research results of Klepeckas & Januskaitienes, (2016) also confirm that plant photosynthesis activity increases with increasing sapropel dosage.

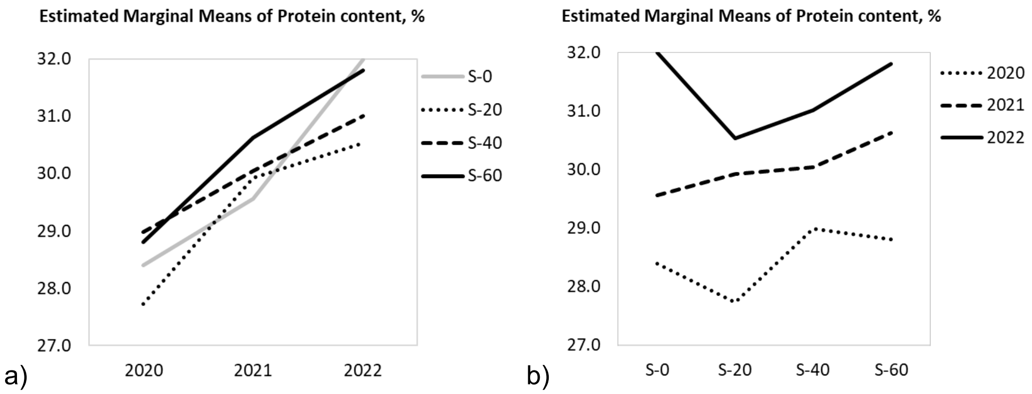

Figure 5. Mean protein content in faba beans depending on the dose of sapropel fertilizer (a) and the year (b).

When starch content in potatoes is considered, the two-way ANOVA indicates interaction effect of the year and variant. The plots of estimated marginal means of protein content are presented in Fig. 6. They show that in the year 2022 the control setting somehow jumps out in the model. When main effects were considered separately the Fisher LSD test indicated the year 2020 to be significantly different from others (p<.001) and that variant S-40 differs from S-20 and S-60 (p = .044 and p = .003 accordingly). The average values had been relatively higher in 2020 for all variants.

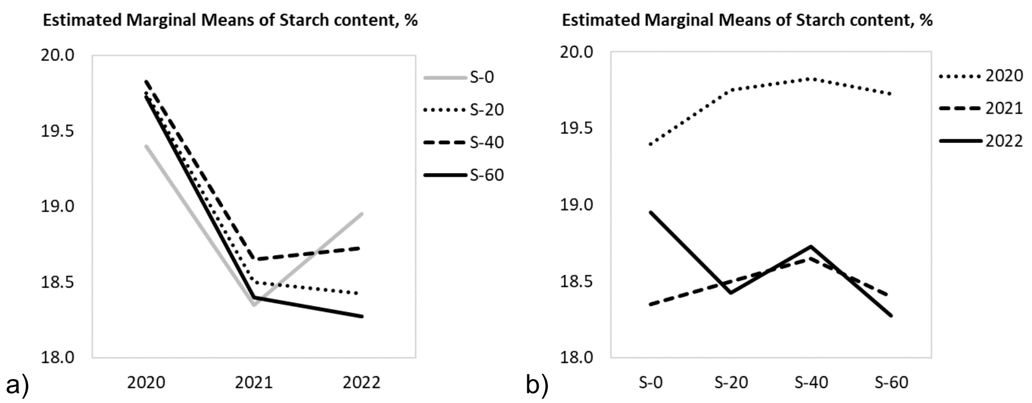

Figure 6. Mean starch content in potatoes depending on the dose of sapropel fertilizer (a) and the year (b).

On the other hand the application of variant S-40 had led to higher starch content in all years. Also in this case it can be noticed that in control settings there have been higher contrasts in comparison to experimental variants. The average starch content in tubers varies by 0.3 = 0.7% depending on the dose of sapropel, but the difference is not significant. Burakova et al. (2018) found that the amount of starch was not influenced by the variety of inserting fertilizer. Unfortunately, there is practically no data in the literature about the effect of sapropel application on the starch content of potato tubers.

Also for measures of winter rye the two-way ANOVA indicated interaction effects as well as significant main factors. When the falling number is considered (Fig. 7), according to the Fisher's LSD test the significantly different from other years was the year 2020 ($p < .004$). The inspections of mean values show that in this year the falling number had been relatively more diverse when all variants are compared and show different tendencies in comparison to both following years. Regarding the differences of the variants the Fisher's *LSD* test indicated mutual significant differences ($p<.006$) in all cases except for control and S-40 ($p = .097$) and S-20 and S-60 ($p = .237$). The average value indicates that the smallest falling number overall had been in control setting and the most stable in variant S-40. However the S-20 and S-60 had overall the highest measures if all years are considered together. Generally the use of sapropel slightly improves rye grain falling number; at the low dose (S-20) it is by 4.7 sec, at the medium (S-40) and large dose (S-60), by 1.7 and 4.9 sec higher, respectively. The fact that the difference between the variants is small is not surprising, as some authors (Grantina-Ievina et al., 2014) have found that effect of sapropel on plant growth is species-specific; substrate substitution at the optimum level of mineral supply resulted not in significant increase in dry matter accumulation in winter rye plants. In general, the indicators of the falling number obtained in all years, regardless of the use of sapropel, are low, because grains not exceeding 120 seconds correspond only to the production of the 2nd category *(https://rigas-dzirnavnieks.lv/grain-quality/*.

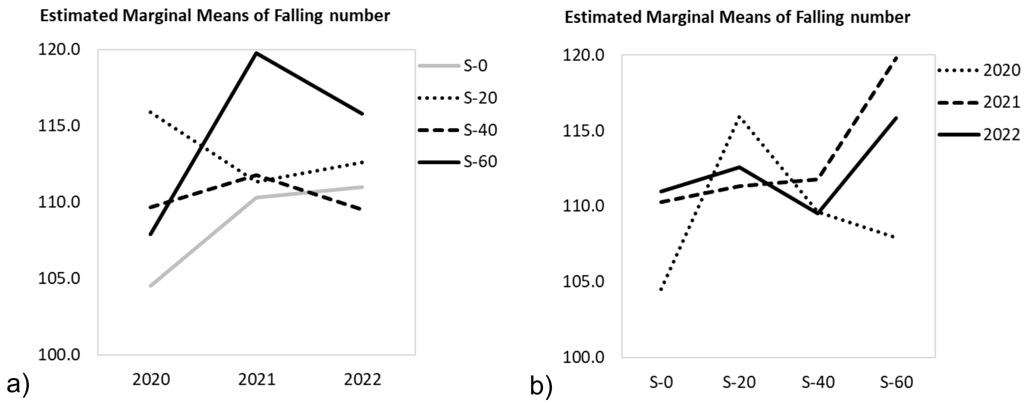

Figure 7. Mean falling number of winter rye grain depending on the dose of sapropel fertilizer (a) and the year (b).

When 1,000 kerner weight is considered, the Fisher's LSD test indicates that all years are mutually different ($p < .001$) which can be observed also in Fig. 8 where different tendencies can be observerd over years. Also regarding variants there are mutual significant differences ($p < .022$) in all comparisons excep fot variant S-20 and S-60 ($p = .957$). The inspection of average values show that there has been relatively much smaller 1,000 kernel weight in the year 2022 and also the effect of sapropel application seem different than in other years.

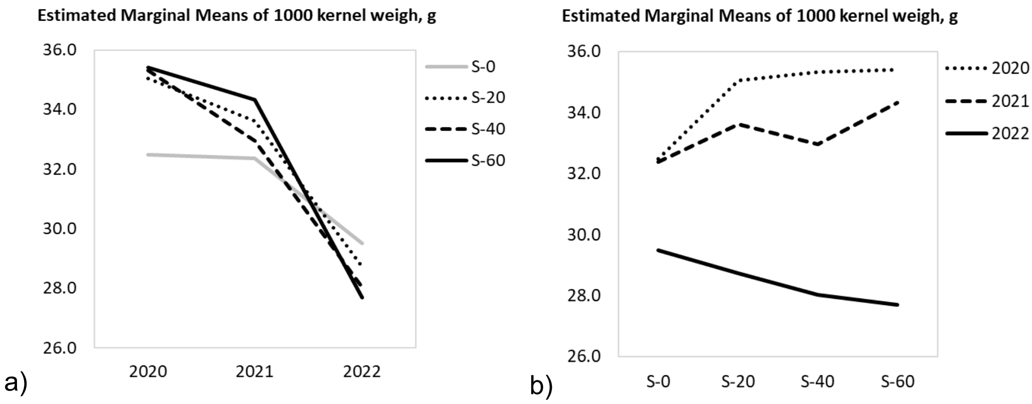

Figure 8. Mean 1000 kernel weight of winter rye grain depending on the dose of sapropel fertilizer (a) and the year (b).

In general, the use of sappropel has contributed to the formation of coarser grains of winter rye; 1,000 kernel weight depending the sapropel doses and the year changing from 27.7 till 35.4 g., which is characteristic of the cultivar 'Kaupo' *(https://www.arei.lv/lv/ziemas-rudzi-kaupo)*.

Crop yields were also recorded during the research. On average, depending on the variant, it was 1.7–1.8 t ha^{-1} for faba beans, 19.7–22.0 t ha^{-1} for potatoes, but for winter rye it was 0.9–2.8 t ha^{-1}. The use of sapropel from Lake Biza only for winter rye ensured a significant yield increase, but the difference between the doses of sapropel was not significant ($p<0.05$). This result is consistent with the results of studies conducted by other scientists in other crops (Vincevica-Gaile et al., 2015). Despite the fact that the use of sapropel for field improvement does not guarantee a significant increase in crop yield or an improvement in its quality indicators, as has been proven many times, the use of sapropel is mainly associted with the improvement of soil properties (Tsiz et al., 2021). For example, studies in Lithuania have found that fertilization with 40 t ha^{-1} of sapropel significantly reduces leaching losses of nitrates in sandy loam and sandy loam soils compared to other used fertilizers (Burakova & Bakšiene, 2021).

CONCLUSIONS

1. Although the use of sapropel in soil improvement and plant fertilization has been proven, a targeted study of its use, emphasizing the impact on crop quality, has not been carried out so far.

2. The results of our research confirm the positive effect of sapropel on yield quality indicators – protein (field beans), starch (potatoes) falling number and 1000 seed mass (winter rye).

3. During three years, in most cases, the differences were not significant, so the potentional value of sapropel as an organic material in improving soil properties and also in reducing nitrate leaching losses should be emphasized.

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