

Evaluation of the effect of sugar mud and organic fertilizers on the productivity of sugar beets in the conditions of Podillia

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Abstract. The application of lime fertilizer “defecation” on acidic and slightly acidic soils has a multifaceted positive effect, eliminating excessive acidity, and creating optimal environmental conditions for agricultural plants and soil microorganisms, increases the water resistance of structural soil aggregates, which determines favourable water and air modes, increases the accumulation of phosphorus, potassium. The goal is to investigate the influence of sugar mud and organic fertilizers on the productivity of sugar beets in the conditions of Podillia. In the presented study was carried out using such methods as field, measuring and weighing, laboratory, statistical. According to the results of the experiment, it was determined that the productivity of sugar beets increased depending on the doses of applied fertilizers. Thus, with the application of 2.0 Hr of sugar mud, the yield increase amounted to 15.27 t/ha. The combination of organic fertilizer and sugar mud 2.0 Hr had the strongest effect on productivity – 29.41 t/ha. The collection of sugar increased according to the experimental variants mainly due to the increase in yield. The increase in digestion was insignificant: from 0.08 to 0.56% according to the experiment variants. The segment of crop production will be profitable due to the drivers of the volume of the harvested crop. The side economic effect of the application of this measure will be to obtain a larger sugar harvest per hectare, which will allow to obtain a larger profit from the processing of sugar beets into sugar. The practical value of the research lies in the formation of recommendations for farms and agricultural enterprises growing sugar beet on acidic and slightly acidic soils in order to increase its productivity

Keywords: plant growing; agricultural techniques; liming; fertilization; soil acidity

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INTRODUCTION

As a result of the significant anthropogenic impact on the agricultural landscapes of Ukraine and the intensification of agricultural production, the state of soil acidification is characterized as catastrophic. The highest level of arable land acidification is characteristic of the Podillia zone, and this especially applies to the soils of the Vinnytsia region, where acidic soils make up more than 80% of the total arable land area (Voitova, 2020).

There are not many comprehensive studies on the impact of manure application and organic fertilizers on sugar beet productivity in the scientific environment. The general physiology of sugar beet and the factors affecting it are studied in the work of C. Hoffmann *et al.* (2021). Physico-chemical indicators and yield of sugar beets were considered in detail by I. Khan *et al.* (2018). M. Rašovský & V. Pačuta (2016) studied quite deeply and thoroughly the influence of certain agrotechnical measures and climatic conditions on the yield of root crops and the digestion of sugar beets. An interesting study is the assessment of the stability and adaptation models of the yield of white sugar from sugar beet varieties in a temperate climate, carried out by M. Studnicki *et al.* (2019). Agrotechnical measures in the management of soil fertility were studied by C. Kabala *et al.* (2016). Certain aspects of adaptive technology in the part of growing sugar beets on acidic soils are studied in the work of O. Balahura *et al.* (2018). The team of authors A. Zaryshniak *et al.* (2019), who examined the productivity of sugar beets under biologicization of their cultivation on weakly acidic soils, continues the development of this scientific direction. The general principles of sugar beet productivity, depending on the system of fertilization and tillage, were studied in the work of such scientists as O. Chernelivska *et al.* (2019).

Despite significant progress in the study of measures to increase the yield of sugar beets, there is a lack of comprehensive systematic work on the effect of applying manure and organic fertilizers on the productivity of sugar beets. One of the effective methods of increasing the fertility of acidic soils and ensuring the productivity of agricultural crops is liming and applying organic fertilizers. However, in the conditions of the existing price disparity for agricultural products and plant protection products, there is a need to find such methods of processing agricultural crops, which, at the lowest costs, ensured not only an increase in yield, but also the restoration of soil fertility. To solve this scientific and practical task, it was proposed to investigate the use of sugar production waste – sugar mud – which is especially relevant for enterprises that provide a full cycle of sugar production: from the provision of raw materials (growing sugar beets) and the actual production of sugar. Compared to traditional liming,

sugar mud has advantages in cost, lower costs for transportation to the fields, in particular, its application allows for more efficient use of organic fertilizers.

MATERIALS AND METHODS

The study of the effect of sugar mud and organic fertilizers on the productivity of sugar beets was carried out in the Podillia area. The experiment was conducted at the limited liability agricultural company named after Bohdan Khmelnytskyi, as well as in the raw materials and factory laboratories of the sugar factory in the village of Horodkivka. The study was conducted on a pilot basis in 2022. The study adheres to the publication ethics established by Convention on Biological Diversity (1992), as any experiment involving plant research (both cultivated and wild). The experimental area is represented by grey podzolized soils mainly on loess rocks. The soil survey showed that the humus content is low, and the decline down the profile is gradual. The soil is slightly acidic, the content of mobile phosphorus is average, exchangeable potassium is high. The density of the arable horizon is 1.09 g/cm³, an increase is observed down the soil profile.

The object of research within the scope of the conducted experiment was the process of formation, development, growth and ensuring the productivity of sugar beet depending on the application of sugar mud with organic fertilizers. Taking into account the pH of the soil at the level of 5.1–5.5, the degree of saturation with bases of 88.6%, the high hydrolytic acidity of 3.5–3.8 mg/eq., as well as the fact that a stable positive effect of liming is observed at the level of soil pH below the level of 5.5 and hydrolytic acidity of more than 2.0 mg/eq., there is a need for liming of this experimental plot. The total area of experimental plots was 45 hectares – 5 hectares for each of the formed schemes.

The predecessor of sugar beets was winter wheat. After harvesting, 2 weeks later, sugar mud was introduced, followed by planting in the soil. The weight rate of the introduced sugar mud was 25% of the full rate, depending on the indicator of hydrolytic acidity of the soil. Chemical composition of sugar mud: CaCO₃ – 44.3%, organic matter – 14%, N – 0.45%, P₂O₅ – 0.57%, K₂O – 0.75%, moisture – 14–23%. Compost with a dose of 12 t/ha was applied as an organic fertilizer. In particular, to prevent direct contact of sugar mud and amorphous phosphorus when applied to the soil, mineral fertilizers were applied during plowing. Plowing in the experiment was carried out at a depth of 28–30 cm (Humentyk *et al.*, 2018). In accordance with the purpose of the experiment to study the influence of sugar mud and organic fertilizers on the productivity of sugar beets, the following scheme was formed (Fig. 1).

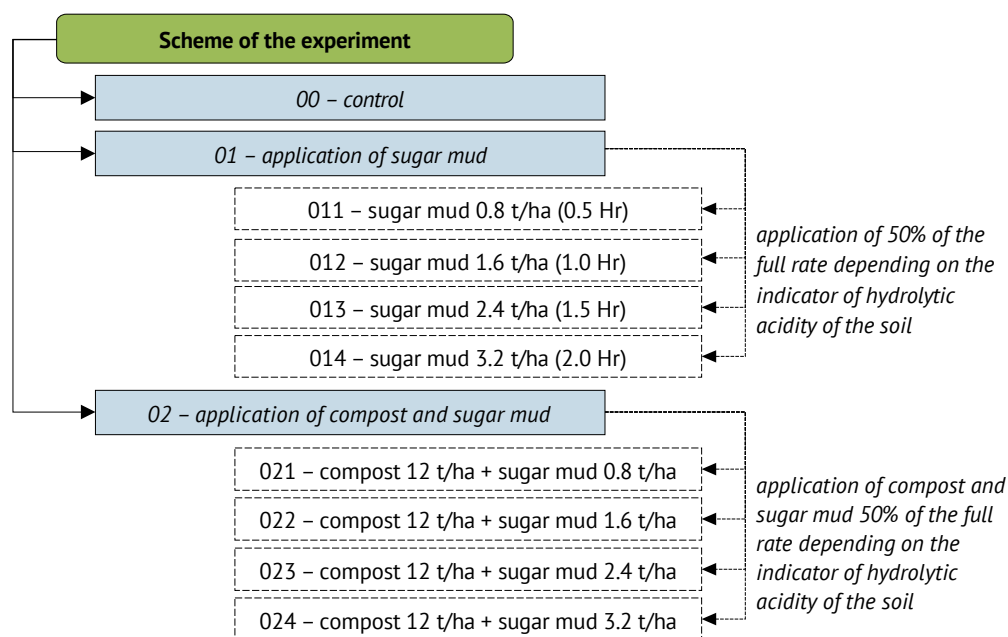


Figure 1. Scheme of conducting an experiment to study the influence of sugar mud and organic fertilizers on the productivity of sugar beets

Source: authors' own development

In the spring, when the physical maturity of the soil was reached, harrowing was carried out. 5 days after harrowing, when the soil was warmed at a depth of 10 cm to +5°C – +6°C, pre-sowing cultivation was carried out to a depth of 4-5 cm (Korovko, 2017). The Concertina KWS hybrid was used as seed material. Sowing rate – 1.2 s.u. on 1 ha. Sowing was carried out in a wide-row method with a Tempo Väderstad precision seed drill with 45 cm between rows, to a depth of 4-5 cm. At the beginning of the appearance of the second pair of true leaves, inter-row cultivation was carried out and the formation of optimal density by means of thinning. The yield of sugar beet was determined using the weighing complex of the beet point, and its technological qual-

ities (digestion, content of dry substances, non-sugars, etc.) were determined in the raw material laboratory.

RESULTS

The main indicator of the effectiveness of the application of organic fertilizers is an increase in the yield of agricultural crops. Thus, the actual yield of sugar beets according to the schemes of the conducted experiment on the assessment of the impact of application of sugar mud and organic fertilizers deviated from the control value from 1.42 to 19.67 t/ha from 3 to 42%. The results of recording the yield indicators of sugar beet grown on the experimental plots according to different schemes are shown in the Figure 2.

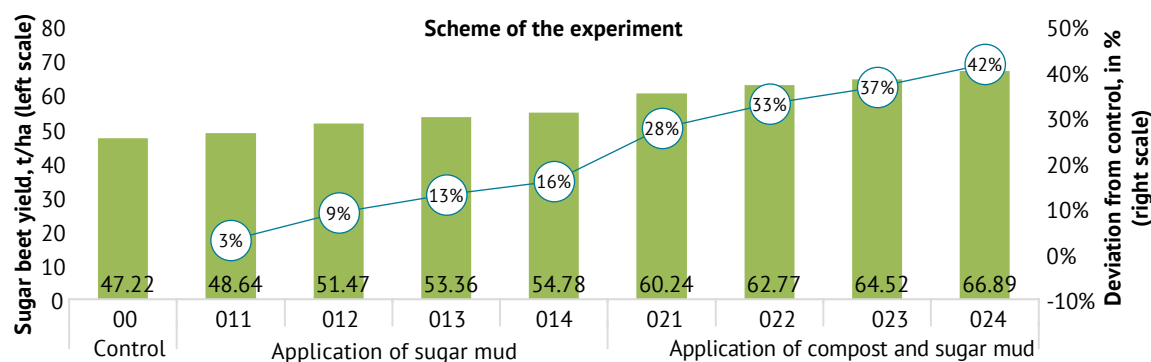


Figure 2. The yield of sugar beets depending on the doses of application of sugar mud in combination with organic fertilizers in 2022

Source: authors' own development

Application of only sugar mud provided an increase in the yield of sugar beets from 1.42 to 7.56 t/ha (from 3 to 16%). In turn, the application of sugar mud against the background of organic fertilizers (compost) ensured an increase in the yield of sugar beets from 13.02 to 19.67 t/ha (from 28 to 42%). Therefore, the application of organic fertilizer (compost) at a dose of 12 t/ha and sugar mud at a dose of 3.2 t/ha had the greatest positive effect on the productivity of sugar beets. This is due to the fact that applied organic fertilizers and sugar mud improve the water-air properties of soils, they become looser. Thanks to this, aeration, water permeability increases and the moisture reserve in the soil increases. What contributes to the powerful development of the

root system of sugar beets, capable of more fully using soil moisture, developing sufficient vegetative mass.

The distribution of sugar in root crops is uneven. In the tail part and especially in the root head, the sugar content is lower than in the central part. The maximum amount of sugar accumulates slightly below the widest part of the root between the periphery and the central zone. Root crops belong to the group of crops that require a large amount of nutrients, so the application of fertilizers strongly affects the size of the harvest and its quality. The results of recording the digestion (sugar) indicators of sugar beet grown on the experimental plots according to different schemes are shown in the Figure 3.

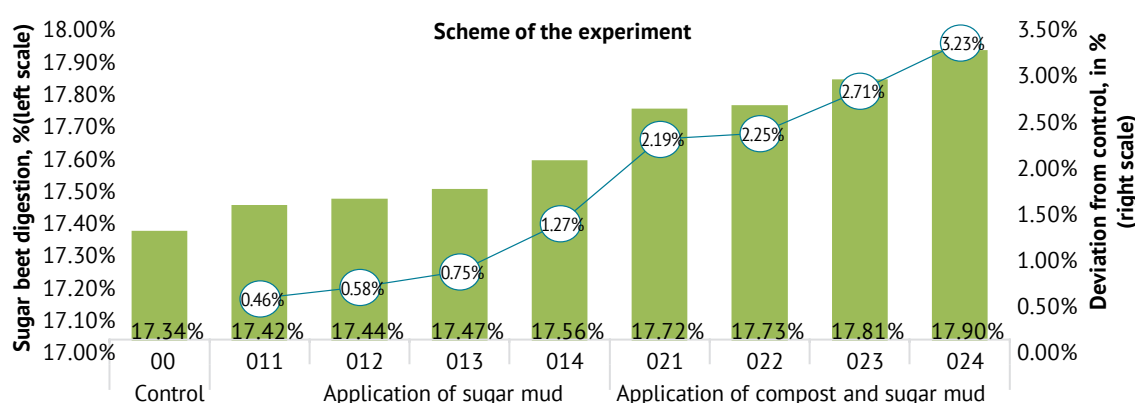


Figure 3. Digestion of sugar beets depending on the doses of sugar mud application in combination with organic fertilizers in 2022

Source: authors' own development

The application of only sugar mud provided an increase in the digestion of sugar beets from 0.08% to 0.22% (from 0.46 percentage points to 1.27 percentage points). In turn, the application of sugar mud against the background of organic fertilizers (compost) provided an increase in the digestion of sugar beets from 0.38% to 0.56% (from 2.19 percent to 3.23 percent). Therefore, the application of organic fertilizer

(compost) at a dose of 12 t/ha and sugar mud at a dose of 3.2 t/ha had the greatest positive effect on the productivity of sugar beets. Based on the obtained results of yield and digestion of sugar beets, let's consider the resulting indicator – harvesting of sugar per hectare – and conduct a factor analysis of the contribution of individual indicators (yield and digestion) to its formation (Fig. 4-5).

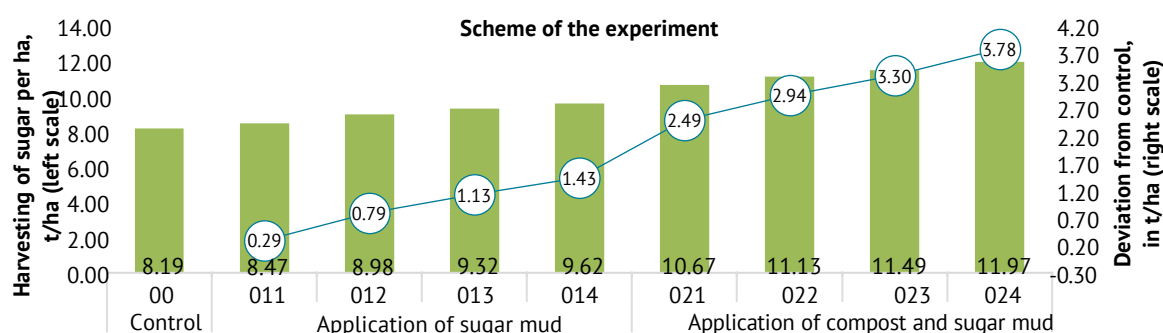


Figure 4. Harvesting of sugar per hectare depending on the doses of application of sugar mud in combination with organic fertilizers in 2022

Source: authors' own development

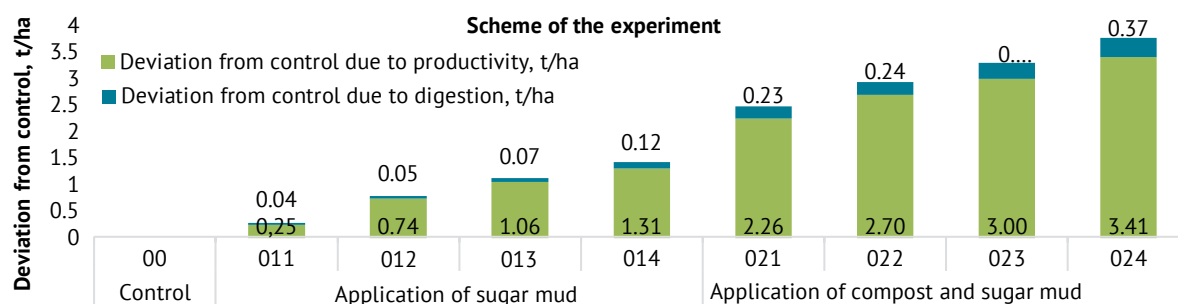


Figure 5. Factor analysis of deviations of harvesting of sugar per hectare depending on the doses of application of sugar mud in combination with organic fertilizers in 2022

Source: authors' own development

The application of only sugar mud provided an increase in the yield of sugar from 1 ha from 0.29 to 1.43 t/ha. In turn, the application of sugar mud against the background of organic fertilizers (compost) ensured an increase in the yield of sugar from 1 ha from 2.49 to 3.79 t/ha. Therefore, the greatest positive impact on sugar collection from 1 ha of sugar beet crops was made by the application of organic fertilizer (compost) at a dose of 12 t/ha and sugar mud at a dose of 3.2 t/ha. At the same time, it can be testified that the factor contribution of productivity in the formation of the indicator of sugar collection from 1 ha is at the level of an

average of 94% against the factor contribution of sugar beet digestion at the level of 6%.

However, it should be noted that if organic fertilizers increase digestion, they simultaneously reduce the content of dry substances in the composition, which accounts for the share of sucrose, increasing the number of non-sugar soluble forms. These sugars, passing into beet juice, sharply deteriorate its quality. According to the results of the experiment, it was determined that with an increase in the doses of applied fertilizers, the content of dry substances and the total amount of non-sugars decreases (Fig. 6-8).

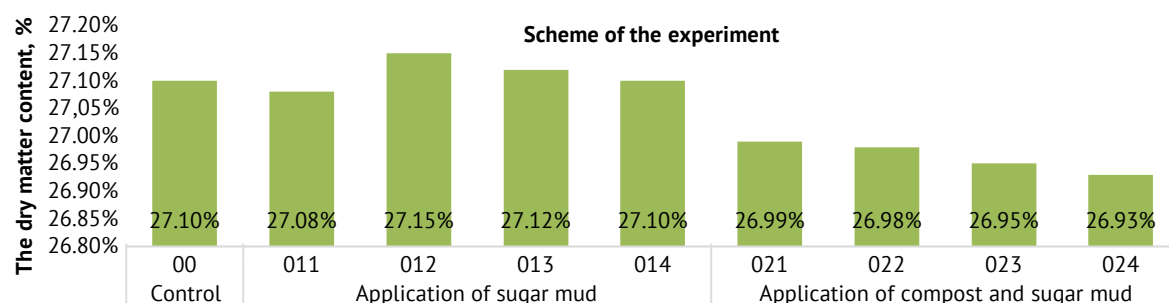


Figure 6. Indicator of the quality of sugar beet "The dry matter content" depending on the doses of application of sugar mud in combination with organic fertilizers in 2022

Source: authors' own development

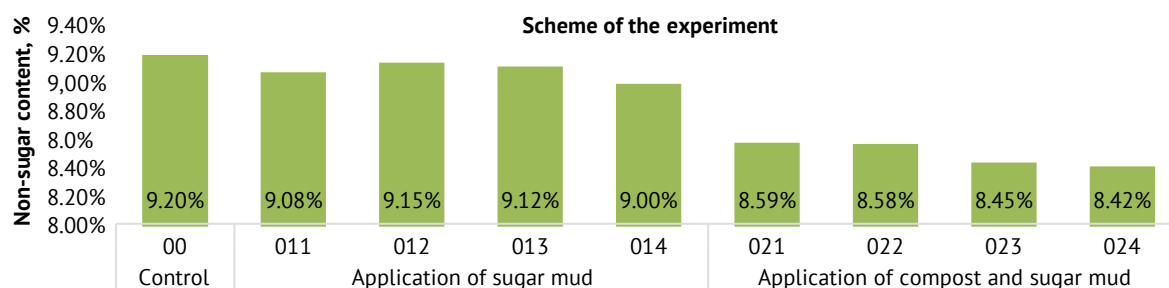


Figure 7. Indicator of the quality of sugar beet "Non-sugar content" depending on the doses of application of sugar mud in combination with organic fertilizers in 2022

Source: authors' own development

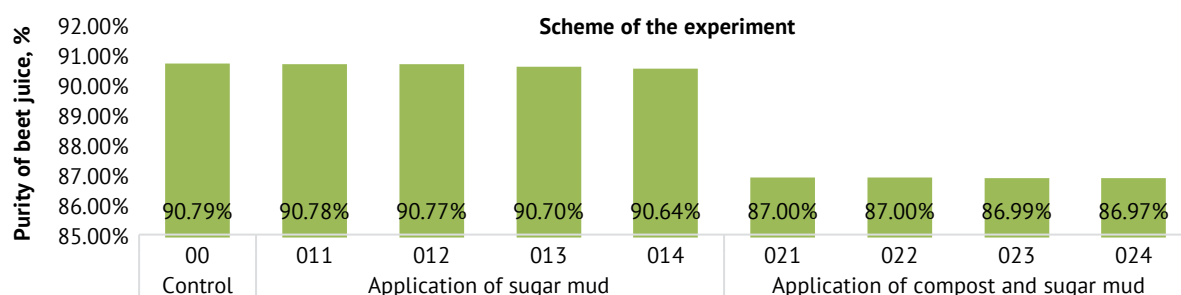


Figure 8. Indicator of the quality of sugar beet "Purity of beet juice" depending on the doses of application of sugar mud in combination with organic fertilizers in 2022

Source: authors' own development

According to the option of compost 12 t/ha + sugar mud 3.2 t/ha, the content of dry matter was 26.93% and non-sugar 8.42%, while in the control it was 27.10% and 9.20%, respectively. Despite the decrease in the content of dry matter in root crops due to the application of organic fertilizers, at the same time, the content of harmful soluble non-sugars increases, thereby worsening the quality of beet raw materials. The application of sugar mud reduces the content of soluble non-sugars. In the case of application of sugar mud with organic fertilizers, the purity of the juice deteriorates.

DISCUSSION

Studies show that the influence of the environment on plants depends on biological features and external factors. Laboratory studies have proven that increasing the concentration of calcium in the nutrient medium weakens the negative effect of hydrogen ions. This is explained by the antagonistic action of calcium in relation to hydrogen. In the presence of high calcium content, hydrogen ions are in the nutrient medium, but their entry into the plant is delayed (Shyrokostup, 2014). Acidic soils are characterized by unfavourable biological, physical and chemical properties. The colloidal part is poor in calcium and other bases. Hydrogen ions displace calcium from humus, increase its dispersion and mobility, and hydrogen saturation of mineral colloidal particles leads to their gradual destruction. This explains the low content of the colloidal fraction in acidic soils, which is why they have poor physical properties, low absorption capacity, and weak buffering capacity. In acidic soils, the activity of nitrifying, nitrogen-fixing and other beneficial bacteria and microorganisms is inhibited (Zaryshniak *et al.*, 2019). The negative effect of increased acidity is largely related to the mobility of aluminium and manganese in the soil. The main mass of aluminium is in the soil in a sedentary state and does

not affect plants, but in acidic, for example, grey, dark-grey podzolic soils, the content of mobile aluminium often ranges from 3 to 20 mg/100 g of soil (Kliachenko & Kolomiets, 2013), per sowing unit 1 ha is 60-400 kg of movable aluminium, which is 120-800 times higher than its content in plants. With increased soil acidity, there is poor growth and strong liquefaction of clover, alfalfa, sugar beets, winter wheat and other crops. Some weeds - horsetail, sedge, sedge, creeping buttercup, sedge, heather grow well on acidic soils and are indicator plants. For each type of plant, there is a certain, most favourable for growth and development reaction interval of the medium (pH 6.5-7.5). Alfalfa, sugar beet, hemp, cabbage do not tolerate acidic soils at all (pH 7.0-7.5).

The process of soil impoverishment with calcium is observed almost everywhere, but it has a different quantitative expression and therefore does not have the same effect on fertility, as evidenced by the data on agrochemical soil survey (Kurylo *et al.*, 2014). Various meliorants can be used to improve soil fertility: lime, gypsum, dolomite flour, etc., as well as sugar mud, the effectiveness of which was not inferior to chalk and dolomite flour. Thus, when applying equal doses of chalk, dolomite flour and sugar mud under sugar beets, the yield was: background (control): 445 t/ha; background + chalk: 477 c/ha; background + dolomite flour: 483 c/ha; background + defect: 490 c/ha. That's why V. Butov & V. Porudiev (2014) also consider fragmentary application of organic fertilizers under sugar beet.

According to research data, defecate is not inferior to gypsum in terms of its remedial effect (Chernelivska, 2012). Fecal doses of 4, 8, 20, 40, 60 t/ha were studied, which were applied respectively in the spring for cultivation and in the fall for plowing. Observation of growth and development showed that the application of sugar mud (4 and 8 t/ha) did not have a significant effect on the initial growth and development of plants,

but their application under cultivation significantly reduced the volumetric weight of the soil, which was 1.13 g/cm against 1.26 g/cm when applying meliorant under plowing (Roik *et al.*, 2014). The volume weight is reduced to 1.12 g/cm, as well as the use of 20 t/ha of manure for cultivation. The use of sugar mud of 4-8 t/ha for cultivation reduces the number of soil particles of 1.0-0.25 mm and increases the number of particles of 5-10 mm (Sinchenko *et al.*, 2014). In this version, the indicators of soil fertility also improved. Thus, the content of mobile phosphorus and exchangeable potassium increased by 17 and 21%, respectively.

In the conditions of the Cherkasy region, the influence of defecation on soil fertility and crop yields was studied (Shevchenko, 2015). The efficiency is shown for single and double doses of sugar mud of 10 t/ha and 20 t/ha. The number of absorbed bases and the degree of saturation with bases increased significantly, the hydrolytic acidity significantly decreased from 6.82 in the control to 2.10 when 1.0 Hr was applied, and 2.27 mg/eq per 100 g of soil when 2.0 Hr was applied. The pH value reached 6.52-6.60 in the arable layer.

Other studies have shown that liming with sugar mud improves the agrochemical properties of the soil (Balahura *et al.*, 2018). On the calcareous areas, the pH changed from 6 to 6.3 mg/eq. (salt extract), hydrolytic acidity from 4.4 to 1.7 mg/eq., phosphorus and potassium reserves increased. The application of sugar mud in a complex with manure contributed to an increase in the humus content compared to the initial indicator by 0.53%; a significant increase in the potassium content in the soil was noted in cases where ameliorants were used in combination with manure up to 138 mg/kg.; on control 78 mg/kg. The use of calcium-containing ameliorants (sugar mud and calcium carbonate) both on the background of manure and in combination with mineral fertilizers contributed to the deacidification of leached soils (Kokovikhin *et al.*, 2012). The pH increased from 5.0-5.3 to 5.9-6.0, the hydrolytic acidity decreased from 6.0-7.0 to 2.6-4.1 mg/eq. per 100 g of soil, and the degree of saturation with bases increased from 79-82 to 88-92%.

Thus, as evidenced by the conducted research, the application of lime fertilizer "defecation" on acidic and slightly acidic soils has a multifaceted positive effect, eliminating excessive acidity, and creating optimal environmental conditions for agricultural plants and soil microorganisms, increases the water resistance of structural soil aggregates, which determines a favourable water and air modes, increases the accumulation of phosphorus, potassium. As a result of this influence, the yield and quality of agricultural crops increase significantly.

CONCLUSIONS

Thus, sugar mud is a valuable ameliorant that has a positive effect on the condition of the soil. The application of sugar mud reduces the exchangeable acidity of the soil from 5.50 to 6.75 pH. The application of sugar mud on acidic and slightly acidic soils has a multifaceted positive effect, eliminating excessive acidity, and creating optimal environmental conditions for agricultural plants and soil microorganisms, increases the water resistance of the structural aggregates of the soil, which determines favourable water and air regimes, increases the accumulation of phosphorus and potassium. As a result of this influence, the yield and quality of agricultural crops increase significantly. Sugar beet productivity increased depending on the applied fertilizer doses. Thus, with the application of 2.0 Hr of manure, the yield increase amounted to 7.56 t/ha. The combination of organic fertilizer and manure 2.0 Hr had the strongest effect on productivity – 19.67 t/ha. The collection of sugar increased according to the experimental variants mainly due to the increase in yield. The increase in digestion was insignificant: from 0.08% to 0.56% according to the experiment variants.

According to the results of the conducted research and experiments, the farm is recommended to apply compost at a dose of 12 t/ha and sugar slurry at a dose of 3.2 t/ha. The specified agronomic measure will allow to increase the productivity of sugar beet - to ensure a high yield of this crop, an increase in digestion and, accordingly, sugar collection per hectare. It should be noted that this measure is economically feasible for both the crop production segment and the sugar production segment. Further directions for deepening the research may be the exclusion of factors of meteorological influence, which are usually carried out in order to determine a reliable assessment of the effectiveness of certain agrotechnical techniques in agricultural practice.

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CONFLICT OF INTEREST

None.

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Оцінка впливу дефекату та органічних добрив на продуктивність буряків цукрових в умовах Поділля

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Анотація. Внесення вапняного добрива «дефекату» на кислих і слабокислих ґрунтах має багатогранний позитивний ефект, усуваючи надмірну кислотність і створюючи оптимальні екологічні умови для сільськогосподарських рослин і ґрунтових мікроорганізмів, підвищує водостійкість структурних агрегатів ґрунту, що визначає сприятливий водний і повітряний режими, збільшує накопичення фосфору, калію. Мета – дослідити вплив цукрового розчину та органічних добрив на продуктивність цукрових буряків в умовах Поділля. У представлених дослідженнях використовувались такі методи: польовий, вимірально-ваговий, лабораторний, статистичний. За результатами дослідження встановлено, що продуктивність буряків цукрових зростала залежно від доз внесених добрив. Так, при внесенні 2,0 д.р. цукрового розчину прибавка врожаю склала 15,27 т/га. Поєднання органічного добрива та цукрового розчину 2,0 грд. мало найсильніший вплив на врожайність – 29,41 т/га. Збір цукру збільшився по варіантах дослідження в основному за рахунок збільшення врожайності. Зростання дигестії було незначним: від 0,08 до 0,56 % відповідно до варіантів експерименту. Сегмент рослинництва буде прибутковим за рахунок драйверів обсягу зібраного врожаю. Побічним економічним ефектом від застосування цього заходу буде отримання більшого збору цукру з гектара, що дозволить отримати більший прибуток від переробки цукрових буряків на цукор. Практична цінність досліджень полягає у формуванні рекомендацій для фермерських господарств та сільськогосподарських підприємств, які вирощують цукрові буряки на кислих і слабокислих ґрунтах, з метою підвищення їх продуктивності

Ключові слова: рослинництво; агротехніка; вапнування; удобрення; кислотність ґрунту