

Restoration and regulation of fertility of acid soils in conditions of Forest-steppe of Ukraine

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The purpose. To study effect of improved techniques of importation of defecate upon dynamics of the content of general humus and its fractions, physical-and-chemical and agrochemical soil characteristics, productivity of sugar beet at growing on grey forest soil and typical leached black earth in conditions of Right-bank and Central Forest-steppe of Ukraine. **Methods.** Physical-and-chemical and agrochemical analysis of soils and plants, phenological observations over propagation and growth of plants. **Results.** Technique of layered importation of ameliorant for grey forest sub-acid soil in reduced norms (0,25 norm by hydrolytic acidity — 1,5–2,0 t/he in physical weight) on the background of mineral fertilizers (N₁₂₀P₁₂₀K₁₂₀) promoted increase of general humus up to 1,92%, general carbon — up to 1,11%, at content of humic acids 0,21% and ratio $C_{\text{humic acids}}/C_{\text{fulvic acids}}$ — 0,77. That testified to formation of humate-fulvat type of humus. **Conclusions.** Use of improver in the form of defecate for grey forest sub-acid soil and typical leached black earth according to the improved methods and techniques of importation promoted increase of organic substances in soil, improved physical-and-chemical and agrochemical properties, heightened productivity of sugar beet.

Key words: *fertility, humus, soil, organic substance, hydrolytic acidity, improver, defecate, alkaline hydrolyzable nitrogen, mobile phosphorus, exchangeable potassium, productivity.*

Reclamation and regulation of acidic soil fertility in Ukraine is a very relevant and important challenge of the agrarian science and agro-industrial production. Soil fertility along with the content of organic matter first of all depends on balanced content of calcium in the soil base-saturation complex. To solve this problem, it is necessary to develop and implement modern technologies for the chemical reclamation of acidic soils.

In Ukraine, there are 13 million hectares of acidic soil, of which about 4 million hectares are referred to strong and medium acidic. The area of acid soils continues to increase. In the Forest-Steppe zone, its area is about 5.0 million hectares. Incomplete harvest of grain on acid soils in Ukraine amounts to 700-750 thousand tons. For the zone of the Forest-Steppe, where more than 2 million hectares of arable land is classified as highly and moderately acidic, this problem is especially urgent, with a significant part of which is attributed to the region of growing sugar beet. At the moment the only 46 sugar beet processing factories are functioning which can provide an insignificant quantity of ameliorant in the form of the defecate. In recent years, liming of acid soils had sharply decreased, which led to an increase in degradation processes, among which the most dangerous are secondary acidification and decalcification of soils. The area of acid soils in the Sumy region increased to 217 thousand hectares, Poltava to 812, Cherkassy to 497, and Vinnutsia to 1.2 million hectares, which can be explained by the difference between the doses of mineral fertilizers and the use of ameliorants.

The growing acidity of the soil is one of the acutest problems of the present and the future. The process of acidification of soils becomes global in scope, causing negative agronomical and geochemical effects. Of particular concern is that the phenomenon of acidification of soils is hidden and secondary in many cases. At first, the decalcification process occurs, and then, much later, there is a process of acidification of the soil.

The increased acidity of the soil solution and insufficient amount of calcium and magnesium are one of the main reasons for the low fertility of many soils. The intensive farming and high yield yield an annual consume of 350-450 kg/ha CaCO₃. Depletion of calcium increases along with the increase of the nitrogen fertilizer doses. In order to ensure stable production, the rate of soil liming should prevent acidity from rising due to the increasing dose of mineral fertilizers.

Earlier studies by domestic and foreign researchers established the significant influence of liming, mineral fertilizers and crop residues on the restoration of the productivity of agrochemical degradation of soils [Witter and Kolbe 1973, . Farina M.P.W., Channon P. 1988, Sumner M.E., Fey M.V., Farina M.P.W. 1987, Kirpichnikov et al. 1986, Knashis 1986].

Prianishnikov D.M. believed that the primary effect of lime on the soil is the elimination of increased acidity of the soil. Calcium promotes the humification of plant residues, the coagulation of humus and forms insoluble calcium humates [Pryanishnikov 1963].

Monitoring of agro-ecological situation in the regions of high soil acidity indicates that in the last 10-15 years, chemical ameliorants were almost not applied. Numerous studies on grey forest and chernozem soils confirm that liming acid soils greatly improves their physical, chemical and agrochemical properties promote crop productivity and quality [Velichko et al.1986, Vasiliev et al. 1998, Ivoilov et al., Mazur et al. 1984, Mazur 2008, Mazur et al. 2009].

The agronomic significance of liming is well-known, but not to a lesser extent, it has an environmental significance too. It is important that the optimization of the soil reaction improves the nitrogen and phosphate soil regimes. The positive effect of ameliorants on the phosphate soil regime is observed for a long time. Therefore, on soils, where the full dose of lime was introduced, it is possible to reduce the dose of nitrogen and phosphorus fertilizers by 15-20%. Improvement of nitrogen nutrition of plants on impacted soils is so significant that it should be taken into account when calculating the doses of nitrogen fertilizers. During calcining, plant's need for potassium significantly grows. In this case, the leaching of potassium in the groundwater decreases by 30-40%. The ecological role of liming is manifested in the activation of useful microorganisms, especially nitrogen-fixing and nitrifying bacteria, improving the development of nodal bacteria, which enhances nitrogen nutrition of plants [Poliiovyi and Derkach 2012, Chorny and Chorna 1981].

Application of 0.5 standard dose of lime into acidic sod-podzolic soils improves their agrochemical properties. Under the influence of fertilizers and lime, the soil increases the content of soluble phosphorus by 19.6-34.8%. Increased content of latter in soil occurs mainly due to soluble aluminum and phosphates. Application of fertilizer increases the amount of water-soluble and exchangeable potassium in soil and the degree of its mobility; liming, on the contrary, decreases some of these forms of potassium but increases the number of non-exchange ones (by 15.4%) [Poliiovyi 2012].

Taking into account the widespread distribution of soils with acidic reaction in Ukraine, further delay with the measures of the chemical melioration of these soils will lead to dangerous agro-ecological situation in these regions: the processes of secondary acidification of soils can be intensified, their decalcification and loss of exchange alkali, activation of aluminum and heavy metals toxicosis will occur. The aggregate deterioration of the agro-ecological status of soils and the loss of their fertility will become the apogee of such degradation. Suspension of the implementation of agricultural measures for the cultivation of acid soils is dangerous because it not only limits production of quality and cost-effective harvest, but also contributes to the intensification of the processes of accumulation of heavy metals and radionuclides in the plant, and in the trophic chain in livestock products and the increased washed biogenic elements in the subsoil-drainage water. In general, these phenomena complicate the agro-

ecological situation in the acid soil areas, which significantly hinders the sustainable social and economic development of entire regions [Tsapko 2010].

The revival of Ukraine's acid soils fertility should provide for the development and introduction into practice of the latest resource-saving and environmentally sound technologies that will allow the preservation and reproduction of the acidity of the soil with increasing productivity.

The purpose of this study to study the effect of advanced technologies of introducing defecation sludge on the dynamics of the total humus content and its fractions, physical, chemical and agronomical properties of the soil, the productivity of sugar beet when growing on grey forest soil and typical leached chernozem under the conditions of the Right Bank and Central Forest-Steppe of Ukraine.

Materials and methods. The research was carried out in grain- row crop rotation from 2011 to 2015 at Yaltushkivska and Uladovo-Lulynetska Research Breeding Stations located on the Right Bank Forest-Steppe of Ukraine.

The soil of the Yaltushkivska RBS is the grey forest podzolic medium loamy weakly acidic soil characterized by following agrochemical indexes: humus content of 1.5%, pH_{sal} of 5.5, hydrolytic acidity of 2.5-2.9 mg/equivalent per 100 g, alkali saturation of 80-83%, hydrolysed nitrogen of 75.0-77.6 mg/kg (by Kornfeld), mobile phosphorus (P_2O_5) of 127.3-131.0 mg/kg, and exchangeable potassium (K_2O) of 115.0-123.4 mg/kg of soil (by Kirsanov).

The sown area was 100m², record area 50m², and replication fourfold. We used defecation sludge of 3-year storage with CaCO_3 content of 75%, organic matter of 12%, nitrogen of 0.3-0.5%, P_2O_5 of 0.2-0.4%, K_2O of 0.2 -0.3%.

The soil of Uladovo-Liulynetska RBS is a typical weakly acidic leached chernozem with the following agrochemical characteristics (0-30 cm): humus (by Turin) 4.1%, total nitrogen 0.28%, mobile phosphorus (P_2O_5) and potassium (K_2O) (by Chirikov), respectively 156-160 and 78-82 mg/kg of soil, pH_{sal} 5.3, hydrolytic acidity (by Kappen) 3.9 mg/equivalent/100 g.

The sown area in the experiment was 100 m², accounting area 50 m², and replication fourfold. Defecation sludge contained: $\text{CaCO}_3 + \text{MgCO}_3$ 84.5%, N 0.6-0.8%, P_2O_5 0.7-0.9%, K_2O 0.7-1.0% organic matter 13-15%. %. Ameliorant was applied along with autumn disking of stubble followed with plowing-in. The doses were calculated by hydrolytic acidity and pH_{sal} values.

The farming practice was typical for growing sugar beet in this region. In the experiment, we used sugar beet seeds of hydride Yaltushkivskiy CMS 72.

To carry out physical, chemical and agrochemical analysis we took samples of soil and plants (for phenological observations) and analysed them according to a method of research in sugar beet [Methods of research in sugar beet 1986].

Research results and discussion. The basis of soil fertility is the content of total humus. The nature of its accumulation is determined by the level of intensification of crop growing technologies in crop rotations. In humus, solar energy is accumulated, which is a source of support for biochemical processes in the soil, and which determines the direction of soil-forming processes and the level of potential fertility of soils.

The liming of acid soils slow down the processes of mineralization of humus in the soil, promotes the humification of the crude organic mass, and ensures the stability of the soil system. When applying ameliorants on acid soil, the processes of humification of introduced organic fertilizers are significantly enhanced, and this contributes to the increased reproduction of humus in the arable layer of soil.

The results of field research carried out in the period of 2011-2015 under the conditions of the Right Bank and Central Forest-Steppe on grey forest weakly acid soil and typical weak-acid chernozem showed that the use of defecation sludge in grain-row crop rotation according to the technologies of layered introduction in autumn under stubble disking with subsequent ploughing into the soil stimulated the humification of organic residues in the soil, increased the content of the general humus and improved its group and fractional composition (Fig. 1)

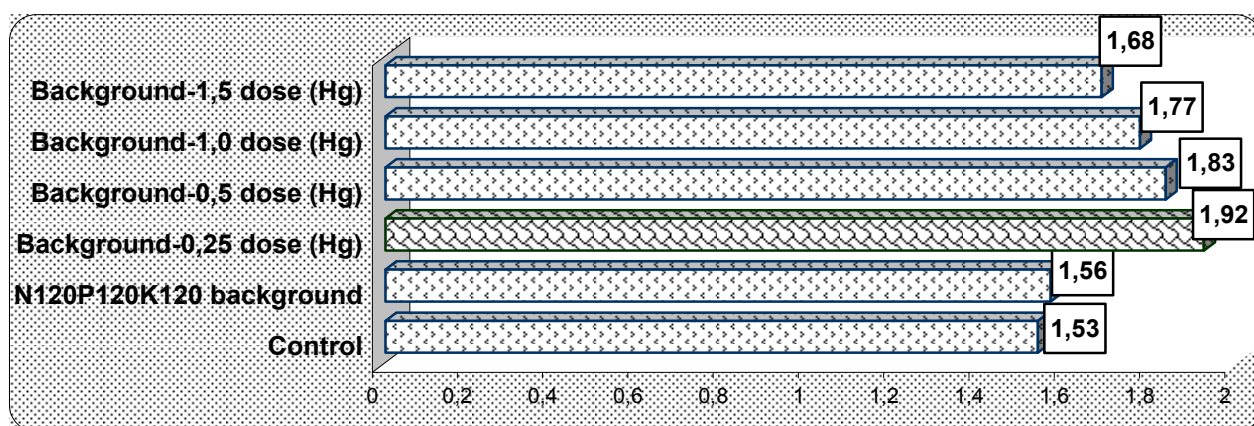


Fig.1. Total humus content of grey forest weakly acid soils for the technology of layered introduction of defecation sludge in the soil layer of 0-30 cm (%), average from 2011 to 2015.

The use of defecation sludge contributed to the formation of a humate-fulvate type of humus in grey forest soil: the content of humic acids made up 0.21% of the soil weight, the ratio of $C_{\text{humic acid}}$ to $C_{\text{fulvic acid}}$ 0.77.

Carrying out chemical reclamation measures on a typical weakly acid chernozem in grain-row crop rotation showed that the introduction of defecation sludge produced by the new technology (dry and purified from impurities) enhances the processes of humification of organic matter in the soil and increases the content of general humus (Fig. 2).

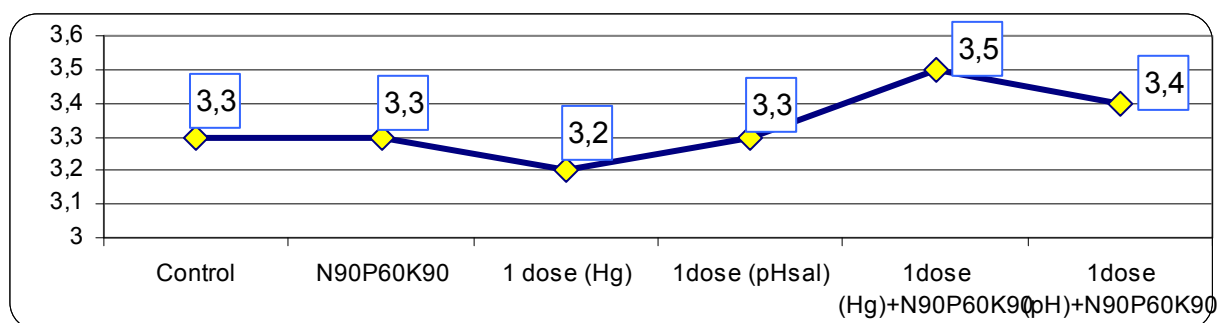


Fig.2. Effect of defecation sludge produced by the new technology on the content of total humus in typical weakly acidic leached chernozem in the soil layer of 0-30 cm (%), average from 2011 to 2015.

In the combined application of a single dose of defecation sludge, calculated by soil hydrolytic acidity (4.9 t/ha in terms of physical weight), and mineral fertilizers ($N_{90}P_{60}K_{90}$) in autumn when stubbling with subsequent ploughing, the total humus content in the soil increased to 3.50%, which was 0.20% higher than in control treatment (without defecation sludge). At the same time, the total carbon content in the soil increased to 2.02%, which was 0.11% higher than in control treatment.

The introduction of defecation sludge contributed to the formation of more stable humus substances in chernozem with an increase in the share of humic acids in their composition. When applying chemical amelioration, humic acid content increased to 0.50-0.54% in terms of soil weight, and the ratio of $C_{\text{humic acid}}$ to $C_{\text{fulvic acid}}$ was 1.64-1.67.

The level of soil fertility greatly depends on the stability of physical and chemical properties. Determination of the dynamics of physical and chemical properties of grey forest soil showed that reclamation in the crop rotation significantly influenced the value of the hydrolytic acidity index in the arable 0-20 cm and the subgroup 20-40 cm layers. For the introduction of $\frac{1}{2}$ dose of defecation sludge in autumn when stubbling with subsequent ploughing into the soil and application of $\frac{1}{2}$ dose of defecation

sludge in the spring under cultivation reduced the hydrolytic acidity of the soil to 0.42-0.54 mg/equivalent /100 g, whereas the value in control treatment was 2.2 mg/equivalent/100 g (Fig. 3).

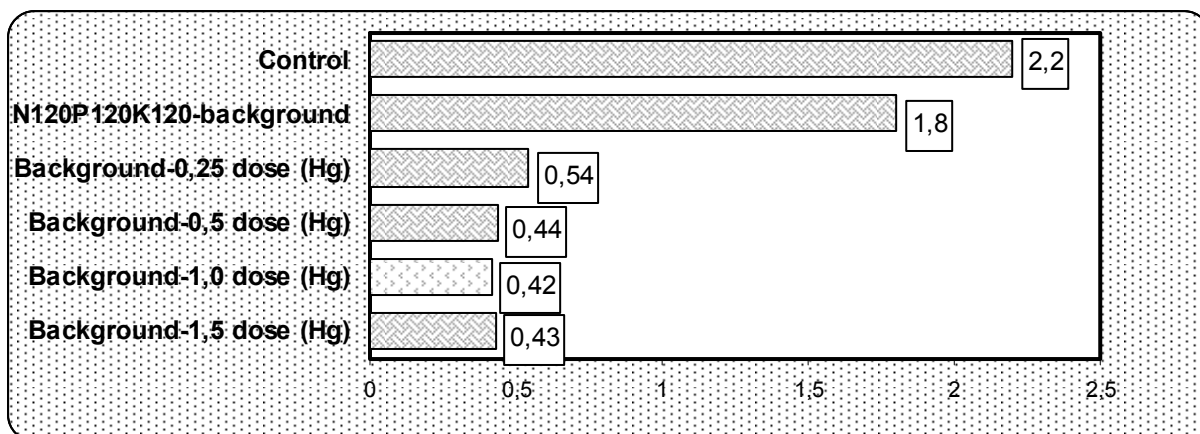


Fig.3. The hydrolytic acidity of grey forest soil per 100 g of soil for the technology of layered introduction of defecation sludge (mg/equivalent), average from 2011 to 2015.

The single dose of defecation sludge calculated in terms of hydrolytic acidity (Hg) (6.0-6.5 t/ha) was proved the most effective for the physical and chemical properties of grey forest soil. In this treatment, the maximum neutralization of soil acidity was achieved: pH_{sal} of the soil solution increased to 7.9, the hydrolytic acidity of the soil decreased to 0.42 mg/equivalent/100 g of soil, the amount of absorbed alkali increased to 26.4 mg/equivalent /100 g, the degree of saturation with the alkali was 95.0%.

The introduction of defecation sludge contributed to the stabilization of the absorption complex of typical black soil. Under the effect of reclamation, the hydrolytic acidity of the soil significantly decreased (Fig. 4).

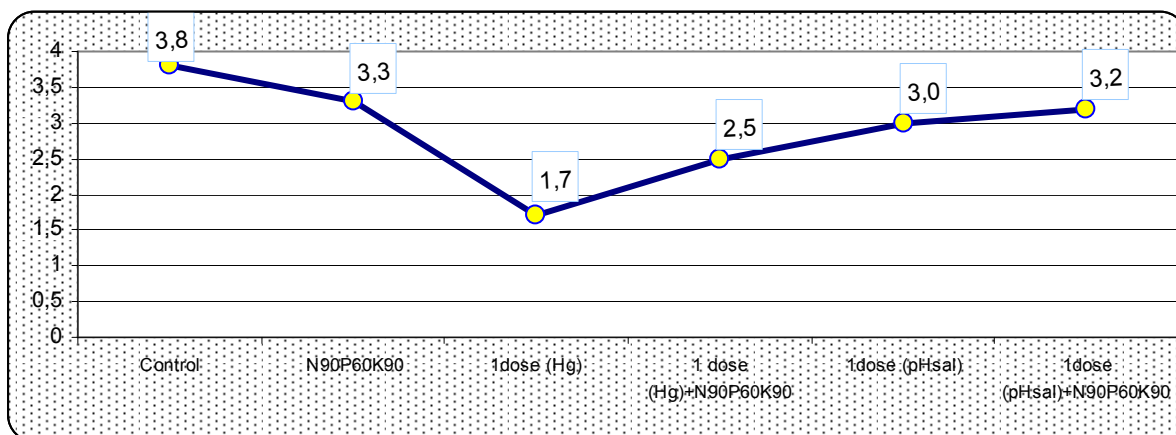


Fig. 4 Hydrolytic acidity of the typical weakly acidic leached chernozem for the introduction of defecation sludge produced by the new technology (mg/equivalent per 100 g of soil), average from 2011 to 2015.

The introduction of a single dose of defecation sludge calculated in terms of H_g (4.9 t/ha) increased the pH_{sal} solution to 7.1, which corresponds to a neutral degree of acidity. At the same time, the hydrolytic acidity of the soil decreased to 1.70 mg/equivalent/100 g, the amount of absorbed alkali increased to 26.0 mg/equivalent/100 g, the degree of saturation with the alkali was 97.0%.

An important factor that reflects the natural fertility of the soil is the nutrition regime. The level of soil acidity significantly affects the mobility of nutrients in the soil: the amount of some substances in the acidification of the soil decreases, while others increases. Liming, changing the reaction of the soil solution, is a powerful factor in the mobilization and immobilization of nutrients in the soil.

The technology of layered introduction of defecation sludge in grain-beet crop rotation of Yaltushkivska RBS, which ensures uniform mixing of it with arable and sub-ploughed layers of grey forest soil, determines the positive effect of reclamation on the content of the main nutrients in the soil. Thus, the content of alkaline hydrolysed nitrogen in the control without chemicals and the background ($N_{120}P_{120}K_{120}$) was 98.7 and 107.8 mg/kg, respectively, mobile phosphorus 180,6 and 211,3 mg/kg of soil, exchangeable potassium 168,1 and 174,8 (Fig. 5)

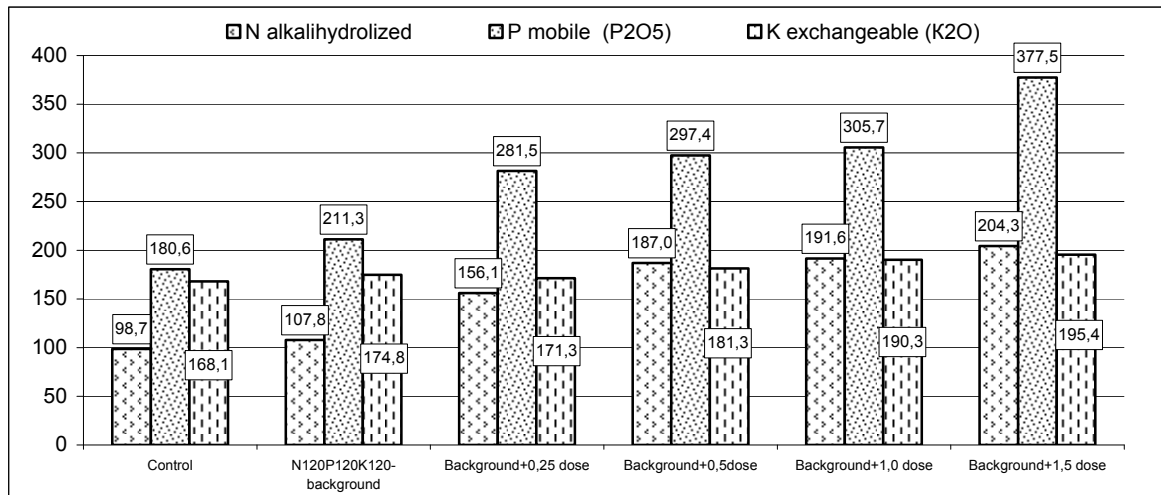


Fig.5. Effect of defecation sludge produced by the new technology on the content of the major nutrients in grey forest weakly acidic soil (mg/kg), average from 2011 to 2015.

The more effective dose of defecation sludge on grey forest soil is the 1.5 calculated on the basis of soil hydrolytic acidity of the soil (9.0-9.5 t/ha). The content of alkaline hydrolysed nitrogen increased to 204,3 mg/kg, mobile phosphorus to 377,5, exchangeable potassium to 195,4, which was higher by 105,6, 196,7 and 27,3 mg/kg, respectively, in comparison with the control treatment without defecation sludge.

The positive effect of defecation sludge produced by new technology on the nutritional regime of typical leached chernozem is proved. Reclamation in dose calculated by hydrolytic acidity of the soil (4.9 t/ha) combined with mineral fertilizers ($N_{90}P_{60}K_{90}$) in autumn stubbling with subsequent ploughing into the soil significantly increased the content of the main nutrients in the soil: the content of alkaline hydrolysed nitrogen was 137,2 mg/kg, mobile phosphorus 201,4, exchangeable potassium 117,3, which was higher by 11,0, 64,0 and 53,3 mg/kg, respectively (Fig.6).

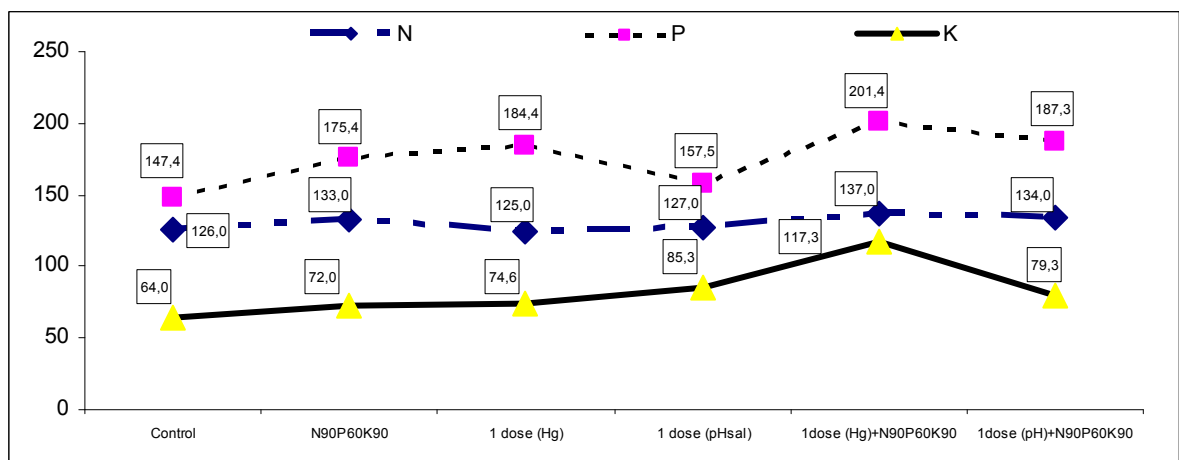


Fig.6. Effect of defecation sludge produced by the new technology on the content of the major nutrients in typical leached chernozem (mg/kg), average from 2011 to 2015.

The research results indicate that a significant increase in crop yields was achieved both through the introduction of mineral fertilizers and defecation sludge. Studies conducted on grey forest soils indicate the high efficiency of the layered introduction of ameliorant, which contributed to the increase in yield and technological quality of beet root.

The most effective dose of defecation sludge for sugar beet is defined as 1.5 and calculated by soil hydrolytic acidity. The yield of sugar beet for introduction of 1.5 dose against the background of $N_{120}P_{120}K_{120}$ amounted to 48.5 t/ha, with sugar yield of 8.3 t/ha, which was higher by 29.8 and 8.3 t/ha, respectively, as compared to control treatment.

The high efficiency in terms of yield and technological quality of sugar beet was showed when using defecation sludge obtained by the new technology in grain-beet crop rotation on typical weakly acid chernozem .

The most effective dose of $CaCO_3$ was 1.0 calculated by pH_{sal} (3.7 t/ha by physical weight) combined with mineral fertilizers ($N_{90}P_{60}K_{90}$). At the same time, the root yield was 53.0 t/ha, sugar yield 8.4 t/ha, which was higher by 18.5 and 3.2 t/ha, respectively, as compared to control treatment. Application of defecation sludge on acid soil creates favourable conditions for obtaining a high yield of sugar beet and other crops.

Consequently, the research confirms the effectiveness of ameliorant in the form of defecation sludge on acidic soils, which contributes to the restoration and preservation of soil fertility of the studied soils.

Conclusions

According to the results of research carried out from 2011 to 2015 under the conditions of the Right Bank and Central Forest-Steppe of Ukraine, the high efficiency of defecation sludge (reclamation) for the use of resource-saving and environmentally safe technologies of chemical reclamation of acid soils in grain-beet crop rotation improved, which ensures the preservation and restoration of fertility of grey forest soil and leached chernozem along with increased productivity of cultivated crops.

Application of defecation on grey forest soil and leached chernozem facilitated restoring their natural fertility. For a permissible lowered dose (0.25 dose by Hg (1.5-2.0 t/ha by physical weight), the layered introduction of defecation on grey forest soil against the background of $N_{120}P_{120}K_{120}$ increased the content of total humus compared to the control treatment by 0.39%, the ratio of $C_{humic\ acid}$ to $C_{fulvic\ acid}$ by 0.77. On chernozem, defecation sludge applied under ploughing at the 1.0 dose by Hg (4.9 t/ha) against the background of $N_{90}P_{60}K_{90}$ increased the content of humus compared to control by 0.20%, and the ratio of $C_{humic\ acid}$ to $C_{fulvic\ acid}$ by 1.67.

A single dose of defecation sludge by Hg is proved to be the most effective on the physical and chemical properties of grey forest soil (6.0-6.5 t/ha). pH_{sal} stabilized at the level of 7.9, hydrolytic acidity and the amount of absorbed alkali at 0.42 and 26.4 mg/equivalents/100 g, respectively, the degree of saturation with alkali at 95.0%. When applying on typical leached chernozem, pH_{sal} stabilized at the level of 7.1; Hg and the amount of absorbed alkali at 1.70 and 26.0 mg/equivalents per 100 g, respectively, the degree of saturation with the alkali at 97.0%.

The maximum increase in the content of nutrients in grey forest soil was achieved using 1.5 dose of defecation sludge (9.0-9.5 t/ha): the content of alkaline hydrolysed nitrogen in soil was 204,3 mg/kg, mobile phosphorus 377,5 , exchange potassium 195,4 mg/kg. In chernozem, the best conditions for the nutrition provision of plants were created when applying a single dose of defecation sludge calculated by Hg (4.9 t/ha) combined with $N_{90}P_{60}K_{90}$: the content of alkaline hydrolysed nitrogen was 137,2 mg /kg, mobile phosphorus 201,4 and exchange potassium 117,3 mg/kg.

The greatest increase in the productivity of sugar beet on grey forest soil was observed when introducing 1.5 dose of defecation sludge (9.0-9.5 t/ha) against the background of $N_{120}P_{120}K_{120}$: root yield 48.5 t/ha, sugar yield 8.3 t/ha. On typical leached chernozem, the highest productivity was achieved when applying 1.0 dose of defecation sludge by pH_{sal} (3.7 t/ha) against the background of $N_{90}P_{60}K_{90}$: root yield 53.0 t/ha, sugar yield 8.4 t/ha.

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