Aim. To investigate the influence of elements of biological farming technologies, which reproduce the potential and increase the effective fertility of gray forest soil, minimize the degradation processes of arable soil. Methods. Field experiment, laboratory, analytical, mathematical-statistical, comparative-calculation. Results. The scientific justification of the authors on the essence of reproduction of the potential fertility of gray forest soils in the northern part of the Right Bank Forest Steppe of Ukraine, its types and forms of manifestation, factors of improvement and regulation by elements of biological farming technologies is presented. On the basis of many years of research, an analysis of fertility indicators for physico-chemical, agrochemical properties and light loamy soil was conducted, a set of agrotechnological measures and laws aimed at preventing the degradation processes of acidic gray forest soil and preserving fertility in the agrocenosis were substantiated. Due to the application of green manure and liming in full dose according to hydrolytic acidity, the content of humus in the 7th year of action was 1.70–1.76%, respectively, the reserves of humus were 51.0–52.8 t/ha, and the number of exchangeable cations in GVK was more than 80%. The combination of these agricultural measures on gray the forest soil not only allowed the humus content to increase to 20%, but also provided a favorable nutrient regime of the soil – N – 72.8; P₂O₅ – 191.3; K₂O – 88.5 mg/kg of soil. Repeated application of the ameliorant in a full dose according to hydrolytic acidity in combination with by-products and green manure in the arable layer of gray forest soil provides, as of the 14th year after the action, the optimal level of physicochemical indicators: hydrolytic acidity – 1.98 mg·eq/100 g of soil, the pH of the soil solution is close to neutral (5.4–5.6), the content of mobile aluminum is 0.16 mg/100 g of soil, as well as an increase in the productivity of grain-grass crop rotation by 10–32%. Conclusions. the main issues of influence of the elements of biological farming technologies, the effectiveness of the action and after-effects of the application of periodic liming in combination with organic fertilizer have been proven. The comparative productivity of the 7-field crop rotation for the III and IV rotations on the gray forest soil of the elements of biological farming technologies, as well as the yield and quality of winter wheat for the 1st year of action of the ameliorant Omya Calciprill, is given.

Key words: liming, content and reserves of humus, acidity, organic fertilizer, by-products, green manure.
biological factors: organic fertilizers, perennial grasses, green manure and non-marketable plant products, taking into account the optimization of acid-alkaline and nutrient regimes in acidic soils of the Forest-Steppe of Ukraine.

**Analysis of latest research and publications.** Acidic soils occupy about 30% of the earth’s land and 40–50% of arable soils worldwide. In Ukraine, acidic soils occupy more than 10 million ha, or 26.3% of arable land. There are especially many acidic soils in the Polissia and Forest-Steppe zones, in such regions as Chernihiv, Zhytomyr, Kyiv, Ivano-Frankivsk, Vinnytsia, Sumy, Cherkasy, the specific gravity of acidic soils is more than 50%. In general, in recent years the processes of soil acidification have been manifested even in the agro-landscapes of the Steppe. The intensity of the increase in areas of acidic soils ranges from 1% to 15% [7; 30].

Acid gray forest soils have a small cation exchange capacity and a low degree of base saturation, sometimes falling to the level of 50–30%. They are characterized by a low content of humus (2.0±0.5% gray forest soil), mobile forms of nitrogen, phosphorus, potassium, calcium, magnesium and other elements necessary for plant nutrition. Along with physico-chemical aspects (toxicity of hydrogen, aluminum, manganese ions, deficiency of nitrogen, phosphorus, potassium, calcium, magnesium and zinc, reduction of the activity of microorganisms), high acidity largely causes unfavorable agrophysical properties of the soil (structurelessness, cohesion, low aeration and filtration) [3; 5; 6; 29].

Statistical data show that the weighted average content of humus in the soils of Ukraine of evaluation (2015–2020) is only 3.2%, which indicates that in order to achieve a balance of humus without deficit, it is necessary to apply organic fertilizers every year at least as: in Polissia – 16 t/ha of arable land, in the Forest Steppe – 11 t/ha, in the Steppe – 8 t/ha [11].

According to expert estimates, 0.5–0.6 t of humus per hectare is lost annually in Ukraine due to erosion processes, which is much more than what is applied with organic fertilizer. It is known that in the 1990s, Ukrainian farmers applied 10 tons of manure per hectare, then animal husbandry became less productive, and as of today, the application of organic matter is 0.4 t/ha, which is a critical figure.

The results of research on the transformation of organic matter in acidic soils without the use of liming indicate that their humus balance is deficient. Elements of biological farming technologies should be applied on such soils, which would influence the processes of transformation of organic matter in acidic soils and contribute to the strengthening of humification, as a result of which the products of the decomposition of organic compounds will be preserved and their fixation in the soil profile [4–11; 15; 16; 20]. Numerous studies have noted the significant impact of liming on the humus condition of soils. Carbonates introduced with meliorants provide favorable conditions for the decomposition of plant residues and their humification, prevent the leaching of humus into the lower layers, as a result of which the quality of humus improves and its decomposition slows down, due to which light loamy gray forest soils become looser, water- and air-permeable [1; 2; 7; 17].

Many years of research [3–7; 12–20] have proven that liming on acidic soils is a mandatory agrotechnological measure, as the exchangeable cations of the meliorant neutralize excessive soil acidity, increase the formation of insoluble calcium humates, and contribute to the fixation of humic substances in the soil. In limed soil, biological activity increases significantly and the nitrogen regime improves, which is due not only to the one-sided decomposition of organic substances, but also to a change in the complex of soil properties due to the neutralization of excessive acidity.

It is known that the acidic reaction of the soil solution inhibits the growth and development of plants, increased damage to them by diseases is observed, and in the interval of the pH-salt index of 6.0–6.2 moderate production of CO₂ by the soil occurs, the processes of synthesis of humic substances prevail, in the acidic interval of pH-salt (<6.0) the biochemical situation determines strengthening of oxidation processes and intensive decomposition of humus, which is one of the problems of the influence of an acidic environment on the soil, changes the speed of the processes [3; 7; 13; 17].

**Relevance.** Currently, there is very little scientific justification for the use of meliorants and the duration of their action under elements of biological farming technologies, for example, on acidic gray forest soils. Therefore, it is very important to find alternative ways to optimize the acid-alkaline and nutrient regimes of the soil and the elements of biological farming technologies, which is especially valuable for reproducing their potential fertility.

**Research purpose** – to investigate the influence of elements of biological farming technologies, under which reproduction of potential and increase of effective...

6 ЗЕМЛЕРОБСТВО, МЕЛЮРАЦІЯ, ГРУНТОЗНАВСТВО, АГРОХІМІЯ
fertility of gray forest soil, minimization of degradation processes of arable soil takes place.

Research materials and methods – field experiment, laboratory, analytical, mathematical-statistical, comparative-calculation.

Research on the reproduction of soil fertility, optimization of its properties and increase in the productivity of agrocenosis due to the use of green manure, the non-marketable part of the crop, increasing the share of leguminous crops in the structure of sown areas, improving agrochemical and physicochemical indicators of the soil was carried out in a long-term field stationary experiment of the department of agro-soil science and soil microbiology of the NSC «IA NAAS» on gray forest soil entered in the register of stationary field experiments of NAAS (Certificate No. 01), which is located at an altitude of 120 m above sea level at 50°26′13″ north latitude, 30°30′20″ east longitude.

The soil of the experimental site is characterized by the following initial parameters: pH(sol.) – 4.6; hydrolytic acidity – 3.6 mg-eq/100 g of soil; exchange bases: calcium – 3.9; magnesium – 0.58 mg-eq/100 g of soil; degree of saturation with bases – 56%, low content of humus – 1.44%, very low content of hydrolyzed nitrogen compounds – 70–90 mg, which indicates its low natural fertility.

Results and their discussion. In our case, research is aimed at finding ways to reproduce the potential and increase the effective fertility of acidic gray forest soil using new alternative neutralizing limestone materials.

In the experiment, the effectiveness of limestone flour (I and II rotations) and manure (III and IV rotations), as well as their combination in a 7-field crop rotation with organic fertilizer, was investigated during four crop rotations. At the end of IV rotation (beginning of V), repeated liming was carried out with the ameliorant Omya Calciprill, which is not contaminated with heavy metals and is environmentally safe for organic production.

In arable soil, the effect of periodic liming (full dose according to hydrolytic acidity (1.0 Hr – 5.0 t/ha CaCO₃)) on the state of potential and effective soil fertility was investigated, depending on the manifestation of processes of strengthening or weakening of the eluvial soil-forming process, the onset of effective action and the duration of the aftereffect in stationary field experiment, the effect of green manure, which was incorporated into the soil in the form of green mass of oil radish up to 5.0 t/ha once per rotation of the 7-field crop rotation (in 2018), as well as the effect of the used crop by-products (the non-marketable part of the spring wheat crop and winter wheat, barley, lupine, soybeans, and buckwheat), which were applied annually up to 5.0 t/ha, which makes it possible to solve the problem of the lack of organic fertilizers and at the same time ensure high energy output from 1 ha of crop rotation area.

To evaluate the effectiveness of the effect and aftereffect of periodic liming of acidic gray forest soil under the influence of elements of biological farming technologies, studies were taken for the last completed IV rotation of the 7-field crop rotation (Table 1). The effectiveness of limestone materials, of course, depends on the system of organic fertilizer, doses and forms of the introduced ameliorant and technological measures of its application. Therefore, it is clear that different organic fertilizers have different effects on changes in the physical and chemical properties of the soil.

Thus, the increased concentration of aluminum in the soil is most observed with a strongly and moderately acidic soil reaction (pH(sol.) 4.0–5.0), i.e., with an increase in metabolic acidity, the content of mobile aluminum increases proportionally. In addition, the content of Al³⁺ at the level of 1.39 mg/100 g of soil was recorded in the soil without fertilizer (control). This regularity can also be observed when applying only organic fertilizer. The reverse pattern is observed during periodic liming.

<table>
<thead>
<tr>
<th>Organic fertilizer</th>
<th>End of the IV crop rotation (14th year of after-action)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pH(sol.)</td>
</tr>
<tr>
<td>No fertilizer (control)</td>
<td>4.6</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha)</td>
<td>5.1</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha) + green manure</td>
<td>5.4</td>
</tr>
<tr>
<td>Byproducts + green manure</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Note. initial 1992: pH – 4.6; Hr₆⁺ – 3.6 mg-eq/100 g of soil, Al³⁺ – 1.24 mg/100 g of soil.
It was established that the application of a meliorant in full dose according to hydrolytic acidity (1.0 Hr – 5.0 t/ha CaCO$_3$) in combination with by-products and green manure in the arable layer of gray forest soil provides the optimal level of physico-chemical indicators as of the 14th year after the action: hydrolytic acidity – 1.98 mg-eq/100 g of soil, compared to the initial value of 3.6 mg-eq/100 g of soil, the pH of the soil solution is close to neutral (5.4–5.6), the content of mobile aluminum is 0.16 mg/100 g of soil. It is known that a slightly acidic and close to neutral reaction of the soil environment is optimal for most crops, which is especially important for organic production.

Under the influence of elements of biological farming technologies, the analysis of indicators of the physical and chemical properties of the soil during four crop rotations (re-liming was carried out after 14 years at the end of the 7-field crop rotation rotation) showed that the introduction of limestone materials leads to a decrease in all types of soil acidity and a reduction to a minimum of mobile aluminum, such a trend was observed when applying only CaCO$_3$ (5.0 t/ha) without organic fertilizer, as well as when combining green manure with CaCO$_3$ (5.0 t/ha). The fact of a slower decline in the remedial action of limestone materials over time was investigated, namely, a high efficiency of repeated liming was observed for ten years without significant deterioration of physicochemical properties. This makes it possible to assume that the duration of the effective action of the applied high-quality ameliorants in a full dose according to hydrolytic acidity, on previously limed gray forest soils, will be longer than 10 years.

The structure of exchangeable cations of gray forest soil (Table 2) shows that the application of liming in a single dose according to hydrolytic acidity (1.0 Hr – 5.0 t/ha CaCO$_3$) contributed to the stabilization of the content of exchangeable cations in GVK and provided a better ratio of Ca$^{2+}$ to Mg$^{2+}$, unlike the options without its introduction. During repeated liming, even on the 14th year of post-action, the amount of exchangeable bases in GVK is approximately 80%.

It has been investigated that during the long-term agricultural use of gray forest soil in the northern part of the Right Bank Forest Steppe, under the condition that only by-products and green manure are applied, the podzolization process does not stop, which is evidenced by the deterioration of the physico-chemical parameters of the GHK at the end of the IV crop rotation. Therefore, these soils require repeated liming to optimize the structure of exchangeable cations in the GVC and increase the productivity of crop rotations that are picky about soil acidity.

As a result of the specific conditions of soil formation and humus accumulation, gray forest soils contain little humus (1.5–2.5%), and due to the acidic reaction, the humus substances in them are enriched with mobile compounds that are weakly retained by the mineral part of the soil [5; 10].

The most important humus characteristics are the total humus content and its reserves. Due to the lack of manure to preserve fertility, the efficiency of plowing the non-marketable part of the crop was determined in the field experiment. The influence of the harvest-root residues of field crops of the 7-field crop rotation on the content and reserves of humus in the arable soil was evaluated according to fertility indicators. According to our research, the harvest and root residues of winter wheat had the greatest impact, taking into account the cultivation of the predecessor of the white lupine. The main requirement for the creation of a deficit-free humus balance for all soils is, first of all, a positive level of nitrogen return with organic fertilizers, because non-return causes the strengthening of mineralization processes of potential humus reserves (Table 3).

The research results indicate that at the end of the IV rotation of the crop rotation, the humus state of the soil

<table>
<thead>
<tr>
<th>Organic fertilizer</th>
<th>IV crop rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7th year of action</td>
</tr>
<tr>
<td></td>
<td>Ca$^{2+}$</td>
</tr>
<tr>
<td>No fertilizer (control)</td>
<td>49</td>
</tr>
<tr>
<td>CaCO$_3$ (5.0 t/ha)</td>
<td>73</td>
</tr>
<tr>
<td>CaCO$_3$ (5.0 t/ha) + green manure</td>
<td>76</td>
</tr>
<tr>
<td>Byproducts + green manure</td>
<td>57</td>
</tr>
</tbody>
</table>
as a whole stabilized and reached a state of equilibrium (the level of self-stabilization of humus) – humus losses compared to the initial state – 1.44% (43.2 t/ha) are clearly observed in the variant without fertilizer (control) – 1.24% (37.2 t/ha) – this indicates that without sufficient fertilization and without liming, the sod process is weakened, which forms a low content of humus, which is concentrated in the upper layer of the soil.

At the same time, the long-term plowing of straw and the use of green manure (by-products + green manure) made it possible to preserve and replenish the reserves of humus in the root layer of the soil, which also affected the increase in the yield of agricultural crops. At the same time, the level of humus content of the main part of the root layer under elements of biological farming technologies reliably increases by an average of 25% compared to the site without fertilizer. Sideratum plowing against the background of reclamation measures ensured an increase in the humus content in the 7th year of repeated liming to 1.76% in the 0–20 cm layer and 1.39% in the 20–40 cm layer.

By-products of the precursor and sider fertilizer are the basis for replenishing humus reserves in conditions of shortage of organic fertilizers and are an effective measure for improving the humus condition of gray forest soil. The use of green manure once per crop rotation and annual plowing of by-products contributed to the increase in humus content. A positive effect on the humus content (1.64%) of by-products and after-effects of green manure was noted, the more post-harvest residues enter the soil, the more mobile humus compounds are formed in it (green manure + by-products), or neutralization of soil acidity by liming with a single dose in combination with green manure, or only the introduction of meliorant (5.0 t/ha), humus reserves under these elements of biological farming technologies at the end of the IV rotation increased by 6.3–12.3 t/ha compared to the control without fertilizer.

The degree of effect of reliming on the 14th year after application varied significantly depending on the level of organic fertilizer in its background, and the efficiency of the application of green manure and by-products of crop production to organic fertilizer depends on the dose of application, as well as weather conditions, which is explained by the instability and fluctuation of the content hummus. The greatest positive effect on the humus state was revealed by the application of green manure against the background of liming (1.0 Hr) – the total content of humus in the 14th year after repeated liming was 1.65%, and its reserves were 49.5 t/ha. Relatively higher reserves of humus here can be explained by the higher yield of agricultural crops, as a result of which the amount of root-harvest residues, which are a source for the formation of humus, increases.

In general, in the IV rotation of the crop rotation, the arable layer of the soil has somewhat lost its fertility, compared to the previous rotation, there is a lack of a sufficient amount of organic fertilizer, which depends on the yield of crops. In addition, the effectiveness of green manure application was affected by weather conditions, but even under these conditions, the humus content when plowing only by-products and green manure increased by 24% on average per rotation compared to unfertilized soil. A similar accumulation was also observed in the 20–40 cm layer, which was 27% relative to the control. Thus, liming gray forest soil with a full dose of hydrolytic acidity is an effective measure for preserving humus reserves and its content not only in the arable, but also in the subsoil layer. It was noted that the humus content of gray forest soil when using green manure with by-products was 1.54% (reserves 46.2 t/ha) for the initial humus content – 1.44% (reserves 43.2 t/ha).

### Table 3. Content and reserves of humus in gray forest soil depending on the elements of biological farming technologies (soil layer 0–20 cm)

<table>
<thead>
<tr>
<th>Organic fertilizer</th>
<th>IV crop rotation</th>
<th>7th year</th>
<th>14th year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>content (%)</td>
<td>reserves, t/ha</td>
<td>content (%)</td>
</tr>
<tr>
<td>No fertilizer (control)</td>
<td>1.24</td>
<td>37.2</td>
<td>1.24</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha)</td>
<td>1.70</td>
<td>51.0</td>
<td>1.45</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha) + green manure</td>
<td>1.76</td>
<td>52.8</td>
<td>1.65</td>
</tr>
<tr>
<td>Byproducts + green manure</td>
<td>1.64</td>
<td>49.2</td>
<td>1.54</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.04</td>
<td>1.2</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Note. The initial content of humus is 1.44%.
The obtained results indicate that an important measure to preserve the decomposition products of organic compounds from their leaching and fixation in the soil profile is liming in combination with organic fertilizer. Due to the introduction of green manure and liming in full dose according to hydrolytic acidity, the humus content was 1.70–1.76%, respectively, humus reserves were 51.0–52.8 t/ha.

According to the studies of the Institute of Agriculture of the Carpathian Region of the National Academy of Sciences, it has been proven that in the process of humus accumulation and stabilization of its content on the light-gray forest surface-glazed soil, the organic fertilization system is effective with the introduction of 10 t/ha of the crop rotation area of manure, during which the humus content increased to 1.68%. With the introduction of only limestone materials, the humus content was 1.51% in the arable layer of the soil. Combined application of organic fertilizers in crop rotation against the background of liming ensures an increase in the level of total humus in the arable layer to 1.75%, and in the subsoil layer to 1.58%. At the same time, humus reserves increased to 47.60 and 32.71 t/ha, respectively [2].

Similar results were obtained on light gray soils of Polissia [1]. According to the literature [1, 2], in 2.5–4 months, up to 46% decomposes in the soil, in 1.5–2 years – up to 80% of the entire organic mass, which is also confirmed by our research.

The results of research on the application of elements of biological farming technologies characterize their impact on the nutrient regime of gray forest soil. It was investigated that the use of the ameliorant in the full dose according to hydrolytic acidity did not significantly affect the content of hydrolyzed nitrogen compounds, since the gray forest soil is poorly supplied with this element, but the positive effect of the ameliorant was observed in the pre-calcified version with organic fertilizer, this was due to the decomposition of the organic mass of the earned green manure and by-products (Table 4).

The lowest indicator (60.2 mg/kg) was characterized by the nitrogen regime of the soil with the introduction of by-products and green manure. The decrease in the content of nitrogen compounds in this case indicates the rapid mineralization of the green mass as a result of increased microbiological activity, the plowing of the post-harvest remains of straw and green manure contributed to a greater removal of nutrients due to the creation of better conditions for the nutrition of crops in the crop rotation, because the nitrogen content was lower than in the control without fertilizer (60.2 and 67.2 mg/kg soil) respectively.

In general, gray forest soils, with the introduction of only by-products, have a low level of provision of basic nutrients, and increasing the amount of application of organic fertilizers and meliorants will further improve the condition of the soils, which will positively affect the productivity and quality of agricultural crops. It was noted that during repeated liming, the nitrogen content of hydrolyzed compounds slightly increases, which may indicate the preservation of decomposition products of organic substances from leaching and fixation in the arable layer of the gray forest soil.

In order to assess the definition of effective fertility, it is especially important to determine that part of phosphorus and potassium compounds that is the most mobile and available to plants. In the process of feeding, plants absorb, first of all, the most mobile forms of phosphorus and potassium. It was found that the soil of the experimental site has a high content of mobile phosphorus compounds (172.5–191.3 mg/kg of soil), this was especially observed in the limed versions of the experiment.

The analysis of the results of research on the content of mobile potassium compounds in the arable layer of gray forest soil in the absence of any fertilizer (control) for 30 years makes it possible to talk about the

<table>
<thead>
<tr>
<th>Organic fertilizer</th>
<th>N, of hydrolyzed compounds</th>
<th>Compounds of mobile P₂O₅</th>
<th>Compounds of mobile K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7th year</td>
<td>14th year</td>
<td>7th year</td>
</tr>
<tr>
<td>No fertilizer (control)</td>
<td>69.6</td>
<td>67.2</td>
<td>146.9</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha)</td>
<td>76.6</td>
<td>68.6</td>
<td>172.5</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha) + green manure</td>
<td>72.8</td>
<td>70.0</td>
<td>191.3</td>
</tr>
<tr>
<td>Byproducts + green manure</td>
<td>64.4</td>
<td>60.2</td>
<td>145.2</td>
</tr>
</tbody>
</table>
significant deterioration of potassium nutrition of crop rotation crops.

It has been investigated that the improvement of the nutrient regime of the gray forest soil using the elements of biological farming technologies can be carried out due to the use of ameliorants, the return of the non-marketable part of the crop to the soil and the systematic use of green manure during crop rotations. The effectiveness of periodic liming on unfertilized soil primarily depends on its complex impact, manifested as ameliorative effect on soil properties, as well as improvement of the nutritional regime.

Carrying out repeated liming on the gray forest coarse dust-light loam soil turned out to be a highly effective measure of increasing the yield of crops of the 7-field crop rotation due to the significant optimization of the fertility indicators of the gray forest soil, which lead to an adequate response of crop rotation crops in the form of additional increases in productivity. At the same time, it is known how dependent the productivity of crops is on the weather conditions of the region.

For the elements of biological farming technologies, the approximate limits of the efficiency of organic fertilizer (precursor by-products, green manure) with separate and simultaneous application with an ameliorant on the productivity of agricultural crops on gray forest soil during two completed rotations of a 7-field crop rotation were investigated (Table 5).

The results of studies on the productivity of crops for two rotations of a 7-field crop rotation show that only organic residues are not enough to significantly increase the yield of crops on gray forest soil. In the conditions of lack of organic fertilizers, effective elements of biological farming technologies are annual plowing of by-products, green manure and periodic liming, which are able to preserve the fertility of gray forest soils and increase the productivity and quality of agricultural crops under unfavorable economic conditions.

It was studied that the productivity of crop rotation exceeded the unfertilized control by 10–32%. Applying only meliorant in a full dose increased productivity by 15–19% for hydrolytic acidity, and for a combination of liming with green manure – by 26–32%.

It was established that repeated liming (the end of IV rotation) with a full dose according to hydrolytic acidity has a positive effect in the next V rotation as well. After applying the ameliorant Omya Calciprill, exchangeable acidity is practically eliminated, the harmful effect of mobile aluminum is neutralized, the structure of GVC is improved, namely, the losses of exchangeable calcium and magnesium are reduced, which helps to optimize the physico-chemical parameters of the soil and allows growing agricultural crops that are more demanding of the reaction of the soil environment.

Studies have confirmed that the level of acidity reduction of gray forest soil is directly dependent on the quality of the meliorant. This was noted as a positive fact of the application of elements of biological farming technologies in the Right Bank Forest Steppe, since the degradation processes in the pre-calcified soil do not occur at such an intensive rate as when applying only side products with green manure without liming.

It was established that the benefits of periodic liming, namely the optimization of the physico-chemical and agrochemical properties of the gray forest soil, lead to an adequate response of crops in the crop rotation in the form of additional increases in productivity. The approximate limits of the effectiveness of organic fertilizer (byproducts + green manure) and the effect of the use of the ameliorant Omya Calciprill on the productivity of winter wheat on gray forest soil were determined (Table 6).

It was investigated that the repeated introduction of only (CaCO₃ (1.0 Hr)) contributed to an increase in the productivity of winter wheat by 11% in the 1st year of action, and by 23% when the meliorant was combined with green manure (CaCO₃ (1.0 Hr) + green manure).

Optimizing the physico-chemical parameters of the soil by combining by-products with green manure (by-products + green manure) helped to increase the yield of winter wheat by only 12% compared to unfertilized soil. Failure to apply mineral fertilizers on soils with a low level of nutrient supply caused a decrease in crop productivity. At the same time, it was established that the efficiency of sideration is extremely dependent on weather conditions.

Table 5. Productivity of crops for two crop rotations depending on the elements of biological farming technology, t/ha. unit

<table>
<thead>
<tr>
<th>Organic fertilizer</th>
<th>III rotation</th>
<th>IV rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>t/ha ±, %</td>
<td>t/ha ±, %</td>
</tr>
<tr>
<td>No fertilizer (control)</td>
<td>2.25 –</td>
<td>2.65 –</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha)</td>
<td>2.68 19</td>
<td>3.04 15</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha) + green manure</td>
<td>2.84 26</td>
<td>3.50 32</td>
</tr>
<tr>
<td>Byproducts + green manure</td>
<td>2.54 13</td>
<td>2.92 10</td>
</tr>
<tr>
<td>LSD 0.05</td>
<td>0.07</td>
<td>0.09</td>
</tr>
</tbody>
</table>
The results of research indicate that the productivity of winter wheat was on average 3.14 t/ha with the elements of biological farming technologies. od, and white lupine 2.41 t/ha from units, at the same time, the increase in re-limed variants of winter wheat was 0.3–0.7 t/ha. od, and white lupine – 0.3–0.5 t/ha. unit (for the 14th year after the application of lime), therefore, the main measures to increase the effective fertility of gray forest soils using elements of biological farming technologies are the maximum use of organic fertilizers and periodic liming, which made it possible to obtain from 11% to 25% yield increase.

The main indicator that determines crop productivity is grain quality. The application of elements of biological farming technologies not only contribute to the increase in productivity, but also to the obtaining of grain quality at the II class level, suitable for export and the production of high-quality bakery products. However, the nature of the effect of any organic fertilizer can change depending on the specific conditions of external factors: the supply of plants with macro- and microelements, the reaction of the soil environment, humidity, air temperature.

Indicators of winter wheat grain quality depending on the elements of biological farming technologies were studied. The soil and climatic conditions of the northern part of the Right Bank Forest Steppe made it possible to obtain winter wheat grain with a protein content of 8.7–9.3%, gluten content of 20.8–21.5%, and starch content of 69.4–72.4%; The higher quality of the main products was obtained against the background of repeated liming (1st year of action). Summing up, it can be stated that the use of high-quality meliorants is a necessity and a prerequisite for the effective use of acidic gray forest soils as elements of biological farming technologies, since liming is the main factor in reproducing the potential and increasing the effective fertility of acidic soils and protects them from the development of degradation processes.

### Table 6. Productivity of crop rotation on gray forest soil depending on the elements of biological farming technologies, t/ha, unit

<table>
<thead>
<tr>
<th>Organic fertilizer</th>
<th>winter wheat (1st year of action)</th>
<th>Increase from organic fertilizer and lime action ± to control, %</th>
<th>white lupine (14th year of action)</th>
<th>Increase from organic fertilizer and after-effect of lime ± to control, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fertilizer (control)</td>
<td>2.81</td>
<td>--</td>
<td>2.04</td>
<td>--</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha)</td>
<td>3.12</td>
<td>11</td>
<td>2.32</td>
<td>14</td>
</tr>
<tr>
<td>CaCO₃ (5.0 t/ha) + green manure</td>
<td>3.47</td>
<td>23</td>
<td>2.56</td>
<td>25</td>
</tr>
<tr>
<td>Byproducts + green manure</td>
<td>3.14</td>
<td>12</td>
<td>2.41</td>
<td>18</td>
</tr>
<tr>
<td>LSD₀.₀₅</td>
<td>0.07</td>
<td></td>
<td>0.09</td>
<td></td>
</tr>
</tbody>
</table>

### Conclusions

1. According to long-term research of the department of agro-soil science and soil microbiology of the NSC «IA NAAS» it was determined that the main measures for preserving the fertility of gray forest soil using elements of biological farming technologies are periodic liming – the best agricultural measure in terms of duration of effective action and after-effect both for regulating potential fertility and on the productivity of agrocnoses, as well as the maximum use of organic fertilizer. Positive changes and a tendency to accumulate humus occur with green manure fertilization against the background of repeated liming in the 7th year of action, where the humus content was 1.70–1.76%, and the amount of calcium and magnesium in the GVK was more than 80%. The combination of these agricultural measures on the gray forest soil not only ensured an increase in humus content up to 20%, but also made it possible to increase the productivity of grain-grass crops by 26–32%.

2. It has been proven that the cultivation of agricultural crops on gray forest coarse-grained and light loamy soil without the use of elements of biological farming technologies leads to its dehumification – a decrease in the content and reserves of humus in the arable layer. Periodic liming with a full dose of hydrolytic acidity contributes to the maintenance of the humus state of the gray forest soil at the level of 1.65% (initial humus content of 1.44%) in the 14th year after the action, humus reserves for the elements of biological farming technologies at the end of the IV rotation increased by 6.3–12.3 t/ha relative to the control.

3. It was determined that the processes of acidification, decalcification and dehumification are closely related to each other, therefore, in order to optimize the acid-alkaline and nutritional regimes and the formation of effective fertility, the elements of biological farming...
4. Therefore, the application of elements of biological farming technologies on gray forest soils is aimed at solving the following problems: extended reproduction of the potential fertility of acidic soils; prevention of degradation processes (secondary acidification, over-consolidation); increasing the efficiency of using green manure, a by-product of crop production, as an organic fertilizer; rational use of agricultural landscapes; ensuring an economically balanced increase in yield and quality of agricultural products.

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Література

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агрохімічними властивостями у легкосуглинковому ґрунті, обґрунтовано комплекс агротехнологічних заходів і закономірностей спрямованих для попередження деградаційних процесів кислого сірого лісового ґрунту та збереження його родючості в агроценозі. Завдяки внесенню сидерату та вапнуванню у повній дозі за гідролітичною кислотністю – вміст гумусу на 7-й рік дії становив 1,70–1,76 %, відповідно запаси гумусу 51,0–52,8 т/га, а кількість обмінних катіонів у ІВК більше 80 %. Посідання цих агрозахідів на сірому лісовому ґрунті не лише дозволило отримати зростання вмісту гумусу до 20 %, але забезпечило сприятливий поживний режим ґрунту – N – 72,8; P₂O₅ – 19,3; K₂O – 88,5 мг/кг ґрунту. Повторне внесення меліоранта повною дозою за гідролітичною кислотністю за поєднання з побічною продукцією та сидератом в орному шарі сірого лісового ґрунту забезпечує станом на 14-й рік післядії оптимальний рівень фізико-хімічних показників: гідролітична кислотність – 1,98 мг-екв/100 г ґрунту, pHₚₚ, ґрунтового розчину близький до нейтрального (5,4–5,6), вміст рухомого алюмінію – 0,16 мг/100 г ґрунту, а також підвищення продуктивності культур зерно-трав’яної сівозміни на 10–32 %. 

Висновки. За багаторічними дослідженнями висвітлено основні питання впливу елементів технологій біологічного землеробства та доведено ефективність дії і післядії застосування періодичного вапнування у поєднанні з органічним удобренням. Наведено порівняльну продуктивність 7-пільної сівозміни за ІІІ та IV ротації на сірому лісовому ґрунті за елементів технологій біологічного землеробства, а також урожайність і якість пшениці озимої на 1-й рік дії меліоранта Omya CalciPrill.

Ключові слова: вапнування, вміст і запаси гумусу, кислотність, органічне удобрення, побічна продукція, сидерати.

**Відомості про авторів**

Tkachenko M.A., доктор с.-г. наук, професор, член-кореспондент НААН, директор, ННЦ «ІЗ НААН», e-mail: i.z.naan.tkachenko@gmail.com, ORCID: 0000-0001-6128-4703.

Кондратюк I.M., кандидат с.-г. наук, завідувач відділу агроґрунтознавства і ґрунтової мікробіології, ННЦ «ІЗ НААН», e-mail: irina_kondratjuk@ukr.net, ORCID: 0000-0002-8953-8194.

Protsuk V.Yu., аспірант денної форми навчання, ННЦ «ІЗ НААН», e-mail: procuk1992@gmail.com, ORCID: 0009-0005-3953-942X.

*Tkachenko M.A., Dr. of Agricultural Sciences, professor, corresponding member, director, NSC «IA NAAS», e-mail: i.z.naan.tkachenko@gmail.com, ORCID: 0000-0001-6128-4703.*

*Kondratjuk I.M., Candidate of Agricultural Sciences, Head of the Department of Agro-Soil Science and Soil Microbiology, NSC «IA NAAS», e-mail: irina_kondratjuk@ukr.net, ORCID: 0000-0002-8953-8194.*

*Protsuk V.Yu., Postgraduate student of full-time form of study, NSC «IA NAAS», e-mail: procuk1992@gmail.com, ORCID: 0009-0005-3953-942X.*