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Phytomeliorative potential of alfalfa (*Medicago sativa* L.) for the restoration of degraded soils

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ABSTRACT

Changes in the agroecological state of the soil were analyzed based on the content of humus, alkaline hydrolyzed nitrogen, available forms of phosphorus and potassium, soil solution reaction (pH), hydrolytic acidity, as well as the mobility of heavy metals - lead, cadmium, copper, and zinc; soil erosion resistance parameters: proportion of agronomically valuable and water-resistant aggregates, structural coefficient and bulk density of gray podzolized soil depending on the duration of cultivation of alfalfa (*Medicago sativa* L.). The study area is characterized by gray podzolized soils of medium loamy grain size distribution.. Alfalfa (*Medicago sativa* L.) was grown for four years with soil samples taken for laboratory analysis at the end of the second and fourth years of vegetation. Alfalfa (*Medicago sativa* L.), as a legume perennial grass, when grown for four years, exhibits powerful phyto-ameliorative properties: it increases the humus content in gray podzolized medium loam soil by 0.1%, alkaline hydrolyzed nitrogen by 2.9%, mobile phosphorus by 8.0%, exchangeable potassium by 25.6%. It optimizes the pH reaction of the soil solution, increasing it from 0.1 to 0.3 pH, achieving a neutral reaction in the range of 7.1–7.3 pH and reduces hydrolytic acidity by 24.5–28.3%. It reduces the mobility of heavy metals in the soil, which reduces their concentrations by 39.0% – lead, by 96.7% – cadmium, by 98.5% – copper and by 87.9% – zinc. The positive role of alfalfa (*Medicago sativa* L.) in increasing soil erosion resistance. It is manifested in an increase in the share of agronomically valuable soil aggregates by 4.9–6.7%, water-resistant aggregates by 32.2%, and the soil structural coefficient by 1.1–1.6. An additional positive factor in growing alfalfa is soil loosening, which is manifested in a decrease in soil bulk density by 5.0–33.3% to a value of 1.14 g/cm^3.

Keywords: *Medicago sativa* L., soil, humus content, phytomelioration, agroecological condition.

INTRODUCTION

In agricultural production, soil is a key resource on which the country's food security, the production of crop products, and the formation of a feed base for livestock depend (Mazur et. al., 2019; Didur et. al., 2019). Agricultural lands of Ukraine occupy about 42 million hectares, which is approximately 70% of the total area of the country's land fund. However, after 2022, a significant part of this territory, more than 10 million hectares, was damaged due to full-scale encroachment, which significantly reduced the area of land suitable for use. The main share of agricultural lands is arable land (about 78%) (Tkachuk et. al., 2025; Bulgakov et. al., 2024). The main characteristic of the soil cover of Ukraine is its great diversity, which includes about 40 types and almost 800 types of soils. At the same time, there is significant unevenness, as well as a significant spread of low-productivity, man-made polluted and degraded soils, the area of which reaches 10–15 million hectares.

More than 60% of the land fund is made up of black soil type soils. However, such soils, due to their intensive use, have become vulnerable to degradation processes due to the prevalence of an unbalanced land use system in agriculture.

This prevents the achievement of positive results in the conservation of soil resources, economic efficiency and environmental safety (Khaietska,et. al., 2025).

Degradation is a set of natural and anthropogenic processes that lead to the deterioration of the natural properties and regimes of soils, causing persistent negative changes in their functions, a decrease in stability and loss of fertility. Under such conditions, destructive processes in the soil occur more intensively than its restoration or formation. Soil in which ecological functions are irreversibly disrupted, and the productivity of agricultural crops remains reduced for a long time (10–15 years), is classified as degraded. The most common cause of degradation is excessive anthropogenic influences, such as mechanical, chemical or hydraulic loading (Vdovenko et al., 2025).

The area of degraded lands in Ukraine varies from 6–8 to 10–15 million hectares. The process of degradation occurs when the impact on soils exceeds their natural ability to self-regulate – that is, the ability to independently restore their characteristic properties without external intervention.

Depending on the degree of development of degradation processes, the yield of agricultural crops can be reduced by 10–20 or even 30–50%, which leads to significant economic losses. Losses due to the lack of production alone can exceed 20 billion hryvnias annually. In parallel with this, a trend towards a decline in the quality of agricultural products is being recorded Among the main degradation problems of Ukrainian soils, the loss of humus (dehumification) and the decrease in the content of basic nutrients (alkaline hydrolyzed nitrogen, mobile phosphorus and exchangeable potassium) prevail, which is widespread in 43.0% of arable land, over-compaction – by 39.0%, flooding and crusting – by 38.0%, water erosion – by 20.0%, acidification – by 14.0%, wind erosion – by 11.0%, and heavy metal pollution – by 8.0% (Tkachuk et. al., 2025).

The Strategy for Soil Protection, Prevention and Control of Land Degradation can solve the above-mentioned problems of Ukrainian soils. It should include the effective functioning of soil protection programs and legislative acts, ensuring their strict compliance, constant monitoring of soil condition, mandatory regulation of anthropogenic impacts, and responsibility of government bodies and land users. It is also necessary to maintain compliance with recommended practices and implement modern soil protection technologies (Okrushko et. al., 2025).

It is necessary to adapt modern agricultural technologies as effectively as possible in order to achieve a state of «neutral soil degradation», taking into account the existing soil conditions and climatic features of the zone. (Didur et. al., 2024; Kupchuk et. al., 2024). To do this, it is necessary to optimize the level of organic matter and mobile forms of nutrients in the soil; ensure a non-deficit balance of humus; protect soils from erosion processes; improve the acid-salt balance of soils; solve the problem of moisture deficiency; protect soils from pollution and compaction. As a rule, to solve all the above-mentioned soil degradation problems, it is necessary to apply a complex of restorative and soil-conserving measures, often expensive and long-lasting. However, a significant reserve of a fast and natural way to restore degraded soils is the widespread use of phyto-ameliorative properties of plants. Among them, leguminous perennial grasses are effective, which are able to form a powerful above-ground and underground mass and accumulate symbiotically fixed nitrogen from the atmosphere. In conditions of global warming and lack of moisture, it is advisable to make wider use of the phyto-ameliorative potential of a drought-resistant and long-lived plant - alfalfa (*Medicago sativa* L.).

MATERIALS AND METHODS

The research methodology involved establishing a field experiment on gray podzolized medium loam soils of the Agronomichne research farm of Vinnytsia National Agrarian University, which was conducted in 2021, followed by laboratory research over the next four years. On a research plot with a registered area of 25 m^2 with four repetitions, alfalfa was sown in early spring with bare sowing with control of the spread of weeds in the year of sowing. During the following years of vegetation, no fertilizers were applied and no care measures were carried out. The formed biomass of alfalfa (*Medicago sativa* L.) was mowed when it reached its flowering phase (BBCH 60).

Soil samples were collected at the end of the second and fourth years of alfalfa (*Medicago sativa* L.) vegetation in October from the accounting area according to a diagonal scheme to the depth of the arable horizon (0–25 cm) in order to determine the agroecological indicators of the soil. Laboratory analysis of the samples was performed in a certified and accredited laboratory of the South-Western Interregional Center of the State Institution «Institute of Soil Protection of Ukraine».

The determination of humus content was carried out in accordance with the requirements of DSTU 26213-91. The amount of alkaline hydrolyzed nitrogen was determined by the Kornfield method according to DSTU 7863:2015. Mobile forms of phosphorus and exchangeable potassium were determined by the Chirikov method according to DSTU 4115-2002. The reaction of the soil solution (pH) was estimated according to DSTU ISO 10390-2007, and hydrolytic acidity – according to DSTU 7537:2014. The content of mobile forms of heavy metals was determined according to current standards: lead – DSTU 4770.9-0007, cadmium – DSTU 4770.7-0007, copper – DSTU 4770.6-0007, zinc – DSTU 4770.2-0007.

The water resistance of soil aggregates was determined by the Vilensky drop method by washing them with water. The proportion of agronomically valuable aggregates was estimated by the structural composition of the soil, using the sieving method for different fractions. The bulk density of the soil was measured by the drilling method using cylindrical drills. The soil structural coefficient was calculated as the ratio of the mass of agronomically valuable aggregates with a size of 10–0.25 mm to the mass of the entire sample. Soil sampling to determine the dynamics of soil bulk density was carried out at the end of each year of research (years 1–4), and other agrophysical characteristics were taken at the end of the first, second, and fourth years of research.

RESULTS

Growing alfalfa (*Medicago sativa* L.) directly affects the increase in soil fertility. Thus, its two-year cultivation contributes to an increase in humus content by 0.03%, while four-year cultivation – by 0.1%. In parallel, the pH of the soil solution is optimized: the indicators increase by 0.1–0.3 units, approaching the neutral level of 7.1–7.3 pH. Hydrolytic acidity during the two-four-year cycle of alfalfa cultivation decreases by 24.5–28.3%. (Figure 1).

Alfalfa (*Medicago sativa* L.) contributes to an increase in the content of alkaline hydrolyzed nitrogen, mobile phosphorus and exchangeable potassium in the soil. In the second year of its vegetation, the content of alkaline hydrolyzed nitrogen slightly decreased by 2.3%, while in the fourth year it increased by 2.9% compared to the indicators before sowing. Mobile phosphorus and exchangeable potassium in the soil increased more intensively: the phosphorus content in the second year increased by 3.7%, and by the end of the fourth year – by 8.0%. Similar dynamics were observed for exchangeable potassium, which increased by 20% at the end of the second year of vegetation, and by the end of the fourth year – by 25.6%. (Figure 2).

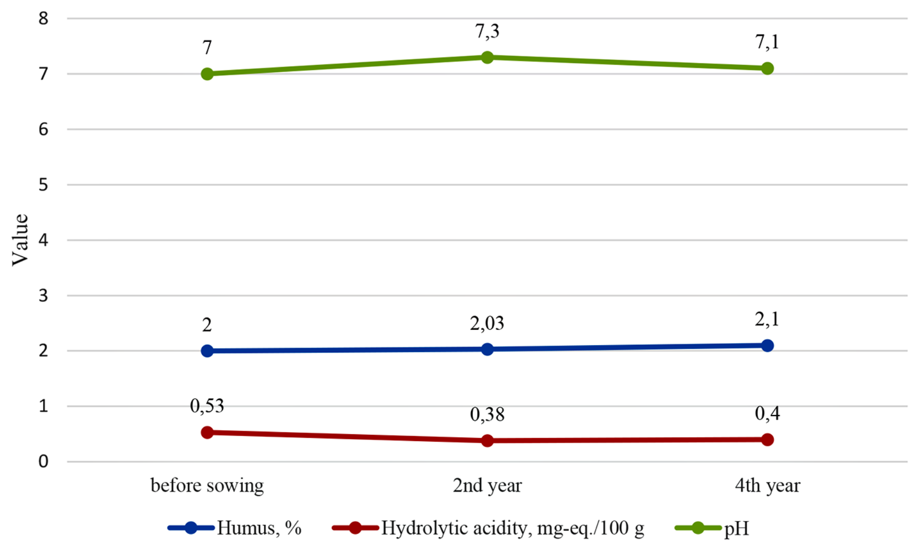

Figure 1. Dynamics of humus content, soil solution pH reaction and hydrolytic acidity of gray podzolized soil depending on the duration of cultivation of alfalfa (*Medicago sativa* L.)

A positive effect of growing alfalfa (*Medicago sativa* L.) on reducing the content of mobile forms of heavy metals in the soil was observed. In particular, at the end of the second year of vegetation, the content of mobile forms of lead decreased by 3.4%, and at the end of the fourth year – by 39.0%. The content of cadmium at the end of the second year of vegetation of alfalfa (*Medicago sativa* L.) in the soil decreased by 91.7%, and at the end of the fourth year – by 96.7%. The concentration of mobile forms of copper in the second year of vegetation of alfalfa (*Medicago sativa* L.) in the soil did not change, and at the end of the fourth year – decreased by 98.5%. The content of mobile forms of zinc at the end of the second year of vegetation of alfalfa (*Medicago sativa* L.) in the soil did not change, and at the end of the fourth year – decreased by 87.9% (Figure 3).

The reduction of soil erosion risk during the cultivation of alfalfa (*Medicago sativa* L.) is manifested in the increase in the share of agronomically valuable aggregates and water-resistant aggregates. In particular, at the end of the first year of alfalfa (*Medicago sativa* L.) vegetation, the share of agronomically valuable aggregates in the soil increases by 6.7% and reaches its maximum, since in the future, during the following years of alfalfa (*Medicago sativa* L.) vegetation, the soil under it becomes more lumpy, which leads to a certain reduction in the share of agronomically valuable soil aggregates, but their number at the end of the fourth year of vegetation remained greater than it was before the cultivation of alfalfa (*Medicago sativa* L.). The increase was 4.9%.

A similar dependence was established for the share of water-resistant soil aggregates after the cultivation of alfalfa (*Medicago sativa* L.). By the end of the first year of vegetation, their share increased by 25.3%, and by the end of the fourth year of vegetation – by 32.2% (Figure 4).

Important agroecological characteristics of the soil in relation to its anti-erosion resistance are the soil structural coefficient and its bulk density. At the end of the first year of *Medicago sativa* L. vegetation, the soil structural coefficient increases by 1.6, and in the fourth year it decreases slightly, but remains higher than before grass cultivation by 1.1.

During the four-year growing cycle of alfalfa (*Medicago sativa* L.), the soil bulk density decreased. At the end of the first year, the indicator decreased by 10.0%, at the end of the second year, by 33.3%, and by the fourth year it increased slightly, remaining 5.0% lower than the initial level. The optimal value of the soil bulk density should not exceed 1.2 g/cm³. At the end of the first and especially the second year of vegetation, the indicators were very low (1.08–0.80 g/cm³), which led to a very loose

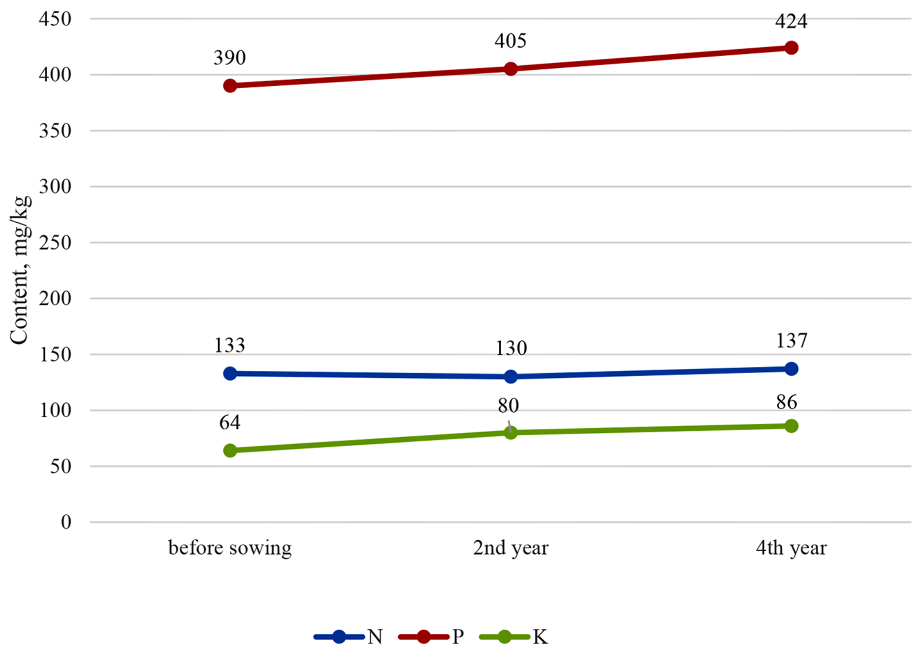

Figure 2. The influence of the duration of alfalfa (*Medicago sativa* L.) cultivation on the content of essential macroelements in gray podzolized soil

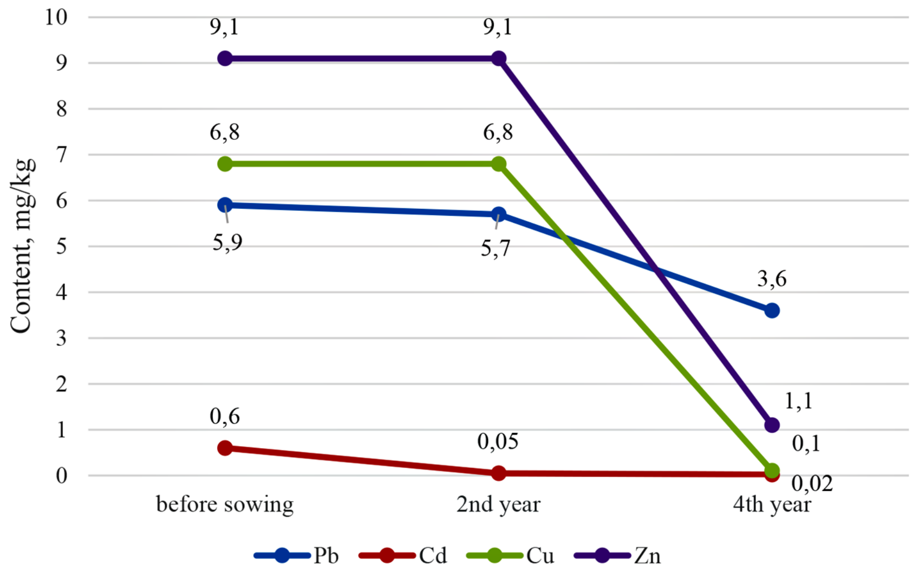

Figure 3. Dynamics of the content of mobile forms of heavy metals in gray podzolized soil depending on the duration of cultivation of alfalfa (*Medicago sativa* L.)

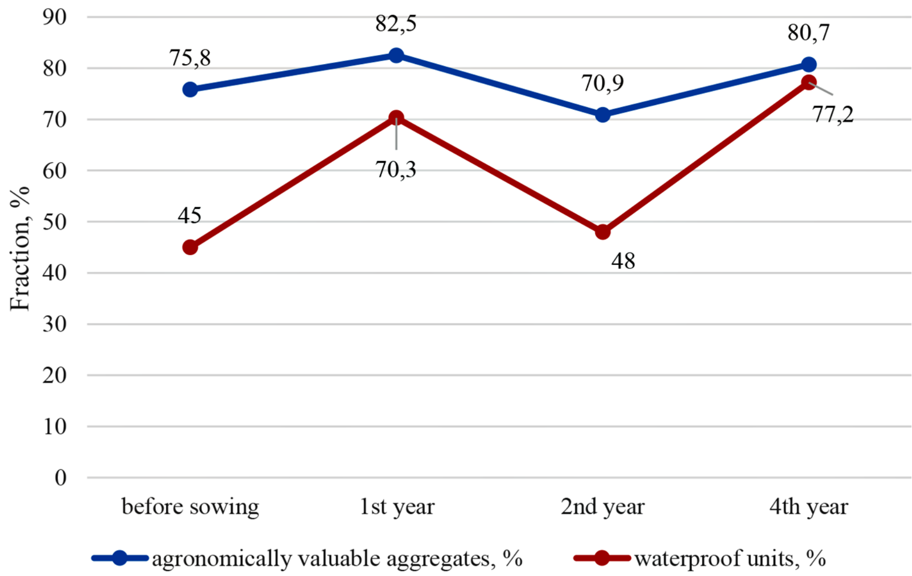

Figure 4. The effect of the duration of alfalfa (*Medicago sativa* L.) cultivation on the structure and water resistance of soil aggregates

soil. By the end of the fourth year, the bulk density stabilized at a favorable level of 1.14 g/cm³. (Figure 5).

Thus, the results obtained show that alfalfa (*Medicago sativa* L.) crops are capable of significantly improving the erosion resistance of soils in one year of vegetation. However, it is impractical to grow alfalfa (*Medicago sativa* L.), as a perennial grass, in one year, therefore, in order to increase the erosion resistance of soils, it is advisable to grow alfalfa (*Medicago sativa* L.) for four years.

DISCUSSION

As Petrychenko notes, the powerful root system of alfalfa (*Medicago sativa* L.) can reach up to 40–60 t/ha of root mass, which decomposes over time, ensuring the formation of a significant amount of organic matter, which gradually turns into humus. The plant also forms a lot of above-ground mass, which, when decomposed, also enriches the soil with organic matter, especially if used as a green fertilizer (Petrychenko et. al., 2025; Tkachuk et. al., 2025).

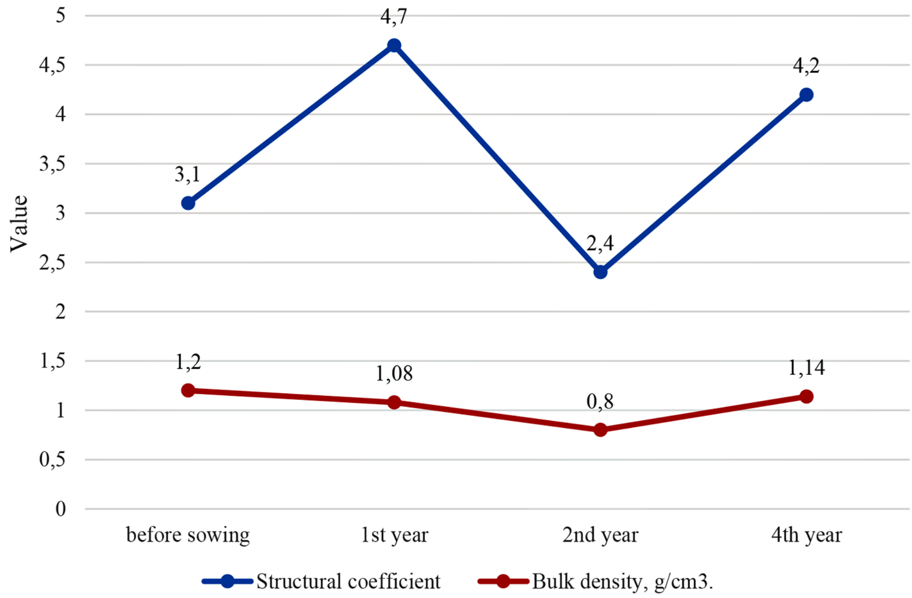

Figure 5. Dynamics of the structural coefficient and bulk density of gray podzolized soil depending on the duration of cultivation of alfalfa (*Medicago sativa* L.)

According to Mazur et al. (2021), the process of humification of alfalfa roots, i.e. their transformation into organic humus, occurs gradually and depends on the stage of decomposition. At the stage of primary decomposition or mineralization, small roots are destroyed most quickly. During the first three months after the end of the growing season or plowing, 56–71% of the mass of thin roots is destroyed.

According to Hetman et al. (2021), the phase of active nutrient release is characterized by a significant influx of nitrogen into the soil. About 45 kg/ha of nitrogen is released during the first year after the root system has completed its life cycle. The transformation of plant residues into stable humus compounds (complete humification) takes longer. The bulk of the organic carbon and nitrogen continues to accumulate in the soil during the second and third years. Okruzhko points out that the long-term impact of the process is observed in the form of an increase in the total amount of humus and stabilization of the soil structure. This usually takes from one to three years after the end of the alfalfa (*Medicago sativa* L.) growing cycle. Favorable conditions for accelerating the humification process include wet conditions, an optimal C:N ratio of 13:1, and the location of root systems close to the soil surface (Hetman et. al., 2021).

The results of the research showed that at the end of the second year of vegetation, the accumulation of humus was minimal and amounted to only 0.03%. Only by the end of the fourth year did the humus content after growing alfalfa (*Medicago sativa* L.) increase by 0.1%.This is fully consistent with scientific data, according to which in the first years of vegetation, the accumulation of humus is minimal due to the slow decomposition of mainly small roots. And only after 3 years of vegetation, when some plants begin to die, the intensity of humus formation significantly accelerates. According to Mazur et al. (2021), alfalfa (*Medicago sativa* L.) contributes to the enrichment of the soil with nitrogen, thanks to symbiosis with nodule bacteria, ensuring the fixation of 50–80 to 300 kg of nitrogen per hectare in 2–3 years. After its cultivation, biomass remains in the soil, which decomposes and turns into a nutrient fertilizer equivalent to the application of 40–60 tons of manure. Over time, especially in the second or third year, this fixed amount of nitrogen accumulates in the root system and green mass of the plant. After the plant dies or is plowed up, the nitrogen becomes easily available for subsequent crops, acting as a high-quality fertilizer (Petrychenko et. al., 2022).

Studies have shown that at the end of the second year of vegetation, the content of alkaline hydrolyzed nitrogen in the soil decreased slightly. This is due to the fact that alfalfa plants (*Medicago sativa* L.) actively used soil nitrogen for growth and development, since mineral fertilizers were not applied. Symbiotically fixed nitrogen accumulated in the roots and aboveground biomass of alfalfa and only after the plants died off did its content in the soil begin to increase, which is confirmed by the increase in the level of alkaline hydrolyzed nitrogen by the end of the fourth year of vegetation. As Hnatiuk et al. (2019) points out, alfalfa (*Medicago sativa* L.) absorbs a significant amount of phosphorus from the soil (2.1–3.0 g per 1 kg of dry matter). At the same time, its root residues contribute to improving the structure and providing nutrients, in particular phosphorus, for subsequent crops. However, the plant also spends phosphorus for its development.

According to Tkach et al. (2023), alfalfa (*Medicago sativa* L.) actively accumulates potassium in the soil, since during growth it removes a significant amount of it (up to 280 kg/ha per year). However, when the remains of alfalfa plants (*Medicago sativa* L.) decompose, potassium returns back to the soil, contributing to an increase in its fertility. This is especially noticeable if the leaves and stems remain on the field, which allows returning from 60 to 150 kg/ha of potassium. The main part of this element is stored in the organic matter and returns to the soil if the plant is not completely removed, thus improving the nutrient balance for future crops (Tkach et al., 2023).

Studies confirm that the accumulation of phosphorus and potassium in the soil occurs due to the organic matter of the roots and above-ground mass of alfalfa (*Medicago sativa* L.). Thus, at the end of the fourth year of vegetation, the content of mobile phosphorus and exchangeable potassium in the soil increased by 34 and 22 mg/kg, respectively. As Kaletnik et al. (2024) notes, growing alfalfa (*Medicago sativa* L.) does not lead to a decrease in soil acidity. On the contrary, this crop requires neutral or slightly soil with a slightly alkaline reaction (pH 6.5–7.5). On acidic soils with a pH below 6.3, alfalfa (*Medicago sativa* L.) develops poorly, as this negatively affects the activity of nodule bacteria and phosphorus absorption. Therefore, liming is necessary before sowing on acidic soils. Alfalfa (*Medicago sativa* L.) itself is not able to reduce soil acidity, but it reacts very sensitively to its level. Our studies revealed the fact of optimizing the soil acidity regime: an increase of 0.1 pH (from 7.0 to 7.1 pH) and a decrease in hydrolytic acidity (from 0.53 to 0.40 mg-eq./100 g). This is explained by the aftereffect of limestone materials introduced before sowing alfalfa (*Medicago sativa* L.), as well as the accumulation of organic matter and its transformation into humus as a result of the decomposition of root and aboveground biomass of plants. It is known that the presence of humus in the soil contributes to the reduction of its acidity. (Kaletnik et. al., 2024).

Razanov notes that due to the widespread phenomenon of bioaccumulation in alfalfa plants (*Medicago sativa* L.), it is able to absorb heavy metals from the soil, accumulating them in its biomass. During the harvesting process, metals are removed from the soil, helping to reduce their accumulation. Also, growing alfalfa (*Medicago sativa* L.) leads to a decrease in the bioavailability of heavy metals in the soil for plants. Phytochemical processes occurring in the plant, as well as changes in soil acidity (neutral reaction), accumulation of humus, mobile phosphorus and exchangeable potassium can reduce the availability of certain heavy metals for plants, such as lead and cadmium (Honcharuk et. al., 2022).

Correlation analysis showed an average negative relationship ($r = -0.5724$) between the dynamics of humus content accumulated by alfalfa crops over four years and the content of mobile forms of heavy metals in the soil. This confirms the hypothesis that an increase in humus content contributes to a decrease in the concentration of mobile heavy metals. The approximation coefficient ($R^2 = 0.3276$) indicates that when the humus content changes by one unit, the content of mobile forms of heavy metals changes by approximately 0.3. Similar negative correlations are observed between the dynamics of mobile phosphorus ($r = -0.5411$), exchangeable potassium ($r = -0.4363$) and the content of mobile forms of heavy metals in the soil. (Figure 6).

Also, as Kolisnyk et al. (2025) notes, growing alfalfa (*Medicago sativa* L.) leads to an improvement in soil structure. A strong root system of alfalfa improves soil aeration and drainage. This indirectly affects the mobility and availability of heavy metals, regulating their behavior in the soil environment.

An average negative correlation ($r = -0.5012$) was found between the dynamics of soil structural properties and the content of mobile forms of heavy metals during the four-year cultivation of alfalfa (*Medicago sativa* L.). The results of our studies confirm that alfalfa significantly reduces the concentration of mobile forms of heavy

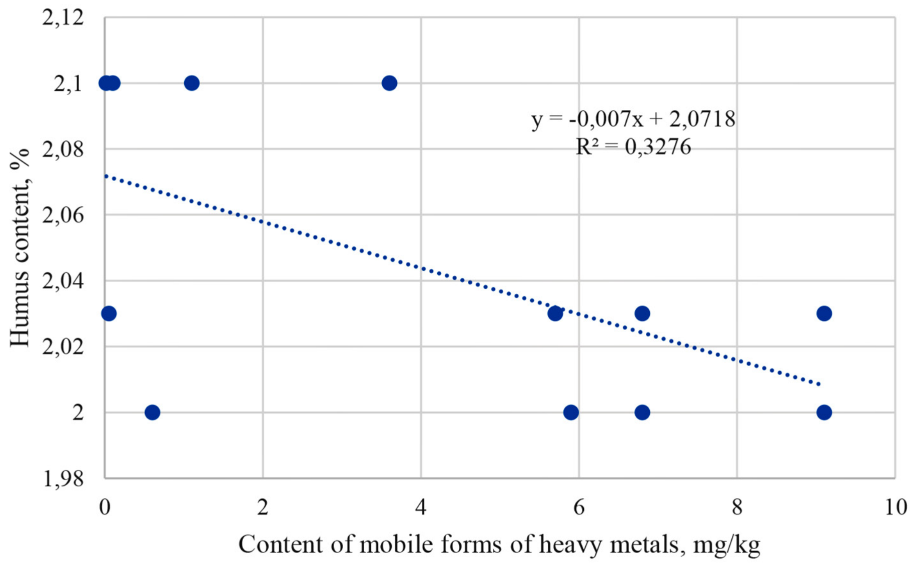

Figure 6. Regression analysis of the relationship between humus and mobile heavy metals in soi under alfalfa (*Medicago sativa* L.)

metals in the soil, demonstrating pronounced phytoremediation properties. This effect is due to the indirect effect through an increase in the content of humus, mobile phosphorus, exchangeable potassium and improvement of soil structural characteristics.

Tsyhanska et al. (2025) points out that growing alfalfa (*Medicago sativa* L.) has a positive effect on the structure of the soil due to its developed and deep root system. It helps loosen the soil, creates channels for air and water access, and after dying off, leaves a significant amount of organic matter.

In addition to enriching the soil with nutrients, this increases its water-holding capacity, improves aeration, and contributes to the formation of structural and fertile soil. Organic matter from plant decomposition and alfalfa root secretions (*Medicago sativa* L.) contribute to the formation of strong soil aggregates, which increase soil resistance to erosion and compaction (Butenko et al., 2025); 2025; Okrushko et al., 2025).

This thesis is fully confirmed by the results of our research. At the end of the second year of alfalfa (*Medicago sativa* L.) vegetation, the proportion of structural aggregates decreased somewhat, which can be explained by their destruction under the influence of precipitation and agricultural machinery, since during this period the accumulation of humus was minimal. Only by the end of the fourth year, when the humus content in the soil increased, the proportion of agronomically valuable structural aggregates also increased (Didur et al., 2025).

The strong positive correlation (r = 0.6820) between humus and the proportion of valuable aggregates indicates an improvement in soil structure as it increases (Figure 7).

According to Solona et al. (2025), growing alfalfa (*Medicago sativa* L.) significantly increases soil water resistance due to its developed root system, which helps improve soil structure. This ensures its porosity, which facilitates water penetration and retention. In addition, alfalfa (*Medicago sativa* L.) enriches the soil with organic matter, which acts like a sponge, preventing erosion. As a result, the soil becomes more resistant to water flows and has improved water permeability. Organic compounds of the roots contribute to the formation of stable soil aggregates, due to which the soil becomes more structured and less vulnerable to erosion (Solona et al., 2025).

These results are fully confirmed by our studies, which showed that soil water resistance increased by the fourth year of alfalfa (*Medicago sativa* L.) vegetation, in parallel with an increase in the proportion of agronomically valuable aggregates. The effect of humus content on the water resistance of soil aggregates is characterized by a high correlation coefficient (r = 0.9776), and the effect of soil structure on the water resistance of aggregates is also significant (r = 0.8208) (Figure 8).

Growing alfalfa (*Medicago sativa* L.) helps reduce soil bulk density due to its powerful root system, which loosens it. This improves soil structure, increases aeration and water permeability. At the same time, the soil is enriched with organic matter

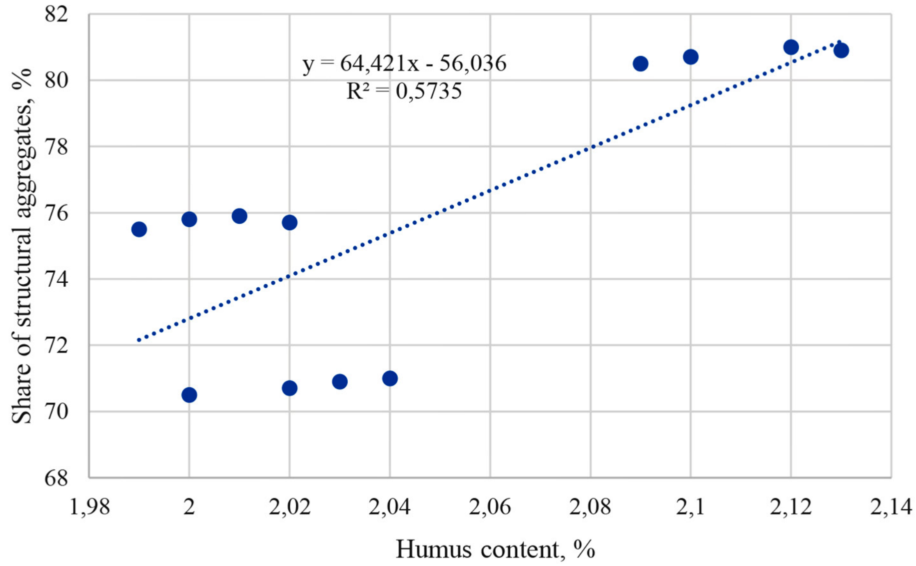

Figure 7. Regression analysis of the dependence of humus on the proportion of valuable structural aggregates in the soil under alfalfa (*Medicago sativa* L.)

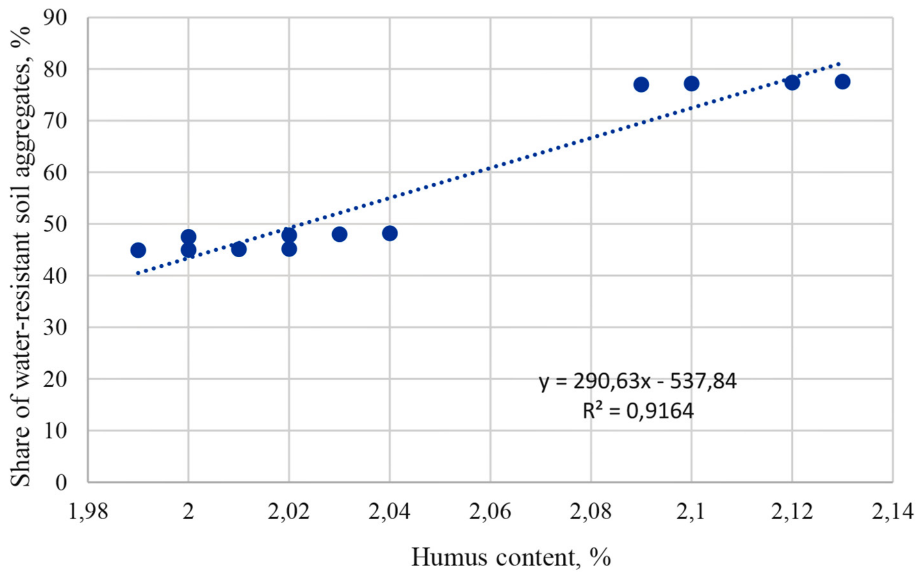

Figure 8. Graphical dependence, regression equation and approximation coefficient between the humus content and the proportion of water-resistant aggregates in the soil during the cultivation of alfalfa (*Medicago sativa* L.)

and nitrogen, which increases its fertility and reduces compaction, especially after the decomposition of the root mass. The results of our research confirm these patterns: in the fourth year of vegetation, the soil bulk density decreased from 1.20 to 1.14 g/cm^3.

CONCLUSIONS

Medicago sativa L., as a legume perennial grass, when grown for four years, exhibits powerful phyto-ameliorative properties: it increases the humus content in gray podzolized medium loam soil by 0.1%, alkaline hydrolyzed nitrogen by 2.9%, mobile phosphorus by 8.0%, exchangeable potassium by 25.6%. It optimizes the pH reaction of the soil solution, increasing it from 0.1 to 0.3 pH, achieving a neutral reaction in the range of 7.1–7.3 pH and reduces hydrolytic acidity by 24.5–28.3%. It reduces the mobility of heavy metals in the soil, which reduces their concentrations by 39.0% – lead, by 96.7% – cadmium, by 98.5% – copper and by 87.9% – zinc. The positive role of alfalfa (*Medicago* *sativa* L.) in increasing soil erosion resistance. There is an increase in agronomically valuable soil aggregates by 4.9–6.7% and water-resistant aggregates by 32.2%, and the soil structural coefficient by 1.1–1.6. An additional positive factor in growing alfalfa is soil loosening, which is manifested in a decrease in soil bulk density by 5.0–33.3% to a value of 1.14 g/cm^3. Further use of the obtained research results is the cultivation of alfalfa (*Medicago sativa* L.) on degraded soils that have processes of dehumification, trophic depletion of basic nutrients, signs of acidification, are contaminated with heavy metals, have the development of erosion processes and soil compaction, which will allow achieving their zero degradation.

REFERENCES

1. Hetman, N., Veklenko, Y., Petrychenko, V., Korniichuk, O., Buhaiov, V. (2024). Agrobiological substantiation of growing Hungarian vetch in mixed crops. *Scientific Horizons*. *27*(4), 61–75.
2. Petrychenko V., Lykhochvor V., Didur I., Pantsyreva H. (2024). Scientific aspects of organic soy productionin Ukraine. *Chemistry-Didactics-Ecology-Metrology. 29*(1–2), 111–121. https://doi.org/10.2478/cdem-2024-0008
3. Razanov S.F., Tkachuk O.P., Bakhmat O.M., Razanova A.M. (2020). Reducing danger of heavy metals accumulation in winter wheat grain which is grown after leguminous perennial precursor. *Ukrainian Journal of Ecology*, *10*(1), 254–260. https://doi.org/10.15421/2020_40
4. Hnatiuk, T.T., Zhitkevich, N.V., Petrychenko, V.F., Kalinichenko, A.V., Patyka, V.P. (2019). Soybean diseases caused by genus *Pseudomonas* phytopathenes bacteria. *Mikrobiol. Z. 81*(3), 68–83. https://doi.org/10.15407/microbiolj81.03.068
5. Mazur, V., Didur, I., Tkachuk, O., Pantsyreva, H., Ovcharuk, V. (2021). Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change. *Scientific Horizons*. *24*(1), 54–60. https://doi.org/10.48077/scihor.24(1).2021.54-60
6. Mazur V.A., Mazur K.V., Pantsyreva H.V. (2019). Influence of the technological aspects growing on quality composition of seed white lupine (*Lupinus albus* L.) in the Forest Steppe of Ukraine. *Ukrainian Journal of Ecology. 9*(1), 66–71.
7. Tkachuk, O., Pantsyreva, H., Mazur, K., Chabanuk, Ya., Zabarna, T., Pelekh, L., Bronnicova, L., Kozak, Yu., Viter, N. (2025). Ecological problems of the functioning of field protective forest belts of Ukrainian Forest Steppe. *Ecological Engineering & Environmental Technology. 26*(1), 149–161. https://doi.org/10.12912/27197050/195735
8. Petrychenko V., Didur I., Pantsyreva H., Volynets Ye. (2025). Agroecological assessment of technologies for growing legumes. *Ecological Engineering & Environmental Technology*. *26*(3), 393–403. https://doi.org/10.12912/27197050/200442
9. Tkachuk O., Pantsyreva H., Kupchuk, I. Volynets Y. (2024). Soybean productivity in the forest-steppe of ukraine under ecologization of cultivation technology. *Journal of Ecological Engineering*. *25*(5), 279–293. https://doi.org/10.12911/22998993/186494
10. Bulgakov, V., Kaletnik, H., Trokhaniak, O., Lutkovska, S., Klendii, M., Ivanovs, S., Popa, L., Yaropud, V. (2023). Investigation of the energy indicators for the surface treatment of soil by a harrow with a screw-type working body. *INMATEH-Agricultural Engineering*. *71*(3), 818–833.
11. Tkach O., Dubik V., Ovcharuk O., L Mikhaylova L., Pantsyreva H., Vilchynska V., Slobodian S., Gorbovy O. (2023). Technological characteristics and potential of landfill biogas for electricity generation. *International Journal of Ecosystems and Ecology Science. 13*(2), 97–108. https://doi.org/10.31407/ijees
12. Petrychenko, V., Petrychenko, O., Fedoryshyna, L., Kravchuk, O., Korniichuk, O., Nitsenko, V. (2022). Agricultural production in ukraine: ecological challenges and impact on the quality of life. *Financial And Credit Activity-problems Of Theory And Practice. 4*(45), 374–384. https://doi.org/10.55643/fcaptp.4.45.2022.3782
13. Honcharuk, I., Matusyak, M., Pantsyreva, H., Prokopchuk, V., Telekalo, N. (2022). Peculiarities of reproduction of pinus nigra arn. In Ukraine. *Bulletin of the Transilvania University of Brasov, Series II: Forestry, Wood Industry, Agricultural Food Engineering. 15*, 64(1), 33–42. https://doi.org/10.1038/s41598-019-44483-x
14. Kaletnik, H., Yaropud, V., Lutkovska, S., Aliiev, E. (2024). Studying the air flow heating process in the vertical type ground heat exchanger. *Przeglad Elektrotechniczny. 100*(10), 46–54.
15. Tkachuk O., Pantsyreva H., Mazur K., Chabanuk Ya., Zabarna T., Pelekh L., Bronnicova L., Kozak Yu., Viter N. (2025). Ecological problems of the functioning of field protective forest belts of Ukrainian Forest Steppe. *Ecological Engineering & Environmental Technology. 26*(1), 149–161. https://doi.org/10.12912/27197050/195735
16. Didur, I., Vdovenko, S., Tkachuk, O., Palamarchuk, I., Pantsyreva, H., Chabaniuk, Ya., Shkatula, Yu., Zabarna, T., Gucol G. (2024). Cultivation of tomatoes using mycorrhizal biological preparations. *Modern Phytomorphology. 18*, 133–138. https://doi.org/10.5281/zenodo.200121

17. Didur I.M., Prokopchuk V.M., Pantsyreva H.V. (2019). Investigation of biomorphological and decorative characteristics of ornamental species of the genus *Lupinus* L. *Ukrainian Journal of Ecology. 9*(3), 287–290.
18. Khaietska, O., Holovnia, O., Pavlyuk, T., Osipova, L., Prylutskyi, A. (2025). Strategic priorities for the development of the national service sector in the face of global challenges. *Financial and Credit Activity-Problems of Theory and Practice*. *1*(60), 453–465. https://doi.org/10.55643/fcaptp.1.60.2025.4527
19. Vdovenko, L., Melnyk, L., Polova, O., Martseniuk, O., Ruda, O. (2025). Structural transformation of the financial market of Ukraine in the environment of innovative technologies of metaspace. *Journal of Systems Science and Information*. *13*(2), 240–273. https://doi.org/10.12012/JSSI-2024-0136
20. Okrushko S.E., Verheles P.N., Aralova T.S. (2025). Effect of Ascochyta rabiei on symbiotic efficiency and productivity of Cicer arietinum. *Regulatory Mechanisms in Biosystems*. *16*(1), e25001. https://doi.org/10.15421/0225001
21. Tkachuk, O., Pantsyreva, H., Zelenchuk, N., Bondaruk, N., Mostovenko, V. (2025). Resistance of sunflower crops to harmful objects when using growth-stimulating bioproducts in their crops. *Journal of Ecological Engineering*. *26*(4), 98–110. https://doi.org/10.12911/22998993/199816
22. Didur, I., Pantsyreva, H. (2025). Prospects for the development of seed production in Ukraine taking into account economic and environmental efficiency. *Baltic Journal of Economic Studies*. *11*(2), 191–196. https://doi.org/10.30525/2256-0742/2025-11-2-191-196
23. Pantsyreva, H., Alieksieiev, O., Tsyhanska, O., Vradii, O., Honchar, M. (2025). Formation of qualitative indicators of chickpea seed production under climatic changes in the right-bank forest-steppe of Ukraine. *International Journal of Ecosystems and Ecology Science (IJEES)*. *15*(2), 51–54.
24. Solona, O., Spirin, A., Zamrii, M., Tverdokhlib, I., Polievoda, Y., Kovalova, K. (2025). Determination of the dependence of the physico-mechanical properties of alfalfa seed pods on moisture content. *Technology Audit and Production Reserves, 3*(83), 84–90. https://doi.org/10.15587/2706-5448.2025.331286
25. Butenko Y., Rudska N., Kovalenko N., Hotvianska A., Horshchar V., Tkachenko R., Turchina S., Dashutina L., Mikulina M., Toryanik V. (2025). The impact of environmentally balanced agricultural systems on changes in the agrophysical state of typical chernozem soil and the energy management of sunflower cultivation. *Journal of Ecological Engineering*. *26*(7), 428–437. https://doi.org/10.12911/22998993/203917
26. Kolisnyk O., Bahorka M., Yurchenko N., Barylko M., Zakharchenko E., Prokopenko R., Tsedilkin A., Bordun R., Kozhushko N., Kryvozub V. (2025). Evaluation of effectiveness indicators of the application of foliar fertilizers in the sustainable economic development of wheat winter productivity. *International Journal of Ecosystems and Ecology Science. 15*(4), 37–44. https://doi.org/10.31407/ijees15.406
27. Didur I., Pantsyreva H. (2025). Peculiarities of soybean growth and development on gray forest soils. *Agronomy Research*. *23*(1), 352–364. https://doi.org/10.15159/AR.25.015
28. Tkachuk O., Pantsyreva H., Zelenchuk N., Bondaruk N., Mostovenko V. (2025). Resistance of sunflower crops to harmful objects when using growth-stimulating bioproducts in their crops. *Journal of Ecological Engineering. 26*(4), 98–110. https://doi.org/10.12911/22998993/199816