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FERTILIZATION SYSTEM AS A FACTOR OF TRANSFORMING THE HUMUS STATE OF THE SOIL

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Aim. To establish the effect of different fertilization systems in short field crop rotation on the change in the state of humus in the dark gray podzolic soils in Western Forest-Steppe of Ukraine. **Methods.** Field studies were carried out in a stationary experiment of the Department of Soil Science and Agricultural Chemistry of the L'viv National Agrarian University; determination of humus content – according to DSTU 4289:2004, and that of its labile forms – in accordance with DSTU 4732:2007, fraction-group composition – by Ponomareva-Plotnikova's method, according to the measurement procedure 31-497058-008-2002. **Results.** The use of organo-mineral fertilizer system in short field crop rotation with the saturation of organic fertilizers of 15 t/ha of crop rotation contributes to the humus content increase by 0.7 % after the third rotation in 0–40 cm layer of dark gray podzolic soil, the increase in the share of stable forms of humic compounds up to 57–59 % and the increase in the ratio of R_{HA}:R_{FA} to 1.3–1.4. The study demonstrated very high dependence of amount of gross energy reserves in the humus on the R_{HA}:R_{FA} ratio. **Conclusions.** The combined application of organic fertilizers in the form of manure, non-market of the crop (straw) and siderate, along with mineral fertilizers is recommended in short field crop rotations of Western Forest-Steppe of Ukraine toensure expanded reproduction of fertility of dark gray podzolic soil, improvement of its humus status, increase in gross energy reserves and the share of the stable forms and humic acids in the humus.

Key words: fertilization system, soil, humus, fraction-group composition, humic acids, fulvic acids.

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INTRODUCTION

A characteristic feature of modern Ukrainian agriculture is insufficient intake of nutrients and energy into agrosystems [1]. At the time of intensified anthropogenic impact on the soil it leads to their agrophysical and agrochemical degradation, in particular, to the reduction in humus content [2, 3]. The degree of providing crops with nutrients depends on the humus content [4], while its qualitative composition reflects the ecological state of the soil [5].

A relevant task of modern agriculture is to attain positive humus balance, and it can be achieved with the introduction of a corresponding amount of organic fertilizers, the increase in the humification intensity for fresh organic substance as well as with the creation of the conditions in the soil which would diminish the intensity of mineralization of organic substances and promote the formation of stable humus forms [2, 6, 7].

Although the systematic application of organic and mineral fertilizers decreases the negative balance of organic compounds in the soil, it does not always prevent the decrease in the humus content which is related to the enhanced mineralization of the organic substance and the removal of nutrients with the harvest and their non-productive losses [6, 7].

Therefore, it is important to estimate the impact of different fertilization systems on the content and quality of humus in the soil and the trends of transforming organic substances under the influence of agricultural chemicals in practice.

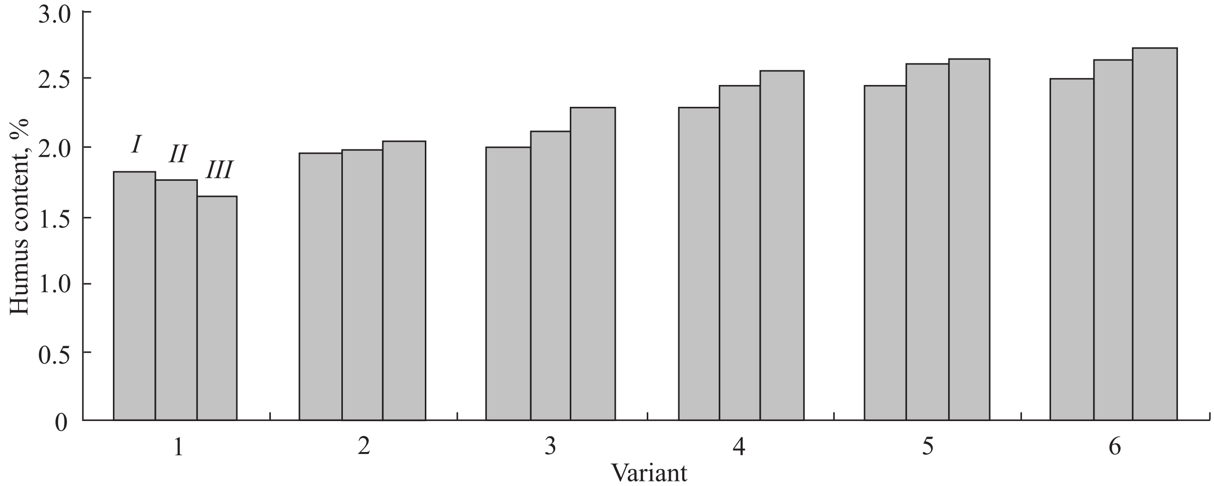

Fig. 1. The dynamics of humus content in the 0–20 cm layer of dark gray podzolic soil of the Western Forest-Steppe of Ukraine under the impact of different fertilization systems: *I* – I crop rotation; *II* – II crop rotation; *III* – III crop rotation

MATERIALS AND METHODS

Field experiments were conducted in the conditions of the stationary experiment of the Department of Soil Science and Agricultural Chemistry of the L'viv National Agrarian University on dark gray podzolic soil for three short field crop rotations (2001–2012) with the following crop rotations: winter wheat – sugar beet – spring barley – red clover.

The experiment scheme involved control, mineral, organic, and organo-mineral fertilization systems of different saturation levels for organic fertilizers: 1) control (no fertilizers); 2) mineral fertilization system $N_{390}P_{210}K_{430}$ (sum of NPK-1030); 3) organo-mineral fertilization system $N_{390}P_{207}K_{430}$, including $N_{270}P_{150}K_{263}$, introduced with mineral fertilizers (sum of NPK-1030), crop rotation saturation with organic fertilizers − 6.25 t/ha of the rotation area; 4) organo-mineral fertilization system $N_{390}P_{210}K_{430}$ (sum of NPK-1030), including $N_{100}P_{170}K_{173}$, introduced with mineral fertilizers; saturation of the crop rotation with organic fertilizers – 12.5 t/ha; 5) organo-mineral fertilization system $N_{390}P_{210}K_{430}$, (sum of NPK-1030), including $N_{50}P_{85}K_{113}$, introduced with mineral fertilizers; the degree of saturation with organic fertilizers – 15.0 t/ha of rotation area; 6) organic fertilization system of $N_{390}P_{210}K_{430}$ (sum of NPK-1030), the degree of saturation with organic fertilizers – 17.5 t/ha.

Field and laboratory experiments were conducted according to common agrochemical methods, in particular, the determination of humus content – according to DSTU 4289:2004; its labile forms – according to DSTU 4732:2007, fraction-group composition – using Ponomariova–Plotnikova method according to the measurement procedure 31-497058-008-2002.

RESULTS AND DISCUSSION

Our studies demonstrated that different fertilization systems have different impact on the humus content in dark gray podzolic soil (Fig. 1).

The application of the organo-mineral fertilization system ensured the increase in the humus content compared with the control and the mineral system.

Even after the first crop rotation the combined introduction of mineral and organic fertilizers with the saturation of the crop rotation with organic fertilizers in the amount of 15–17 t/ha of the rotation area, the content of total humus in the soil increased by 0.33 % and amounted to about 2.4 %. After the third rotation the humus content in the variants of organo-mineral fertilization system exceeded the variants of the mineral system and control by 0.7–1 %. Similar regularity was observed in the subsurface (20–40 cm) layer of soil, but with lesser absolute indices of total humus content.

Fertilization systems had considerable differences regarding their impact on the synthesis of different groups of humus compounds which are divided into labile and stable ones in accordance to modern notions on heterogeneity and their different resistance to mineralization [6].

Organic and organo-mineral fertilization systems condition extended restoration of the fertility of dark gray podzolic soil and promote the formation of stable

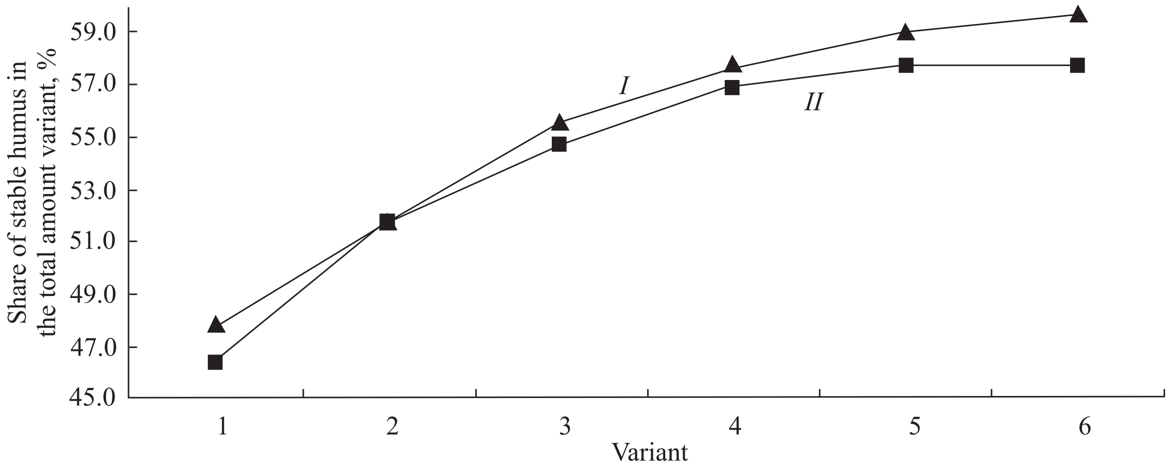

Fig. 2. The change in the share of stable humus in dark gray podzolic soil depending on the fertilization system after the third short field crop rotation: *I* – 0–20 cm; *II* – 20–40 cm

compounds of humus, especially after the second and third crop rotations (Fig. 2). Mineral fertilizers have positive impact on the increase in the content of labile compounds in the humus.

The regularities of stabilization of the humus state of the soil can be described using the following linear equations of multiple regression:

$y = 2.2011\,x + 46.51$ ($R^2 = 0.85$) –
for the upper (0–20 cm) soil layer;
$y = 2.3802\,x + 46.93$ ($R^2 = 0.92$) –
for the lower (20–40 cm) soil layer,

where y – share of stable humus in its total content, %; x – saturation degree of organic fertilizers for the rotation area, t/ha.

The fraction-group composition of humus in the 0–20 cm layer of dark gray podzolic soil (average for 2009–2012)

Variant	Humic acids (HA)			Sum HA	Fulvic acids (FA)				Sum of FA	HA/FA
	HA-1	HA-2	HA-3		FA-1a	FA-1	FA-2	FA-3		
No fertilizers (control)	9.4/27.1	16.2/46.7	9.1/26.2	34.7/100	6.6/19.1	7.9/22.9	12.4/36.0	7.6/22.0	34.5/100	1.01
$N_{390}P_{210}K_{430}$	9.5/27.1*	16.5/47.0	9.1/25.9	35.1/100	6.5/19.0	7.7/22.5	12.7/37.1	7.3/21.4	34.2/100	1.03
20 t/ha of manure + 5 t/ha of straw + $N_{270}P_{153}K_{260}$	10.6/28.3	17.5/46.8	9.3/24.9	37.4/100	4.5/14.7	6.7/21.9	12.5/40.8	6.9/22.6	30.6/100	1.22
30 t/ha of manure + 15 t/ha of siderates + 5 t/ha of straw + $N_{100}P_{110}K_{173}$	10.8/28.1	18.3/47.5	9.4/24.4	38.5/100	3.5/12.0	6.4/22.0	12.5/43.0	6.7/23.0	29.1/100	1.32
40 t/ha of manure + 15 t/ha of siderates + 5 t/ha of straw + $N_{50}P_{85}K_{113}$	11.1/28.5	18.4/47.2	9.5/24.3	39.0/100	3.5/12.2	5.7/19.9	12.6/44.1	6.8/23.8	28.6/100	1.36
50 t/ha of manure + 15 t/ha of siderates + 5 t/ha of straw + $N_{25}P_{60}K_{50}$	11.3/28.8	18.4/46.8	9.6/24.4	39.3/100	3.4/12.0	5.8/20.4	12.7/44.7	6.5/22.9	28.4/100	1.38

Note. *Percentage from the total carbon/percentage of the fraction from the sum of HA or FA.

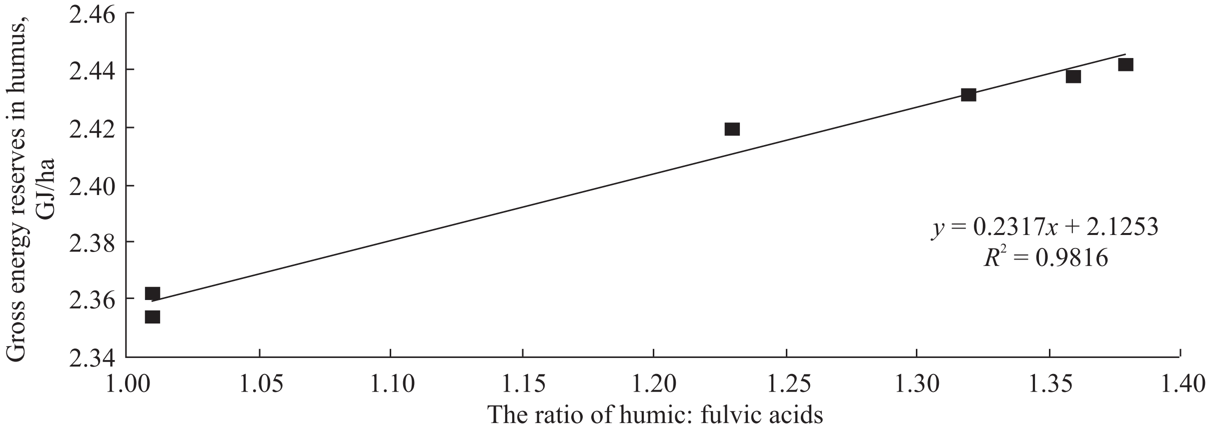

Fig. 3. The dependence of the content of gross energy reserves in humus (0–20 cm soil layer) on the R_{HA}:R_{FA} ratio

Multiple determination coefficients (R^2) indicate close correlation between the introduced organic fertilizers and the increase in the share of stable humus in the soil.

It should be noted that practically in all the experiment variants in the upper soil layer (0–20 cm) the content of labile humus forms after the third rotation fluctuated in the range of 1.0–1.2 %. Contrary to the indices of labile humus, the indices of the content of its stable forms by the crop rotations changed considerably under the impact of fertilization systems.

The fraction-group composition of humus is considered to be the most relevant index of humus state of the soil [8]. Our studies identified a considerable impact of the fertilization systems on the fraction-group composition of dark gray podzolic soil [9] (Table). The indices of the fraction-group composition of humus demonstrate that the absence of fertilizers leads to the aggravation of the humus state of the soil. It reflects in the increased share of fulvic acids (FA), in particular, aggressive groups FA-1a and FA-1, the decreased share of the non-hydrolyzed residue in the humus, gradual transition of the soil type from the humic-fulvic to fulvic-humic one.

The mineral system of fertilization suspends the degradation processes to some degree, and also promotes the increase in the FA content, especially in the subsurface (20–40 cm) layer.

Only the organo-mineral and organic fertilization systems ensure qualitative enhancement of the fraction-group content of humus which is reflected in the increase in the share of humic acids. It determined higher humic:fulvic acids (R_{HA}:R_{FA}) ratio, including the subsurface layer.

R_{HA}:R_{FA} reflects the direction of the processes of organic matter mineralization and serves as an indicator of the humus state of the soil. There were considerable changes in R_{HA}:R_{FA} in the upper (0–20 cm) layer of the soil. Although the humus type in all the variants was humic-fulvic, it should be noted that the share of humic and fulvic acids was almost the same for the control variant and the one with the use of the mineral fertilization system. The ratio was shifted towards HA only due to the introduction of organic fertilizers. The best ratio was ensured by the organic (1.38) and organo-mineral (1.36) fertilization systems with the highest saturation for organic fertilizers.

The fraction-group composition of humus has direct impact on the energetic state of the soil, which correlates with the humus content [10]. It has positive impact both on the soil fertility and its energetic potential, which increases the stability and productivity of agricultural systems [11]. Proper estimation of the energetic state of the soil humus required the consideration of its fraction-group composition, the heat intensity of all the groups of humic substances [10, 11] as well as its agrophysical state which also fluctuated under the influence of different fertilization systems [12].

Combined application of organic and mineral fertilizers ensures the accumulation of humic substances in the soil and the increase in the share of humic acids and non-hydrolyzed forms of humic substances that are remarkable for the highest heat intensity which promotes the increase in the gross energy reserves in humus. The heat intensity of humus increases with the increase in the share of introduced organic fertilizers. The highest indices of gross energy reserves in the soil humus were noted for the variants of organic and organo-mineral systems with the highest saturation level of organic fertilizers. In these variants the energy intensity was on the level of 5.0 gigajoule/ha which exceeds a similar index for the control variant by 0.26 gigajoule/ha.

There is an established correlation between the gross energy reserves, accumulated humus and the $R_{HA}:R_{FA}$ ratio (Fig. 3).

The multiple determination coefficient ($R^2 = 0.98$) illustrates close dependence of the accumulated energy index in the humus on the content of humic acids.

The results of estimations of the gross energy reserves in the humus under experimental conditions demonstrated the tendency towards the increase in the energy intensity of the humus under the impact of organic fertilizers. Still, it is the organo-mineral system with the saturation of 15.0 t/ha of organic fertilizers that ensures one of the highest energy intensity indices in the upper surface layer and the highest one – in the subsurface layer. The application of the mineral fertilization system does not condition the increase in the energy intensity index for the humus even compared to the non-fertilized areas.

CONCLUSIONS

The application of organo-mineral fertilization systems for the short field crop rotation leads to the emergence of new levels of stable humus state in the soil which correspond to the specificities of the intake of the organic matter, its chemical composition and the direction of the mineralization processes.

The highest indices (2.7 %) of the content of total humus in the 0–40 cm layer of dark gray podzolic soil after the third crop rotation are ensured by the organo-mineral fertilization system with the saturation with organic fertilizers at the level of 15 t/ha of the rotation area. The increase in the norms of the organic fertilizers does not lead to the increase in the total content of humus and the mineral fertilization system promotes the dehumification of the surface (0–20 cm) and the subsurface (20–40 cm) soil layers.

The absence of fertilizers and the mineral fertilization system lead to the aggravation of the humus state of dark gray podzolic soil which is manifested in the increase in the share of fulvic acids up to 34 %, in particular, it pertains to the most aggressive fractions (FA-1a and FA-1), the decrease in the share of the non-hydrolyzed residue in the humus, gradual transition of the soil humus from the fulvic-humic to the humic-fulvic type.

The application of the organo-mineral fertilization system results in the increase in the energy intensity of the humus. The multiple determination coefficient ($R^2 = 0.98$) illustrates close dependence of the accumulated energy index in the humus on the content of humic acids. The gross energy reserves, accumulated by humus in the 0–40 cm soil layer, are the highest (5.0 gigajoule/ha) on average for three crop rotations, while using the organo-mineral fertilization system, which requires the application of 40 t/ha of manure + 15 t/ha of siderates + 5 t/ha straw + $N_{50}P_{85}K_{113}$.

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Система удобрення як чинник трансформації гумусового стану ґрунту

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Мета. Встановити вплив різних систем удобрення у короткоротаційній польовій плодозмінній сівозміні на зміну гумусового стану темно-сірого опідзоленого ґрунту в Західному Лісостепу України. **Методи.** Польові дослідження проведено в стаціонарному експерименті кафедри агрохімії та ґрунтознавства Львівського національного аграрного університету; визначення вмісту гумусу – згідно з ДСТУ 4289:2004; його лабільних форм – згідно з ДСТУ 4732:2007, фракційно-групового складу – за методом Пономарьової–Плотникової відповідно до МВВ 31-497058-008-2002. **Результати.** Застосування органо-мінеральної системи удобрення в короткоротаційній польовій сівозміні з насиченням органічними добривами (15 т/га) сівозмінної площі сприяє підвищенню вмісту гумусу на 0,7 % після третьої ротації в шарі 0–40 см темно-сірого опідзоленого ґрунту, збільшенню частки стабільних форм гумусових сполук до 57–59 % і зростанню співвідношення гуміновi:фульвокислоти ($С_{ГК}:С_{ФК}$) до 1,3–1,4. Виявлено суттєву залежність величини валових запасів енергії в гумусі від $С_{ГК}:С_{ФК}$. **Висновки.** У короткоротаційних польових плодозмінних сівозмінах Західного Лісостепу України у системах удобрення, окрім використання мінеральних добрив, варто сумісно застосовувати органічні добрива у вигляді гною, нетоварну частину врожаю (солому) та сидерати, що забезпечує розширене відтворення родючості темно-сірого опідзоленого ґрунту, покращення його гумусового стану, зростання валових запасів енергії, частки стабільних форм і гумінових кислот у гумусі.

Ключові слова: система удобрення, ґрунт, гумус, фракційно-груповий склад, гумінові кислоти, фульвокислоти.

Система удобрения как фактор трансформации гумусового состояния почвы

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Цель. Установить влияние различных систем удобрения в краткоротационном полевом плодосменном севообороте на изменение гумусового состояния темно-серой оподзоленной почвы в Западной Лесостепи Украины. **Методы.** Полевые исследования проведены в стационарном эксперименте кафедры агрохимии и почвоведения Львовского национального аграрного университета; определение содержания гумуса – по ДСТУ 4289: 2004; его лабильных форм – по ДСТУ 4732:2007, фракционно-группового состава – по методу Пономаревой–Плотниковой согласно МВИ 31-497058-008-2002. **Результаты.** Применение органо-минеральной системы удобрения в краткоротационном полевом севообороте с насыщением органическими удобрениями (15 т/га) площади севооборота способствует повышению содержания гумуса на 0,7 % после третьей ротации в слое 0–40 см темно-серой оподзоленной почвы, возрастанию доли стабильных форм гумусовых соединений до 57–59 % и повышению соотношения гуминовые:фульвокислоты ($С_{ГК}$:$С_{ФК}$) до 1,3–1,4. Выявлено существенную зависимость величины валовых запасов энергии в гумусе от $С_{ГК}$:$С_{ФК}$. **Выводы.** В краткоротационных полевых плодосменных севооборотах Западной Лесостепи Украины в системах удобрения, кроме использования минеральных удобрений, следует совместно применять органические удобрения в виде навоза, нетоварной части урожая (солома) и сидераты, что обеспечивает расширенное воспроизводство плодородия темно-серой оподзоленной почвы, улучшение его гумусового состояния, возрастание валовых запасов энергии, доли стабильных форм и гуминовых кислот в гумусе.

Ключевые слова: система удобрения, почва, гумус, фракционно-групповой состав, гуминовые кислоты, фульвокислоты.

REFERENCES

1. *Lisovyj MV, Nikitjuk ML*. Balance of nutritives in the agriculture of Ukraine. *Protection of soil fertility.* Kyiv. 2006;Is. 1:55−8.
2. *Zarishnjak AS, Baljuk SA, Lisovyj MV, Komarysta AV*. Balance of humus and nutrients in soils of Ukraine. *Visnyk agrarnoi nauky*. 2011;(1):28−32.
3. *Balajev AD*. The fertility of the soil, its quantitative and qualitative assessment. *Agricultural Chemistry and Soil Science.* Kharkiv. 2006;Vol. 3:4−6.
4. *Gonchar LV, Kuzik NV*. The influence of the systematic application of organic and mineral fertilizers in field crop rotation on soil fertility. *Agricultural Chemistry and Soil Science.* Kharkiv. 2006;Vol. 3:33−4.
5. *Baljuk SA, Vernichenko GA*. Concept of environmental risk of degradation of soil covering of Ukraine. *Visnyk agrarnoi nauky*. 2011;(6):5−11.
6. *Bakina LG, Chugunova MV, Zajceva TB, Nebol'sina ZP*. Influence of liming on the complex of soil microorganisms and humus state of sod-podzolic soil in long-term experience. *Pochvovedenie*. 2014;(2):225−34.
7. *Skrylnik EV*. Transformation of the humus condition of soils and their energy capacity under the impact of different systems of fertilizers. *News AIP of Kharkiv region*. 2010;Is. 7:184−94.
8. *Orlov DS., Grishina L A*. Practical work on chemistry of humus. Moscow, Publ. Moscow Univ. 1981;272 p.
9. *Lopushnjak V, Kostyuk B, Hrytsulyak G*. The dynamics of content humus and nitrogen alkaline hydrolyzed forms in sod-podzolic soils under the influence of fertilizer energy of willow sewage sludge. *Foothill and mountain agriculture and stockbreeding*. Lviv-Obroshyno. 2014; 56(2):19−24.
10. *Orlov O*. Energy capacity of humus as a criterion of the humus condition of soils. *News of the National University of Lviv*. 2002;Is. 31:111−5.
11. *Tarariko YuO*. Influence of agrotechnical factors on the humus condition and energy capacity of soils. *Agricultural Chemistry and Soil Science.* Kharkiv. 2002;Vol. 3:289−91.
12. *Lopushnyak V.* The impact of fertilizing system on structural aggregate composition of dark-gray podzolized soil. *News of LSAU: agronomy*.2012;(16):493–9.