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IMPACT OF SEWAGE SLUDGE APPLICATION ON THE HUMUS STATE OF SOD-PODZOLIC SOIL OF SUBCARPATHIA UNDER ENERGETIC WILLOW PLANTATION

V. I. Lopushniak [1, 3], G. M. Hrytsulyak [2]

[1] Lviv National Agrarian University (LNAU)
1, V. Velykoho Str., Lviv-Dubliany, Ukraine, 80381
[2] Ivano-Frankivsk College of LNAU
11, Yunosti Str, Ivano-Frankivsk, Ukraine, 76492
[3] University of Science and Technology (UTP)
Al. prof. S. Kaliskiego 7, Bydgoszcz, Poland, 85796

e-mail: Vasyll@mail.ru

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Aim. To determine the impact of energetic willow fertilization with sewage sludge (SS) and manure on the change in the humus state of sod-podzolic soil of Subcarpathia under energetic willow plantation. **Methods.** Soil samples were collected on the experimental field of Ivano-Frankivsk College of LNAU. The humus content was determined according to DSTU 4289:2004; that of its labile forms – according to DSTU 4732:2007, the content of organic matter in SS and manure – according to GOST 27980-88. **Results.** The application of sewage sludge for energetic willow grown in sod-podzolic soil of Subcarpathia led to the increase in the total humus content by 0.5–1.1 % compared to the control (without fertilizers). The use of SS preconditioned the change in the humus quality, including the increase in humic acids in humus by 0.05–0.07 %, which promoted the increase in the share of stable humus up to 68–70 % and the stabilization of the humus state of sod-podzolic soil. **Conclusions.** The application of sewage sludge impacts the change in the indices of humus quality, in particular, its group composition. The level of humic acids content in humus increases with the increase in the dose of the introduced sewage sludge and manure, based thereon. It ensures the increase in the share of stable humus in soil, which, in its turn, conditions the stabilization of humus state of sod-podzolic soil. However, this dependence weakens with depth.

Keywords: sewage sludge, soil, humus, humic acids, fulvic acids.

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INTRODUCTION

The quantity and quality of organic matter in soil determine the level of its fertility. All the factors of forming effective fertility of soil are interrelated and closely related to the formation of stable non-deficient balance in humus [1, 2]. Sewage sludge (SS) is determined by high content of organic matter, a wide spectrum of macro- and microelements [3–5], and its introduction into soil increases the content of humic substances in the latter [6, 7]. On the other hand, the use of SS in field agroecosystems may condition the introduction of heavy metals and other pollutants from the sludge into environment and agricultural products [8–10].

The aim of this work was to study the impact of SS on the change in the humus state of soil, in particular, while growing non-food crops, namely, energetic willow.

MATERIALS AND METHODS

Soil samples were collected on the experiment field of Ivano-Frankivsk College of LNAU in the village of Chukalivka, Tysmenytsia district. The scheme of planting energetic willow is 0.33 × 0.70 m. Experiment variants: 1) no fertilizers – control; 2) mineral fertilizers –

$N_{100}P_{100}K_{100}$; 3) SS – 40 t/ha; 4) SS – 60 t/ha; 5) SS – 80 t/ha; 6) SS manure + saw dust (3:1) – 60 t/ha; 7) SS manure + straw (3:1) – 20 t/ha; 8) SS manure + straw (3:1) – 40 t/ha; 9) SS manure + straw (3:1) – 60 t/ha; 10) SS manure + straw (3:1) + finished cement dust, 10 % – 40 t/ha. The determination of humus content was made according to DSTU 4289:2004; that of its labile forms – according to DSTU 4732:2007, the content of organic matter in SS and manure, based on the latter – according to GOST 27980-88. Experimental data were submitted to regression and statistical analysis.

RESULTS AND DISCUSSION

It was determined that the content of organic matter in SS was about 95 %, while it was 74–76 % in manure with different organic fillers (calculated per absolutely dry substance). Due to their introduction the content of total humus (H_{tot}) in sod-podzolic soil demonstrated significant changes three years later (Table 1).While the content of total humus in the control variant in the soil layer of 0–20 cm was 1.64 %; in the layer of 20–40 cm – 1.46 %, and at the depth of up to 40 cm it decreased down to 0.38 %.

The application of SS ensured a considerable increase in the humus content in humus-eluvial horizon. There was a decrease in the humus content down to 0.40 % in the eluvial horizon. However, this index was higher compared to the control without fertilizers at the same depth. After the introduction of manure, based on SS and straw in the doses of 20 and 40 t/ha respectively, the humus content decreased regarding the parts with freshly introduced sludge and fluctuated slightly in the range of 1.66–1.74 % at the depth of 0–20 cm.

Table 1. Dynamics of the content of labile (H_L) and stable (H_S) forms of humus at the depth of 0–40 cm at the introduction of sewage sludge (2011–2014), %

Experiment variant	H_L	H_S	H_{tot}	H_L/H_{tot}	H_L/H_S
1. No fertilizers – control	0.64	1.00	1.64	39	0.64
	0.47	0.98	1.45	32	0.48
2. $N_{100}P_{100}K_{100}$	0.63	1.02	1.65	38	0.62
	0.44	1.00	1.44	31	0.44
3. SS, 40 t/ha	0.64	1.01	1.66	37	0.63
	0.49	1.07	1.56	31	0.46
4. SS, 60 t/ha	0.65	1.05	1.70	38	0.62
	0.51	1.11	1.62	31	0.46
5. SS, 80 t/ha	0.62	1.12	1.74	37	0.55
	0.52	1.16	1.68	30	0.44
6. Manure (SS + saw dust (3:1)), 60 t/ha	0.60	1.10	1.70	35	0.55
	0.51	1.17	1.68	30	0.44
7. Manure (SS + straw (3:1)), 20 t/ha	0.61	1.05	1.66	36	0.58
	0.54	1.06	1.60	31	0.51
8. Manure (SS + straw (3:1)), 40 t/ha	0.61	1.08	1.69	36	0.56
	0.52	1.17	1.69	30	0.44
9. Manure (SS + straw (3:1)), 40 t/ha	0.62	1.08	1.70	36	0.57
	0.51	1.18	1.69	30	0.43
10. Manure (SS + straw (3:1) + finished cement dust 10 %), 40 t/ha	0.61	1.01	1.67	36	0.60
	0.53	1.14	1.70	31	0.46
LSD_{05}	0.1	0.2			
	0.1	0.1			

Note. Above the line – in 0–20 cm soil layer; below the line – in 20–40 cm soil layer.

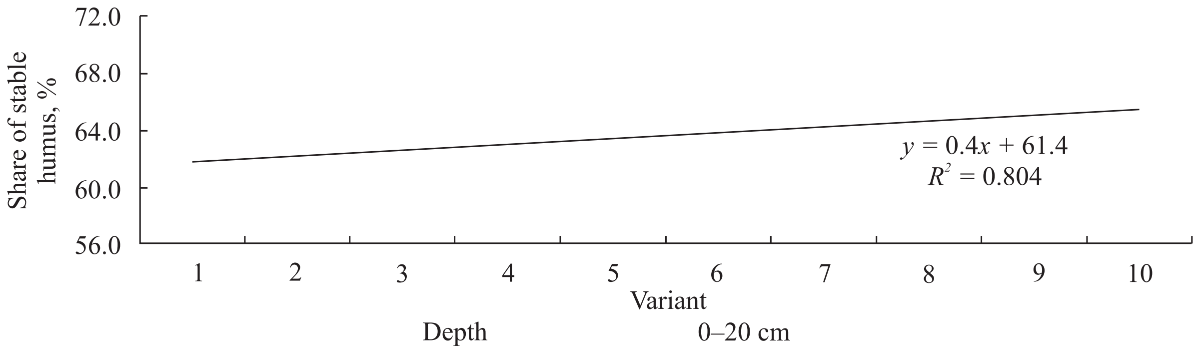

Fig. 1. The change in the share of stable humus in soil at the depth of 0–20 cm depending on the dose of the introduced sewage sludge and manure, based thereon, 2011–2014

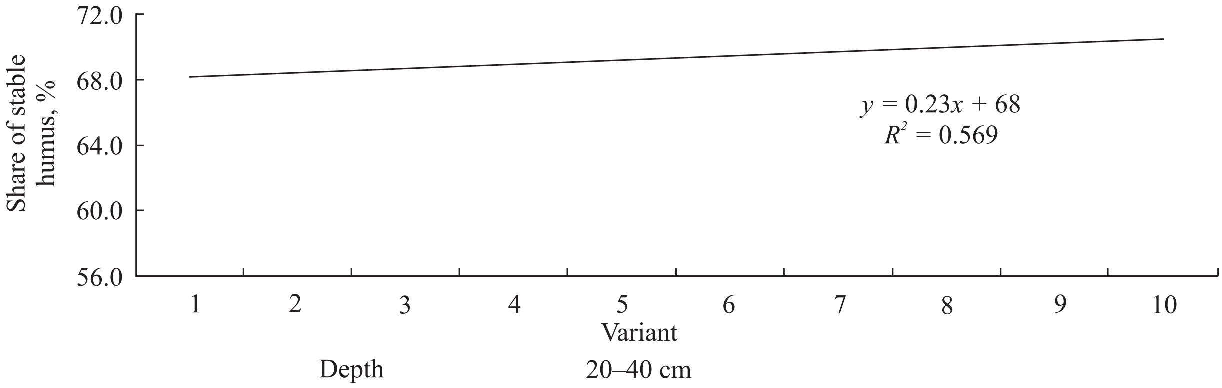

Fig. 2. The change in the share of stable humus in soil at the depth of 20–40 cm depending on the dose of the introduced sewage sludge and manure, based thereon, 2011–2014

The results of determining the content of labile humus (H_L) demonstrated the increase in this index at the introduction of SS. The highest indices of H_L content were noted in variants, where maximal doses of organic fertilizers were introduced. It should be noted that practically in all the experiment variants in the upper soil layer the content of labile humus fluctuated in the range of 0.60–0.65 %.

After the introduction of SS the content of stable humus (H_S) in soil also increased up to 1.1 %, and its share was 68–70 %.

The regularities of stabilization of the humus state of the soil can be described using the linear equations of regression, stated below (Fig. 1, 2):

y = 0.4 x + 61.4 (R^2 = 0.80) – for 0–20 cm soil layer;

y = 0.2364 x + 68 (R^2 = 0.57) – for 20–40 cm soil layer.

Multiple determination coefficients (R^2) indicate close correlation between the introduced dose of SS and the increase in the share of H_S in the soil. At the same time, regardless of the application of high doses of SS, the intensity of total humus accumulation changed insignificantly.

Thus, with the introduction of fresh SS the content of active humus in sod-podzolic soil decreases, whereas that of passive humus increases. After the introduction of manure, based on SS and organic materials (saw dust, straw), the content of passive humus decreases compared to the variants with the introduction of fresh SS, but it remains at a high level compared to the control without fertilizers.

The introduction of fresh SS led both to the increase in the content of H_{tot} and the change in its group composition (Table 2). The index of humus quality is the ratio of humic acids to fulvic acids [4] which changes considerably in experiment conditions under the impact of applying fertilizers.

The comparison of the change in the content of labile and stable humus, humic and fulvic acids demonstrates some dependencies between these indices, which may be reflected in regression equations, presented in Fig. 3 and 4.

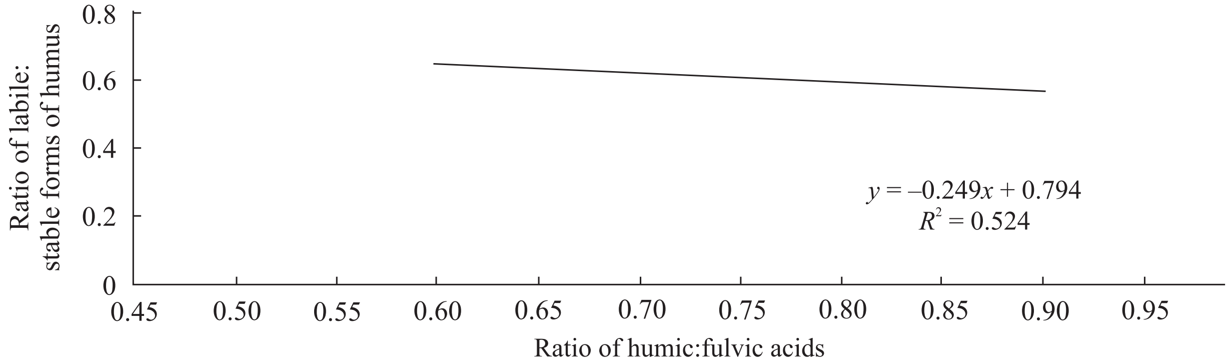

Fig. 3. The dependence of the labile:stable humus ratio on the C_{HA}:C_{FA} ratio in 0–20 cm layer of sod-podzolic soil

Table 2. Group composition of humus of sod-podzolic soil using different systems of fertilizing energetic willow, average for 2011–2014

Variant	HA/FA	Group of humus substances, %		
		Σ Humic acids	Σ Fulvic acids	Humins
1. No fertilizers – control	0.6	0.22	0.34	0.60
	0.3	0.09	0.33	0.60
2. N100P100K100	0.7	0.24	0.33	0.79
	0.4	0.14	0.34	0.63
3. SS, 40 t/ha	0.8	0.25	0.30	0.78
	0.4	0.12	0.34	0.58
4. SS, 60 t/ha	0.8	0.27	0.28	0.82
	0.4	0.13	0.33	0.61
5. SS, 80 t/ha	0.9	0.27	0.28	0.87
	0.4	0.15	0.32	0.63
6. Manure (SS + saw dust (3:1)), 60 t/ha	0.9	0.25	0.29	0.79
	0.4	0.14	0.34	0.54
7. Manure (SS + straw (3:1)), 20 t/ha	0.8	0.25	0.28	0.72
	0.4	0.12	0.35	0.52
8. Manure (SS + straw (3:1)), 40 t/ha	0.8	0.28	0.26	0.76
	0.4	0.12	0.33	0.53
9. Manure (SS + straw (3:1)), 40 t/ha	0.9	0.30	0.25	0.80
	0.4	0.14	0.34	0.54
10. Manure (SS + straw (3:1) + finished cement dust 10 %), 40 t/ha	0.9	0.23	0.28	0.79
	0.4	0.13	0.33	0.54
LSD_{05}		0.03	0.06	
		0.01	0.05	

Note. Above the line – in 0–20 cm soil layer; below the line – in 20–40 cm soil layer.

It was determined that the higher the content of humic acids in the composition of organic matter was, the higher the share of passive humus in soil was. This dependence was clearly traced in the upper (0–20 cm) layer of sod-podzolic soil (the multiple coefficient of determination is 0.52 which indicates rather a close connection). At the same time this dependence was almost vanishing with depth, as the multiple coefficient

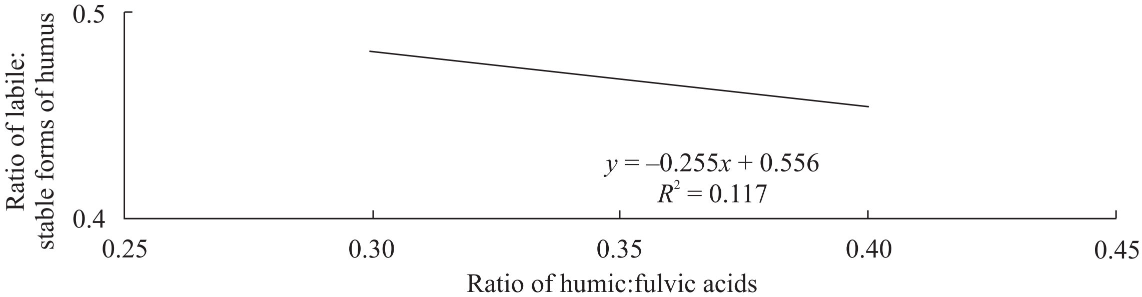

Fig. 4. The dependence of the labile:stable humus ratio on the C_{HA}:C_{FA} ratio in 20–40 cm layer of sod-podzolic soil

of determination decreased down to the values of R^2 = 0.12, which indicated insignificant connection between the indices of the content of humic acids and passive humus.

CONCLUSIONS

According to the results of the study on specificities of accumulation and transformation of humic compounds in sod-podzolic soil of Subcarpathia it was determined that after the introduction of sewage sludge for energetic willow the content of total humus in sod-podzolic soil of Subcarpathia increases compared to the control (without fertilizers). In particular, after its introduction in the dose of 40 t/ha the humus content is 1.76 % in the 0–20 cm layer and 0.40 % – in the 27–42 cm layer. After the introduction of 60 and 80 t/ha of sewage sludge the humus content increases at the depth of 0–20 cm up to 1.88 and 1.97 % respectively, but decreases down to 0.43 % with depth. After the introduction of 60 t/ha of manure of SS + saw dust (3:1) the humus content is 1.70 % in the upper (0–20 cm) soil layer.

The application of sewage sludge also impacts the change in the indices of humus quality, in particular, its group composition. The level of humic acids content in humus increases with the increase in the dose of the introduced sewage sludge and manure, based thereon. It ensures the increase in the share of stable humus in soil, which, in its turn, conditions the stabilization of humus state of sod-podzolic soil. However, this dependence weakens with depth.

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Зміна гумусового стану дерново-підзолистого ґрунту Передкарпаття за внесення осаду стічних вод під вербу енергетичну

В. І. Лопушняк [1], Г. М. Грицуляк [2]

e-mail: Vasyll@mail.ru

[1] Львівський національний аграрний університет
Вул. В. Великого, 1, Львів-Дубляни, Україна, 80381
[2] Івано-Франківський коледж ЛНАУ
Вул. Юності, 11, Івано-Франківськ, Україна, 76492
[3] Университет Технологічно-природничий,
Вул. проф. С. Каліцкего 7, Бидгощ, Польща, 85796

Мета. Встановити вплив удобрення верби енергетичної осадом стічних вод (ОСВ) і компостами на його основі на зміну гумусового стану дерново-підзолистого ґрунту Передкарпаття. **Методи.** Зразки грунту відбирали на колекційно-дослідному полі Івано-Франківського коледжу ЛНАУ; визначення вмісту гумусу – згідно з ДСТУ 4289:2004; його лабільних форм – згідно з ДСТУ 4732:2007, вмісту органічної речовини в ОСВ та компостах на його основі – згідно з ГОСТ 27980-88. **Результати.** За результатами вивчення особливостей нагромадження і трансформації гумусових сполук у ґрунті під впливом внесення ОСВ встановлено, що вміст загального гумусу при цьому підвищується порівняно з контролем (без внесення добрив) на 0,5–1,1 %. Використання ОСВ обумовлює зміну якості гумусу, у тому числі підвищення вмісту гумінових кислот у гумусі на 0,05–0,07 %, що сприяє зростанню частки стабільного гумусу до 68–70 % і стабілізації гумусового стану дерново-підзолистого ґрунту. **Висновки.** Застосування осаду стічних вод впливає на зміну показників якості гумусу, зокрема, його груповий склад. Із збільшенням дози внесення ОСВ та компостів на його основі підвищується рівень вмісту гумінових кислот у гумусі. Це забезпечує зростання частки стабільного гумусу в ґрунті, що, в свою чергу, зумовлює стабілізацію гумусового стану дерново-підзолистого ґрунту. Однак з глибиною ця залежність зменшується.

Ключові слова: осад стічних вод, ґрунт, гумус, гумінові кислоти, фульвокислоти.

Изменение гумусного состояния дерново-подзолистой почвы Предкарпатья при внесении осадка сточных вод под иву энергетическую

В. И. Лопушняк [1], Г. М. Грицуляк [2]

e-mail: Vasyll@mail.ru

[1] Львовский национальный аграрный университет
Ул. В. Великого, 1, Львов-Дубляны, Украина, 80381
[2] Ивано-Франковский колледж ЛНАУ
Ул. Юности, 11, Ивано-Франковск, Украина, 76492
[3] Университет Технологическо-естествознательный,
Ул. проф. Калицкего 7, Быдгощ, Польша, 85796

Цель. Установить влияние удобрения ивы энергетической осадком сточных вод (ОСВ) и компостами на его основе на изменение гумусного состояния дерново-подзолистой почвы Предкарпатья. **Методы.** Образцы почвы отбирали на коллекционно-опытном поле Ивано-Франковского колледжа ЛНАУ; определение содержания гумуса − по ГОСТ 4289:2004; его лабильных форм − по ГОСТ 4732:2007, содержания органического вещества в ОСВ и компостах на его основе − по ГОСТ 27980-88. **Результаты.** По результатам изучения особенностей накопления и трансформации гумусных соединений в почве под влиянием внесения ОСВ установлено, что содержание общего гумуса при этом возрастает по сравнению с контролем (без внесения удобрений) на 0,5−1,1 %. Использование ОСВ обеспечивает изменение качества гумуса, в том числе повышение содержания гуминовых кислот в гумусе на 0,05−0,07 %, что способствует росту доли стабильного гумуса до 68−70 % и стабилизации гумусного состояния дерново-подзолистой почвы. **Выводы.** Применение осадка сточных вод влияет на изменение показателей качества гумуса, в частности, его групповой состав. С увеличением дозы внесения ОСВ и компостов на его основе повышается уровень содержания гуминовых кислот в гумусе. Это обеспечивает рост доли стабильного гумуса в почве, что, в свою очередь, приводит к стабилизации гумусового состояния дерново-подзолистой почвы. Однако с глубиной эта зависимость снижается.

Ключевые слова: осадок сточных вод, почва, гумус, гуминовые кислоты, фульвокислоты.

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