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Agro-Ecological, Marketing Assessment for Siderate in Potato Cultivation

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ABSTRACT

Under current conditions, ecological component is becoming increasingly important. Restoration of potential soil fertility by their saturation with organic matter of intermediate crop siderates is the basis for growing environmentally friendly and high-quality products.Development and adaptation of effective agricultural technologies for growing potatoes in order to obtain organic products is an important scientific area today. One of the tasks of our research was to identify the payback of organic farming elements at current prices, in particular material resources directed on obtaining maximum and quality of potato harvest in the process of its growing.The results of farming and economic efficiency of using intermediate cultivation crops on green manure while growing potato are given. As a result of the conducted research was revealed positive influence of intermediate crops of sideral crops on economic efficiency of potato growing. Application of post-harvest Raphanus sativum siderate provided the highest yield of potato tubers – 30.9 $t \cdot ha^{-1}$ and starch yield – 4.08 $t \cdot ha^{-1}$. In the case of post-harvest Raphanus sativum siderate when growing potato, the highest net profit was obtained – 1369 $€ \cdot ha^{-1}$ and an additional profit of 460 $€ \cdot ha^{-1}$. Application of post-harvest Raphanus sativum siderate provided the lowest cost of potato growing – 36.35 $€ \cdot t^{-1}$, and the highest profitability level of its cultivation – 121.7%, with a payback of additional costs – 0.43 $€ \cdot t^{-1}$.

Keywords: fertilizers, green manure, yield, economic regulation of nature use, phytomass, potato, economic efficiency.

INTRODUCTION

Global agriculture requires the implementation of agrotechnical measures aimed at preserving and improving soil fertility indicators when growing potatoes. Restoration of soil fertility makes it possible to obtain high and stable yields of potatoes at relatively low production costs. This ensures the competitiveness and strong economic attractiveness of organic agricultural technologies [Woźniak, 2019; Sumbul et al., 2020; Mishchenko et al., 2022a; Mischenko et al., 2024]. In the conditions of Ukraine, fertility of black soils suffers from lack of organic fertilizers and excessive tillage of the soil. To ensure favourable conditions for growing potatoes on soils with lost optimal fertility parameters, farmers are forced to invest significant financial resources in application of mineral fertilizers, growth stimulants, pesticides and additional soil loosening. As a result, the product loses its quality indices, and its economic recoupment and, accordingly, sale price become quite high [Murtić et al., 2021; Tonkha et al., 2021; Tsyuk et al., 2022; Karbivska et al., 2023]. Therefore, adaptation of organic farming elements to soil and climatic conditions of Ukraine is an actual scientific direction nowadays.

Ukrainian farms mainly use potato growing technologies which require application of mineral fertilizers, chemical products for plant protection, which cause a risk of soil contamination, cultivated products and the environment. Intensive technologies with insufficient application of organic fertilizers lead not only to excessive chemical stress [Kolisnyk et al., 2024; Hryhoriv et al., 2024]. But also in adverse weather conditions require additional agricultural measures which reduce economic attractiveness of the production as a whole [Seaman, 2016; Bondarchuk et al., 2018; Karbivska et al., 2020; Mishchenko et al., 2022a].

Under current conditions, ecological component is becoming increasingly important. Restoration of potential soil fertility by their saturation with organic matter of intermediate crop siderates, which is the basis for growing environmentally friendly and high-quality products, provides high economic efficiency of potatoes [Butenko et al., 2022; Radchenko et al., 2024], thanks to balancing nutrient regime of crops, improvement of agrophysical properties [Mooleki et al., 2016; Yakupoglu et al., 2021], its phytosanitary state [Isselstein and Kayser, 2014; Woźniak, 2019] and water [Düll et al., 2014; Flaig et al., 2015] and microbiological regimes [Mishchenko et al., 2022b; Möller et al., 2022].

Potatoes are quite demanding to growing conditions, and to obtain high and quality yields they require uncompacted soils with good aeration, free of weeds, sufficiently provided with moisture and nutrients. High economic profitability provision of potato cultivation is quite possible with application of the cheapest agricultural measure for replenishment of organic matter in the soil – intermediate crops on siderate [Mishchenko et al., 2022b; Kovalenko et al., 2024a]. Therefore, development and adaptation of effective agricultural technologies for growing potatoes in order to obtain organic products is an important scientific area today [Caldiz et al., 2016; Lü et al., 2019; Argenti et al., 2021; Kovalenko et al., 2024b].

One of the tasks of our research was to identify the payback of organic farming elements at current prices, in particular material resources directed on obtaining maximum and quality of potato harvest in the process of its growing.

MATERIAL AND METHODS

Determination of farming and economic efficiency of potato cultivation when using intermediate post-harvest siderate crops was carried out in the conditions of the left-bank Forest-Steppe in the research field of Sumy NAU during 2019–2021 years. The study was conducted in a field experiment according to the scheme:

1. Control (without application of organic fertilizers to potatoes);
2. Application of *Raphanus sativum* post-harvest siderate;
3. Application of *Phacelia tanacetifolia* post-harvest siderate;
4. Application of *Fagopyrum sagittatum* post-harvest siderate;
5. Application of manure – 25 $t \cdot ha^{-1}$.

The area of the accounting plot is 60 m^2. The method of placing variants in repetition is systematic. Repetition of the experiment – three times. The soil of experimental field is typical deep low-humus medium loam black. The humus content in the soil layer 0–30 cm was 3.9 ± 0.3, and in the layer 40–100 cm – 2.02 ± 1.0%. Reaction of soil solution in the arable layer is close to neutral: pH of aqueous extract is 6.7, hydrolytic acidity – 1.47 mg eq./100 g. of soil, the sum of absorbed bases – 24.4 mg-eq./100 g of soil, degree of saturation with bases – 94.3%.

The soil is characterized by low level of hydrolyzed nitrogen supply – 101 $mg \cdot kg^{-1}$ (according to Cornfield), high content of moveable compounds P_2O_5 and K_2O – respectively 135 and 117 $mg \cdot kg^{-1}$ of soil (according to Chirikov) [Horodniy et al., 2005].

Structure coefficient of arable layer was 2.38, the content of waterproof units with a size of 3–5 mm – 42.8%. The density of composition and solid phase in the arable layer of soil was 1.20 and 2.46 g/cm^3, and in the meter layer – 1.24 and 2.52 g/cm^3, respectively. Total porosity in 0-30 cm layer was 51.16%, in the meter layer it decreased to 50.94%. The lowest moisture content was 28.27% in the arable layer, and in the layer 0–100 cm – 27.13%.

Postharvest siderates were sown in the first decade of August, and plowing of their mass – at the end of the third decade of October. The technology of growing potatoes variety Slovianka was generally accepted for the soil and climatic zone.

For specifical determination of economic efficiency was used a system of calculated indices indicating profitability or unprofitability of cultivation technology in specific soil and climatic conditions [Pivovar, 2013; Karbivska et al., 2022].

RESULTS AND DISCUSSION

Post-harvest *Raphanus sativum* siderate, on average in the years of research, provided the highest potato yield – 30.9 t·ha^{-1} and the highest yield increase – 6.1 t·ha^{-1}, compared to the control without siderate, where the yield was 24.8 t·ha^{-1} (Fig. 1).

Post-harvest *Raphanus sativum* siderate under potatoes had an advantage over traditional fertilizers. It provided a significant difference in the yield of tubers: 1.2 t·ha^{-1} more than with manure application and 1.7 t·ha^{-1} more than with mineral fertilizers.

Application of post-harvest phacelia siderate was significantly inferior to *Raphanus sativum* in terms of potato yield – by 1.6 t·ha^{-1}, and prevailed the control without siderates by 4.5 t·ha^{-1}. Here, the yield was at the level of plowing traditional fertilizers. Green fertilizer of buckwheat provided the lowest increase in potato yield compared to the control – 0.9 t·ha^{-1}, and was significantly inferior to other fertilizers in terms of yield – by 14–20%. Fertilizer background had 26.5% share of influence on the formation of potato yield. Phytomass of postharvest siderates of *Raphanus sativum*, *Phacelia tanacetifolia* and *Fagopyrum sagittatum* was closely correlated with potato yield (Fig. 2).

The share of weather condition influence in vegetation period on the formation of potato yield was – 70.1% (Fig. 1). The yield of testing crops was significantly influenced by air temperature and precipitation amount (Fig. 3).

Correlations between potato yield and average daily temperature and precipitation amount

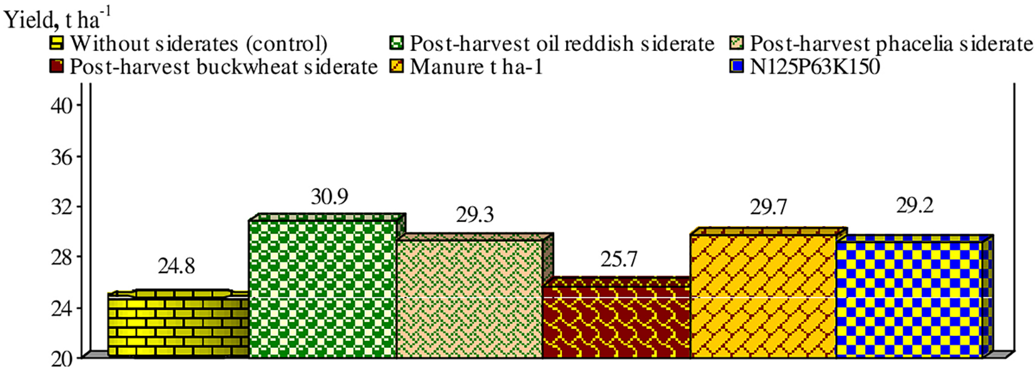


Figure 1. Potato yield under different fertilizer backgrounds, t·ha^{-1}

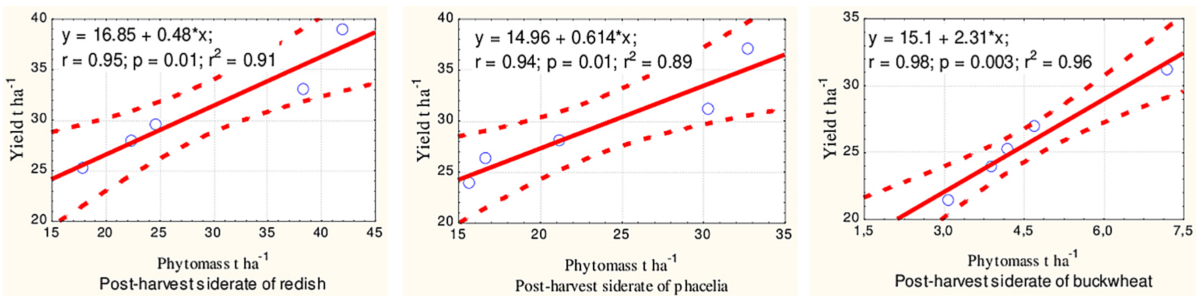
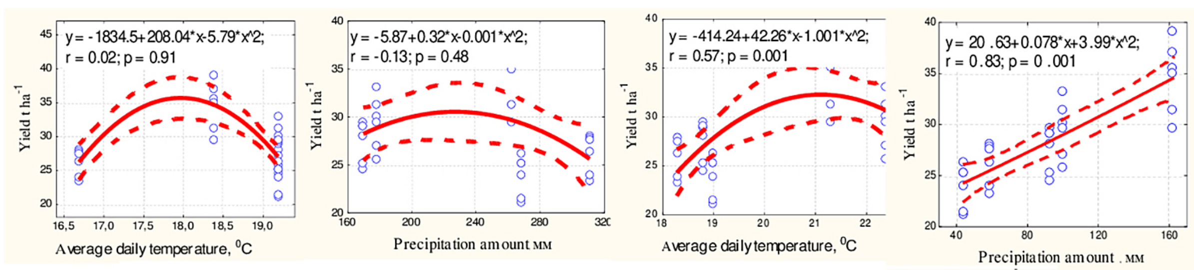


Figure 2. Correlation between potato yield and phytomass of post-harvest siderates



during the period of potato growing during budding-flowering

Figure 3. Correlation between weather elements and potato yield

during the growing period were generally insignificant. Potato productivity depended more on weather elements in critical phases of growth and development. In the phase of budding and flowering potatoes suffered from a lack of moisture, as indicated by a direct close correlation between the level of crop yield and precipitation amount – r = 0.83. Although air temperature in the critical periods of potato development correlated with the crop yields, it did not negatively affect the yield. It is evidenced by the stationary area of the yield response curve within the average long-term indices – 20.5–21.5 °C.

Potatoes are mainly grown for starch production. Its content in tubers is a very important indicator of quality which depends on both the level and balance of plant nutrition and are higher on organic fertilizer backgrounds (Table 1).

The starch content in potato tubers ranged from 12.7 to 13.2%. Compared to the control, it was significantly lower (0.4%) in the variant with application of mineral fertilizer $N_{125}P_{63}K_{150}$. With organic fertilizer the increase of starch content in tubers dominated over the control without siderates by 0.1%, exception was for green manure of *Fagopyrum sagittatum*.

Starch gathering on all fertilizer backgrounds was significantly higher than the control without green manure, except *Fagopyrum sagittatum* green manure. The influence share of fertilizers on starch gathering was 52%, weather conditions – 42%, and other factors – 6%.

According to the yield data of our research, the value of potatoes calculated at Ukrainian prices in 2021 (2361.3–2493.5 € ha^{-1}) indicates a high financial potential of post-harvest siderates of *Raphanus sativum* and *Phacelia tanacetifolia*. These green fertilizers are equivalent to application of 25 $t \cdot ha^{-1}$ of manure or mineral fertilizer $N_{125}P_{63}K_{150}$, significantly prevailed control without green manure by the cost of production by 17–25%; in the variant of *Fagopyrum sagittatum* greens, the increase of grown production cost was only within 4% (Table 2).

Additional production costs for application of green manures increased compared to the control

Table 1. Technological indices of potato quality on different fertilizer backgrounds

Technological indices	Variant						
	Without siderate (control)	Post-harvest siderate				$N_{125}P_{63}K_{150}$	$LSD_{0.05}$
		Raphanus sativum	*Phacelia tanacetifolia*	*Fagopyrum sagittatum*	Manure 25 $t \cdot ha^{-1}$		
Starch content, %	13.1	13.2	13.2	13.1	13.2	12.7	0.14
Starch gathering, $t \cdot ha^{-1}$	3.25	4.08	3.87	3.37	3.92	3.71	0.25

Table 2. Economic efficiency of potato growing on different fertilizer backgrounds

Index	Fertilizer background					
	Without siderate (control)	Post-harvest siderate			Manure 25 $t \cdot ha^{-1}$	$N_{125}P_{63}K_{150}$
		Raphanus sativum	*Phacelia tanacetifolia*	*Fagopyrum sagittatum*		
Yield, $t \cdot ha^{-1}$	24.8	30.9	29.3	25.7	29.7	29.2
Sales price, $€ \cdot t^{-1}$	80.64	80.64	80.64	80.64	80.64	80.64
Cost of production, $€ \cdot ha^{-1}$	1996.77	2493.55	2361.29	2075.80	2391.94	2358.06
Production costs, $€ \cdot ha^{-1}$	1087.77	1124.55	1134.48	1129.65	1362.71	1374.90
Additional costs in total, $€ \cdot ha^{-1}$	–	36.77	46.71	41.87	274.93	287.13
Including application of fertilizers, $€ \cdot ha^{-1}$	–	3.87	3.87	3.87	97.84	3.26
Purchase of fertilizers, $€ \cdot ha^{-1}$	–	14.52	29.03	34.84	161.29	269.35
Net profit, $€ \cdot ha^{-1}$	909	1369	1226.80	946.16	1029.23	983.16
Additional income, $€ \cdot ha^{-1}$	–	460	317.81	37.16	120.23	74.16
The cost of 1 ton, €	43.94	36.35	38.74	43.87	45.94	47.03
Cost of yield increase, $€ \cdot t^{-1}$	–	5.97	10.32	42.74	56.10	64.10
Profitability level, %	83.6	122	108	83.8	75.5	71.5
Payback of additional costs, €/€	–	0.44	0.25	0.06	0.05	0.04

without siderate by 36.77–46.71 €·ha^{-1}, at the same time for application of 25 t·ha^{-1} of manure or $N_{125}P_{63}K_{150}$ they were almost 6–8 times higher and reached the level of 274.93–287.13 €·ha^{-1}, due to modern high prices for manure, mineral fertilizers and work related to manure application.

Due to the lowest seed cost, the increase in production costs for *Raphanus sativum* siderate was the smallest – by 3.8%, compared to the control without siderate, where they were 1087.77 € ha^{-1}. For *Phacelia tanacetifolia* siderate the costs increased by 4.3%, and for *Fagopyrum sagittatum* sowing – by 3.8%.

The largest net profit was obtained when growing potatoes on the background of *Raphanus sativum* green fertilizer – 1369 €·ha^{-1}, as well as additional profit – 460 €·ha^{-1}. Lower profitability was found on the background of *Phacelia tanacetifolia* green manure – net profit from growing potatoes was – 1226.80 €·ha^{-1}, and additional – 317.81 €·ha^{-1}. *Fagopyrum sagittatum* siderate provided lower additional income – 37.16 €·ha^{-1}.

Profit for the technology of growing potatoes with manure was determined in amount 1029.23 €·ha^{-1} or for mineral fertilizers – 983.16 €·ha^{-1}. There was an additional income of 120.23 and 74.16 €·ha^{-1}, which was by 4 and 6 times less than for siderate of *Raphanus sativum*.

For *Raphanus sativum* siderate was the lowest prime cost of growing potato tubers – 36.35 € per ton. Prime cost of yield increase for potato growing on the background of *Phacelia tanacetifolia* green fertilizer, compared to *Raphanus sativum*, increased – by 4.36 € t^{-1}. Prime cost for green manure of *Fagopyrum sagittatum* was equal to the level of control without green manure – 43.87 €·t^{-1}, and the cost of yield increment increased, compared to *Raphanus sativum*, by 6–7 times to 42.74 €·t^{-1} of potato tubers.

Application of manure 25 t·ha^{-1} increased the cost of potato tubers – by 5% to 45.94 €·t^{-1} compared to the control without green manure, and with mineral fertilizer $N_{125}P_{63}K_{150}$ the prime cost increased by 7% to 47.03 €·t^{-1}. Compared to *Raphanus sativum* siderate, prime cost of yield growth with application of traditional organic or mineral fertilizers was by 8–10 times more expensive.

On the background of post-harvest *Raphanus sativum* siderate the maximum level of profitability for potato growing was set – 122%, which differed from the control without siderate by 38%. For green manure of *Phacelia tanacetifolia* was determined lower profitability level of potato growing technology – 108%, which prevailed the control without green manure in terms of profitability level by 24%. Plowing green manure of *Fagopyrum sagittatum* under potatoes provided profitability level equal to the level of control without green manure – 83.6%.

The lowest profitability was determined for application of manure 25 t·ha^{-1} under potatoes – 75.5% and mineral fertilizer $N_{125}P_{63}K_{150}$ – 71.5%, which was 2 times less than in the control without green manure and 3 times less compared to siderate of *Raphanus sativum*.

High economic efficiency of *Raphanus sativum* siderate is evidenced by payback calculations of additional costs for its use in potato growing. Financial return of invested money on application of *Raphanus sativum* green fertilizer was the largest – 0.44 €/€; payback of additional costs for green manure of *Phacelia tanacetifolia*, compared to *Raphanus sativum*, decreased by 60% to 0.25 €/€. Among the siderates, *Fagopyrum sagittatum* had the lowest payback – 0.06 €/€.

Additional costs were also recouped with application of manure 25 t·ha^{-1} under potatoes – 1.44 times or mineral fertilizer $N_{125}P_{63}K_{150}$ – 1.26 times, but comparing to *Raphanus sativum* siderate, they were by 9.4 and 10.7 times lower.

Thus, among the backgrounds of potato fertilization, post-harvest siderate of *Raphanus sativum* prevailed by all economic indices.

CONCLUSIONS

Thus, in unstable moisture zone of the Left-Bank Forest-Steppe on the typical black soils, the most optimal conditions for the formation of the maximum potato yield and starch gathering were created with application of *Raphanus sativum* siderate. So, application of intermediate crops *Raphanus sativum* as siderate in crop rotation is a low-cost agricultural measure with maximum payback, which provides high economic efficiency of growing crops due to obtaining the lowest prime cost of production and the highest net profit and profitability.

REFERENCES

1. Argenti G., Parrini S., Staglianò N., Bozzi R. 2021. Evolution of production and forage quality in sown meadows of a mountain area inside Parmesan cheese consortium. Agronomy Research, 19(2), 344–356.

doi.org/10.15159/AR.21.061

2. Bondarchuk A.A., Molotskyi M.Ya., Kutsenko V.S. 2018. Siderate fertilizers for potatoes in Ukraine. Vinnytsia, Niland LTD, 270.
3. Butenko S., Melnyk A., Melnyk T., JIA P., Kolosok V. 2022. Influence of growth regulators with anti–stress activity on productivity parameters of *Sinapis alba* L. Journal of Ecological Engineering, 23(9), 128–135. https://doi.org/10.12911/22998993/151780
4. Caldiz D.O., de Lasa C., Bisio P.E. 2016. Management of grass and broadleaf weeds in processing potatoes (*Solanum tuberosum* L.) with Clomazone, in the Argentinian Pampas. American Journal of Plant Sciences, 7(16), 2339–2348. https://dx.doi.org/10.4236/ajps.2016.716205
5. Düll E., Flaig H. 2014. Bodenwasserhaushalt und konservierende Bodenbearbeitung. Forschungsbericht. KLIMOPASS, 59.
6. Flaig Holger, Düll Evelyn. 2015. Bodenfeuchte bei Pflugbearbeitung, Mulch- und Direktsaat. VDLUFA-Kongress. Göttingen, VDLUFA-Schriftenreihe, 71, 350–357.
7. Horodniy M.M., Lisoval A.P., Bykin A.V., Serdyuk A.G. Kalenskyi V.P. 2005. Agrochemical analysis. National Agrarian University. Kyiv, Aristeus, 476.
8. Hryhoriv Y., Butenko A., Solovei H., Filon V., Skydan M., Kravchenko N., Masyk I., Zakharchenko E., Tykhonova O., Polyvanyi A. 2024. Study of the Impact of Changes in the Acid-Base Buffering Capacity of Surface Sod–Podzolic Soils. Journal of Ecological Engineering, 25(6), 73–79. https://doi.org/10.12911/22998993/186928
9. Isselstein J., Kayser M. 2014. Functions of grasslands and their potential in delivering ecosystem services. EGF at 50: the future of European Grasslands. Proceedings of the 25 general meeting of the European grasslands federation. Aberystwyth, Wales, 19, 199–214.
10. Karbivska U., Kurgak V., Gamayunova V., Butenko A., Malynka L., Kovalenko I., Onychko V., Masyk I., Chyrva A., Zakharchenko E., Tkachenko O., Pshychenko O. 2020. Productivity and quality of diverse ripe pasture grass fodder depends on the method of soil cultivation. Acta Agrobotanica, 73(3), 1–11. https://doi: 10.5586/aa.7334
11. Karbivska U., Masyk I., Butenko A., Onychko V., Onychko T., Kriuchko L., Rozhko V., Karpenko O., Kozak M. 2022. Nutrient balance of sod–podzolic soil depending on the productivity of meadow agrophytocenosis and fertilization. Ecological Engineering & Environmental Technology, 23(2), 70–77. https://doi.org/10.12912/27197050/144957
12. Karbivska U., Butenko A., Kozak M., Filon V., Bahorka M., Yurchenko N., Pshychenko O., Kyrylchuk K., Kharchenko S., Kovalenko I. 2023. Dynamics of productivity of leguminous plant groups during long-term use on different nutritional backgrounds. Journal of Ecological Engineering, 24(6), 190–196. doi:10.12911/22998993/162778
13. Kolisnyk O., Yakovets L., Amons S., Butenko A., Onychko V., Tykhonova O., Hotvianska A., Kravchenko N., Vereshchahin I., Yatsenko V. 2024. Simulation of high–product soy crops based on the application of foliar fertilization in the conditions of the right bank of the forest steppe of Ukraine. Ecological Engineering & Environmental Technology, 25(7), 234–243. https://doi.org/10.12912/27197050/188638
14. Kovalenko V., Kovalenko N., Gamayunova V., Butenko A., Kabanets V., Salatenko I., Kandyba N., Vandyk M. 2024a. Ecological and technological evaluation of the nutrition of perennial legumes and their effectiveness for animals. Journal of Ecological Engineering, 25(4), 294–304. https://doi.org/10.12911/22998993/185219
15. Kovalenko V., Tonkha O., Fedorchuk M., Butenko A., Toryanik V., Davydenko G., Bordun R., Kharchenko S., Polyvanyi A. 2024b. The Influence of elements of technology and soil–dimatic factors on the agrobiological properties of *Onobrychis viciifolia*. Ecological Engineering & Environmental Technology, 25(5), 179–190. https://doi.org/10.12912/27197050/185709
16. Lü H., Kang J., Long R., Xu H., Chen X., Yang Q., Zhang T. 2019. Effects of seeding rate and row spacing on the hay yield and quality of alfalfa in saline-alkali land. Acta Prataculturae Sinica, 28(3), 164–174. https://doi.org/10.11686/cyxb2018153
17. Mishchenko Y., Kovalenko I., Butenko A., Danko Y., Trotsenko V., Masyk I., Stavytskyi A. 2022b. Microbiological activity of soil under the influence of post–harvest siderates. Journal of Ecological Engineering, 23(4), 122–127. https://doi.org/10.12911/22998993/146612
18. Mishchenko Y., Kovalenko I., Butenko A., Danko Y., Trotsenko V., Masyk I., Zakharchenko E., Hotvianska A., Kyrsanova G., Datsko O. 2022a. Postharvest siderates and soil hardness. Ecological Engineering & Environmental Technology, 23(3), 54–63. https://doi:10.12912/27197050/147148
19. Mischenko Y., Butenko A., Bahorka M., Masyk I., Yurchenko N., Skydan M.S., Onopriienko I., Hotvianska A., Tokman V., Ryzhenko A. 2024. Justification of organic agriculture parameters in potato growing with economic and marketing evaluation. AgroLife Scientific Journal, 13(1), 139–146. https://doi.org/10.17930/AGL2024115
20. Möller K., Sauter G., Mann T., Flaig H., Breuer J. 2022. Wissenschaftliche Bewertung der Methoden der Regenerativen Landwirtschaft. Conference: 132. VDLUFA-Kongress: Optionen für die zukünftige Landnutzung, 107–117.

21. Mooleki S.P., Gan Y., Lemke R.L., Zentner R.P., Hamel C. 2016. Effect of green manure crops, termination method, stubble crops, and fallow on soil water, available N, and exchangeable P. Canadian Journal of Plant Science, 96(5), 867–886. https://doi.org/10.1139/cjps-2015-0336
22. Murtić S., Zahirović Ć., Čivić H., Sijahović E., Jurković J., Avdić J., Šahinović E., Podrug A. 2021. Phytoaccumulation of heavy metals in native plants growing on soils in the Spreča river valley, Bosnia and Herzegovina. Plant Soil Environment, 67, 533–540.
23. Pivovar V.S. 2013. Methodical provisions and standards of productivity and fuel consumption for soil cultivation. Kyiv, 584.
24. Radchenko M., Trotsenko V., Butenko A., Hotvianska A., Gulenko O., Nozdrina N., Karpenko O., Rozhko V. 2024. Influence of seeding rate on the productivity and quality of soft spring wheat grain. Agriculture and Forestry, 70(1), 91–103 https://doi.org/10.17707/AgricultForest. 70.1.06
25. Seaman A. 2016. Production Guide for Organic Potato. New York State Department of Agriculture. Geneva, 98.
26. Sumbul A., Ansari R.A., Rizvi R., Mahmood I. 2020. Azotobacter: A potential bio-fertilizer for soil and plant health management. Saudi journal of biological sciences, 27(3), 3634–3640. doi.org/10.1016/j.sjbs.2020.08.004
27. Tonkha O., Butenko A., Bykova O., Kravchenko Y., Pikovska O., Kovalenko V., Evpak I., Masyk I., Zakharchenko E. 2021. Spatial heterogeneity of soil silicon in Ukrainian phaozems and chernozems. Journal of Ecological Engineering, 22(2), 111–119. doi.org/10.12911/22998993/130884
28. Tsyuk O., Tkachenko M., Butenko A., Mishchenko Y., Kondratiuk I., Litvinov D., Tsiuk Y., Sleptsov Y. 2022. Changes in the nitrogen compound transformation processes of typical chernozem depending on the tillage systems and fertilizers. Agraarteadus*,* 33(1), 192–198. doi.org/10.15159/jas.22.23
29. Woźniak A. 2019. Chemical Properties and enzyme activity of soil as affected by tillage system and previous crop. Agriculture, 9(12), 262. https://doi.org/10.3390/agriculture9120262
30. Yakupoglu T., Gundogan R., Dindaroglu T., Kusvuran K., Gokmen V., Rodrigo–Comino J. Gyasi–Agyei Y., Cerdà A. 2021. Tillage impacts on initial soil erosion in wheat and sainfoin fields under simulated extreme rainfall treatments. Sustainability, 13, 789. https://dx.doi.org/10.3390/ su13020789