АГРОНОМІЯ

UDC 631.582-027.236

Main criteria for evaluation of efficiency and contradictions in the process of crop rotation implementation

Prymak I., Karpuk L., Yermolaiev M., Pavlichenko A., Filipova L.

Bila Tserkva National Agrarian University

m.yerm_2@ukr.net

OPEN ACCESS

Prymak I., Karpuk L., Yermolaiev M., Pavlichenko A., Filipova L. Main criteria for evaluation of efficiency and contradictions in the process of crop rotation implementation. Zbirnyk naukovyh prac' «Agrobiologija», 2021. no. 1, pp. 7–14.

Рукопис отримано: 23.11.2020 р.
Прийнято: 07.12.2020 р.
Затверджено до друку: 25.05.2021 р.

doi: 10.33245/2310-9270-2021-163-1-7-14

The nature of subjective positioning on the role of crop rotations in agriculture from many points of view, namely – agrochemical, biological, geological and energetic. This leads to the belief that crop rotation arose as a need for reasonable human interaction with nature, a careful attitude to it. However, a comprehensive ecological and biosphere approach to understanding the essence of crop rotation requires the resolution of certain contradictions that arise in the implementation of modern farming systems.

Based on the data of long-term field experiments, the main indicators of the biological cycle of humus carbon in black soil are calculated. The calculation is based on the balance of humus as the difference between the final and initial content and reserves in the soil under different crop rotations.

We found that the joint application of organic and mineral fertilizers had a positive effect on the balance of humus and nitrogen in the soil and, ultimately, on crop yields and crop rotation productivity. Against this background, a positive balance of humus (+1.29 t/ha) and total nitrogen (+80 kg/ha) in the soil is observed. Strengthening the organic fertilizer system by using, in addition to manure, by-products of crops – cereal straw, peas, corn stalks contributed to the formation of a positive balance of humus and nitrogen in the soil: the annual accumulation of humus was 0.28 t/ha, nitrogen 14 kg/ha.

Due to the humification of crop residues of cereals, peas and perennial legumes during the 7-year study period in the soil of control crop rotation 1 formed humus 2.85 t/ha, in crop rotation 14 with grasses – 7.0, the rest of crop rotations – from 3.4 up to 4.0 t/ha.

In general, 5.5 % of the initial stock of humus or 8.9 t/ha was mineralized in the crop rotation without fertilizers during the specified period. If we add to this about 3 t/ha of humus, the decomposition of which in the process of mineralization was compensated by plant residues, then during this period decomposed about 12 t/ha of humus. This value of mineralization characterizes the parameters of the biological cycle of humus in the control crop rotation.

Key words: soil, fertilizers, crop rotations, crop yield, crop rotation productivity, plant residues, humification, humus, humus mineralization, humus balance.

Problem statement and analysis of recent research. The research network in field and model experiments and the practice of crop production has accumulated a significant array of initial data for the development of scientific principles for the crop rotations use in agriculture. In particular, in the main regions of grain production, the level of development of previously relevant 7–10-field crop rotations was 90 %. Fundamental transformations of the agricultural sector of the economy in the direction of market relations have led to the formation of agricultural enterprises with a small land area and narrow specialization, but, unfortunately, they also caused the destruction of the existing system of crop rotation.

Analysis of modern land management in agriculture shows that it is more consistent with market conditions than with scientifically and environmentally sound land use [1–3]. Analysis of operational and statistical reporting shows that most land users do not take any measures to preserve soils and increase their fertility.

In Ukraine, the history of crop rotations dates back to the 10-13th centuries, when the three-field system of agriculture was put into operation. In the 18th century it was proposed to switch to seven-field crop rotations. This system implied growing "better" spring crops (wheat, barley, flax) after fertilized fallow, followed by "worse" spring ones such as oats, and the fifth, sixth and seventh crops were to become the uncultivated fallows (cited in [4]). This was based on the need to improve the soil not only with the manure, but with natural vegetation as well. After that, propaganda was launched for the development of crop rotation with legumes and root crops.

At the current stage of agriculture development with the introduction of resource-saving and environmentally sound agricultural technologies, the role of crop rotation as an organizing and functional link of agricultural systems in solving basic provisions of the concept of its development is growing. It is extremely important that arable land productivity can increase by 25–30 % under full development of scientifically sound crop rotations under specific conditions and in combination with other technological measures.

Thus, crop rotation is an important factor in the management of all subsystems of the agricultural system. Their development, introduction and improvement are the main stages of implementation of adaptive landscape systems of agriculture, designed to make full use of natural and manmade resources of the industry. Their final effect depends on the structure of sown areas, the composition of crops and the order of their alternation.

Crop rotation plays an extremely important role here, because from the agrochemical point of view it as a factor of cultivation that largely determines the vector of use and reproduction of soil fertility, primarily the formation of a favorable balance of nutrients and humus. Crop rotation also carries out the cycle of nutrients, affects soil absorption, nutrients and their redistribution in the soil profile, and most importantly – contributes to their uniform use by different crops.

From the biological point of view, crop rotation contributes to the balance in the environment, has a positive effect on the phytosanitary condition, biological activity of the soil. It stabilizes the synthesis of humic substances and their destruction. According to the data (F.I. Pchelnikov, 1989), crop rotation with 50 % saturation of perennial grasses with additional application of 4 tons of organic fertilizers per 1 ha of crop rotation area provides expanded reproduction of the humus fund with a humification coefficient of more than 1.0. Continuous cultivation of cereals reduces the content of organic matter in the soil by 20 %, and row crops, including potatoes – even more.

From the geological point of view, crop rotation carries out biological weathering, actively influences the combination of biological and geological cycles of substances in nature, the formation of landscapes and the state of the environment. From energy one – it is a biological accumulator of solar energy, it carries out the processes of energy and mass transfer in the soil-plant-atmosphere system.

Unfortunately, nowadays the idea of crop rotation is in many cases reduced to a simplified technocratic understanding of its essence. At the present stage of development, a science of agriculture requires a comprehensive ecological and biosphere approach to understanding the essence of crop rotation, including the resolution of contradictions that arise in the implementation of modern farming systems considered in their agronomic, economic and environmental classifications [5].

The first contradiction is that the change of crops and mechanical tillage, which is carried out in the vast majority of cases annually, cause a violation of the established mechanisms of biogeocenosis and soil formation. Due to the use of heavy agricultural machinery and numerous technological operations, the soil structure is destroyed, sprayed, followed by compaction and deterioration of the water-air regime, the development of erosion and other negative processes. The contradiction can be solved due to reasonable reduction in the share of arable land and the periodic transformation of some lands into others.

The second contradiction of the agricultural system is that the results of in-farm land management, especially on light granulometric composition, in particular, sod-podzolic soils often fails to achieve the desired soil homogeneity not only on a large crop rotation, but also on one crop rotation field. As a result, we have a variety of yields in different fields of crop rotation against the background of inefficient use of fertilizers and ameliorants.

The elimination of this contradiction, as in the first case, helps the crop rotation factor, or rather – the differentiated use of different quality lands in the field crop rotations, other types and types of crop rotations and output fields. Some, especially economically profitable crops that require a high agricultural background, can be placed either in specially designated areas of enhanced environmental control, or in the most favorable links of crop rotations. The third contradiction in modern economic conditions arises due to the lack of proper interaction between the main branches of agricultural production – agriculture and animal husbandry [6]. The latter is essentially out of sight of land management. This has led to the widespread introduction of specialized crop rotations, saturated with one or two crops or groups of crops, among which there is no place for fodder due to lack of production and economic needs.

This contradiction is the main one and its solution can be achieved, on the one hand, by deconcentration of agricultural production, improvement of the structure of sown areas in crop rotations, their saturation with green manures, perennial grasses and intermediate crops.

With the development of farming and homestead land use, the importance of intermediate (especially green) crops increases even more, given the acute shortage of manure, peat and compost. Legumes have a special priority for these purposes. However, the most important thing in this case is the restoration of the full range of the livestock industry, its integration, primarily with crop production, which is the basis of agriculture in general.

Undoubtedly, the process of intensification of agriculture is primarily associated with increasing soil fertility. In world practice, landowners who increase soil fertility receive a triple economic effect: from income from land rent 2, associated with increased yields from improving the quality of land (and land rent 2 is not taxed because the land tax rate remains unchanged); from improving the conditions for granting loans for the use of land as collateral and from partial reimbursement by the state of the costs of reclamation in the framework of national agro-industrial projects. Accordingly, the owners who allow the deterioration of agricultural land, there are problems with bank lending and withdraw part of the profits in the form of penalties for reducing the natural fertility of soils.

The regrettable situation in Ukraine is that that companies that master the advanced, primarily landscape, farming systems, incur losses from the tax press in addition to extra technological costs.

The aim of the research. Currently, there is an urgent need to develop the optimal new forms of land use organization based on the introduction of highly specialized crop rotations with short rotation. But when they are introduced into production, there arise difficulties with growing crops that require a long break to return to the previous place of cultivation (sugar beets, flax, legumes, sunflowers, etc.) or crops similar in biological properties (winter rye and wheat, barley, oat). With a high saturation of such crops, and even more so – their long-term continuous cultivation, the phenomenon of allelopathic soil fatigue, deterioration of phytosanitary condition of crops, imbalance of water consumption of crops inevitably increases.

The use of fertilizers and pesticides can somewhat alleviate these negative effects, but the predecessor in crop rotation is crucial, in particular, we found a difference in the nature of the use of soil moisture by winter wheat plants depending on the predecessor. During its cultivation in the 4-field crop rotation after peas, moisture consumption per unit of dry matter of the crop was equal to 354 conventional units, and in the 3-field crop with increasing wheat saturation and changes in the predecessor (instead of peas – soybeans, not to mention the worst) yield of dry matter of the crop (according to our data – exactly 1.0 t/ha), but also a significant increase in water consumption to 390 um. from

The dependence of crop water consumption on the level of crop rotation saturation is most clearly manifested in crop rotations with a clearly "market" crop today – sunflower. Thus, in a 2-field crop rotation, where it occupies 50 % of the area and returns to the previous place of cultivation in one year compared to a 5-field crop rotation, where the return period is 4 years, not only reduces its yield (6.0 kg/ha), but also 17 % increase in moisture consumption for the formation of the unit yield of dry matter. This leads to a significant increase in the intensity of the water regime of the soil.

Similarly, the return of a much more adequate (compared to sunflower) in terms of impact on soil fertility soybeans to the previous place in crop rotation after 1 year causes a significant decrease in yield due to liquefaction of crops and fewer beans per plant. Even its cultivation after post-harvest crops did not eliminate the negative impact of such convergence of soybean fields in crop rotation. Returning two years later to the previous place of cultivation also reduced the grain yield of this crop compared to crop rotations, where it was grown after 4 years. Comparison of soybean and pea units showed that winter wheat after soybean provided 7 % higher yield of whole grain (weight of 1000 grains 40 g and more) than after pea, but the quality of winter wheat grain for growing after peas is higher than after soybeans.

Material and methods of research. Specifically, in a long-term experiment on chernozem typical Forest-steppe of the Left Bank, the efficiency of crop rotation and fertilizer systems in 4-field crop rotations at different saturation of cereals was determined: 1) 100 % (including 25 % – peas), 2) 75 % – grain, 25 % – perennial legumes and 3) 75 % – cereals and 25 % – sugar beets. For comparison, separate organic and mineral fertilizer systems and their combinations were used.

Research results and discussion. The main indicators of the biological cycle of humus carbon in the soil-plant system of different crop rotations are determined. Indicators of the degree of humification of the whole set of organic substances (manure, by-products and crop residues) that entered the soil during the observation period were used in the study. In parallel, the change in total nitrogen reserves in the soil (kg/ha) was determined.

Currently, it is indisputable and unanimous that the majority of scientists in the area believe that the humus content in the soil is an integral indicator of its fertility [7–9]. The permanent decrease in the humus content in the soils of Ukraine is unequivocally negative. Over the past two decades, according to the state institution "Institute of Soil Protection of Ukraine", it lost from 0.4 to 0.8 tons per hectare, which is equivalent to a loss of 453.4 billion hryvnias [10]. Over a long period of 133 years (1882–2015), the humus content in absolute terms decreased by 1.01 % of the original value or 24.2 %. In the Forest-Steppe zone, these figures were 1.3 and 28.8 % [11].

Apart from other diagnostic criteria, the actual content and absolute reserves of humus was determined and the soil studied under the research was identified as a typical shallow low-humus chernozem. Its arable layer contains 3.08–3.14 % or 95–99 t/ha of humus and 5.1 t/ha of total nitrogen, subsoil – respectively 2.72–2.89 % or 50–58 t/ha of humus and 3.2 t/ha of nitrogen.

Under the hydrothermal conditions characteristic of the subzone of unstable moisture, this amount of humus and nitrogen is quite adequate to ensure the proper intensity of biological and physicochemical processes in the soil, which determine the level of yield of crops grown.

However, the reduction of humus and nitrogen content in the soil inevitably leads to a decrease in crop productivity and crop rotation in general. This is evidenced by the rather low, compared to other variants of the experiment, crop yields and crop rotation productivity obtained on the variant without fertilizers. Here, the yield of winter wheat was 4.22 t/ha, corn – 5.1, barley – 2.74, peas – 1.95 t/ha. The productivity of 1 hectare of arable land was 3.51 tons of grain yields, 5.93 tons of feed units, and 0.51 tons of digestible protein.

Undoubtedly, root and post-harvest crop residues are an important source of organic matter in the soil. However, under a mineral system of crop fertilization and the absence of fertilizers, crop residues compensate for the loss of humus by only 24–40 %. In this regard, there is now a need to involve alternative forms of organic fertilizers, including by-products (non-commercial) of crop yields in the process of soil humus reproduction [12–16].

The entry of dry organic matter and nitrogen into the soil by plant residues in the system of crop rotations studied by us is shown in table. 1. So, during the above period in the soil in crop rotations with 100 % saturation with grain crops (including 25 % of peas and corn for grain) (var. 1–7) received from 18.2 to 26.4 t/ha of plant residues, in grain and beet (var. 6) – 23.8 t and in crop rotation with perennial legumes (var. 14) – 42.2 t/ha. In accordance with the plant residues received nitrogen for var. 1 without fertilizers – 229 kg/ha, in fertilized variants of crop rotations 2–7 – 296–352, in crop rotation with perennial grasses – 586 kg/ha.

Table 1 – **Intake of organic matter and nitrogen into the soil with plant residues in various crop rotations**

Crop rotation option							
1	4	5	2	3	6	7	14
Plant residues (root and postharvest), t / ha							
18,2	21,9	22,1	22,8	24,5	23,8	26,4	42,2
Nitrogen total, kg / ha							
229	296	294	301	324	322	352	586

If we take the coefficient of humification of crop residues for 15 %, peas – 20, perennial legumes – 25 %, then from the specified number during the specified period of research in the soil of control crop rotation 1 formed humus 2.85 t/ha, in crop rotation 14 grasses – 7.0, other crop rotations – from 3.4 to 4.0 t/ha.

However, it was found that the actual humic substances formed from plant residues cannot fully compensate for the loss of humus from the cultivation of annual crops without the use of organic and mineral fertilizers. According to previously obtained data in long-term field experiments using isotopic indication of plants and soil 15N [17], the annual mineralization of humus for growing without fertilizers of winter wheat is 0.71 t/ha, barley – 0.57, corn – 0.83–1, 1, sugar beets – 1.29–1.34, legumes – 0.8, perennial grasses – 0.09–0.2 t/ha.

These data also indicate unequal influence on the formation balance of humus and nitrogen in the soil of different species and doses of fertilizers in crop rotations. At the same time, in crop rotations with peas, which differ only in the level of fertilizer application (var. 2–5), manure application as fertilizer significantly improved the balance in the layer of 0–40 cm compared to the option without fertilizers, bringing it closer to deficit-free but completely humus deficient. has not been eliminated. Even more insufficient to eliminate the deficit of humus and nitrogen in the soil, which was created in the absence of fertilizers in the control crop rotation, was the use of mineral fertilizer system.

Strengthening the organic fertilizer system by using, in addition to manure, by-products of crops

– cereal straw, peas, corn stalks contributed to the formation of a positive balance of humus and nitrogen in the soil: the annual accumulation of humus was 0.28 t/ha, nitrogen 14 kg/ha.

Given that crop yields and crop rotation productivity for mineral fertilizers, despite the shortage of humus and nitrogen in the soil were high and not inferior even to options with organo-mineral fertilizer system, it can be argued that a significant proportion of nitrogen for crop formation was used from the soil. , the mineralization of organic matter which under the influence of nitrogen mineral fertilizers is known to increase slightly [18–20].

plant system. As can be seen from table. 2, the biological cycle of organic matter in general (in terms of humus) significantly exceeds balance indicators. If we add to this about 3 t/ha of humus, the decomposition of which in the process of mineralization was compensated by plant residues, then for the specified term decomposed about 12 t/ha of humus. This value of mineralization characterizes the parameters of the biological cycle of humus in the control of crop rotation.

In the rest of crop rotations under application of some organic fertilizers, as well as under their combination with mineral ones or in the presence of perennial legumes in the accumulation of humus content and reserves, its real biological cycle ranged from 3.3 tons, 3 t/ha in crop rotation using straw as fertilizer (var. 5). In crop rotation 2 under the mineral fertilizer system, taking into account the compensation of decomposition of 3.5 t/ha of humus due to plant residues, its real cycle was 7.37 t/ha.

Table 2 – **Humus cycle in the 0-40-cm layer of soil in the crop rotation system**

Variants	Fertilizers applied for 7 years					Stock of humus in the soil, t/ha		New formation of humus in the soil, t/ha, due to:			Balance of humus, t/ha	Biological cycle of humus, t/ha
	organic, t/ha		mineral kg/ha			day off	At the end of research	Manure	Straw	Vegetatable remains		
	manure	Straw	N	P	K							
1	-	-	-	-	-	147.3	138.4	-	-	2.85	-8.90	11.75
4	60	-	-	-	-	147.3	146.8	4.0	-	3.4	-0.47	7.87
5	60	36	-	-	-	147.3	149.2	4.0	5.8	3.4	+1.94	11.26
2	-	-	330	295	375	147.3	143.5	-	-	3.5	-3.84	7.37
3	60	-	330	295	375	147.3	148.6	4.0	-	3.8	+1.29	6.51
6	60	-	340	310	385	147.3	147.7	4.0	-	3.7	+0.45	7.25
7	60	-	330	295	375	147.3	148.1	4.0	-	4.0	+0.84	7.16
14	-	-	330	295	375	147.3	151.0	-	-	7.0	+3.69	3.31

We found that the combined application of organic and mineral fertilizers in the experiment had a positive effect on the balance of humus and nitrogen in the soil and, ultimately, on crop yields and crop rotation productivity. Against this background, a positive balance of humus (+1.29 t/ha) and total nitrogen (+80 kg/ha) in the soil is observed.

Undoubtedly, the most noticeable role in creating a positive balance humus and nitrogen in the soil play perennial legumes. Replacement of peas with perennial grasses in a 4-field crop rotation (var. 14) contributed to the formation of a positive balance of humus and nitrogen in the soil even with a purely mineral fertilizer system in this crop rotation in contrast to similar crop rotation with peas (var. 2). The annual increase in humus and nitrogen content in the soil in crop rotation with perennial grasses was the highest.

It is obvious that the difference between the initial and final reserves of humus in the soil makes it impossible to get a complete picture of the biological cycle of organic matter in the soil-

Conclusions. Thus, the protective effect of both organic and mineral fertilizers in preserving the humus fund of the studied typical chernozem is obvious, although it differed to some extend in quantity and quality: the effect of organic fertilizers is direct and significant, and the effect of mineral fertilizers in replenishing the soil with humic substances is less significant and it is not direct but rather indirect.

Thus, crop rotation is a dominant factor in the agricultural system. Crop productivity, technological and fodder value of cultivated products, soil fertility, energy conservation are adequate to it in all cases, which makes the basis for developing effective technologies for growing all crops.

LIST OF REFERENCES

1. Жученко А.А. Стратегия адаптивной интенсификации сельського хазяйства. Пущино, 1994. 148 с.

2. Odum E.P. Basic Ecology. Sauners Publ.Comp. Phyladelphija, 1983. P. 16–79.

3. Гринченко Т.О., Кошкалда І.В., Роман Б.В. Щодо визначення економічної оцінки земель сільськогосподарського призначення. Вісник аграрної науки. 2012. № 4. С. 67–71.

4. Иванов А.Л. Критерии оценки эффективности севооборотов во Владимирском ополье. Аграрная наука. 1996. № 5. С. 23–25.

5. Манько Ю.П., Танчик С.П., Примак І.Д. Зміст сучасних систем землеробства в Україні та пропозиції щодо їх класифікації. Вісник аграрної науки. 2015. № 12. С. 17–21.

6. Єщенко В.О. Місце науково обґрунтованих сівозмін у сучасному землеробстві. Вісник Уманського НУ садівництва. 2014. № 2. С. 3–6.

7. Сайко В.Ф. Проблема забезпечення ґрунтів органічною речовиною. Вісник аграрної науки. 2003. № 5. С. 5–8.

8. Скрильник Є.В., Кутова А.М., Гетманенко В.А. Зміни органічної речовини чорноземів під впливом тривалого сільськогосподарського використання. Посібник українського хлібороба. 2016. Т. 1. С. 121–123.

9. Баланс гумусу в короткоротаційній сівозміні Правобережного Лісостепу України залежно від систем удобрення чорнозему типового / Примак І.Д. та ін. Агробіологія. 2020. № 1. С. 151–159.

10. Яцук І., Панасенко В. Ґрунти потребують захисту. Віче: журнал Верховної Ради України. 2013. № 15. URL: http://veche.kiev.ua/journal/3785/

11. Балюк С.А., Даниленко А.С., Фурдичко О.І. Звернення до керівництва держави щодо подолання кризової ситуації у сфері охорони земель. Вісник аграрної науки. 2017. № 11. С. 5–8.

12. Молдован В.Г., Квасніцька Л.С. Залежність показників родючості чорнозему опідзоленого від сівозмінного чинника та систем удобрення. Вісник аграрної науки. 2012. № 5. С. 16–18.

13. Іваніна В.В. Оптимізація зерно-бурякової сівозміни в умовах біологізації землеробства. Вісник аграрної науки. 2012. № 6. С. 10–14.

14. Панченко О.Б. Відтворення родючості чорнозему типового залежно від систем основного обробітку ґрунту і удобрення в зернопросапній сівозміні Правобережного Лісостепу України: автореф. дис. ... канд. с.-г. наук: 06.01.01. Київ, 2016. 22 с.

15. Кривенко А.І. Агробіологічні основи технологій вирощування озимих зернових культур у Південному Степу: монографія. Вінниця: Нілан ЛТД, 2018. С. 106–108.

16. Гангур В.В. Агробіологічні основи формування сівозмін різної ротації в Лівобережному Лісостепу України: автореф. дис. ... д-ра. с.-г. наук: 06.01.01. Чабани, 2019. 54 с.

17. Застосування мітки 15N в агрохімічних дослідженнях / Захарченко І.Г. та ін. Землеробство. Київ: Урожай, 1974. Вип. 36. С. 43–49.

18. Mazur G.A., Yermolayev N.N. Some features of humus accumulation mechanisms in a sod-podzolic loamy sandy soil as related to liming and fertilization. Soviet Soil Sci. 1985. № 4. P. 58–64.

19. Цвей Я.П. Родючість ґрунтів і продуктивність сівозмін: монографія. Київ: Компринт, 2014. С. 78–86, 331 с.

20. Трус О.М. Біологічна активність чорнозему опідзоленого після тривалого застосування добрив у польовій сівозміні. Агробіологія. 2018. Вип. 1. С. 106–114.

REFERENCES

1. Zhuchenko, A.A. (1994). Strategija adaptivnoj intensifikacii sel's'kogo hazjajstva [Strategy of adaptive intensification of agriculture]. Pushchino, 148 p.

2. Odum, E.P. (1983). Basic Ecology. Sauners Publ. Comp. Phyladelphija, pp. 16–79.

3. Grinchenko, T.O., Koshkalda, I.V., Roman, B.V. (2012). Shhodo vyznachennja ekonomichnoi' ocinky zemel' sil's'kogospodars'kogo pryznachennja [Regarding the definition of economic valuation of agricultural land]. Visnyk agrarnoi' nauky [Bulletin of Agricultural Science], no. 4, pp. 67–71.

4. Ivanov, A.L. (1996). Kriterii ocenki jeffektivnosti sevooborotov vo Vladimirskom opol'e [Criteria for assessing the efficiency of crop rotations in the Vladimir region]. Agrarnaja nauka [Agricultural science], no. 5, pp. 23–25.

5. Manko, Yu.P., Tanchik, S.P., Primak, I.D. (2015). Zmist suchasnyh system zemlerobstva v Ukrai'ni ta propozycii' shhodo i'h klasyfikacii' [Content of modern systems agriculture in Ukraine and proposals for their classification]. Visnyk agrarnoi' nauky [Bulletin of Agricultural Science], no. 12, pp. 17–21.

6. Yeshchenko, V.O. (2014). Misce naukovo obg'runtovanyh sivozmin u suchasnomu zemlerobstvi [The place of scientifically substantiated crop rotations in modern agriculture]. Visnyk Umans'kogo NU sadivnyctva [Bulletin of Uman National University of Horticulture], no. 2, pp. 3–6.

7. Saiko, V.F. (2003). Problema zabezpechennja g'runtiv organichnoju rechovynoju [The problem of providing soils with organic matter]. Visnyk agrarnoi' nauky [Bulletin of Agricultural Science], no. 5, pp. 5–8.

8. Skrylnyk, E.V., Kutova, A.M., Getmanenko, V.A. (2016). Zminy organichnoi' rechovyny chornozemiv pid vplyvom tryvalogo sil's'kogospodars'kogo vykorystannja [Changes in the organic matter of chernozems under the influence of long-term agricultural use]. Posibnyk ukrai'ns'kogo hliboroba [Guide for Ukrainian farmers]. Vol. 1, pp. 121–123.

9. Prymak, I.D., Panchenko, O.B., Voytovyk M.V., Obrazhiy, S.V., Panchenko, I.A. (2020). Balans gumusu v korotkorotacijnij sivozmini Pravoberezhnogo Lisostepu Ukrai'ny zalezhno vid system udobrennja chornozemu typovogo [Humus balance in short-rotation crop rotation of the Right-Bank Forest-Steppe of Ukraine depending on typical chernozem fertilization systems]. Agrobiologija [Agrobiology], no. 1, pp. 151–159.

10. Yatsuk, I., Panasenko, V. (2013). G'runty potrebujut' zahystu [Soils need protection]. Viche: zhurnal Verhovnoi' Rady Ukrai'ny [Viche: journal of the Verkhovna Rada of Ukraine], no. 15. Available at: http://veche.kiev.ua/journal/3785/

11. Balyuk, S.A., Danylenko, A.S., Furdichko, O.I. (2017). Zvernennja do kerivnyctva derzhavy shhodo po-

dolannja kryzovoi' sytuacii' u sferi ohorony zemel' [Appeal to the state leadership to overcome the crisis situation in the field of land protection]. Visnyk agrarnoi' nauky [Bulletin of Agricultural Science], no. 11, pp. 5–8.

12. Moldovan, V.G., Kvasnitskaya, L.S. (2012). Zalezhnist' pokaznykiv rodjuchosti chornozemu opidzolenogo vid sivozminnogo chynnyka ta system udobrennja [Dependence of chernozem podzolic fertility indicators on crop rotation factor and fertilizer systems]. Visnyk agrarnoi' nauky [Bulletin of Agricultural Science], no. 5, pp. 16–18.

13. Ivanina, V.V. (2012). Optymizacija zerno-burjakovoi' sivozminy v umovah biologizacii' zemlerobstva [Optimization of grain and beet crop rotation in the conditions of biologization of agriculture]. Visnyk agrarnoi' nauky [Bulletin of Agricultural Science], no. 6, pp. 10–14.

14. Panchenko, O.B. (2016). Vidtvorennja rodjuchosti chornozemu typovogo zalezhno vid system osnovnogo obrobitku g'runtu i udobrennja v zernoprosapnij sivozmini Pravoberezhnogo Lisostepu Ukrai'ny: avtoref. dys. ... kand. s.-g. nauk: 06.01.01 [Reproduction of fertility of typical chernozem depending on the systems of basic tillage and fertilizer in grain crop rotation of the Right-Bank Forest-Steppe of Ukraine: author's ref. dis. for science degree of Cand. of Agricultural Science: 06.01.01]. Kyiv, 22 p.

15. Kryvenko, A.I. (2018). Agrobiologichni osnovy tehnologij vyroshhuvannja ozymyh zernovyh kul'tur u Pivdennomu Stepu: monografija [Agrobiological bases of technologies of cultivation of winter grain crops in the Southern Steppe]. Vinnytsia, Nilan LTD, pp. 106–108.

16. Gangur, V.V. (2019). Agrobiologichni osnovy formuvannja sivozmin riznoi' rotacii' v Livoberezhnomu Lisostepu Ukrai'ny: avtoref. dys. ... d-ra. s.-g. nauk: 06.01.01 [Agrobiological bases of formation of crop rotations of different rotation in the Left-Bank Forest-steppe of Ukraine: author's ref. dis. for science degree of Dr. of Agricultural Science: 06.01.01]. Chabani, 54 p.

17. Zakharchenko, I.G., Pirozhenko, G.S., Shilina, L.I., Medvid, G.K. (1974). Zastosuvannja mitky 15N v agrohimichnyh doslidzhennjah [Application of the 15N label in agrochemical studies]. Zemlerobstvo [Agriculture]. Kyiv, Harvest, Issue 36, pp. 43–49.

18. Mazur, G.A., Yermolaiev, M.M. (1985). Some features of humus accumulation mechanisms in a sod-podzolic loamy sandy soil as related to liming and fertilization. Soviet Soil Sci. no. 4, pp. 58–64.

19. Tsvey, Ya.P. (2014). Rodjuchist' g'runtiv i produktyvnist' sivozmin: monografija [Soil fertility and productivity of crop rotations]. Kyiv, Komprint, pp. 78–86, 331 p.

20. Trus, O.M. (2018). Biologichna aktyvnist' chornozemu opidzolenogo pislja tryvalogo zastosuvannja dobryv u pol'ovij sivozmini [Biological activity of podzolic chernozem after long-term application of fertilizers in field crop rotation]. Agrobiologija [Agrobiology]. Issue 1, pp. 106–114.

Основні критерії оцінювання ефективності і протиріч у процесі реалізації сівозмін

Примак І.Д., Карпук Л.М., Єрмолаєв М.М., Павліченко А.А., Філіпова Л.М.

Досліджено характер суб’єктивного позиціонування щодо значення сівозмін у землеробстві з багатьох поглядів, а саме – агрохімічного, біологічного, геологічного та енергетичного. Це зумовлює переконання, що сівозміна виникла як необхідність розумної взаємодії людини з природою, бережливого ставлення до неї. Однак комплексний еколого-біосферний підхід до пізнання суті сівозміни вимагає вирішення певних протиріч, які виникають за реалізації сучасних систем землеробства.

На основі даних багаторічних польових дослідів розраховано основні показники біологічного колообігу вуглецю гумусу в чорноземному грунті. В основу розрахунку покладено баланс гумусу як різницю між кінцевим і вихідним умістом і запасами в ґрунті під різними сівозмінами.

Встановлено, що сумісне внесення органічних і мінеральних добрив позитивно вплинуло на баланс гумусу і азоту в ґрунті та, у підсумку, на врожайність культур і продуктивність сівозмін. На цьому фоні удобрення відмічається позитивний баланс гумусу (+1,29 т/га) і загального азоту (+80 кг/га) у ґрунті. Посилення органічної системи удобрення через використання, окрім власне гною, побічної продукції культур – соломи зернових колосових, гороху, стебел кукурудзи, сприяло формуванню позитивного балансу гумусу і азоту в ґрунті: щорічне нагромадження гумусу становило 0,28 т/га, азоту – 14 кг/га.

Завдяки гуміфікації рослинних решток зернових культур, гороху і багаторічних бобових трав упродовж 7-річного терміну досліджень у ґрунті контрольної сівозміни 1 утворювалося гумусу 2,85 т/га, у сівозміні 14 з травами – 7,0, решті сівозмін – від 3,4 до 4,0 т/га.

Назагал у сівозміні без добрив упродовж означеного терміну мінералізувалося 5,5 % від вихідного запасу гумусу, або 8,9 т/га. Якщо додати до цього ще приблизно 3 т/га гумусу, розкладання якого в процесі мінералізації було компенсовано через рослинні рештки, то за вказаний період розклалося приблизно 12 т/га гумусу. Ця величина мінералізації характеризує параметри біологічного кругообігу гумусу в контрольній сівозміні.

Ключові слова: ґрунт, добрива, сівозміни, урожайність культур, продуктивність сівозмін, рослинні рештки, гуміфікація, гумус, мінералізація гумусу, баланс гумусу.

Основные критерии оценки эффективности и противоречий в процессе реализации севооборотов

Прымак И.Д., Карпук Л.М., Ермолаев Н.Н., Павличенко А.А., Филипова Л.М.

Исследован характер субъективного позиционирования относительно значения севооборотов в земледелии из многих точек зрения, а именно – агрохимической, биологической, геологической и энергетической. Это приводит к убеждению, что севооборот возник как необходимость разумного взаимодействия человека с природой, бережного отношения к ней. Однако комплексный эколого-биосферный подход к познанию сути севооборота требует решения определенных противоречий, возникающих при реализации современных систем земледелия.

На основе данных многолетних полевых опытов рассчитаны основные показатели биологического круговорота углерода гумуса в черноземной почве. В основу расчета положен баланс гумуса как разница между конечным и исходным содержанием и запасами в почве под разными севооборотами.

Установлено, что совместное внесение органических и минеральных удобрений положительно повлияло на баланс гумуса и азота в почве и, в итоге, на урожайность культур и продуктивность севооборотов. На этом фоне удобрения отмечается положительный баланс гумуса (+1,29 т/га) и общего азота (+80 кг/га) в почве. Усиление органической системы удобрения за счет использования, кроме собственно навоза, побочной продукции культур – соломы зерновых колосовых, гороха, стеблей кукурузы способствовало формированию положительного баланса гумуса и азота в почве: ежегодное накопление гумуса составило 0,28 т/га, азота – 14 кг/га.

За счет гумификации растительных остатков зерновых культур, гороха и многолетних бобовых трав в течение 7-летнего срока исследований в почве контрольного севооборота 1 образовывалось гумуса 2,85 т/га, в севообороте 14 с травами – 7,0, остальных севооборотов – от 3,4 до 4,0 т/га.

В общем в севообороте без удобрений в течение указанного срока минерализировалось 5,5 % от исходного запаса гумуса, или 8,9 т/га. Если добавить к этому еще около 3 т/га гумуса, разложение которого в процессе минерализации было компенсировано за счет растительных остатков, то за указанный период разложилось около 12 т/га гумуса. Эта величина минерализации характеризует параметры биологического круговорота гумуса в контрольном севообороте.

Ключевые слова: почва, удобрения, севооборот, урожайность культур, продуктивность севооборотов, растительные остатки, гумификация, гумус, минерализация гумуса, баланс гумуса.

Prymak I.D. https://orcid.org/0000-0002-0094-3469
Karpuk L.M. https://orcid.org/0000-0002-5860-5286
Pavlichenko A.A. https://orcid.org/0000-0002-4795-5643
Filipova L.M. https://orcid.org/0000-0002-7447-5418