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Influence of by-products under different methods of soil cultivation on the yield of winter rape in the Western Forest-Steppe

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Abstract. The absence of a clear position on the application of a particular method of basic tillage and the use of post-harvest residues in crop rotation draws attention to the minimisation of tillage. Therefore, the need to substantiate and develop efficient energy-saving tillage technologies and the use of by-products in crop rotation is quite important and remains relevant. The aim of the research is to study the impact of by-products and soil cultivation, which will create optimal conditions for the development of winter rape in the Western Forest-Steppe of Ukraine. The research was carried out during 3 rotations of 4 crop rotation in a stationary field experiment of the Institute of Agriculture of Western Polissya of the National Academy of Agrarian Sciences in 2009-2020. Against the background of soil cultivation, including ploughing, disc cultivation to a depth of 10-12 and 6-8 cm, two methods of using crop residues of crop rotation were studied - diversion and use as fertiliser with the addition of compensatory nitrogen in the amount of N_{10} per 1 tonne. The results showed that when growing winter rape with the removal of the predecessor straw from the field during ploughing to a depth of 20-22 cm and disc cultivation to a depth of 10-12 and 6-8 cm, the soil density at a depth of 0-10 cm was 1.22-1.28, 1.23-1.28 and 1.23-1.35 g/cm^3, respectively, and at a depth of 10-20 cm – 1.26-1.30, 1.30-1.35 and 1.32-1.36 g/cm^3. The use of straw as an organic fertiliser led to a decrease in the bulk mass of all the studied soil layers under any method of treatment, but at

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the same time contributed to an increase in the number of weeds, which increased with a decrease in the depth of treatment. On average, over the three years of crop rotation, the seed yields for ploughing by 20-22 cm, disking by 10-12 cm and disking by 6-8 cm against the background of straw alienation were 2.91, 2.83 and 2.59 t/ha, respectively, and for incorporating it into the soil – 3.04, 2.88 and 2.72 t/ha. As noted in the studies, tillage and fertilisation using non-commodity crop residues increase the soil protection effect, significantly reduce the negative impact of weeds in crops, improve soil fertility and increase the productivity of crops in the rotation

Keywords: crop rotation; soil density; ploughing; disking; weediness

INTRODUCTION

The transition of agricultural production to a market-based system is accompanied by significant changes in crop cultivation technologies due to the need to increase their competitiveness. One of the important reserves for reducing technological costs and improving the environmental condition of soils is the transition to no-till tillage methods (Kartashov *et al.*, 2019).

Mechanical tillage measures have a more intense impact on soil structure density than natural processes. Progressive soil compaction is a disadvantage of intensive tillage, which negatively affects its physical properties and reduces crop productivity (Orzech *et al.,* 2021). Therefore, in modern agricultural production, simplified tillage, reducing the number and intensity of operations to mitigate the negative impact on the soil while maximising crop yields in crop rotation, is becoming more common (Augustin *et al.*, 2020).

In addition, due to the impact of global warming since the 2010s, in particular in the Western Forest-Steppe zone, in the summer months and in September, there is an increasingly frequent lack of productive moisture reserves in the one-metre soil layer, which prompts the need to switch to moisture-saving and conservation tillage systems (Novokhatsky *et al.*, 2019). Conservation agriculture is a farming system that includes minimal mechanical disturbance of the soil, its permanent organic cover, and diversification of plant species in crop rotation (Kassam *et al.*, 2020). Currently, in Ukraine, most by-products remain on the field as organic fertiliser. Its positive effect is primarily due to the recycling of a significant part of the nutrients removed from the soil by crops to form the crop, as well as a positive impact on the humus state of the soil (Tkachuk, 2020). However, minimising tillage is not effective in all soil and climatic conditions and not for all crops, and can sometimes be inferior to ploughing in terms of its impact on yields. For example, J. Xu *et al.* (2019) point out that the introduction of rotational tillage is vital for grain production. The authors K. Orzech *et al.* (2021) also note that when growing winter rape, compaction and simplified tillage did not cause significant changes in bulk density, soil moisture, and yield.

Minimising tillage, including the use of no-till, can significantly increase weed infestation and, as a result, reduce crop yields. Therefore, the use of ploughing is primarily driven by the need to control weeds, for which sufficient moisture conditions are extremely favourable (Snizhok & Shevchenko, 2022). Therefore, it is important to track changes in soil physical properties, phytosanitary condition of agrocenosis under the influence of straw preservation under different tillage practices and their impact on crop productivity for a particular soil type and growing conditions. The aim of the article was to compare the effect of ploughing and different depths of disc cultivation and by-products on the volume mass of dark grey podzolic soil, weediness of crops and yield of winter rape in the Western Forest-Steppe.

LITERATURE REVIEW

Creating optimal agrophysical indicators of soil fertility for each crop in the crop rotation remains an important problem in agriculture as of 2023 (Yevtushenko *et al.*, 2018; Tsyuk *et al.*, 2021). Soil tillage is a key element of crop production technologies. It should provide favourable conditions for seed placement and germination and active growth of the root system, production of nutrient residues and phytomass, fertilisers and chemical ameliorants, accumulation and preservation of soil moisture, control of soil erosion, weeds, diseases, crop pests, etc. (Kolomiiets, 2000). In addition to many other functions, it should ensure optimal soil density, which directly or indirectly affects the conditions for seed placement and germination, root growth, aeration and soil moisture accumulation, microbiological activity, and other indicators (Biberdzic *et al.*, 2020). Thus, soil tillage is carried out mainly to optimise soil productivity by changing its chemical, physical and biological properties (Gawęda & Haliniarz, 2022). The most popular method of pre-sowing tillage is still the traditional system, which includes ploughing. However, the authors highlight its disadvantages, such as the destruction of the topsoil structure, a decrease in microbial biodiversity, and increased production costs (Li *et al.*, 2019; Yadav *et al.*, 2020; Afshar & Dekamin, 2022).

Therefore, traditional ploughing is being replaced by other cultivation methods, such as disking and no-till. In the current climate change context, with the shortage of traditional organic fertilisers and the regime of saving material resources, so-called resource-saving technologies are gaining momentum (Pooniya *et al.*, 2021). Conservation tillage practices, such as no-till (NT) or reduced tillage, are widely used to mitigate the negative impacts caused by intensive tillage methods. One of the key principles of these technologies is the presence of permanent organic mulch on the field (crop residues, cover crops) aimed at optimising soil health (Jat *et al.*, 2023). The results of a study in conservation agriculture showed that plant residues stored on the soil surface have a greater impact on soil aggregation and organic matter retention (Mondal *et al.*, 2021).

The choice of tillage system is determined by the goal of creating optimal conditions for high crop yields with favourable quality indicators. However, the impact of tillage systems on yields remains uncertain. The results of tillage are largely influenced by environmental conditions and the specific types of crops grown (Gamayunova & Garo, 2017). In their works, most scientists and practitioners believe that the main reason for significant fluctuations in crop yields in 2023 is a decrease in potential soil fertility, deterioration of its structure due to excessive physical impact during annual ploughing (Poliovyi *et al.*, 2023). In crop rotations of different soil and climatic regions of Ukraine, it is necessary to carry out multi-depth cultivation, taking into account the agrophysical properties of the soil and biological characteristics of crops, using both shelf and non-shelf type tools (Kartashov *et al.*, 2019).

It is known that the decrease in crop yields occurs due to deviations in soil bulk mass, both in the direction of its decrease and increase, and it decreases sharply with compaction. The plough sole, which is formed as a result of constant ploughing to the same depth, negatively affects most soil processes (Havrylov, 2017). R. Zayats (2018) notes that soil density is significantly affected by the return of crop residues in the crop rotation and their distribution in the soil layers under different methods of tillage. In the Western Forest-Steppe, a limited number of studies have been conducted on the impact of minimising tillage and by-products of predecessors on the yield of winter rape.

MATERIALS AND METHODS

In the course of the research were used: field experiment to assess the impact of tillage and by-products on the yield of winter rape seeds and weediness of crops; laboratory methods to determine agrochemical (humus content, basic nutrients) and physical (bulk soil mass) indicators; accounting methods by counting the number and weighing the mass of weeds, seed yield from the experimental plot; comparative analysis to compare quantitative features of soil density, weediness of crops and yield of winter rape seeds obtained depending on the effect of the studied factors; statistical methods to assess the reliability of research results.

Field studies were conducted in a stationary experiment of the Institute of Agriculture of Western Polissya of the National Academy of Agrarian Sciences from 2009 to 2020 on dark grey podzolic soil. The arrangement of the variants in the experiment was sequential, replicated three times, and the area of the accounting plot was 50 m^2. The winter wheat was the predecessor of winter rape in the crop rotation, with a crop rotation of winter wheat – corn for grain – spring barley – winter rape.

The soil cultivation methods under study (factor A) included the following technological operations: ploughing at 20-22 cm, disking at 10-12 and 6-8 cm. The experimental design also included two options for the use of the predecessor's by-products (factor B): alienation and use for fertilisation with a compensatory dose of N_{10} per 1 tonne of straw. Mineral fertilisers, which served as a background for nutrition, were applied to winter rape at a dose of N_{150} P_{90} K_{150} in the form of ammonium nitrate, ammophos and potassium chloride.

For the agrochemical analysis of the soil, an average sample was prepared by mixing five diagonally collected samples and determined by the following methods: humus content by Tyurin, easily hydrolysable nitrogen compounds by Kornfield, and mobile phosphorus and potassium compounds by Kirsanov (Yeshchenko *et al.*, 2005). The soil was characterised by the following indicators: humus content of 1.93%, easily hydrolysable nitrogen content of 99 mg/kg of soil, mobile phosphorus content of 238 mg/kg and potassium content of 85 mg/kg of soil.

The winter rape protection system involved the use of pesticides with different mechanisms of action, namely a mixture of soil herbicides Clodex Pro (clomazone, 480 g/l) – 0.15 l/ha + Proxanil (propizochlor, 720 g/l) – 2.5 l/ha, against annual and perennial cereal weeds, herbicide Oreol Maxi KE (chisalofop-p-ethyl, 125 g/l) – 1.2 l/ha; insecticides Karate Zeon (lambda-cyhalothrin, 50 g/l) – 0.15 l/ha, Mospilan (acetamiprid 200 g/kg) – 0.12 kg/ha; fungicide Amistar Extra (ciproconazole, 80 g/ha + azoxystrobin, 200 g/ha) – 0.75 l/ha.

Before harvesting the winter rape, the soil compaction density was determined in triplicate diagonally by the method of 100 cm^3 cutting rings in the modification N. Kachynskyi (State Standard of Ukraine..., 2002) at a depth of 0-10, 10-20, 20-30 cm, the number of weeds and their weight were determined from an area of 1 m^2 by the method of S. Trybel *et al*. (2001). The yield of winter rape was determined by weighing the seeds from the plots and then recalculating them per 1 ha of area. The results of the research were analysed using multivariate analysis of variance (MANOVA) in Microsoft Excel software, followed by the F-test to determine the significance of differences at $p \leqslant 0.05$.

RESULTS AND DISCUSSION

The density of soil compaction largely determines its water, air and nutrient regime and its biological activity, so it is considered one of the most important indicators of the physical condition of the soil. The experimental data obtained during three rotations of crop rotation indicate a significant effect of different methods of tillage for winter rape and vegetative mass of predecessors as fertiliser on the formation of its bulk (Table 1). Against the background of alienation of by-products from the site, ploughing 20-22 cm, disking 10-12 and 6-8 cm, the density of soil compaction in the 0-10 cm layer was 1.22-1.28, 1.23-1.28 and 1.26-1.35 g/cm^3, respectively, and in the 10-20 cm layer – 1.26-1.30, 1.30-1.35 and 1.32-1.36 g/cm^3.

Table 1. *Soil compaction density under winter rape depending on tillage methods and use of by-products, g/cm^3*

Soil cultivation (factor A)	The use of the predecessor's by-products (factor B)	Soil layer, cm	Crop rotation I	Crop rotation II	Crop rotation III
Ploughing at 20-22 cm	alienation	0-10	1.22	1.28	1.23
		10-20	1.26	1.30	1.29
		20-30	**1.42**	**1.39**	**1.40**
	for fertiliser	0-10	1.20	1.24	1.20
		10-20	1.23	1.27	1.26
		20-30	**1.40**	**1.36**	**1.37**
Disking at 10-12 cm	alienation	0-10	1.23	1.28	1.28
		10-20	1.30	1.35	1.34
		20-30	**1.45**	**1.43**	**1.43**
	for fertiliser	0-10	1.19	1.25	1.24
		10-20	1.27	1.33	1.33
		20-30	**1.43**	**1.41**	**1.38**
Disking by 6-8 cm	alienation	0-10	1.26	1.32	1.35
		10-20	1.32	1.36	1.36
		20-30	**1.46**	**1.49**	**1.48**
	for fertiliser	0-10	1.22	1.30	1.25
		10-20	1.27	1.34	1.32
		20-30	**1.42**	**1.46**	**1.45**
HIP_{05} factor A		0-10	0.03	0.02	0.04
		10-20	0.02	0.03	0.03
		20-30	0.03	0.02	0.02
Factor B		0-10	0.01	0.01	0.02
		10-20	0.01	0.02	0.02
		20-30	0.02	0.02	0.02
Interactions AB		0-10	0.02	0.02	0.03
		10-20	0.02	0.03	0.03
		20-30	0.03	0.03	0.03

Source: *compiled by the authors*

That is, the lowest values of this indicator both in the 0-10 cm layer and in the 10-20 cm layer occurred during ploughing. Replacing it with disking was accompanied by an increase in the volume mass of not only the 10-20 cm layer of soil, which was not loosened, but also the 0-10 cm layer, which indicates worse loosening of the cultivated soil layer by disking compared to ploughing. The density of the 20-30 cm soil layer under all tillage options was significantly higher compared to the upper layers, which may indicate the tendency of the soil of the experimental plot to form a plough sole. During the three rotations of crop rotation, the lowest, in the range of 1.39-1.42 g/cm^3, was for ploughing. In the variants with disking at 10-12 and 6-8 cm, the value of the indicator increased to 1.43-1.45 and 1.46-1.49 g/cm^3, respectively.

The use of crop residues as organic fertiliser, regardless of tillage methods and soil depth, contributed to a decrease in the volume mass of all soil layers studied: 0-10, 10-20 and 20-30 cm. In particular, in the 20-30 cm layer, the soil density in the variants with by-products compared to its alienation from the field decreased by 0.02-0.03, disking by 10-12 cm – by 0.02-0.05, and disking by 6-8 cm – by 0.03-0.04 g/cm^3.

The study in a stationary field experiment of the influence of different variants of soil tillage and the use of straw of the predecessor for fertilisation on the weediness of winter rape crops showed that, despite the use of herbicides, it significantly depended on the factors under study. During the three rotations of crop rotation, the number of weeds in the variants with straw alienation for ploughing varied within 5.0-9.0 pcs./m^2, disking by 10-20 cm – 17.0-27.0 pcs./m^2, disking by 6-8 cm – 35.0-47.0 pcs./m^2, and for the use of straw for fertilisation, respectively, 9.0-17.0, 28.0-39.0 and 46.0-57.0 pcs./m^2 (Table 2).

Table 2. *Influence of tillage and methods of using straw of the predecessor on weed infestation of winter rape crops*

Soil cultivation (factor A)	The use of the predecessor's by-products (factor B)	Crop rotation I		II		III	
		pcs/m^2	gm/m^2	pcs/m^2	gm/m^2	pcs/m^2	gm/m^2
Ploughing at 20-22 cm	alienation	9.0	8.2	5.8	6.1	5.0	4.5
	for fertiliser	17.0	14.9	10.0	9.6	9.0	7.2
Disking at 10-12 cm	alienation	27.0	22.5	20.0	16.0	17.0	14.2
	for fertiliser	39.0	30.1	35.0	28.0	28.0	22.1
Disking at 6-8 cm	alienation	47.0	40.6	42.0	38.4	35.0	30.1
	for fertiliser	57.0	47.9	53.0	42.8	46.0	39.7
HIP_{05} factor A		2.17	0.81	1.72	0.89	1.89	0.70
Factor B		2.22	0.60	1.45	0.54	1.76	0.46
Interactions AB		3.50	0.83	2.86	0.86	3.29	0.81

Source: *compiled by the authors*

These data show that minimisation of tillage for winter rape was accompanied by an increase in weed infestation of its crops. After all, most of the weeds accumulate in the upper soil layer of 0-5 cm, while during ploughing they are in deeper layers: 5-10 and 10-20 cm. Also, a higher percentage of perennial weeds was observed with minimal tillage. The use of spring barley straw for fertilisation, which was the predecessor of winter rape, led to a significant increase in weed infestation of the latter compared to its removal from the field, especially in the variants with disking and reduced depth. Among the crops in the crop rotation, which included winter wheat, corn for grain, spring barley and winter rape, the latter had the least yield reduction from the transition to minimum tillage.

The obtained experimental data on the influence of the studied factors, namely the methods and depth of tillage, the use of by-products on the yield of winter rape seeds and its dynamics in crop rotation, indicate its rather high stability over time. Only when disking to a depth of 6-8 cm, without the use of by-products for fertilisation, a decrease in seed yield was observed from 2.81 t/ha in the first rotation to 2.46 t/ha in the third rotation of crop rotation. However, without alienation of by-products in this cultivation variant, the yield during crop rotation varied only within 2.68-2.77 t/ha. When ploughing by 20-22 cm and disking by 10-12 cm in the variants with alienation of by-products, the seed yield during the rotation of crop rotation varied within the range of 2.85-2.96 and 2.62-2.94 t/ha, respectively, and when incorporating by-product biomass into the soil – 2.98-3.11 and 2.85-3.1 t/ha. The yield of winter rape seeds averaged 2.91, 2.83 and 2.59 t/ha for three rotations of crop rotation for ploughing by 20-22 cm, disking by 10-12 cm and disking by 6-8 cm for alienation of the previous year's straw from the field and 3.04, 2.88 and 2.72 t/ha for its use as organic fertiliser, respectively (Table 3).

Table 3. *Yield of winter rape under different methods of tillage and use of by-products, t/ha*

Soil cultivation (factor A)	The use of the predecessor's by-products (factor B)	Crop rotation I	II	III	Average for three rotations
Ploughing at 20-22 cm	alienation	2.96	2.91	2.85	2.91
	for fertiliser	3.04	3.11	2.98	3.04
Disking at 10-12 cm	alienation	2.94	2.62	2.94	2.83
	for fertiliser	2.85	2.79	3.01	2.88
Disking at 6-8 cm	alienation	2.81	2.49	2.46	2.59
	for fertiliser	2.77	2.68	2.70	2.72

Table 3, Continued

Soil cultivation (factor A)	The use of the predecessor's by-products (factor B)	Crop rotation I	II	III	Average for three rotations
HIP_{05} factor A		0.17	0.15	0.19	0.17
Factor B		0.12	0.16	0.13	0.14
Interactions AB		0.26	0.28	0.24	0.26

Source: *compiled by the authors*

That is, the by-product vegetative mass of the predecessor provided an increase in the yield of winter rape seeds, depending on the methods of tillage, of only 2.0-5.0%.

Modern agricultural production provides for the possibility of replacing energy-intensive ploughing with simplified tillage, reducing the number and intensity of tillage operations (Orzech *et al.,* 2021). Although this impact, according to Z. Wang *et al.* (2020), has a protective effect on the conservation of the ecosystem's natural value, it needs to be studied in terms of agrocenosis productivity. Different methods of soil cultivation are an important factor in regulating its physical parameters. In the study by M. Jat *et al.* (2023), minimising tillage led to a degradation of the exchange density index. The volumetric density of the soil in the system of minimised tillage is particularly high with little or no plant residues. The results of the analysis of this study show a statistically significant decrease in density from ploughing by 20-22 cm to disking by 6-8 cm. At the same time, the highest values of 1.36-1.49 g/cm^3 were obtained at a depth of 20-30 cm, depending on the method of cultivation, which is 12.7-14.8% higher than in the soil layer 0-10 cm deep. A similar trend was found in studies with winter wheat by M. Biberdzis *et al.* (2020). Soil compaction in all tillage systems increased with increasing depth, reaching its highest value at 30-40 cm.

One of the ways to prevent soil degradation during cultivation is to apply straw. The reduction in bulk density in conservation tillage compared to conventional tillage is due to less soil disturbance and preservation of crop residue mulch, which improves organic matter content, aggregation, porosity, and fauna activity. S. Jayaraman *et al.* (2021) and J. Dhaliwal *et al.* (2020) also reported that the residual retention of wheat residue reduced bulk density by 1.8% compared to no residue in the 0-15 cm layer. In the experiment with winter rape, straw incorporation contributed to a decrease in soil density in all cultivation options at all depths. At the same time, the greatest changes from straw harvesting for fertilisation were obtained for disking at 6-8 cm. On average, the use of straw allowed to reduce the bulk density of the soil under this tillage method in the soil layer 0-10 cm by 0.05 g/cm^3, 10-20 cm by 0.04 g/cm^3 and 20-30 cm by 0.03 g/cm^3 compared to the options for its removal from the field, which is significant at the $p = 0.05$ significance level. The positive effect of straw on reducing soil density is explained by J. Chen *et al.* (2020) by the greater storage of organic carbon (SOC) in the soil, improvement of the proportion of macroaggregate state and its stability in the arable layer. In their experiments, the bulk density decreased by 1.22-8.74% compared to the straw removal option, which is similar to the current figures.

Tillage is one of the main weed control measures. However, due to the growing use of herbicides, expansion of their range and improvement of quality indicators, this tillage function has significantly narrowed. In particular, some authors note that there is no statistical difference in the intensity of weed infestation depending on the treatment, but point to significant changes in the species composition of weeds (Winkler *et al.*, 2023). While others have pointed out that minimising tillage increases weed infestation, leading to a greater reliance on herbicides compared to conventional tillage (Steponavičienė *et al.*, 2021). The latter statement was true in the current research. In particular, during three rotations of crop rotation, the number of weeds in the alienation of the predecessor's by-products with minimal tillage increased significantly compared to ploughing. At the same time, reducing the depth of disking to 6-8 cm on average increased the weed infestation by almost 2 times, and their biological mass increased by 1.8-2.4 times, depending on the period of research.

According to the results of research on weed infestation, the leaving of crop residues in the field also had a significant impact, regardless of the method of tillage. However, an analysis of studies by different authors shows a contradictory result regarding the impact of crop residues on the spread of weeds. According to S. Fonteyne *et al.* (2020), only the combination of three components of conservation agriculture – minimal soil disturbance, constant presence of organic residues and species diversity in crop rotation when using herbicides – reduced weed biomass by 81-91% compared to conventional tillage. In studies of winter rape cultivation, leaving straw in the field and incorporating it into the soil at different depths led to an additional significant increase in the number of weeds.

The highest number of weeds was found at the lowest depth of disking. N. Verhulst *et al*. (2011) noted that without retention of residues on the field surface, the soil degrades, showing worse fertility and infiltration. Conversely, treatments with crop residue retention increased the ability of maize plants to compete with weeds, leading to higher yields.

Agricultural practices, such as tillage and crop rotation, are the main factors that have a significant impact on soil quality, crop productivity and, ultimately, the sustainability of cropping systems. A decline in soil physical quality, characterised by excessive topsoil compaction, is considered to be the main reason for the decline in yields of uncultivated soil. Studies conducted on sandy soils by the Lithuanian Research Centre of Agriculture and Forestry showed that the most favourable physical properties of the soil, including density, shear strength and air permeability, were achieved by conventional (deep) ploughing (Steponavičienė *et al.*, 2020).

In studies with winter oilseed rape, neither alienation nor straw harvesting of the predecessor had a significant effect on seed yield within a particular cultivation method on average over three rotations of crop rotation. Variations within the rotations were largely due to climatic conditions. However, the comparison of different tillage methods indicates the advantage of ploughing compared to shallow disking by 6-8 cm. D. Gawęda & M. Haliniarz (2022), in a four-year study, also found that both seed and straw yields of winter rape were significantly higher under conventional tillage compared to no-till. Ploughing to a depth of 20-22 cm and disking to 10-12 cm with the harvesting of the predecessor's by-products resulted in significant increases in rape seed yields at a significance level of $p = 0.05$ compared to disking to 6-8 cm.

The obtained results of the research are generally consistent with the data of other authors on the impact of minimising tillage on soil bulk, crop weediness and crop yields. Despite a certain increase in soil density and weediness of winter rape crops, the minimisation of tillage resulted in almost the same seed yield for ploughing and disking by 10-12 cm, which indicates the possibility of introducing more energy-saving and soil-protective tillage systems in the Western Forest-Steppe, which is in line with global trends.

CONCLUSIONS

Studies have shown that the replacement of shelf tillage for winter rape by disking by 10-12 and 6-8 cm led to an increase in soil density in the layers 0-10, 10-20 and 20-30 cm, respectively, amounting to 1.28-1.32, 1.35-1.36 and 1.43-1.49 g/cm^3. It should be noted that the soil density in the 20-30 cm layer for all treatment options was significantly higher compared to the upper layers, which may indicate the soil's tendency to form a tilthy sole. The introduction of straw of the predecessor into the soil contributed to its reduction, but as soil tillage was minimised, its bulk mass increased. Weed infestation of winter rape crops after replacing ploughing with disking by 10-12 and 6-8 cm, regardless of the use of herbicides, increased from 5.0-9.0 to 17.0-27.0 units/m^2, and to 35.0-47.0 units/m^2 when removing the straw of the predecessor from the field, and from 9.0-17.0 to 28.0-39.0 and 43.0-57.0 units/m^2, respectively, when using it for fertilizer. On average, over three rotations of crop rotation, the yield of winter rape against the background of removal of by-products of the predecessor by replacing ploughing with disking by 10-12 and 6-8 cm decreased from 2.91 to 2.83 and 2.59 t/ha, respectively. When using by-products for fertilisation, the yield of winter rape within a particular cultivation method increased by 2.0-5.0%, which is insignificant at $p = 0.05$. Reliable yield increases were obtained on average for ploughing to a depth of 20-22 cm, as well as for disking to a depth of 10-12 cm when incorporating the straw of the predecessor into the soil.

The Western Forest-Steppe is traditionally a zone of sufficient moisture, but as a result of global climate change, there is an increasing shortage of productive soil moisture reserves, especially in the second half of the growing season. From time to time, this causes early maturation of late crops such as corn, sunflower and soybeans and problems with germination of winter crops and green manure. The amount of unearned crop residues and crop by-products that mulch the soil surface, weakening surface runoff, promoting snow retention and reducing moisture evaporation, is crucial for the accumulation and preservation of soil moisture reserves. In view of this, it is promising to study the impact of soil cultivation methods on its water regime by expanding the above experimental design to include options that maximise the retention of plant residues on the soil surface: direct seeding, chiselling, strip-till, etc.

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CONFLICT OF INTEREST

None.

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Вплив побічної продукції за різних способів обробітку ґрунту на врожайність ріпаку озимого в умовах Західного Лісостепу

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Анотація. Відсутність чіткої позиції щодо застосування того чи іншого способу основного обробітку ґрунту та використання післяжнивних решток в сівозміні, привертає увагу до мінімалізації обробітку ґрунту. Виходячи з цього, необхідність обґрунтування і розробки ефективних енергоощадливих технологій обробітку ґрунту та використання побічної продукції в сівозміні є досить важливими і не втрачають своєї актуальності. Мета досліджень – вивчення впливу використання побічної продукції і обробітку ґрунту, які створюватимуть оптимальні умови для розвитку ріпаку озимого у Західному Лісостепу України. Дослідження проводилися впродовж 3-х ротацій 4-х пільної сівозміни у стаціонарному польовому досліді Інституту сільського господарства Західного Полісся Національної академії аграрних наук в 2009-2020 рр. На тлі обробітку грунту, включаючи оранку, обробку дисками на глибину 10-12 см і 6-8 см, було проведено дослідження двох способів використання побічної продукції культур сівозміни - відведення та використання як добрива з додаванням компенсаційного азоту в кількості N10 на 1 т. Результати показали, що при вирощуванні озимого ріпаку із видаленням соломи попередника з поля під час оранки на глибину 20-22 см та обробки дисками на глибину 10-12 см та 6-8 см, щільність грунту на глибині 0-10 см становила відповідно 1,22-1,28; 1,23-1,28 і 1,23-1,35 г/см^3, а на глибині 10-20 см – 1,26-1,30; 1,30-1,35 і 1,32-1,36 г/см^3. Використання соломи як органічного добрива призвело до зменшення об'ємної маси всіх досліджуваних шарів грунту при будь-якому методі обробки, але при цьому сприяло збільшенню кількості бур'янів, яка зростала зі зменшенням глибини обробки. В середньому за три роки ротації сівозміни врожайність насіння за оранки на 20-22 см, дискування на 10-12 см і дискування на 6-8 см на фоні відчуження соломи склала відповідно 2,91; 2,83 і 2,59 т/га, а за заробки її в ґрунт – 3,04; 2,88 і 2,72 т/га. Як зазначено у дослідженнях, обробіток ґрунту і удобрення із використанням нетоварної продукції врожаю підвищують ґрунтозахисний ефект, суттєво послаблюють негативний вплив бур'янів у посівах, покращують родючість ґрунту та збільшують продуктивність культур сівозміни

Ключові слова: сівозміна; щільність ґрунту; оранка; дискування; забур'яненість