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INFLUENCE OF SUNFLOWER SATURATION ON PRODUCTIVITY OF SHORT-TERM CROP ROTATIONS

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Abstract

The place of sunflower in crop rotation is determined by its special requirements for the frequency of return to the previous place of cultivation. Without this requirement, there are insufficient guarantees to obtain a high yield of this crop. For efficient sunflower cultivation, crop rotations with a small set of crops and a short rotation period are recommended. Studies on the possibility of increasing the share of sunflower in crop rotations of short-term crop rotations and determining the impact on the productivity of the entire crop rotation were conducted in the Left Bank Forest-Steppe of Ukraine. It is established that increasing the saturation of sunflower in crop rotation leads to a decrease in its yield and productivity of the entire crop rotation.

Key words: *sunflower, short-term crop rotations, yield, productivity.*

INTRODUCTION

It is known that crop rotations are the basis system of farming (Boiko et al., 2014; Kaminskyi & Boiko, 2013). They are being developed in compliance with the norms of alternation in rotation, adaptability of crops to specific soil and climatic conditions and specialization of the economy (Boiko et al., 2007; Boiko, & Kovalenko, 2008). Rational crop rotations provide conditions for the systematic application of technologies in each field, increasing soil fertility and productivity of each crop and, accordingly, the productivity of crop rotation itself. The level of productivity of crops that are part of crop rotation is the result of all technological measures of their cultivation (Dorozhko et al., 2011). The higher the impact of predecessors, tillage systems, organic and mineral fertilizers, plant protection products and plant growth regulators, the higher the level of yield of each individual crop and crop rotation productivity in general (Boiko & Kovalenko, 2003; Brazhenko & Brazhenko, 2005). Thus, productivity can be considered one of the main indicators that characterizes the adaptation of crop rotations to specific soil and climatic conditions (Ryzhuk et al., 2002; Litvinov & Tovstenko, 2010). This is especially true at present, when most agricultural formations have a narrow production direction, which necessitates the widespread introduction of crop rotations with a short period.

Productivity of crop rotations depends on different saturation, ratio and location of crops. Modern market conditions of production in Ukraine require such a placement of crops that would meet the needs, lead to increased productivity of crops, contribute to the stabilization of soil fertility (Kovalenko, 2014; Litvinov, 2015; Yurkevych et al., 2011) and ecological balance of the environment (Shuvar, 1998). In modern agriculture of Ukraine new agricultural enterprises with different areas of land tenure, land use and areas of specialization have been created. In this regard, there is a need to develop and improve the optimal forms of organization of the territory and innovation of short-term crop rotations with the optimal combination of different levels of intensification (Boiko et al., 2012; Dehodiuk & Boiko, 2008; Lebid, 2006; Saiko, 2002; Kaminskyi, 2012; Cherenkov et al., 2012).

Sunflower is the main oil crop of Ukraine. In recent years, there has been increased demand (in the domestic market and abroad) for sunflower seeds and products of its processing. Growing sunflowers has become quite profitable due to rising prices for its products. This is an important incentive to increase the area under this strategic crop in the forest-steppe zone of Ukraine. The high potential productivity of modern sunflower hybrids is not fully realized in production conditions. This is due to insufficient supply of nutrients to the soil. In some regions of Ukraine, sunflower is an unalterable crop for most producers. They return this culture every 2-3 years. In the northern part of the Steppe and Forest-Steppe zone, farmers manage to return sunflower to its previous place in 4-5 years (Beliakov et al., 2008; Boiko & Borodan, 2000; Boiko et al., 2005).

There is no unequivocal opinion among scientists and producers about the maximum saturation of crop rotations with sunflower. The vast majority of scientists who touch on this problem believe that sunflowers should return to their previous location no more than 8-10 years later (Dolgova, 1986; Inshin, 1985). At the same time, some scientists argue that this interval may be shorter (Lebid & Boiko, 2000; Pastushenko, 1972). Of great importance is the correct location in the crop rotation of sunflower. When developing crop rotations with this crop, the minimum allowable return period should be considered. However, in the literature, the authors estimate this interval differently, it ranges from 5 to 10 years (Boiko et al., 2005).

MATERIALS AND METHODS

Field research to determine the effect of saturation of short-term crop rotations with sunflower was conducted on the basis of the chair of agriculture named after O. M. Mozheiko of the research field of KhNAU named after V. V. Dokuchaev. This place is located in the eastern part of the Kharkiv district of the Kharkiv region of the territory of Ukraine. The soil cover of the experimental field is represented by typical chernozem heavy loam on loess-like loam. This soil is characterized by good physico-mechanical, agrochemical and physico-chemical properties, fairly high reserves of nutrients available to plants, high humus content and intensive biological activity (Tykhonenko & Dehtiarov, 2016).

Scheme of experiment and alternation of crops in five-field crop rotations of the Left-Bank Forest-Steppe of Ukraine:

- proportion of sunflower sown area in crop rotation 20%: 1. Pea. 2. Winter wheat. 3. Corn. 4. Winter rye. 5. Sunflower;
- proportion of sunflower sown area in crop rotation 40%: 1. Pea. 2. Winter wheat. 3. Sunflower. 4. Winter rye. 5. Sunflower;
- proportion of sunflower sown area in crop rotation 60%: 1. Sunflower. 2. Winter wheat. 3. Sunflower. 4. Winter rye. 5. Sunflower.

Sunflower hybrid - Cruiser LG59580.

In the conditions of Richland Invest Limited Liability Company (LLC) of Balakliia district of Kharkiv region the productivity of four-field crop rotation with grain crops saturation by 75%, sunflower by 25% was studied: winter wheat - corn - spring barley - sunflower, which is based on three tillage systems: traditional, minni-till, strip-till. In this territory of Ukraine, the soil cover is represented by ordinary chernozem. Repetition in the experiment is four times, the placement of plots is consistent. The sown area is 1800 m^2, the total area of the experiment is 12.8 ha.

Agrometeorological conditions for growing field crops, including wintering conditions, have changed along with climatic changes. Despite a certain increase in precipitation, the snow cover became unstable. Significant temperature fluctuations - from abnormally high to abnormally low - cause abiotic stress of plants. Sometimes the mild, warm nature of winter contributes to the intensification of pests and diseases of crops (Tsykov, 1984; Shapoval et al., 2008). Therefore, it is now important to assess the impact of sunflower depending on its location in short-term crop rotations on productivity and gross harvest of crops.

According to the KhNAU meteorological post, the average annual rainfall is 529 mm, the average annual air temperature is +7.2°C. Analyzing the weather conditions for 2020-2021, we can conclude that the indicators of heat and moisture significantly affected the length of the sunflower growing season, its growth and development, and ultimately the yield of sunflower and seed quality. In 2020-2021, the amount of precipitation during the sunflower growing season was 208.2 mm, which is 70.8 mm lower than the long-term data.

Richland Invest LLC is located in the territory of insufficient humidification of the Northern Steppe of Ukraine. During the study period, there was a significant deviation of the average daily temperature and rainfall from the average long-term values. The temperature regime confirms the trend of warming in the Northern Steppe of Ukraine. The largest deviations of air temperature from the average long-term indicators were observed in the spring and summer. There was an acute shortage of moisture throughout the growing season. In general, compared to long-term indicators, the decrease in precipitation at this time was 66.3 mm or about 24%. During the years of research, there were drought periods, which had a negative impact on the conditions of growing crops.

Comparative assessment of the productivity of short-term crop rotations in studies was calculated by the volume of production per 1 ha of crop rotation area, which was converted into feed and feed protein units and digestible protein (Grevtcov, 1991). By-products were not taken into account in determining these indicators.

To find out the possibility of scientifically substantiated expansion of sunflower crops and to determine the impact on the productivity of the crop itself and other crops in field crop rotations.

RESULTS AND DISCUSSIONS

There are many factors that determine the efficiency of agriculture, and crop rotation is one of the most important. With the increase in the diversity of cultivated crops, the efficiency of crop rotation increases. The leading factor in the high productivity of crops is their placement after the best predecessors in compliance with the norms of rotation. Highly productive are short-term rotation grain, grain-row, grain-fallow-row, row, fodder with a wide range of grain saturation - from 33.3-50.0-66.3% to 70-80-100%. In particular, cereals, row crops, legumes (pea, soy), as well as annual herbs (oats) and perennial legumes (sainfoin, clover, alfalfa). Realization of all the advantages of proper crop rotation increases crop yields, reduces the density of weeds, diseases, pests and reduces the cost of their control, ensures environmental balance, soil protection. Trends in the biologization of agriculture are intensifying in the world, starting with the improvement of crop rotations, which include grasses, legumes (pea, soy), intermediate and green crops, use non-commodity (by-products) of crops and increased doses of organic fertilizers. There is a direct relationship between the length of rotation of crop rotations and productivity of crops: with decreasing length of rotation, their productivity decreases.

According to the obtained results, the most promising option is crop rotation with a share of 20% vapors, grain crops - 50 (including food group from 20 to 40%) and industrial crops - 30% (including 10% of sunflower). There is an opinion that in the structure of field crop rotation it is necessary to reduce the share of sunflower to the level of scientifically sound standards. This is possible by replacing part of its sown area with corn and rapeseed (respectively 10 and 20%), which will expand the group of profitable industrial crops in short-rotation crop rotations to 30% (Shevchenko et al., 2015).

All types of field short-term crop rotations are rational. With the observance of the technology of growing field crops in such crop rotations the yield of pea is provided - 4.05-4.28 t/ha, winter wheat - 5.16-6.63, winter rye - 5.49–5.69, corn grain - 7.48-8.88, spring barley - 5.03-5.78, sunflower - 4.14-4.26, rape - 3.59, corn for green fodder - 43.82-44.82, hay of perennial grasses - 6.60 t/ha. Estimation of the total productivity of short-term crop rotations shows that the yield of grain crops in crop rotations is in the range of 4.61-6.15 t/ha, and the harvest from 1 ha of arable land was: grain - 3.00-6.00, fodder units - 6.73-11.18, digestible protein - 0.60-1.08 t/ha (Kokhan et al., 2015).

Kokhan et al. (2015) determined the highest yield of sunflower (2.82 t/ha) in the seven-field crop rotation, where its share was 14.3%. At saturation of crop rotation with sunflower to 20%, 25%, 33.3%, 50% its productivity gradually decreases. Particularly sharp decline occurred in the two-field crop rotation - by 0.54 t/ha and the three-field crop rotation - by 0.28 t/ha. In seven-field, five-field and four-field crop rotations with a share of sunflower, respectively 14.3%, 20% and 25%, the yield of sunflower fluctuated slightly - 2.82-2.67 t/ha. The increase in the sown area under sunflower in crop rotations does not affect the yield of other field crops, in particular corn, winter wheat, pea. Regardless of the degree of saturation of crop rotations with sunflower, the difference in yield does not exceed 0.29 t/ha, or 4.6%.To some extent, this also applies to winter wheat. Its yield in crop rotations with a share of sunflower from 14.3% to 33.3% at the level of 4.59-4.65 t/ha. Crop rotation differs little in terms of pea yield - 1.76-1.89 t/ha. Only in the five-field crop rotation, where the share of sunflower is 20% and the predecessor is spring barley, pea grains were harvested by 0.023 t/ha or 13% more. If you place crops in crop rotations after the best predecessors and adhere to their alternation, you can ensure high yields of winter wheat - 4.0-6.17 t/ha, spring wheat - 3.1-4.0 t/ha, spring barley - 3, 4-5.48 t/ha, oats - 3.26-4.8 t/ha, pea - 3.2-4.2 t/ha, corn for grain - 7.38-10.0 t/ha, sugar beet roots - 43.0-67.2 t/ha, sunflower seeds - 2.46-3.82 t/ha, green mass of annual and perennial grasses - 24.7-48.0 and 28.3-54.8 t/ha, green mass of winter green manure - 45.8-52.0 t/ha (Boiko et al., 2015).

To increase the overall productivity of crop rotations, tillage is also of great importance. Today's conditions require a rational self-healing system of agriculture with the involvement of non-traditional sources of mineral nutrition of plants and the use of moderate doses of fertilizers. This is possible in combination with the post-harvest residues of the predecessor for the expanded reproduction of fertility and restoration of natural soil formation of chernozems in agrocenoses. The distribution of crop residues on the field surface is regulated primarily by improving the methods of basic tillage, which are the foundation of any technology for growing field crops in different farming systems (Saiko & Maliienko, 2007).

In the conditions of Research Enterprise «Research Economy» (RE«RE») «Dnipro» of the Institute of Agriculture of the steppe zone (Dnipropetrovsk region) it was found that in the three-field crop rotations the highest productivity (grain yield, sunflower seeds, grain and feed units, digestible protein) depends primarily on recruitment and yields of field crops in crop rotations. This indicator is determined by the combined effect of environmental factors, as well as technological features and differences of different tillage systems. It was found that in grain-fallow-row crop rotation with sunflower field, productivity indicators do not depend on the cultivation system. However, there may be an increase in grain yield - by 0.06 t/ha and grain yield - by 0.02 t/ha of crop rotation area due to the shallow (subsoil tillage) system compared to the ploughing. Replacement of sunflower in crop rotation with spring barley leads to a decrease in crop rotation productivity in general by 2.9-5.9%, as well as to a decrease in the efficiency subsoil tillage system compared to the ploughing (Lebid & Tsyliuryk, 2014). It is proved that ploughing and differentiated tillage do not have a significant impact on crop rotation productivity. But with ploughing and disk plowing, compared with ploughing, it is significantly reduced (Prymak et al., 2018).

Analyzing the data obtained in the period 2020-2021, it is seen that the correct alternation of crops improves the conditions of growth and development of plants, which in turn affects the level of yield. Winter wheat was the most sensitive to the increase in the sown area of sunflower in crop rotation. Crop rotations, in which the share of sunflower was 20 and 40% provided the maximum level of winter wheat yield: 5.83 (Figure 1) and 5.54 t/ha (Figure 2), respectively.

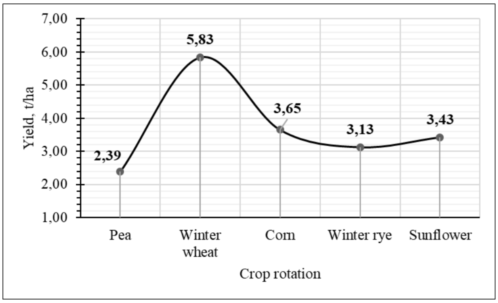

Figure 1. Yield of crops depending on the share of sunflower 20% in crop rotation

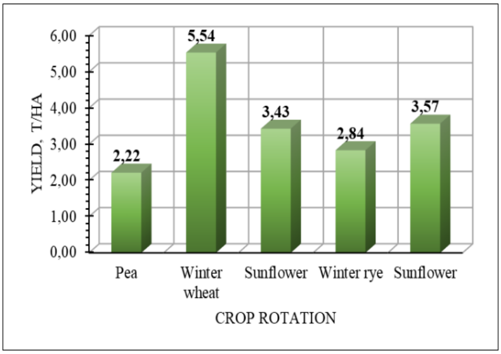

Figure 2. Yield of crops depending on the share of sunflower 40% in crop rotation

Winter wheat reacted negatively to increasing the saturation of crop rotation with sunflower up to 60%. In such crop rotation, the yield of this crop was reduced by 1.02-0.73 t/ha (Figure 3). The yield of winter rye also depended on the share of sunflower in crop rotation. The yield of this crop varied from 3.13 t/ha to 2.70 t/ha. In the crop rotation with a share of sunflower of 20% among the predecessors of winter rye, corn had an advantage, after which the yield was 3.13 t/ha. Placement after sunflower in crop rotations with shares of 40 and 60% led to a decrease in winter rye yield by 0.29 and 0.43 t/ha.

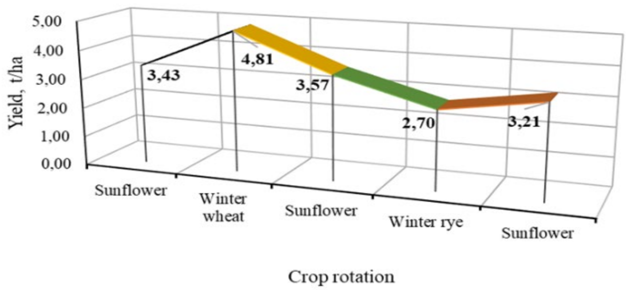

Figure 3. Yield of crops depending on the share of sunflower 60% in crop rotation

The highest yield of sunflower (3.57 t/ha) was obtained in the five-field crop rotation, where its share was 40%. At saturation of crop rotation with sunflower up to 20% there was a slight decrease in its yield by 0.14 t/ha. Saturation of crop rotation with sunflower up to 60% led to a significant reduction in its yield - 3.21 t/ha.

The highest yield of grain crops was obtained in the five-field crop rotation with grain saturation by 80% and sunflower by 20% - 3.75 t/ha. In this crop rotation, the food output per hectare of forage and fodder protein units was 3.37 and 4.56 t/ha, digestible protein - 0.52 t/ha (Table 1). In this variant, the dependence of the total productivity of crop rotation on the cultivation of corn in it, where it was: fooder - 0.73 and fodder protein units - 2.01 t/ha, digestible protein - 0.04 t/ha. When replacing corn with sunflower, the yield of grain crops was 3.53 t/ha, which is 0.22 t/ha less than the previous version.At the same time, to gather from 1 ha of crop rotation area increased by 0.21 t fooder and 0.67 t fooder protein units, digestible protein by 0.17 t.

When using the five-course crop rotation, where sunflower was grown for two years, the yield of fodder units was the highest (3.58 t/ha). The option with 60% sunflower saturation provided a lower yield of fooder units in crop rotation by 0.23 t/ha. In the short crop rotation with 40% grain crops saturation and 60% sunflower, the yield of the first was 3.76 t/ha, and the yield of fooder units was 3.35 t/ha, digestible protein - 0.75 and fooder protein units - 5.45 t/ha. The best precursor for winter wheat is peas. In the first variant of crop rotation after this predecessor, the total productivity of winter wheat was the highest and amounted to 7.00; 7.87 and 0.87 t/ha of fooder, fooder protein units and digestible protein, respectively. Saturation of crop rotation with sunflower by 40% reduced the productivity of winter wheat, which was placed after peas by 0.36 t/ha fooder units, digestible protein by 0.05 t/ha and 0.40 t/ha fooder protein units. Growing sunflower as the first crop in crop rotation ensured the productivity of winter wheat at the level of 5.77 t/ha of fodder units, 0.72 t/ha of digestible protein and 6.49 t/ha of fodder protein units.

Table 1. Total productivity of crop rotations with different saturation of sunflower

Crop rotations	Yield from 1 ha of crop rotation area		
	fooder units	fooder protein	digestible protein
1. Pea	2.80	0.47	3.73
2. Winter wheat	7.00	0.87	7.87
3. Corn	0.73	0.04	2.01
4. Winter rye	3.69	0.26	3.16
5. Sunflower	2.62	0.95	6.05
Average in crop rotation	**3.37**	**0.52**	**4.56**
In general, in crop rotation	**16.83**	**2.58**	**22.82**
1 Pea	2.59	0.43	3.46
2. Winter wheat	6.64	0.82	7.47
3. Sunflower	2.62	0.95	6.05
4. Winter rye	3.35	0.24	2.86
5. Sunflower	2.72	0.99	6.30
Average in crop rotation	**3.58**	**0.69**	**5.23**
In general, in crop rotation	**17.92**	**3.43**	**26.14**
1. Sunflower	2.62	0.95	6.05
2. Winter wheat	5.77	0.72	6.49
3. Sunflower	2.72	0.99	6.30
4. Winter rye	3.18	0.22	2.72
5. Sunflower	2.45	0.89	5.66
Average in crop rotation	**3.35**	**0.75**	**5.45**
In general, in crop rotation	**16.74**	**3.77**	**27.23**

Proper placement of pea in short crop rotations is of particular importance. It helps to improve the physical properties of the soil, reduce weediness. In 2020-2021, the yield of pea grain depended on the saturation of crop rotations with sunflower and ranged from 2.59 to 2.80 t/ha. In two variants of crop rotation, pea were grown after its worst predecessor - sunflower. The high level of productivity of this leguminous crop was manifested in the five-field crop rotation, where sunflower was grown one year. In this embodiment, the yield of fooder units of pea was 2.80 t/ha, digestible protein - 0.47 and 3.73 t/ha of fooder protein units. A slight decrease in the total productivity of pea (by 0.21, 0.04 and 0.27 t/ha) occurred during its cultivation in crop rotation with a share of sunflower 40%.

Over the years of research, the dependence of winter rye productivity on the saturation of short-term crop rotations with sunflower has been observed. Crops of winter rye in crop rotation with a share of sunflower 20% provided the largest collection of fooder, fooder protein units and digestible protein: 3.69, 0.26 and 3.16 t/ha. In the second variant, the yield of fooder units per 1 ha was 3.35 t, digestible protein - 0.24 t and fooder protein units - 2.86 t. The negative impact of increasing the saturation of crop rotation with sunflower to 60% on the total productivity of winter rye was revealed: 3.18 t fooder units, 0.22 t digestible protein and 2.72 t fooder protein units.

The overall productivity of sunflower depended largely on its yield. Placement of sunflower in the chain wheat - peas - winter wheat - sunflower - winter rye - sunflower contributed to the formation of the highest productivity: fooder units - 2.72, fooder protein - 6.30, digestible protein - 0.99 t/ha.

Not the last place in the formation of the productivity of short-term crop rotations is given to tillage systems. In the four-year crop rotation, the highest productivity indicators (yield of fooder units, digestible protein and fooder protein units) depended on sunflower saturation, yield of field crops and tillage systems (Table 2).

Table 2. Total crop rotation productivity depending on tillage

Crop rotation culture	Productivity by main tillage systems, t/ha								
	Plowing, 25-27 cm			TopDown, 25-27 cm			Strip-till, 27-30 cm		
	fooder units	digestible protein	fooder protein units	fooder units	digestible protein	fooder protein units	fooder units	digestible protein	fooder protein units
1	2	3	4	5	6	7	8	9	10
1. Winter wheat	7.19	0.89	8.09	7.45	0.93	8.38	6.94	0.86	7.80
2. Corn	0.66	0.03	1.83	0.75	0.04	20.6	0.73	0.04	2.01
3. Barley spring	6.41	0.54	6.24	6.64	0.56	6.47	6.50	0.55	6.33
4. Sunflower	1.69	0.62	3.92	1.66	0.60	3.85	1.75	0.63	4.04
Average in crop rotation	**3.99**	**0.52**	**5.02**	**4.13**	**0.53**	**5.19**	**3.98**	**0.52**	**5.04**

The productivity of Strip-till technology at 27-30 cm and plowing to a depth of 25-27 cm were equivalent: digestible protein yield - 0.52 t/ha, fooder units (3.99-3.98 t/ha), fooder protein units (5.02-5.04 t/ha). The Minni-till system had the advantage over all productivity indicators due to better loosening, thorough mixing of the soil and crop residues to a depth of 30 cm. The use of the combined assembly TopDown, 25-27 cm increased the productivity of crop rotation in terms of feed yield - 4.13 t/ha and forage protein units - 5.19 t/ha of crop rotation area. The tillage technologies under study ensured the yield of digestible protein in the range of 0.52-0.53 t/ha. Therefore, in short-term crop rotations (at least four fields) it is possible to place sunflower of modern varieties and hybrids under conditions of high level of agricultural technology.

CONCLUSIONS

It is proved that increasing the share of sunflower in short-term crop rotations leads to a decrease in the yield of the crop by 0.22-0.36 t/ha. The yield of sunflower seeds is at the same level with a saturation of 20% and 40% (3.43 and 3.57 t/ha). In the zone of unstable moisture of the Left-Bank Forest-Steppe the most productive were short-term crop rotations with sunflower saturation of 40 and 60%. The increase in the share of sunflower in crop rotations is negatively reflected in the yield of cereals. But this oil crop provides a high yield of fooder protein units (5.23-5.45 t/ha) and digestible protein (0.69-0.75 t/ha). In order to increase the productivity of short-term crop rotations, it is necessary to take into account the tillage system. The productivity of crop rotation with a share of sunflower of 25% was best influenced by the system of surface tillage using the TopDown assembly to a depth of 25-27 cm. In this crop rotation, the yield of feed and feed protein units was: 4.13 and 5.19 t/ha.

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