Scientific Papers. Series A. Agronomy, Vol. LXVI, No. 2, 2023
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

# INFLUENCE OF SATURATION OF SHORT-TERM CROP ROTATIONS WITH SUNFLOWER ON SOME AGROPHYSICAL PARAMETERS OF TYPICAL CHERNOZEM

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***Abstract***

*The article presents the results of the 2020-2021 research carried out in the experimental field of Kharkiv National Agrarian University named after V. V. Dokuchaev, located in the area of the Left Bank Forest-Steppe of Ukraine. The experiment was conducted on typical heavy loamy chernozem on loess-like loam. We aimed to find out the possibility of scientifically based expansion of sunflower crops and determine its productivity in field crop rotations. The effects of increasing the share of sunflower in short-term crop rotations on some agrophysical parameters in the topsoil (0-30 cm) were determined. The results show the influence of crop rotations with different sunflower saturation on the structure-aggregate composition, soil density, etc. Correlation analysis between these indicators and sunflower yield was also carried out. During the period of research, it was found that the increase in the share of sunflower in short-term crop rotations did not lead to a significant deterioration in the fertility of typical chernozem.*

***Key words**: sunflower, saturation, agrophysical parameters, typical chernozem.*

## INTRODUCTION

Sunflower is one of the most widely grown crops in Ukraine. This is due to the high profitability of its production, which in 2021-2022 amounted to 61%, while grain production was only 30-35%. Low labor costs for cultivation, an unlimited domestic market, and sales of products on the world market make sunflower profitable for cultivation (Debaeke, et al., 2017). All soils have their own agrophysical and agrochemical properties, which depend on the nature of the mineral and organic components, their relative amounts, and the ways in which minerals and organic matter interact (Kharytonov et al., 2019). Soil structure, density, water, air, heat and other conditions are important factors in soil formation. The intensity and direction of microbiological processes, mineralization of organic matter largely depend on the agrophysical properties of the soil. The problem of optimizing the agrophysical properties of typical chernozem can be successfully solved by creating favorable parameters of structural composition and density in the root layer of the soil (Shevchenko et al., 2012). Studies of short-term crop rotations show that they improve soil fertility. This is due to the formation of a clumpy-grained structure and an increase in soil cohesion, water content, and better nutrient retention (Igbal et al., 2005; Zhang et al., 2011; Zhernova et al., 2022).

High saturation of crop rotation with sunflower has become the main issue of the Ukrainian agricultural sector today. Such an imbalance in the structure of crops can lead, first of all, to the depletion of moisture reserves in the root layer of the soil. The solution to this problem can be the establishment of a scientifically based interval for returning the culture to the crop rotation (Kharytonov et al., 2019).

The density and structural and aggregate composition of the soil are quite dynamic indicators that largely depend on weather conditions and many other factors. Soil response to density is different, so establishing patterns of its change in crop rotations with a short rotation, set and order of crop rotation is an important task of our research. Soil density affects the root system of crops in turn on the whole plant's physiological maturation, growth and yield, and additionally affects the nutrient intake, independent of the culture (Czyž et al., 2001; Wolkowski and Lowery, 2008; Lipiec et al., 2012; Nyéki et al., 2017). The aim of the research was to find out the effect of saturation of short-term crop rotations with sunflower on the structural and aggregate composition and density of soil compaction. And also, to find out the regularity of yield formation from agrophysical indicators on the studied variants.

## MATERIALS AND METHODS

The study to determine the agrophysical parameters of typical chernozem was conducted on the basis of the chair of Farming named after O. M. Mozheiko of the experimental field of Kharkiv National Agrarian University named after V. V. Dokuchaev (KhNAU). The complexity of the climatic conditions of the Kharkiv region of Ukraine for agriculture is also revealed in not existing guaranteed annual sufficient moisture apart from it in certain years warm resources are much lower than are needed for crops. In addition, in some years, thermal resources are much less than the needs of crops. It is well known that precipitation affects soil compaction, which is a variable property.

The study by Nyéki et al. (2013) found that soil compaction as a factor of influence does not manifest itself in a direct way. However, they concluded that natural changes in soil compaction with changes in moisture (precipitation) for different soil types (first of all for different clay content %) can in some cases lead to significant differences in crop yields. According to the meteorological station of KhNAU, during the growing season of sunflower the average long-term precipitation was 278 mm, and the air temperature was +17.7°C. Precipitation in 2021 was 197.7 mm, which is 81.3 mm less than the long-term average, and the excess of the average daily air temperature by 2.5°C compared to the long-term average. Therefore, sunflower vegetation during this period took place in relatively unfavorable conditions. During the growing season of sunflower in 2022, precipitation was 97 mm above normal, and the average air temperature was 17.7°C, which is 1.7°C higher than the climatic norm.

The physical properties of the soil are affected by many factors that change vertically with depth, laterally across fields and temporally in response to climate and human activity (Debaeke et al., 2017). The soil cover of the experimental field is represented by typical chernozem heavy loam on loess-like loam. In terms of agrophysical and agrochemical properties, it is one of the most favorable soils for growing field crops. It is also characterized by high reserves of nutrients available to plants, high humus content and intense biological activity.

The arable layer of the soil (0-30 cm) contains humus (according to Tyurin) - 4.9-5.1%, easily hydrolyzable nitrogen (according to Kornfield) - 81 mg/kg of soil, mobile forms of phosphorus and potassium (according to Chirikov) - 100 and 200 mg/kg of soil. Content of exchangeable cations: calcium - 37.8%, magnesium - 6.6%, sodium - 0.49%, potassium - 0.5%, hydrogen - 21 mg-equiv./kg soil. The soil reaction - pH: aqueous - 7.0, salt - 5.2-5.6. Groundwater lies at a depth of about 18 m (Tykhonenko and Dehtiarov, 2016). Sunflower hybrid - Cruiser LG59580. The size of the sowing area is 750 $m^2$, the accounting area is 100 $m^2$. Variants of short-term (5-field) crop rotations with different proportions of sunflower in the structure of the sown areas were studied (Table 1).

Table 1. Crop rotation structure, %

| Pea | Winter wheat | Corn | Winter rye | Fallow | Sunflower |
|---|---|---|---|---|---|
| 20 | 20 | 20 | 20 | – | **20** |
| 20 | 20 | – | 20 | – | **40** |
| – | 20 | – | 20 | – | **60** |
| – | 20 | 40 | 20 | 20 | **0** |

The study was conducted by the following methods: the density of the composition of the intact soil by the method of the cutting cylinder according to N.A. Kaczynski (DSTU ISO 11272-2001); structural-aggregate composition and water resistance of structural aggregates by the method of fractionation on sieves according to M.I. Savvinov (DSTU 4744-2007).

## RESULTS AND DISCUSSIONS

The density of soil composition is an important indicator of its agrophysical properties. This indicator plays a significant role in the growth and development of crops and the formation of the harvest. The optimal soil density for most crops is in the range of 1.0-1.3 $g/cm^3$. The given intervals are not constants. They vary over time and, above all, depending on soil moisture. With high moisture, the optimum shifts to lower values, and with insufficient moisture - to higher values (Birkas et al., 2009). Numerous studies have established the optimal parameters of soil density for growing sunflower in the Forest-Steppe zone of Ukraine on typical black soil - 1.0-1.1 g/cm$^3$.

The root system of agricultural plants mainly develops in the upper 0-30 cm layer of soil, which accounts for 80-90% of its total mass. It is important to know the generalized density of this soil layer, as well as its dynamics during the growing season. Porosity, water permeability, productive moisture reserves, root system growth, and plant development in general depend on the density of the topsoil (0-30 cm) (Yevtushenko et al., 2018).

In our research, we noted the regularity of soil density distribution by variant. These indicators increased from the upper to the lower soil layers. It should be noted that the crop rotation without sunflower and the crop rotation with a 20% share had similar values. Figure 1 shows the average results for two years (2021-2022) of the soil density study depending on the saturation of short-term crop rotations with sunflower. It was found that an increase in the share of sunflower in the crop rotation contributes to the compaction of the arable (0-30 cm) soil layer. Nevertheless, this soil layer had optimal values of compaction density for all variants, which were in the range of 1.09-1.14 g/cm$^3$. It was highest in the variant where sunflower occupied 40 and 60% of the crop rotation area - 1.13 and 1.14 g/cm$^3$. In crop rotations without sunflower and with a share of 20%, the density of the tilth layer was 1.09 g/cm$^3$.

The highest soil layer density of 0-10 cm was in the crop rotation with a share of sunflower of 40% - 1.11 g/cm$^3$. Gradually, it decreased to 1.09 and 1.07 g/cm$^3$ in the variants with sunflower saturation of 60 and 20%. Crop rotation without sunflower contributed to a decrease in soil density in the upper (0-10 cm) soil layer by 0.3 g/cm$^3$. In the soil layer of 10-20 cm, the soil density had optimal values, which ranged from 1.08-1.16 g/cm$^3$ in short-term crop rotations. It was highest in the crop rotation, where sunflower occupied 60% of the crop rotation area. The lowest values of this indicator were observed in the control variant of crop rotation and with a share of sunflower of 20%: 1.09 and 1.08 g/cm$^3$. Increasing the saturation of the crop rotation with sunflower to 40% led to a slight compaction of the soil layer of 10-20 cm by 0.04 g/cm$^3$ compared to the control. The density of soil compaction in the lower (20-30 cm) soil layer increased significantly in all variants. This soil layer was the most compacted in the crop rotation, where the share of sunflower was 60% - 1.17 g/cm$^3$. In the specified soil layer, the density decreased in the variants with 40 and 20% saturation of sunflower by 0.03 and 0.05 g/cm$^3$. Crop rotation without sunflower provided the lowest density of this soil layer at 1.10 g/cm$^3$.

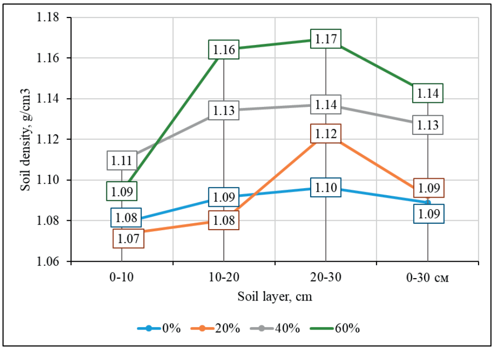


Figure 1. Density of soil composition, 2021–2022

Soil aggregation withstands soil fertility by reducing erosion and improving soil aeration, as well water retention. In addition, soil aggregation prevents soil organic matter from being mineralized by physically reducing the accessibility of organic compounds for microorganisms, and oxygen (Spohn and Giani, 2010).

The study of aggregates is one way to quantify whether management practices improve natural characteristics and agricultural capacity of soil. Soil aggregate and structure stability is the result of the interaction among many agents, such as the environment, management practices, crop, inherent soil features, and soil biological and non-biological processes (Bronick and Lal, 2005). The size of soil aggregate and stability are also used to characterize soil structure because those indicators are correlated with various soil functions (Rabot et al., 2018). Land use and associated management practices, such as crop sequencing, are the major and most direct ways of affecting soil structure and properties by their impact on destruction forces and aggregate-creating processes (Lehrsch et al., 2012).

Soil structure is defined as aggregates of various sizes and shapes that are glued together from soil particles and have the ability to break down. A structure with a lump size of 10-0.25 mm in diameter is considered particularly valuable. The higher its value, the longer the favorable conditions for the growth and development of crops are maintained, and the better the soil resists water and wind erosion. It is destroyed and restored under the influence of various factors: mechanical destruction, physical, chemical and biological processes. The soil structure is dynamic. Important measures aimed at maintaining the soil structure include a reasonable selection, ratio, and rotation of crops in crop rotation, etc. (Kudria et al., 2020).

The research results show that the number of soil structural aggregates depends on the share of sunflower in the structure of sown areas (Table 2). It was found that the structural composition of the tilth soil layer was almost the same across the experimental variants. The amount of agronomically valuable soil fractions with a size of 10-0.25 mm in the tilth layer of soil in the crop rotation with a share of sunflower of 20% was 64.2%. When the share of sunflower increased to 40 and 60%, the content of these aggregates decreased to 60.2 and 60.4%. The introduction of fallow in the crop rotation and the absence of sunflower resulted in an increase in the number of agronomically valuable aggregates to 66.0%.

Crop rotation with a 20% share of sunflower had a significant impact on the structural composition (78.5%) of the surface (0-10 cm) soil layer. Crop rotations without sunflower and with 40% saturation had a slightly worse impact. The number of soil aggregates in these variants was 9.9 and 16.9% less. The worst performance was in the crop rotation, where the share of sunflower was 60%. The average soil layer studied (10-20 cm) was characterized by almost the same aggregate content across variants and ranged from 61.8-63.3%. The only variant that stood out was the one with 60% sunflower saturation. The soil layer of 20-30 cm had an unequal number of aggregates of 10-0.25 mm in size. There was an increase in the number of lumps to 66.4% in the crop rotation without sunflower. The worst structural indicators were characterized by a plot under crop rotation with a share of sunflower of 20%. The quantity of structural particles in the bottom layer decreased by 15.5% compared to the previous variant. The structural parameters of typical chernozem under crop rotations with sunflower saturation of 40 and 60% did not differ significantly.

Table 2. Structural state of typical chernozem

| Share of sunflower in crop rotation | Structural and aggregate composition of the soil (10-0.25 mm), % | | | | Content of water-resistant soil aggregates (5.0-0.25 mm), % | | | |
|---|---|---|---|---|---|---|---|---|
| | 2021-2022 | | | | 2021-2022 | | | |
| | 0-10 | 10-20 | 20-30 | 0-30 | 0-10 | 10-20 | 20-30 | 0-30 |
| 0% | 68.6 | 63.0 | 66.4 | 66.0 | 49.1 | 66.9 | 66.9 | 61.0 |
| 20% | 78.5 | 63.3 | 50.9 | 64.2 | 62.2 | 84.0 | 86.7 | 77.6 |
| 40% | 61.6 | 61.8 | 57.1 | 60.2 | 66.9 | 78.7 | 76.1 | 73.9 |
| 60% | 47.4 | 72.2 | 61.8 | 60.4 | 68.7 | 74.1 | 73.3 | 72.0 |

Under the influence of short-term crop rotations, the content of agronomically valuable fractions of 0.25-5.0 mm in the arable 0-30 cm soil layer slightly changed. This figure was the highest in the second variant of the study (77.6%). There was a consistent increase in water-resistant aggregates with a depth of 62.2% (0-10 cm) to 86.7% (20-30 cm). This pattern did not occur for other variants. In the variant without sunflower, the content of aggregates in the soil layers 10-20 and 20-30 cm was at the same level. In the surface (0-10 cm) soil layer, there was a gradual increase in aggregates of 0.25-5.0 mm from 49.1

(control variant) to 68.7% (saturation of crop rotation with sunflower 60%). The content of water-resistant aggregates in the layers of 10-20 and 20-30 cm tended to decrease in accordance with the increase in the share of sunflower in crop rotations.

Typical untreated chernozem is characterized by the highest content of agronomically valuable water-resistant aggregates. Growing crops on this soil leads to dispersion of structural aggregates. Agrogenic chernozems contain four times less agronomically valuable (3-1 mm) water-resistant aggregates and twice as many aggregates < 0.25 mm in the 0-20 cm layer compared to virgin soil (Panasenko, 2015). Some studies on crop rotations show that the worst structure is characterized by a grain and fallow crop rotation. It has a structural coefficient of 3.4, which is 9.7 and 9.4% less than the grain crop rotation, respectively (K = 3.74 and 3.73). The deterioration of the soil structure in the grain and fallow crop rotation is due to the presence of a field of fallow and more intensive humus decomposition. The structure of crop rotations has a significant impact on improving the agrophysical properties of the soil. This leads to an increase in crop productivity, especially in dry years (Dehtiarov, 2013).

The results of Lebed et al. (1992) indicate the formation of better indicators of the structural state of the soil after growing crops of continuous sowing method, compared to row crops. They found that in crop rotations with a high proportion of row crops, soil structure deteriorates significantly. To avoid the negative effects of row crops on the soil structure, it is necessary that the period of their cultivation on the same field should not exceed three years.

This is confirmed by our research results. The influence of short-term crop rotations with different proportions of sunflower on some agrophysical parameters of typical chernozem in comparison with the control variant was revealed. The density of typical chernozem in crop rotation with a share of sunflower of 40 and 60% compared to the control is slightly worse, and the arable layer is compacted. The greatest compaction is in the subsoil layer of 20-30 cm, as a result of the formation of the plow sole. The density of the topsoil at 20% saturation with sunflower is at the level of the control variant.

Crop rotation without sunflower was characterized by the highest content of agronomically valuable aggregates - 66%. An increase in the share of sunflower in crop rotations is accompanied by a decrease in their number from 1.8 to 5.8%. The water resistance of the structure of typical chernozem was largely dependent on the cultivation of sunflower in crop rotations. In the control variant, the content of water-resistant aggregates ranged from 49.1% to 66.9%. In the variants of crop rotations with the inclusion of sunflower fields, there is an increase in the number of water-resistant aggregates both in the individual layers studied and in general in 0–30 cm. The highest water resistance of the soil structure was observed in the variant with 20% saturation of crop rotation with sunflower.

An average (0.48) correlation was found between sunflower yield and the density of 0-30 cm layer of the typical chernozem. There was no significant relationship between soil structure and yield.

## CONCLUSIONS

Studies have shown that with different saturation of short-term crop rotations with sunflower, the topsoil was heterogeneous in terms of density and structural and aggregate composition. In crop rotation variants, the pattern of distribution of the zone between the upper (0-10, 10-20 cm) soil layers and the deeper compacted soil layer (20-30 cm) was manifested. In general, the structural condition of the tilth soil tends to improve. Namely, an increase in agronomically valuable fractions in the absence of sunflower in the crop rotation. The first variant of crop rotation, with a wider range of crops and the introduction of clean fallow, provided better agrophysical indicators of the tilth (0-30 cm) soil layer. It is worth noting the crop rotation with 20% sunflower, where the content of 10-0.25 mm fractions is only 2.2% lower than the control, and the density of the compound was on par with it.

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