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**THE STRUCTURAL CONDITION AND STRUCTURE OF THE ARABLE LAYER OF TYPICAL BLACK EARTH IN VARIOUS SYSTEMS OF THE BASIC PROCESSING AND FERTILIZERS IN SPECIALIZED SEED ROTARY OF CROP ROTATION OF CENTRAL FOREST-STEPPE OF UKRAINE**

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*We have investigated the influence of longitude effect of different systems of the main processing of soil and different fertilization levels on changes of agrophysical and agrochemical properties of typical black earth and productivity of specialized grass and grain plowed crop rotation. We can observe higher indexes of soil productivity of arable layer of soil of typical black earth in Forest-Steppe of Ukraine after its three-year use in the duration of shallow treatment compared to subsurface tillage and longitude surface tillage. We recommend deep (25–27 cm) tillage on one part and a shallow one (10–12 cm) on the rest parts in a five-part crop rotation.*

***Keywords:*** *cultivation, fertilizers, soil, structure, density, porosity, productivity.*

**Statement of the problem**. In the 21st century the crop growing power availability which provides virtually unlimited possibilities in intensity and deepening of soil cultivation has been fast-growing. However, the experience and practice show that in many cases, the increase of soil cultivation intensity more often leads the negative consequences: the outlay on its implementation is growing, the productivity doesn’t increase, the mineralization of humus is being accelerated, the soil is being sprayed, it’s resistance to erosion decreases. It is known that multiple passes of tractors and tillage implements across the field lead the soil overconcentration that adversely affects the quality of the following cultivations and the crop productivity.

In the second half of the 20th century a sharp turn from the practice of multiple runs of tillage equipment to their reduction or even the complete abandonment of mechanical cultivation began. The theoretical basis of soil cultivation minimization are the advances in the field of soil argophysics, in particular, the theory of equilibrium and optimum density of soil [6, 7, 8].

**Analysis of recent research and publications.** Today there is no doubt about the positive effect soil cultivation minimization on soil fertility. The challenge is to establish the optimal level of its intensity in specific soil and climatic conditions [1].

Mechanical cultivation as it is known affects the conditions of growing plants, primarily due to changes in the structure of the soil. Therefore, we need to have the in-depth knowledge of the optimum structure and the agrophysical nature of each measure and the instrument for cultivation, as well as a clear idea of the fundamental changes in the structure of topsoil that provide positive effect of mechanical cultivation on growing conditions of plants.

Only in this way, the further development of theoretical and practical bases of cultivation becomes possible. Comparing the actual optimal values ​​and the current ones in the field, and, if it’s necessary, agrophysical characteristics of the instruments for soil cultivation, creates the opportunity to choose the rational ways, the measures, the depth and the instruments for soil cultivation, or the most effective combination of the foregoing, that is the system of cultivation. But the influence of soil structure on the living conditions of plants is so multifaceted and complex, that it is not easy to define these parameters.

The study of soil density, which depends primarily on the grain size and structural condition of the soil and cultivation technology, has the leading role in soil physics.

There were not so much studies about the direct effects of different types of soil conditioning on the field crops productivity, but their results did not always confirm the direct connection between the soil structure and its fertility.

But considering that the aggregated soils do not occlude, preserve the given structure, do not overconcentrate, require less traction efforts at cultivation, they are more resistant to water and wind erosion, it becomes clear that although the structure and fertility are not identical, a close relation exists between them.

In the experiments conducted in Bila Tserkva NAU [9] on the typical low-humus and clayed black soil during the last five years, at the date of sowing cultivated crops the average content of impermeable structures was slightly higher in plowing at different depths than in the permanent cultivation with a blade cultivator and flat disk harrow.

The improvement of soil structure in the upper layers with the lowest ground treatment is explained by M. K. Shykula and G. V. Nazarenko [10] to take place due to a superficial wrapping of organic fertilizers and accumulation of a significant amount of plant residues in the topsoil.

The vast majority of scientists suggest that the depth of soil as well as the cultivation methods have no significant effect on the structural and physical state of topsoil [1, 2, 3].

The appearance of a compacted layer of 10–20 cm of soil during a long-term (5–12 years) minimum black earth cultivation in the experiments of M. K. Shykula and G. V. Nazarenko there was no obstacle to obtaining higher yields of better quality [10].

Many scientists point to the immaterial effect of depth and methods of soil cultivation on the arable soil density [1, 4, 8].

 **The purpose of research** was to establish the most effective system for mechanical soil cultivation at different levels of fertilization in conditions of soil rotation, including seed cultivation, which ensures its performance at the level of 75–80 c/ha of dry matter with the simultaneous high anti-weeds effect.

*The objectives of research* were to study the effect of different systems of primary soil cultivation and fertilization on changing structural state, structural density, capillary and non-capillary porosity of typical black earth topsoil and the productivity of specialized crop rotation.

 **Research methodology.** The study was conducted during 2004–2014 in the stationary field experiment at the experimental field of Bila Tserkva NAU (National Agrarian University). The black earth (chernozem) is a deep low-humus and clayed soil. The repetition of the experiment – three times, the size of the accounting site – 112 m2.

 In crop rotation, four variants of the basic processing (pic. 1) and four fertilizing systems were investigated. The standards of annual fertilizing per 1 ha of crop rotation were as follows: zero level – without fertilizers, the first level – 4 t of humus + N26P44К44, the second level – 8 t of humus + N58P80К80,the third level – 12 t of humus + N83P116К116.

 Plowing to a depth of 16–18, 20–22 and 25–27 cm was carried out using the plow PLN 3-35, the fine processing of 10–12 cm – using a heavy disc harrow BDT – 3,0; the subsurface cultivator processing was carried out with a help of the blade cultivator KPG-250. Among the organic fertilizers there was a haft-rotten humus from the cattle on a straw bedding, the mineral one was the ammonium nitrate, simple granular superphosphate and potassium salt.

The potential weediness was determined by the method of washing off silty fractions on sieves with the holes diameter 0,25 mm. As for the actual weediness, it was determined using the quantitative method of gravimetric analysis. Water resistance of the soil structure was determined using the method of I. M. Baksheyev and the structure of soil – using the method of saturation of the soil sample with the water in the cylinders [3].

**The results and discussion**. The results of the research have shown that the structural condition of the topsoil was not appreciably different in the first and second versions of cultivation. The content of water-resistant units during sowing and harvesting with a long subsurface cultivation was respectively 58,7 and 63,0 %, and when differentiated cultivation was used – 59,5 and 163,7 % (Table 2). Permanent cultivation with the use of a blade cultivation (compared with the control), respectively has led to the decrease by 1,0 and 0,8 % of water-resistant agronomical valuable aggregates (with a size of 0,25–10 mm) in the plow layer of soil during the sowing and harvesting period. The best structural condition was marked when a long shallow cultivation was used. There were found 60,2 and 64,2 % waterproof units in the topsoil or 1,5 and 1,2 % more than in the control.

***Table 1*. *The scheme of soil cultivation for the samples in crop rotation***

|  |  |  |
| --- | --- | --- |
|   №of the field | Crop rotation | Variants of crop cultivation |
| 1(long subsurface cultivation, control) | 2(chiselling, with the use of a blade cultivation) | 3(differentiated cultivation ) | 4(long shallow cultivation) |
| Depth (сm) and the instrument for cultivation |
| 1 | Pea | 16–18 (p.) | 16–18 (bl.) | 16–18 (p.) | 10–12 (d.h.) |
| 2 | Winter wheat | 10–12 (d.h.) | 10–12 (d.h.) | 10–12 (d.h.) | 10–12 (d.h.) |
| 3 | Buckwheat | 16–18 (p.) | 16–18 (bl.) | 16–18 (bl.) | 10–12 (d.h.) |
| 4 | Maize for seed | 25–27 (p.) | 25–27 (bl.) | 25–27 (p.) | 25–27 (p.) |
| 5 | Spring barley | 20–22 (p.) | 20–22 (bl.) | 20–22 (d.h.) | 10–12 (d.h.) |

*Note:* P – ploughing, bl – blade flat cultivation, d.h. – disc harrow cultivation.

In all variants of the experiment the lower part of topsoil (20–30 cm) was revealed to be the most aggregated with a noticeable difference on the content of agronomical valuable aggregates between the lower and upper parts of the arable soil layer observed in the shallow cultivation, especially in chiselling. The difference in aggregation of lower and upper parts of the arable soil on the date of sowing and harvesting was the following: in the first version of cultivation – 2,9–4,3 %, in the second one – 8,0–8,8 %, in the third – 4,5 and 6,4 %, and in the fourth – 6,5 and 8,7 %.

 The growing number of water-resistant aggregates in the bottom of the topsoil, compared with the top can be partially explained by higher soil compaction, providing better contact between the particles and their stronger bonding, as well as almost complete absence of the ravages on the structural units of agricultural machinery, tools and atmospheric factors.

***Table 2****.* ***The content of water-resistant aggregates in the arable soil layer depending on the cultivation system and fertilizer, %***

|  |  |  |  |
| --- | --- | --- | --- |
| Variants of soil cultivation | Levels of soil cultivation | Sowing | Harvesting |
| Soil layer, cm |
| 0–10 | 10–20 | 20–30 | 0–10 | 10–20 | 20–30 |
| 1.(long subsurface cultivation, control) | 0 | 52,4 | 53,2 | 55,3 | 57,2 | 58,9 | 62,4 |
| 1 | 55,3 | 56,5 | 58,2 | 59,1 | 60,1 | 63,6 |
| 2 | 58,8 | 60,4 | 62,3 | 63,3 | 64,0 | 67,2 |
| 3 | 62,9 | 63,5 | 65,4 | 65,3 | 66,1 | 68,8 |
| 2.(chiselling) | 0 | 50,1 | 53,3 | 56,2 | 54,2 | 59,2 | 63,6 |
| 1 | 52,9 | 56,2 | 59,8 | 57,1 | 58,8 | 65,0 |
| 2 | 54,2 | 58,9 | 63,8 | 59,0 | 63,4 | 68,8 |
| 3 | 57,4 | 62,9 | 66,8 | 62,2 | 64,9 | 70,1 |
| 3.(differentiated cultivation) | 0 | 52,2 | 53,8 | 56,4 | 56,8 | 58,8 | 64,7 |
| 1 | 54,7 | 57,2 | 60,2 | 58,0 | 61,8 | 65,8 |
| 2 | 59,0 | 61,9 | 63,4 | 62,8 | 65,1 | 68,7 |
| 3 | 63,2 | 64,7 | 66,8 | 65,7 | 67,0 | 69,5 |
| 4.(long shallow cultivation) | 0 | 52,4 | 54,2 | 57,5 | 57,0 | 58,4 | 66,4 |
| 1 | 53,9 | 58,7 | 62,5 | 57,9 | 61,8 | 66,7 |
| 2 | 58,6 | 62,7 | 65,8 | 62,3 | 64,8 | 70,0 |
| 3 | 62,8 | 65,3 | 67,7 | 64,8 | 66,9 | 73,5 |

The reduction of agronomical valuable aggregates in the top of the arable soil, using the blade cultivation, compared to the control, was mainly due to the formation of clods more than 10 mm in diameter.

A better structural condition of the bottom of topsoil in a long shallow cultivation, compared to other variants, apparently can be explained by almost complete absence of mechanical action of the cultivation instruments on it. Thus, the content of water-resistant aggregates in the topsoil on the date of sowing and harvesting was respectively: in the first version – 60,3 and 65,5 %, in the second one – 61,7 and 66,9 %, in the third – 61,7 and 67, 2 %, and in the fourth – 63,4 and 69,2 %.

It was found out that with the increasing amounts of fertilizers soil conditioning improves. Thus, applying 4 tons of manure + N26R50K50, 8 tons of manure + N58P80K80 and 12 tons of manure + N83P116K116 per hectare of arable crop rotation each year, the content of the impermeable aggregates in the plow layer of soil at the date of the harvest increased respectively by 1,4; 5,3 and 7,2 % in the first version of cultivation, by 1,3; 4,7 and 6,7 % – in the second one, by 1,8; 5,4 and 7,3 % – in the third and by 1,5; 5,1 and 7,8 % – in the fourth cultivation, as compared to unfertilized plots. It can be explained with a more powerful development of the root system of plants, which makes the structure of small lumps of soil water-resistant, as well as with an increased leaf surface of crop that protects the surface of the field from the ravages of water and wind.

The more powerfully developed root system of plants is, the more evenly it penetrates soil, and the higher its total mass per volume unit of soil is, the less deconstructed soil clods and lumps remain and the less silty fine microaggregates it consists, and thus, it has a higher structuring rate [5].

 During the decomposition of plant residues the humus substances are formed, pectins, pectose, sugars and mucous allocations of soil microorganisms start to release. It makes soil aggregates water-resistant. Black soil conditioning under the crops during the growing season improves in all parts of topsoil.

The soil condition is much better characterized by its structure, which plays an essential role in a plant life, as it defines the environment where the water, air, nutrients, microorganisms, plant roots are placed.

***Table 3.******The change of bulk density (g/cm3) and total porosity (%) depending on soil cultivation and fertilization system***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variants of soil cultivation | Levels of fertilization | Bulk density (d) and general soil porosity (V2) | Sowing | Harvesting |
| Soil layer, cm |
| 0–10 | 10–20 | 20–30 |  | 0–10 | 10–20 | 20–30 |  |
| 1.(long subsurface cultivation, control) | 0 | d | 1,13 | 1,16 | 1,22 | 1,17 | 1,25 | 1,28 | 1,33 | 1,29 |
| V2 | 56,4 | 52,2 | 48,2 | 52,3 | 52,2 | 51,1 | 48,4 | 50,6 |
| 3 | d | 1,12 | 1,15 | 1,20 | 1,16 | 1,24 | 1,25 | 1,30 | 1,26 |
| V2 | 58,3 | 53,4 | 49,2 | 53,7 | 54,5 | 52,1 | 46,9 | 51,9 |
| 2.(chiselling) | 0 | d | 1,18 | 1,27 | 1,36 | 1,27 | 1,29 | 1,36 | 1,44 | 1,36 |
| V2 | 55,3 | 50,8 | 42,2 | 49,5 | 50,5 | 46,2 | 40,1 | 45,6 |
| 3 | d | 1,15 | 1,22 | 1,33 | 1,23 | 1,26 | 1,33 | 1,41 | 1,33 |
| V2 | 57,1 | 51,7 | 43,4 | 50,7 | 53,6 | 47,3 | 42,4 | 47,8 |
| 3.(differentiated cultivation) | 0 | d | 1,14 | 1,25 | 1,35 | 1,25 | 1,25 | 1,33 | 1,40 | 1,33 |
| V2 | 54,5 | 50,2 | 43,1 | 49,3 | 52,9 | 47,2 | 42,1 | 47,4 |
| 3 | d | 1,13 | 1,22 | 1,33 | 1,23 | 1,23 | 1,31 | 1,39 | 1,31 |
| V2 | 56,8 | 51,4 | 43,8 | 50,6 | 54,9 | 50,1 | 42,9 | 49,3 |
| 4.(long shallow cultivation) | 0 | d | 1,11 | 1,15 | 1,24 | 1,17 | 1,22 | 1,27 | 1,35 | 1,28 |
| V2 | 57,2 | 53,5 | 48,6 | 53,1 | 54,0 | 52,2 | 47,8 | 51,4 |
| 3 | d | 1,10 | 1,13 | 1,20 | 1,14 | 1,20 | 1,23 | 1,32 | 1,25 |
| V2 | 58,8 | 55,2 | 49,4 | 54,4 | 56,2 | 53,3 | 47,6 | 52,4 |

Soil structure is characterized by many parameters. Most often the structure of the soil is judged by its density, which is measured by its volume weight.

Research has found that in chiselling and differentiated cultivation the density of arable soil structure, compared with control, was higher respectively by 0,08 and 0,06 g/cm3. There was no noticeable difference in the size of bulk weight of black earth topsoil in the control and long shallow cultivation (respectively 1,22 and 1,21 g/cm3 (Table 3).

Topsoil compaction in the differentiated cultivation and the one with the use of a blade cultivation was mainly due to the size of the lower parts (10–20, 20–30 cm) of it. Thus, during the growing season of crops rotation the volumetric weight of soil layers of 0–10, 10–20 and 20–30 cm in the first version of cultivation amounted to 1,19; 1,21 and 1,26 g/cm3, in the second one – 1,22; 1,30 and 1,39 g/cm3, in the third – 1,19; 1,28 and 1,37 g/cm3, and in the fourth – 1,16; 1,20 and 1,28 g/cm3. The lowest index of bulk density of the upper (0–10 cm) soil layer (1,16 g/cm3) was marked in a long shallow cultivation.

An important indicator of the soil structure is the size of the threshold space and the correlation in pore volumes of different sizes.

The indicators of total arable soil porosity didn’t differ a lot in the plots with a long subsurface cultivation and long shallow cultivation. In the variants of cultivation with the use of a blade cultivation and the differentiated cultivation the total pore volume of the topsoil was respectively smaller by 3,7 and 2,9 %, compared to the control plots (Table 4).

***Table 4. The replacement of the capillary and non-capillary porosity (%) of soil depending on soil cultivation and fertilization system***

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Variants of soil cultivation | Levels of fertilization | Porosity: capillary (V3) and non-capillary (V4) | Sowing | Harvesting |
| Soil layer, cm |
| 0–10 | 10–20 | 20–30 | 0–10 | 10–20 | 20–30 |
| 1.(long subsurface cultivation, control) | 0 | V3 | 35,4 | 35,4 | 32,4 | 32,3 | 31,8 | 33,1 |
| V4 | 21,0 | 16,8 | 15,8 | 19,9 | 19,3 | 15,3 |
| 3 | V3 | 37,4 | 37,2 | 33,3 | 34,5 | 32,5 | 33,4 |
| V4 | 20,9 | 16,2 | 15,9 | 20,0 | 19,6 | 15,5 |
| 2.(chiselling) | 0 | V3 | 35,3 | 36,5 | 31,0 | 28,8 | 27,2 | 29,4 |
| V4 | 20,0 | 14,3 | 11,2 | 21,7 | 19,0 | 10,7 |
| 3 | V3 | 36,1 | 37,7 | 32,4 | 30,2 | 27,2 | 29,8 |
| V4 | 21,0 | 14,0 | 11,0 | 23,4 | 20,1 | 2,6 |
| 3.(differentiated cultivation) | 0 | V3 | 32,4 | 34,2 | 31,2 | 29,7 | 28,1 | 27,4 |
| V4 | 22,1 | 16,0 | 11,9 | 23,2 | 19,1 | 14,7 |
| 3 | V3 | 31,3 | 35,3 | 32,2 | 30,4 | 29,2 | 28,6 |
| V4 | 25,5 | 16,1 | 11,6 | 24,5 | 20,9 | 14,3 |
| 4.(long shallow cultivation) | 0 | V3 | 38,8 | 35,8 | 33,9 | 34,7 | 33,9 | 32,1 |
| V4 | 18,4 | 17,7 | 14,7 | 19,3 | 18,3 | 15,7 |
| 3 | V3 | 39,7 | 36,2 | 35,5 | 35,9 | 34,4 | 33,1 |
| V4 | 19,1 | 19,0 | 13,9 | 20,3 | 18,9 | 14,5 |

The correlation between capillary and non-capillary porosity of arable soil layer at the date of sowing and harvesting was respectively: in the first version of cultivation – 1,98 and 1,80, in the second one – 2,29 and 1,62, in the third – 2,14 and 1,91, and in the fourth – 1,91 and 1,49.

At the date of sowing the capillary spaces in the plow layer of soil were mostly marked in the fourth variant (36,2–37,1 %) and the least – in the third (32,6–32,9 %) variant of cultivation. On the day of harvesting the volume of a capillary pore of arable soil did not appreciably differ in the plots of a long subsurface cultivation and long shallow cultivation. In the cultivation with the use of a blade cultivation and the differentiated cultivation the capillary porosity of arable topsoil on the date of harvesting was 4,0–4,2 % lower compared with the control.

In our experiments we didn’t find any significant difference in the size of black earth topsoil aeration in different variants of cultivation. However, one remarkable difference was observed between the control, the second and third versions of cultivation in the lower parts of topsoil. Thus, the non-capillary porosity in the soil layers of 10–20 and 20–30 cm at the date of sowing was the following: the first version – 16,5 and 15,9 %, in the second one – 14,2 and 11,1 %, in the third – 16,1–11,8 %, in the fourth one – 18,4 and 14,3 %. At the date of the harvest the value of aeration in the soil of 10–20 cm did not appreciably differ in the variants of cultivation. As for the layer of 20–30 cm with the use of a blade cultivation and the differentiated cultivation it was respectively 3,7 and 0,9 % lower than in the control one.

A noticeable improvement of the structural condition of the soil with higher levels of fertilizers provided a slight decrease of the soil bulk density and increased its total porosity. One with another, as our experiment has shown, by bringing the highest standards of fertilizer the soil structure density was 0,03 g /cm3 lower, and the total pore volume was 1,5% higher compared to unfertilized plots.

It was established that by conducting a deep plowing (4th version of cultivation) only once in the rotation we eliminate the heterogeneity of topsoil up to 1,5–2 years. The differentiation of the black earth topsoil according to the plant remains, the available forms of plant food elements and agronomical valuable aggregates on the day of pea harvesting was already clearly traced.

The productivity of crop rotation in the differentiated and long shallow cultivation was at the control, and in the cultivation with the use of a blade productivity it was significantly lower. The collection of a dry matter was 0,5–0,7 t/ha lower in the second variant of cultivation than in the control one.

**Conclusion.** Continuous cultivation with the use of a blade cultivation leads the worsening of a structural state of arable soil. The arable layer was the most aggregated in a long shallow cultivation. The density of the bottom of the topsoil significantly increases during the cultivation with the use of a blade cultivation and differentiated one, as compared to the control cultivation. Bulk density and total porosity of topsoil does not appreciably differ on the plots where the long subsurface cultivation and a long shallow cultivation are applied. The total pore volume of the topsoil is 3–4 % less in the cultivation with the use of a blade cultivation and in differentiated one than in a long subsurface cultivation.

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