Structural state of soddy-podzolic soils under the influence of different cultivation systems

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Abstract. Some favorable physical properties and the modes of soil are the basis and a necessary condition for realization of potential soil fertility for receiving high harvest of crops. Therefore, creation and maintenance of optimal composing of the arable soil layer by means of different cultivation systems is an up-to-date objective of modern intensive agriculture.

1. Introduction
In the modern conditions of direct sowing technologies implementation, the issue of transformation of the soils physical properties with exclusion of operations for main cultivation again becomes critical. In this regard, the problem of agrophysical degradation of arable land is acute and it determines the relevance of assessing changes in the level of physical indicators of fertility to correct and develop new agrotechnological techniques for cultivation of agricultural crops and to design the machines and tools [1].

The impact of machinery on soil leads to an increase in density for all soils, but to the greatest extent for wet loam and clay ones in terms of textural composition [2].

The structural composition and content of water-stable units characterize the composition of the soil, its resistance to erosion and compaction, optimize soil regimes and determine the productivity of field crops. The optimal content of the water-resistant macrostructure (aggregates with a size of 0.25-10 mm or more) for sod-podzolic soils is 30-45 %. With such structurality, the soil retains for a long time the stable addition given to it by processing.

Structural soil loses its positive qualities when the number of microstructural aggregates (particles less than 0.25 mm in size) increases to 30-40 % [3].

The problem of optimizing the structural state of the arable layer is one of the most important problems of modern physics and agricultural engineering [4].

The optimal value of equilibrium density for soddy-podzolic soil is 1.25-1.50 g/cm³, which determines the optimal or similar to indicators of other physical properties. The lower limit of the optimal density mentioned range is necessary for row crops that are more demanding for bulk density. The upper limit of density is optimal for less demanding grain crops of unstriped seeding [5].

Therefore, the most important agrophysical basis of processing is the requirements of crops for the density of the arable layer of the soil, the structural composition and degree of crumbling of the soil, the power of the arable layer, hardness and other properties on which plant growth and yield depend.
is found that the use of minimal cultivation leads to formation of an indurated horizon. Density of the soil arable layer (0-20 cm) with minimal cultivation is 1.39 g/cm³ and 1.46 g/cm³ at plowing. At the same time, in favor of minimal cultivation porosity increases from 19.0 % to 26.0 % and from 47.4 % water-stable units.

The conducted research of minimal cultivation effectiveness allows to state deterioration of the physical parameters of soddy-podzolic light loamy soil composition.

2. Methods
The research was carried out on the experimental field of the Precise Farming Center (PFC) at the Field Experimental Station of the Russian State Agrarian University-Moscow Agricultural Academy named after K. A. Timiryazev. The object of the study was the agrophysical properties of the soil and grain crops (barley and winter wheat), which alternate in the crop rotation as follows: vico - oat mixture for green fodder – winter wheat + white mustard for siderate - potatoes-barley. In this experiment, two systems of basic tillage were studied – the moldboard (annual plowing to a depth of 20-22 cm) and the minimum (to a depth of 10-12 cm). The soil cover of the experimental site is represented by sod-podzolic, light loamy soils. The humus content in the arable layer (0-20 cm) is from 2.0 to 2.5% (according to Tyurin), the supply of total nitrogen (according to Cornfield) is low – 35.5 mg / kg of soil, while the supply of mobile phosphorus (according to Kirsanov) is high – (200-250 mg/kg of soil). The content of exchangeable potassium (according to Maslova) is average (150-200 mg/kg of soil). The pH of the water extract ranges from 5.8 to 6.2.

The object of the research is soddy-podzolic light loamy soil. The following methods are used in the research:

- Soil structure (%) is determined by N.I. Savvinov’s method using AS-200 device;
- Addition density (g/cm³) is determined by volume-weight method;
- Water stability of macrostructure (%) is determined by swinging sieves in water using AS-200 device.

Main cultivation options are moldboard (plowing at the depth of 20-22 cm) and minimal (depth of 10-12 cm).

3. Results and discussion
The use of different cultivation systems in a crop rotation has unequal influence on composing of the arable (0-20 cm) and subarable (20-30 cm) layers of the soddy-podzolic soil in barley crops. So, the higher level of density, porosity of aeration and hardness of the arable layer optimization is reached at the minimal cultivation system on depth of 10-12 cm, than at the moldboard system.

The optimal density of composing of the arable layer under barley is noted in the variant of the minimal cultivation, where it is 1.39 g/cm³, that is 0.07 g/cm³ less in comparison with ploughing (table 1). Thus, considerable overstocking of the subarable layer (20-30 cm) up to 1.50 g/cm³ is noted in the variant with the minimal cultivation. It is to assume that there is decompaction of the top layer at long-lasting use of surface cultivation, because of predominant intake of some plant residues and processes of humification.

In accordance with the results of our research, the porosity of aeration of the arable soil layer does not drop below the optimal values during the vegetative period of barley at the usage of the minimal cultivation at 10-12 cm, and ploughing at 20-22 cm.

However, reduction of cultivation intensity due to the methods of minimization stimulates significant increase in porosity of aeration of the arable layer, especially of the top layer (0-10 cm), where this indicator was 1.6 times higher in comparison with ploughing (table 1). This increase happens due to formation of complete vertical holes, which are formed when moving of earthworms and extinction of a deeply penetrating root system of weedy (burr, stemrooted, etc.) plants [6].

The usage of ploughing for the depth of 20-22 cm leads to 1.5 times increase in hardness of the arable layer in comparison with the minimal cultivation for the depth of 10-12 cm.
It is explained by more intensive loosening of the top layer at the cultivation by the assembled unit "Pegasus" for the depth of 10-12 cm [7].

**Table 1. Influence of different cultivation methods on the agrophysical properties of soil.**

| Cultivation method | Layer of soil, cm | Density, g/cm³ | Porosity, % | Hardness, kPa |
|--------------------|------------------|----------------|-------------|---------------|
| Minimal            | 0-10             | 1.36           | 26.4        | 11.1          |
|                    | 10-20            | 1.42           | 25.5        | 16.1          |
|                    | 20-30            | 1.5            | 23.4        | 18.8          |
| Moldboard          | 0-10             | 1.47           | 16.7        | 16.8          |
|                    | 10-20            | 1.44           | 21.2        | 19.2          |
|                    | 20-30            | 1.47           | 21.4        | 23.5          |

HCPₜₒₜ=1.05

The analysis of the soil structural condition under the crops of bailey shows that equal distribution of agronomically valuable units (10-0.25 mm) is observed at the moldboard cultivation almost in all the studied layers (table 2). Their insignificant increase is noted in the layer (10-20 cm), where it is 39.6%, and this increase is connected mainly with the fraction (3-1 mm), resistant to degradation.

**Table 2. Influence of technologies of barley cultivation on the soil structural-aggregate state.**

| Cultivation method | Layer of soil, cm | Dry screening, % | Moist screening, % |
|--------------------|------------------|------------------|--------------------|
|                    |                  | >10 mm           | 10-0.25 mm         | Fraction, % | 0.25 mm | >0.25 mm |
| Minimal            | 0-10             | 44.7             | 33.9               | 22.2        | 0.5     | 47.8     |
|                    | 10-20            | 55.6             | 29.2               | 19.9        | 0.3     | 47       |
|                    | 20-30            | 56.3             | 30                 | 23.5        | 0.4     | 39.1     |
| Moldboard          | 0-10             | 52.1             | 37.4               | 20.6        | 1.4     | 43.3     |
|                    | 10-20            | 33               | 39.6               | 29.3        | 2.2     | 49.5     |
|                    | 20-30            | 36.6             | 37.7               | 22.1        | 3.6     | 48.2     |

Thus, the number of water-stable units (>0.25 mm) in the same layer increases to 49.5 %. At the same time the maximum content of the agronomically valuable fraction and water-stable macrostructure is noted at the minimal cultivation mainly in the top layer (0-10 cm), and it is 33.9 % and 47.8 % respectively, that is 4.7 % and 0.8 % more than in the lower layer (10-20 cm).

It is caused by the fact that the reversing of soil and equal distribution of the organic substance at the ploughing promotes aggregation of the lower part of the arable layer, whereas at the minimum cultivation for the depth of 10-12 cm the top layer (0-10 cm) is more humus-enriched and better aggregated than the lower one (10-20 and 20-30 cm), mainly, due to accumulation of plant and root residues in this layer.

Water permeability of soil is closely connected with the structure, density and other indicators of the soil physical condition. The use of the minimal cultivation leads to the increase of soil water-permeability under the barley crops for 1.56 mm/min, or 37.4 % of the arable layer, and for 1.07 mm/min, or 32.5 % of the subarable layer, in comparison with the moldboard cultivation (table 3).

It is connected with the fact that the conditions for active zoofauna development are created at the plowless cultivation. The zoofauna not only promotes biological loosening of the underlying soil layers, improving its structure, but also provides with permeability of the soil profile at the expense of the numerous passages reaching 1 m depth [8].
Table 3. Soil water-permeability under the barley crops.

| Cultivation method | Layer of soil, cm | 0-10 | 10-20 | 20-30 |
|--------------------|-------------------|------|-------|-------|
| Minimal            |                   | 3.67 | 4.68  | 3.29  |
| Moldboard          |                   | 3.15 | 2.08  | 2.22  |
| HCP₀₅=2.16         |                   |      |       |       |

The usage of cultivation systems different in the way, depth and intensity in the experiment predetermines an unequal extent of optimization of separate physical factors of the soil fertility.

Thus, the crop capacity of barley at the minimal cultivation is 4.92 t/ha, that is 19.7 % more than at the ploughing (table 4). This is due to the higher humus content of the arable soil layer in the version with minimal processing.

Table 4. Crop capacity of barley, t/ha.

| Cultivation method | Crop capacity |
|--------------------|---------------|
| Minimal            | 4.92          |
| Moldboard          | 3.95          |

HCP₀₅=0.21

4. Conclusions

It is found that minimal cultivation does not lead to deterioration of the arable (0-20 cm) soil layer.

Significant compaction up to 1.47 and 1.5 g/cm³ in both variants is observed in the subarable (20-30 cm) soil layer.

Water permeability in the variant of minimal cultivation is 2.5 times higher than after plowing.

Difference in grain yield between the variants is 0.97 t/ha in favor of minimal cultivation.

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