Influence of soil-protective technologies on the characteristics of the soils of hop plants

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Abstract. It is known that one of the main and complex indicators of the soil is the density of its composition (volume mass). The widespread introduction of new technologies of tillage in our country only increases interest in the values of density in the new conditions. At the same time, soil hardness is also an important parameter characterizing agrophysical conditions of plant growth. We believe that research on the diagnosis of these soil parameters is not enough, so we have conducted research in this area. Traditional methods of tillage do not have a significant compacting effect in the surface layer. Most of the acquired parameters of the additional density are characterized by us as optimal. Only in some cases of ploughing the soil density decreased to 0.7...0.99 g/cm³. This indicates an excessively friable state. Processing of fields by "no-till" (zero) type leads to an increase of values of density of addition of the soil to 0.94...1.25 g/cm³. Hardness values also increased and reached 22.8 kgf/cm² (2.24 MPa). We see the reason for this phenomenon in the inevitability of the use of heavy-duty tractors. At the same time, the mass of the tractor itself almost levels the type of engine used – caterpillar or pneumatic wheels. Therefore, the objects of study were tractors of different classes, energy saturation, and weight. Soil samples were taken from arable and subsurface horizons from five conventional layers. The results showed that the impact of the drivers of the tractors increases the density of the composition of the soil in all conditional layers. However, the compact intensity on the layers differentiated depending on the weight of the tractor. The soil in the traces of tractors weighing up to 6-7 tons was compressed mainly in the Arab horizon (at a depth of 0.3 m), and in the subsurface (at a depth of 0.3-0.5 m) the compact was practically absent. Soil compaction by tractors weighing 8-11 tons occurred to a depth of 0.5 m. At the same time, the increase in volume mass in the layers of the arable horizon was from 0.25 to 0.35 g/cm³. The most effective way to restore the subsurface layer is the use of various subsurface agents in the autumn. Application in the winter of snow retention techniques allows one to accumulate in the loosened subsurface layer of additional moisture needed in the spring presowing period.

1. Introduction
The last decades are characterized by a wide spread of technologies of minimum tillage in the cultivation of crops in our country. For the implementation of such methods of tillage, the industry has established a range of powerful tractors, soil-cultivating tools, etc. At the same time, the total mass of the aggregate inevitably increased, and the influence of propulsion systems of the undercarriage systems on the arable and subsurface soil layers increased [¹, ²].
It is known that the main functions of tillage are the creation of optimal addition of the arable layer, the formation of conditions for the preservation of potential and effective fertility, as well as the protection of arable land from erosion. At the same time, the following indicators of the physical properties of the soil are mandatory: mechanical and granulometric compositions, micro- and macro-structural formulations, the hardness, and density of the addition of soil (bulk density) and its moisture content [3, 4].

2. Purpose of research
Study of the influence of dump and minimum processing technologies on the change in the density of addition and hardness of gray forest soils of the Chuvash Republic.

3. The object of research
Studies on the effect of resource-saving methods of tillage on its agro-physical parameters were carried out in the current hop gardens of the Chuvash State Agricultural Academy, LLC "Agrokhmel" Vurnary district and LLC "Agricultural Resources" of Urmar district of the Chuvash Republic. Garden hops and land with a total area of about 20 hectares were investigated in these farms [5, 6].

The topsoil is represented by a combination of gray and light gray forest soils. Their mechanical composition is medium-loamy and heavy-loamy. According to the agrochemical analysis in the fertile layer of 2.1 … 2.5% humus. Humus content up to 2.8 … 3.1% was recorded on separate garden hops. The depth of the fertile layer is 23 … 28 cm. The reaction of the soil is average. The slope of all of the hop gardens – out of or within 1.5…5% [7, 8].

The following tractors were chosen as the objects of our research:
- wheel Agromash-30TK (22,1 kW, 2500 kg), MTZ-1025 (77 kW, 4500 kg), BTZ-243K (184 kW, 8660 kg), CLAAS Atles 926 (166 kW, 10200 kg);
- crawler Agromash-90TG (69.1 kW, 6900 kg).

4. Method of research
Chemical and physicochemical parameters were obtained by the generally accepted formulations of modern methods. The density of the soil was determined by the drilling method and was evaluated on a scale of N.A. Kachinsky; soil hardness-in the field using a hand penetrometer Wile soil; humidity - thermostatically-by weight method. Statistical data analysis was carried out using MS Excel software package [9,10].

5. Results and discussion
When studying the impact of basic tillage on crop yields, special attention should be paid to the soil layer below the plant roots. It is known that the ratio of soil moisture and density affects the absorption of mineral elements by plants. As a result of the use of tillage tools (or their complex) in the soil, the density of the arable layer characteristic for this processing is formed. Getting the maximum yield depends on the moisture regime. It is known that plowing provides the lowest soil density. Therefore, it is used in excess of precipitation. The lack of moisture transferred to the treatments, providing a denser structure of the plough layer.

Let's consider how the studied methods of processing changed the addition of soil at a depth of 20 cm. According to the estimates, the density was characterized as "negligible". In the conditions of dump plowing in all terms of observations of 2018, the density of the addition of the arable layer did not exceed the border of 1 g/cm³ and corresponded to the level of "loose" (Table 1).

The data obtained indicate the reduced values of the indicator and are consistent with a number of soil researchers in the Volga region. The loose structure of soils of the agricultural part of the Chuvash Republic is associated with their long stay in the frozen state, cracking as a result of periodic drying in the summer and increasing porosity. Research materials also indicate a significant unproductive loss of moisture on
physical evaporation when the density of the soil is below optimal. It should be noted that all these characteristics were obtained for soils treated by the classical dump method.

**Table 1.** Statistical parameters of the density of addition of gray and light gray forest soils. (2018)

| Option of tillage | Layer, cm | 20.05.2018 | 29.06.2018 | 02.10.2018 |
|-------------------|-----------|------------|------------|------------|
|                   |           | The bulk density of the layers, g/cm³ | Humidity, % | The bulk density of the layers, g/cm³ | Humidity, % | The bulk density of the layers, g/cm³ | Humidity, % |
| Stoker            | 0-5       | 0.68±0.05  | 16         | 0.76±0.06  | 14         | 0.83±0.05  | 5          |
|                   | 5-20      | 0.70±0.06  | 11         | 0.86±0.04  | 9          | 0.82±0.04  | 5          |
|                   | 0-5       | 0.87±0.06  | 13         | 0.85±0.09  | 17         | 0.78±0.06  | 13         |
|                   | 5-20      | 0.87±0.06  | 13         | 0.95±0.05  | 10         | 0.91±0.06  | 11         |
| Minimum           | 0-5       | 1.08±0.07  | 12         | 1.07±0.06  | 10         | 0.94±0.06  | 11         |
|                   | 5-20      | 1.20±0.06  | 9          | 1.19±0.07  | 10         | 1.17±0.04  | 6          |

Replacement of the dump treatment with surface loosening (for example, disk coulters) was accompanied by a significant increase in the density of all the studied layers in the spring and summer of 2018 (Table 1). By the end of the growing season, there was a significant decrease in density from 0.88 to 0.78 g/cm³. Probably, one of the factors that influenced the formation of the loose structure is the impact of the core root grain crops and the formed mulching layer from the plant material of field crops of previous years.

Rejection of mechanical tillage found exceeding the level of its compaction in comparison with the dump and minimal processing, but still, it was within the optimum. It is interesting to note that the greatest changes affected only the top 0 ... 5 cm of the root layer of grain crops: from summer to autumn there was a significant decrease in density. In layer 5 ... 20 cm its parameters remained statistically equivalent. It is obvious that the preservation of plant residues of previous field crops on the soil surface, activating the accumulation of young organic substances, increases resistance to deformation and improves the macroporosity of the soil.

Immediately after treatment, the soil has agrophysical characteristics favorable for plant development. However, it is derived from its equilibrium state and, as a rule, its density is lower than the equilibrium state. Subsequently, rapid shrinkage of the soil occurs, the speed of which is determined by the amount and intensity of precipitation, by permeability.

During the growing season of 2018, the values of the density of addition in the conditions of dump plowing did not exceed the level of the first gradation but slightly exceeded the parameters of the previous year. Thus, the traditional method of tillage created its excessively loose structure, which, according to the principles of agrophysics, leads to poor seed contact with the soil, unproductive diffuse moisture loss, increased mineralization processes of organic matter and damage to root systems of field crops during subsidence.
The use of surface loosening revealed a significant decrease in density in a layer of 0 ... 5 cm from mid-summer to autumn. There were no significant changes with the depth, and the soil level varied in the range of 1.01...1.06 g/cm³, significantly exceeding the top layer.

Thus, the maximum density was reached by the soil in the layer of 5 ... 20 cm to the autumn period in the absence of machining and corresponded to the level of "dense". Whereas in the upper 0 ... 5 cm layer, "biological self-loosening" appears - the result of the accumulation of a layer of mulch on the soil surface along with the passages of dead root systems of crops. We believe that a slight differentiation of the arable layer by density can slow down the involuntary evaporation of moisture and contribute to the activation of the natural processes of soil formation.

Thus, the estimated methods of influence on the soil as a whole did not exert a compaction effect on critical values. Density parameters were characterized as "optimal", and as excessively loose in the variant with dump plowing, in some periods. When using soil-protective technologies, there was a tendency to differentiation of the studied layers of the root-inhabited stratum according to the density of structure.

Hardness is an integral indicator of the physical condition and indicates the measure of the strength of the soil against the destructive mechanical action of external forces: roots of plants, tillage implements, raindrops. It is functionally dependent on the granulometric composition, structure, density, and humidity of the soil.

In order to determine the depth of the spreading of the compacting effect of tractors in the soil, two-year (2017-18) studies were carried out by a model field method on experimental garden hops. The objects of study selected tractors, differing class, type of propulsion, engine power, and total weight. The evaluation criterion is the bulk density of the soil - the most comprehensive indicator of soil condition. The results of the study are presented in Table 2.

**Table 2.** The change in bulk density of the soil under the action of running systems of tractors.

| Option             | The bulk density of the layers, g/cm³ |
|--------------------|--------------------------------------|
|                    | 0 ... 10 cm  | 10 ... 20 cm  | 20 ... 30 cm  | 30 ... 40 cm  | 40 ... 50 cm  |
| Control            | 1.00         | 1.21          | 1.31          | 1.42          | 1.40          |
| Agromash-30TK      | 1.21         | 1.29          | 1.36          | 1.42          | 1.40          |
| MTZ-1025           | 1.26         | 1.40          | 1.39          | 1.41          | 1.42          |
| Agromash-90TG      | 1.23         | 1.32          | 1.41          | 1.43          | 1.41          |
| BTZ-243K           | 1.31         | 1.48          | 1.57          | 1.57          | 1.59          |
| CLAAS Atles 926    | 1.35         | 1.46          | 1.58          | 1.59          | 1.60          |

Analyzing the values of the bulk density by layers, it can be noted that the density of the addition of the soil increases depending on the depth. For example, the original soil (control) was loose and had a bulk density in the topsoil up to 1.21 g / cm³. In the subsurface horizon, this value increased from 1.31 (20 ... 30 cm) to 1.40 g / cm³.

The mechanical effect of tractor thrusters increased the density of the soil in all layers, and the intensity of compaction attenuated with depth. So, in a layer of 0 ... 10 cm, the increase in bulk density was 0.23 ... 0.35 g / cm³, in a layer of 20 ... 30 cm - 0.08 ... 0.27 g / cm³, and at a depth of 50 cm, the soil compacted only 0.01 ... 0.20 g / cm³.

After the use of various tractors, the intensity of soil compaction was different. The soil was compacted in traces of tractors up to 7,000 kg in the arable horizon, and the sealing effect of these tractors was almost the same. Note that the layers of 30 ... 40 cm and 40 ... 50 cm after their passage remained almost
uncompacted. In other words, light tractors compact mainly the arable horizon of gray and light gray forest soils in layers up to 30 cm.

In traces of tractors weighing more than 7,000 kg, the soil compaction pattern is different. Heavy tractors compacted the soil to a depth of 50 cm and the degree of compaction was defined as "significant". The increase in volume mass in the layers of the arable horizon ranged from 0.25 to 0.35 g/cm³. Moreover, the degree of compaction of such tractors was almost the same and depended mainly on the design features of tractors (twin wheels, caterpillar engines, etc.).

Thus, studies have shown that the soil is compacted not only in the arable horizon but also in the deeper layers of the soil under the action of the tractor's running systems. It should be noted that the compaction of the upper layers of the soil is affected by the specific pressure of machines on the soil, and the lower layers (up to 50 cm) are compacted mainly under the influence of the weight of the tractor.

It is necessary to pay attention to rather high values of the hardness of hop rows. In our opinion, there are several reasons:

first, during the low level of mechanization rows of hops were weeded and loosened manually and efficiently;

second, the aisle on the garden hop is normally 2.2...3.3 m; therefore, each pass of the tractor compacts the row of hops.

The results of the research allowed substantiating the ways to justify the methods of deep tillage, allowing neutralizing the negative impact of tractor running systems. A compacted arable horizon can be brought to an optimal state by conventional tillage implements, and new treatment methods are required to eliminate the negative effects of compaction of the subsoil layers of the soil. Carrying out deep loosening of the subsurface soil layers without inverting the horizon can significantly improve the drainage of the arable layer and aeration of the entire root layer, increases the accumulation of productive moisture in the lower loosened horizons.

Research materials show that soil over-compaction by tractor and agricultural machinery engines violates growth conditions and reduces crop yields. Pressure on the soil causes not only a decrease in yield but also a change in the microrelief of the field – this affects the reliability and performance of machines. In addition, re-compaction of the soil will increase the resistivity of tillage tools in subsequent treatments.

| Table 3. Soil moisture in the experimental plots of the hop garden in the spring of 2018. |
|------------------------------------------|----------------|----------------|----------------|----------------|----------------|
| Option | Soil moisture, % | 0 ... 10 cm | 10 ... 20 cm | 20 ... 30 cm | 30 ... 40 cm | 40 ... 50 cm |
| Section No. 1 | 18.8 | 23.1 | 25.1 | 25.7 | 27.8 |
| Section No. 2 | 17.4 | 20.2 | 23.6 | 25.3 | 27.4 |
| Section No. 3 | 37.6 | 37.1 | 31.7 | 24.2 | 23.0 |
| Section No. 4 | 36.8 | 35.9 | 30.5 | 23.8 | 23.1 |

The next stage of our study is to study the method of increasing the moisture content in the subsurface layer. For this, we carried out the methods of snow retention in winter 2017-2018 on the garden hop of the Chuvash State Agricultural Academy. Garden hop was divided into four conditional plots of 1 ha each. The row spacing in the sections No.1 and No.2 after harvesting hops in the autumn of 2017 were treated with a deep-ripper to a depth of 45 ... 50 cm. Sections No.3 and No.4 were not exposed to tillage. Then, during the winter period, snow retention was conducted twice in sections No.1 and No. 3. In the period from December to the end of February (3 months), measurements were made of the thickness of snow cover in all four sections. We found out that the height of the snow cover by the end of February at sections No.2 and No.4 (without snow retention) reached 45 ... 50 cm, and at sections No.1 and No.3 (with snow retention) was
equal to 70 ... 80 cm. The results of soil moisture measurement in the spring pre-sowing period of 2018 are presented in Table 3.

It follows from it that the soil moisture in the arable and subsurface layers on the experimental section №1 is higher than on section No.2. The same pattern was observed in the comparison of sections No. 3 and No. 4. Thus, the use of snow retention in the winter period makes it possible to accumulate in the loosened subsurface layer the additional moisture required during the spring pre-sowing period.

It should be noted that observations in the spring of 2018 revealed another feature – the difference in soil ripeness in the experimental plots. For example, sections No. 3 and No. 4 were in the condition bogged by thawed waters till the middle of May. Row spacing on sections No. 1 and No. 2 in mid-April, was freed from meltwater. Thus, the autumn deep tillage to a depth of 50 cm contributed to the destruction of the subsurface layer in the aisle. This allowed the spring meltwater to penetrate into the subsurface horizon. At the same time, the top layer of soil 0...20 cm reached its physical ripeness much earlier.

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