Wave roller research on barley crops

Vladimir Kurdyumov¹, Vyacheslav Proshkin¹, Sergey Streltsov¹, Roman Bogatsky¹, and Ivan Sharonov¹

¹Federal State Budgetary Educational Institution of Higher Education "Ulyanovsk State Agrarian University named after P.A. Stolypin", 1, Novy Venets boulevard, Ulyanovsk, Ulyanovsk region, 432017, Russian Federation

Abstract. A completely new design of the wave roller is presented, which has no analogues produced by the industry. As a result of research on barley crops, it was revealed that the optimization criterion kse after treatment with the developed wave roller is 0.81. The density and aggregate composition of the soil in all parts of the field (in the ridges and in the troughs of the wave relief) fully meets the agrotechnical requirements. In the area after treatment with a serial roller KKZ-6, the optimization criterion kse = 0.67, which is significantly lower than that of the proposed wave roller. At the same time, soil clods were found on the soil surface, the size of which exceeds 50 mm, which does not meet the agrotechnical requirements for rolling. Studies conducted under production conditions made it possible to determine that the rolling of barley crops with the proposed wave roller increased its yield to 47.2 centners per hectare (by 12.4%) compared to 42 centners per hectare after rolling the crops with ring-toothed rollers KKZ-6.

1 Introduction

Increasing crop yields is a priority for the development of crop production in all countries of the world. It should be noted that at the present stage, the main direction of improving agricultural machines is associated with their technical complication, in particular, due to the introduction of digital technologies, which inevitably increases the cost of such machines [1-3]. Therefore, the development of new relatively simple tools for tillage, capable of providing the required quality of tillage or improving it, is an urgent task [4–7].

Let's pay attention to one of the important operations in the cultivation of crops - rolling the soil. With the correct implementation of this operation and compliance with agrotechnical requirements, it is possible to increase crop yields up to 30% by improving the contact of seeds with soil and providing a better water-air regime.

At the same time, the applied roller designs do not provide high-quality soil compaction, which leads to a decrease in field germination of seeds, deterioration in plant development and, as a result, to a decrease in yield [8-9].
2 Materials and methods

After analyzing the scientific, technical and patent literature on the problem under study, we have developed a new wave roller for soil compaction (figure 1). It is made in the form of a hollow cylinder with ribs evenly spaced along the circumference connecting the vertical disks. The ribs are made in the form of a profile tube of square section and are located at the same distance from each other and below the generatrix of the hollow cylinder. Holes are made in the ribs at an equal distance from each other, in which studs of the same length are installed. At the outer ends of the studs, sealing elements are rigidly installed, having the shape of segments in cross section. Elastic elements are installed on the studs between the sealing elements and the ribs. The distance between the ribs and the generatrix of the hollow cylinder is equal to the length of the elastic element in a fully compressed state. The outer ends of the studs are equipped with self-locking nuts, and holes of the same diameter are made along the generatrix of the hollow cylinder.

![Figure 1](image.jpg)

**Fig. 1.** Wave roller: 1 - generatrix of a hollow cylinder; 2 - rib; 3 - vertical disk; 4 - hairpin; 5 - sealing element; 6 - elastic element; 7 - self-locking nut; 8 - hole.

The main feature of the proposed roller is the presence of sealing elements protruding above the surface of the hollow cylinder, mounted on elastic elements.

Due to the fact that the compacting elements form a wave relief on the soil surface, “there is a difference in heating and illumination of plants from different side parts of ledges and depressions, which increases the difference in the development of plants during the period of autumn preparation for winter. This contributes to the survival of plants in the winter, as well as their subsequent growth and efficient development. Depressions, oriented in an appropriate way, accumulate snow during the cold period of the year, and ice during thaws, saving plants from death” [10]. These advantages of rolling the soil with wave rollers are especially important for winter crops sown in the zone of risky farming.

For a qualitative assessment of the operation of the wave roller, we conducted studies directly in the conditions of real production on the chernozem soils of the Ulyanovsk region. Preparation of the field for sowing included standard operations of moldboard plowing and subsequent cultivation.

Before sowing barley, soil moisture was measured in the seed layer [10]. To do this, we used a resistor-type moisture meter TDR 100 (Figure 2).
As a result of the research, it was found that the indicator of soil moisture before rolling corresponds to agrotechnical requirements.

Sowing was carried out using a seeder SZ-5.4. At the same time, for comparison, post-sowing rolling was carried out with two rollers: a new wave roller (Figure 3) and a commercially available KKZ-6 roller.

The quality of the work of both rollers was evaluated using the optimization criterion (coefficient of compliance with the \( k_{sc} \) standard), which is an integrated indicator that takes into account the degree of compliance of the structural composition and density of the soil with agrotechnical requirements (table 1).

Density is one of the most important characteristics of the soil, as it plays an important role in the development and growth of crops. The desired density value, and more specifically, 1200 kg/m\(^3\), is mainly provided by surface tillage, more precisely by rolling. If the density value corresponds to the required agrotechnically specified interval, then the seeds of the planted crops are in good contact with the soil, and are also supplied with the necessary moisture, air and nutrients.

To determine the density of the soil at the experimental and control sites, a density meter was used (RF patent for utility model № 149064), which measured the density of the soil in the depressions and in the crest of the wave relief formed by the developed roller.

The structural composition of the soil or, in other words, the structure is soil aggregates, the sizes of which vary from soil dust, which is less than 0.025 mm, to soil blocks, the size of which is more than 50 mm. At the same time, in order to obtain more yield, the sizes of soil aggregates should be in the range from 0.025 mm to 50 mm.

In the course of field studies of the wave roller, soil samples were taken to determine its structural composition. To ensure better and more reliable results, soil samples were taken in three-fold repetition along the diagonal of the treated area. When assessing the structural
composition of the soil, soil samples must be completely dried, for this we placed them in a
drying cabinet. Next, it is required to divide the samples into different fractions using a set
of sieves with hole diameters from 50 mm to 0.025 mm, equipped with a vibrator. Filling
the sample into the upper sieve, the device turns on for a minute, during which the sample
is divided into fractions. Each fraction of the sample was weighed separately and the result
was entered into the table, and to increase the quality of the experiment, the total mass of
the sample fractions was compared with the initial mass of the sample, the deviation should
not exceed 2%.

<table>
<thead>
<tr>
<th>Ice rink</th>
<th>Optimization criterion $k_{xc}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave roller</td>
<td>0.81</td>
</tr>
<tr>
<td>Ring-toothed roller</td>
<td>0.57</td>
</tr>
</tbody>
</table>

According to the data obtained, it can be concluded that the density and structure of the
soil after its treatment with a wave roller is much better than after treatment with a ring-
toothed roller KKZ-6.

As a result of improving the quality of soil cultivation with the proposed roller, we
obtained earlier shoots of barley, while their height on the seventh day after sowing was on
average 10% higher than that of the same crop rolled by KKZ-6 (figure 4).

![Fig. 4. Barley seedlings rolled with a wave roller.]

### 3 Results

After the ripening of barley (figure 5), samples were taken to determine the yield of barley.
Sampling was performed from one square meter in four repetitions for each rink. Then the
harvested barley was weighed, and the measurement results were entered in table 2.
Fig. 5. Barley before harvest.

Table 2. The results of measuring the mass of samples to determine the yield of barley from 1 m$^2$.

<table>
<thead>
<tr>
<th>Ice rink</th>
<th>Mass of barley crop samples, g</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$m_1$</td>
</tr>
<tr>
<td>Wave roller</td>
<td>486.6</td>
</tr>
<tr>
<td>Ring-toothed roller</td>
<td>443.2</td>
</tr>
</tbody>
</table>

According to the data presented in table 2, it was found that the rolling of barley crops with the proposed wave roller gives an increase in yield by 5.2 c/ha, and the relative increase in yield was 12.4% in comparison with the mass-produced roller of the KKZ-6 brand.

4 Discussion

The result of our field experiments on barley crops confirmed an improvement in the quality of soil rolling (from the standpoint of compliance with the density and structure of the soil with agrotechnical requirements), if we compare the treatment with a commercially produced ring-spur tillage roller with the treatment with a wave roller developed by us. This made it possible to increase the yield of the cultivated crop by 12.4%.

5 Conclusion

Summing up the results of the work we have done, it suggests that the quality of rolling the soil with the developed wave roller ($k_{se} = 0.81$) is significantly better than that of the mass-produced ring-spur roller ($k_{se} = 0.57$). Thanks to this, the yield of barley was increased by 5.2 q/ha.

Acknowledgments

The work is carried out within the framework of the grant of the President of the Russian Federation for state support of young Russian scientists - candidates of sciences MK-5360.2022.4.
2. *New technologies and means of mechanization in crop production* 2018 (Stavropol: Stavropol State Agrarian University) 380
3. Agricultural machinery and technologies 2006 (Moscow: Kolos) 647
4. *Fundamentals of soil destruction by mechanical means* 1968 (Moscow: Mashinostroenie) 367
6. *Designing tillage machines* 1965 (Moscow: Mashinostroenie) 312
9. *Soil tillage machines with conoidal rotary working bodies* 2001 (Kazan: Kazan State Agrarian University) 328