

### Theoretical Analysis of the Impact of Minimal Tillage on the Soil

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#### ANNOTATION

*The solution to this problem is to use a mechanical-bionic approach to analytically describe the optimal shapes and parameters of the working bodies of soil-cultivating rollers in order to more effectively influence the soil. Currently, bionics methods are widely used in the development of design schemes and justification of the parameters of various agricultural and soil-cultivating machines. Therefore, to justify optimal parameters and operating modes, it is necessary to use agricultural technical bionics in combination with a biosystems approach.*

An increase in agricultural yields is inextricably linked with improving the quality of soil preparation, the purpose of which is to create the required structure and density of the seed layer. In this regard, special attention should be paid to the processes of loosening, rolling and leveling the soil. Existing designs of serial tillage rollers cannot provide the required quality of loosening, compacting and leveling the soil surface, especially in soil-climatic zones with insufficient precipitation. The purpose of the research is to develop theoretical prerequisites for the bionic substantiation of the parameters of the working parts of a ring-cutting soil-cultivating roller.

**Material and methods.** The scientific foundations for substantiating the rational parameters of agricultural machines and tools were laid by Academician V.P. Goryachkin, who was the first to apply the laws of mechanics to the description of the operating processes of agricultural machines and implements. Based on an in-depth analysis of the literature, which described methods of preparing soil for sowing, in particular, it was revealed that many scientists paid great attention to the process of compacting the soil using tillage rollers. The theoretical foundations of the process of soil compaction were developed by such scientists and researchers as V.M. Akulova, A.K. Amatanyuk, A.E. Benkendorf, P.M. Vasilenko, A.A. Gelashvili, V.P. Goryachkina, A.I. Derepaskina, V.N. Drobot, A.F. Zhuka, N.I. Klenina, A.A. Knausa, B.M. Kozyreva, Yu.A. Kuznetsova, V.I. Kurdyumova, V.B. Lovkisa, A.P. Mayevsky, N.K. Mazitova, V.A. Milyutkina, A.F. Poletaeva, N.E. Rudenko, S.S. Sahakyan and many other scientists. The works of these authors describe the processes interaction of the working surface of the roller with the soil, as well as their design parameters. The works of Yu.A. are devoted to the practical aspects of the process of surface tillage. Vinogradova, V.V. Golubeva, N.N. Krashennnikova,

Yu.I. Kuznetsova, V.P. Marmalyuka, P.N. Rozhkova, I.M. Sukhova, V.M. Shevelev and other authors. An analysis of many sources of scientific and technical literature devoted to the technological process of compacting soil with tillage rollers has shown that this topic has been studied quite well. However, it was revealed that the designs of modern soil-cultivating rollers have many shortcomings, which does not allow them to meet the quality requirements for this operation. Also, modern roller designs are not universal enough and do not have the necessary adjustments and design parameters that allow expanding their technological capabilities. Thus, the task of improving the designs of soil-cultivating rollers is currently unsolved and urgent, so there is a need to carry out further research that will allow us to find new technical solutions to improve the designs of soil-cultivating rollers and other tools for compacting soil. Taking into account the above, there is a need to develop new designs of tillage rollers that are capable of meeting agricultural requirements for the quality of surface tillage, reducing operating costs and increasing the yield of cultivated crops. The purpose of this work is to improve the quality of the technological operation - compacting by developing a new soil-cultivating roller, which is able to ensure the fulfillment of agrotechnical requirements for surface tillage and increase the yield of cultivated crops.

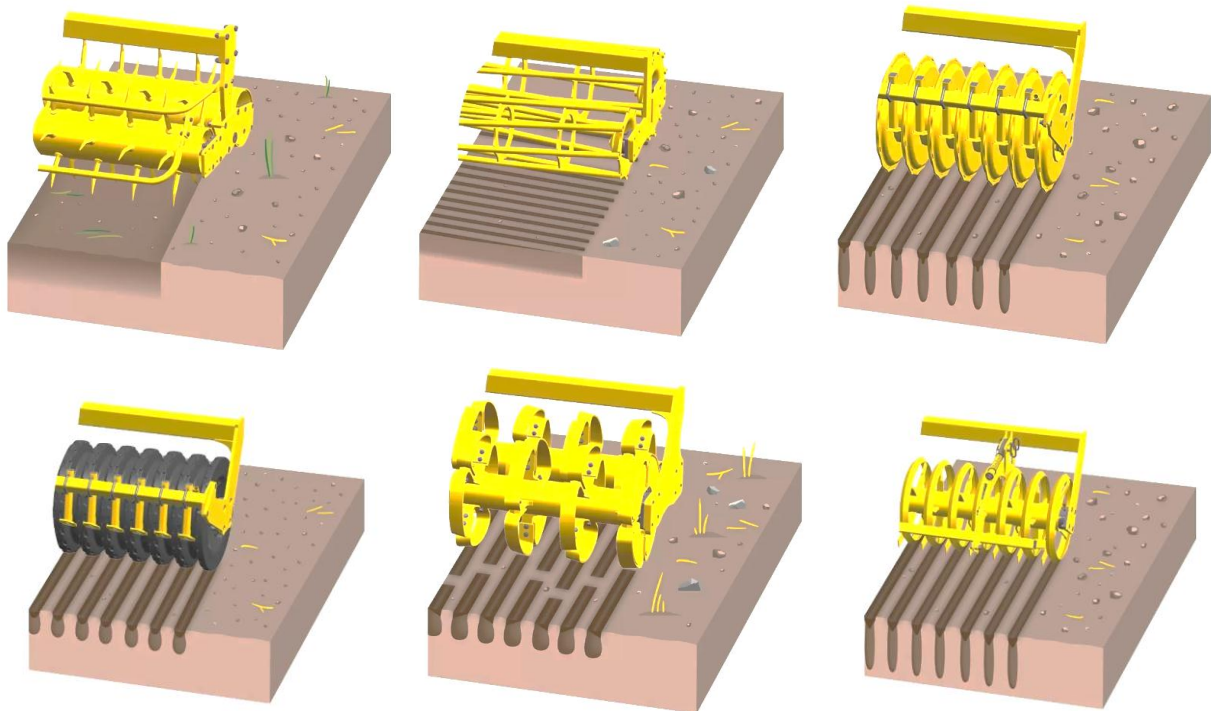
To achieve this goal, the following research plan has been developed:

- analyze the means of mechanization of surface tillage and determine ways to improve their designs;
- develop a soil-cultivating roller, theoretically substantiate its design and operational parameters; - conduct field studies of the developed soil-cultivating roller with subsequent determination of the optimal parameters and modes of its operation;
- conduct production studies of the developed soil-cultivating roller with theoretically and experimentally substantiated parameters and operating modes and calculate the economic effect of introducing the developed roller into production

To cultivate the soil in preparation for sowing, steam cultivators, flat cutter cultivators, harrows, cutters, rollers, as well as combined units that perform several technological operations in one pass are used. On light sandy and sandy loam soils in areas of sufficient moisture, when cultivating spring crops after harrowing, one is limited to one pre-sowing cultivation to a seeding depth (5-6 cm) with harrowing and leveling the soil surface. For this purpose, steam cultivators KPS-4A, KShU-6-12, KShP-8 and others equipped with lancet, loosening working bodies with rigid and spring struts and additional leveling working bodies (harrows and rollers of various designs) can be used. On heavy clay and loamy soils, for better aeration and warming, deeper loosening is recommended - up to 10÷12 cm. For these purposes, heavy disc harrows, heavy cultivators of the KPE3.8 type, chisel cultivators and other implements are used. It is also possible to use units with active working bodies. If the field is heavily infested with root shoot weeds, it is advisable to use plowshare ploughs or plows that perform shallow plowing (16÷17 cm) with harrowing or rolling to level the soil surface. To cultivate fields after perennial grasses, heavy disc harrows BDT-3, BDT-7, BDT-10 are used in conjunction with tooth harrows, which effectively loosen the soil without extracting perennial grasses to the surface of the turf. The use of combined soil-cultivating units such as RVK-3.6 is effective; RVK-5.4, as well as milling cutters and milling cultivators KFG-3.6, which loosen the soil, crumble blocks, level and compact the surface in one pass. This ensures uniform placement of seeds, increasing the completeness of seedlings and increasing the yield of cultivated crops

Modern science has developed a number of methods and technologies aimed at protecting soils and preserving the fertile layer. The latest soil protection technologies include adaptive landscape, precision, unmanned farming, etc., which are based on the principles of cultivating agricultural crops taking into account the soil and climatic characteristics of the territory, including the use of geographic information systems that can differentiate each step of the

technological process, taking into account field inhomogeneity. In tillage operations, it is recommended to follow the path of reducing the depth and frequency of tillage, giving preference to cultivation to a depth of 5-10 cm or less. As working bodies, it is proposed to use soil-filling tools that have a minimum angle of attack and a minimum number of surfaces along which the soil moves during the cultivation process. In this case, the impact on the soil will be minimal, which means its structure will be better preserved with lower energy costs. It is known that soil cultivation should be carried out during the period of its physical ripeness, when soil resistance indicators are minimal and amount to about 1 kgf/cm<sup>2</sup>. This means that to overcome the total resistance force, it is sufficient to use light equipment with moderately active working parts. The fact that soil moisture and shear resistance are in a hyperbolic relationship shows that tilling the soil only during the period of physical ripeness is both an energy- and soil-saving .



There is not enough research on the effect of soil compaction before sowing; there are much more scientific works related to soil compaction by the propulsors of tillage machines and implements. However, it is reliably known that rollers provide the soil density necessary for seeds, destroy large soil lumps, level the field surface and ensure the rise of moisture from the lower layers of the soil. Rollers with a non-smooth working surface compact the seedbed soil layer and create a mulching surface layer. The use of rollers before sowing small-seeded crops is mandatory. To theoretically determine the rolling resistance force of a roller working body, use the formula of Academician V. P. Goryachkin

$$P = 0,86 \cdot \sqrt[3]{\frac{G^4}{bqD^2}} \quad (1)$$

where  $G$  is the weight of the roller, N;  $q$  – coefficient of volumetric soil collapse (for freshly plowed soil  $q = 2 \div 4$ ; for stubble, fallow  $q = 5 \div 7$ ; for stubble, meadows  $q = 10 \div 20$  N/cm<sup>3</sup>);  $b$  – drum width, cm;  $D$  – drum diameter, cm.

Formula (1) is applied to smooth rollers. For rollers with a non-smooth working surface, the rolling resistance is 10-30% greater. Lattice rollers (Figure 1) consist of two main elements: disks mounted on an axis with the possibility of their rotation, and working elements that connect these disks. Lattice rollers are divided into three groups, depending on the type of

working elements: slatted, rod and mesh. "Based on the way the working elements are arranged, lattice rollers can be divided into inclined, screw, parallel, cross and v-shaped. Also, according to the method of fastening and the method of connecting the working elements, lattice rollers are respectively divided into rigidly and elastically fixed and fixedly and movably connected" "Depending on the shape of the working elements, lattice rollers are used for different types of impact on the soil as part of a combined unit, such as crumbling, leveling, surface loosening and compaction, and it is also possible to combine several types". The star and toothed rollers shown in Figure 1 are used to process the soil surface and efficiently destroy lumps. After the treatment has been carried out using these rollers, a mulched top soil layer is formed on the surface, reducing the volume of evaporated moisture. Moreover, the use of these rollers does not allow achieving the required soil density in the area where the seeds are located. This leads to a decrease in seed germination, and, as a result, to lower yields. Cable rollers (Figure 1) usually consist of a number of disks mounted on an axle and cables that are threaded through the disks. The disks can be rigidly mounted on an axle or mounted with the possibility of rotation on an axle. Cable rollers are classified into the following types: with helical, cross and parallel winding of the cable. Cable rollers are used to crush large soil lumps located on the soil surface. However, these rollers do not compact the soil well, as they have insufficient mass.

The winding can be directed to the left, to the right. It is also possible to perform combined winding. Through the use of these rollers, a loose upper layer with a finely ridged profile is formed. The formation of such a layer has a positive effect on the quality of the structural seed layer. But this design does not allow achieving the optimal value of soil density and its uniformity over the field area.

According to the geometric shape of the working surface, tillage rollers can be divided into the following types: cylindrical, conical, and barrel-shaped rollers. "Cylindrical rollers (Figure 1) can be made with a smooth surface, elastic working elements, protrusions, spiral and teeth". The disadvantage of smooth rollers is that after rolling wet clay soils, a hard soil crust is formed, which prevents seed germination. Smooth cylindrical rollers serve to compact the surface layer of soil and crumble lumps. The pressure on the soil is adjusted by adding sand or water ballast. "However, the roller has significant disadvantages: after the smooth roller passes over the soil surface, large lumps of soil are pressed into the soil surface, remaining undestroyed; and also after the passage of a smooth soil cultivator, a soil crust is formed on the soil surface, which interferes with seed germination."

To improve the quality of rolling with a cylindrical roller, holes of different shapes are cut out on its outer surface. Also, cylindrical rollers are additionally equipped with working elements (knives, hammers and others), which improve the process of crumbling soil lumps that enter through the holes into the inner surface of the roller

One such example of an improvement on a cylindrical roller is the tillage roller shown in Figure 1. The purpose of this improvement is to intensify the crushing of soil clods. The tillage roller consists of a smooth hollow cylinder, the surface of which is equipped with rectangular holes located at regular intervals in a checkerboard pattern. Flat knives fixed at an obtuse angle to the surface are placed in the indicated holes in the diagonal direction. This design makes it possible to intensify the crumbling of soil clods, and a crust does not form on the soil surface. However, this design has not found much use at present. The clod-crushing type of rollers includes the gear-slat structure shown in Figure 1 which consists of disks placed on an axis. The discs are equipped with toothed bars placed parallel to the axis. Each strip has slots and bent teeth. The work is accompanied by stirring that helps dry out the soil, as well as intensive crumbling of lumps. Moving the implement to roll the soil over the surface leads to its leveling and compaction. In this case, soil lumps are not destroyed, since the surface of the rollers is smooth. The lumps are pressed into the surface, and a hard soil crust is formed on the surface if the soil being rolled is wet. Depending on the purpose of cultivation, tillage rollers can be used, which

form the profile of the soil surface. After treatment, the profile of the soil surface can be: smooth, furrowed, holed or ridged. The shape of the soil surface profile is selected based on the climatic conditions of the region and soil properties

New design solutions should provide higher quality indicators for the use of tillage units. In order to improve the quality of their use, it is necessary to improve the design and operating parameters taking into account various soil and climatic conditions. Thus, it is necessary to ensure the versatility of the designs of tools and machines used for tillage, taking into account the characteristics of the environment in which the tillage is carried out. The structures being developed must ensure optimal soil density and structure at the lowest operating costs while meeting safety requirements for the natural environment

To create optimal conditions for the growth and development of plants, soil rolling is almost always used. The soil is rolled, depending on the situation, either before or after sowing. Rolling is carried out most often with the help of soil-cultivating rollers; they are used as separate tools, or as part of 42 soil-cultivating units, which include a whole complex of soil-cultivating implements. Tillage rollers have a wide variety of designs, the classification of which allows, using scientific and technical literature, to note and select the main ways to improve the designs of tillage rollers, based on the modular design principle, which is a stage in the development of a controlled technological process. The analysis of tillage rollers made it possible to identify shortcomings in their designs, which do not allow them to fully meet the agricultural requirements for tillage. The main disadvantages of tillage roller designs include: excessive metal consumption; pressing in soil lumps, leaving them undestroyed or, on the contrary, destroying them into too small fractions, the lack of a sufficient number of adjustments that make it possible to provide the necessary roller pressure for different types of soil, and also many rollers cannot be used as part of a combined soil-cultivating unit. Taking into account the shortcomings listed above, we have developed a scheme that includes the main ways to improve soil-cultivating rollers.

For the further development of agriculture, the development and creation of machine and tractor units is required, with the help of which it is possible to carry out high-quality pre-sowing tillage of the soil, while reducing 43 labor costs and saving fuel consumption. The main result of scientific research should be the development, application and implementation of these devices. It is planned to increase productivity by combining various tillage machines for pre-sowing tillage into a single module, which also includes rollers. This method is based on the block-modular design principle. The next step is to reduce the metal capacity by 15...20% through the use of lighter metal alloys and by reducing the diameter of the rollers to 400...500 mm. The use of rollers in a single module with tillage implements or seeding machines makes it possible to reduce the amount of harmful emissions into the environment and reduce fuel consumption, since using all units in a single module reduces the number of passes of tillage units across the field. Designing the designs of soil-cultivating rollers based on the above principles will make it possible to create a soil-cultivating roller capable of performing the compacting operation with the required quality.

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