Justification of the rotary working body for soil cultivation when fertilizing in the garden

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Abstract. The paper considers the effect of milling the soil for fertilizing with the ability to obtain a soil structure, in which there will be a uniform distribution of fertilizers for their more active assimilation. The device of the rotary working body for the implementation of this technological process is presented. The theoretical substantiation of the curvilinear working surface of the knife is carried out to obtain the optimal structure of the soil. The dependence of the shape of the knife working surface on the parameter of the parabola $p$ is plotted. The results of experimental studies are given. It was concluded that the quality of soil cultivation required by agricultural technology by this working body with a knife working surface made in a parabola was obtained with a parameter $p = 2.5$.

1. Introduction
Ensuring the country's food security is a strategic task, the achievement of which is based on the formation and development of an import substitution system. Currently, horticulture is not considered a priority branch of the state's agri-food policy, although its products contribute to maintaining the population's health. Due to its production, the country provides only 25-30% of the minimum required amount of fruits and berries. Fruit imports to the Russian Federation in 2000–2014 increased 2.7 times, and production – only 1.1 times, that is, it can be stated that domestic production remains at a low level with an increasing demand for it. [1-2]

Efficient production of horticultural products is possible with the introduction of intensive technologies that involve the use of high-performance machines that ensure compliance with all agrotechnical requirements when performing basic technological operations [2, 3].

Most researchers note that because of the loss of humus, calcium, and magnesium, the stability of the soil absorbing complex decreases [1]. In the soil, the content of organic and organomineral colloids decreases, which plays a significant role in forming a water-resistant structure. The loss of humus, calcium, and magnesium causes a decrease in the aggregation of soil particles. Highly dispersed clay minerals of the montmorillonite and hydromica groups, released during the destruction of water-resistant aggregates, for the above reasons, freely move with water currents and fill large inter-aggregate and intra-aggregate pores, which leads to compaction of the soil and structural aggregates.

Analysis of the results of many studies shows it is possible to obtain a soil structure in which there will be a uniform distribution of fertilizers for their more active assimilation when milling the soil. A more uniform crumbling and a significant increase in the air supply of the soil subjected to rotary tillage contribute to the strengthening of both microbiological processes and the mineralization of its reserves.
In comparison with passive working bodies, milling tools can loosen the soil better, cut weeds more completely, embed organic fertilizers and plant residues more evenly into the soil, and mix it with it [2, 4].

It should be noted that the degree of efficiency of fertilizers largely depends on the method (surface or subsurface), place, time, and depth of application [5]. This circumstance is due to the structural features of the root system of trees.

In the autumn, the formation of primary roots can stop at the stage of root tubercles, the number of which is determined by the genotypic characteristics of plants and the level of agricultural technology. The more root tubercles are laid in the autumn, the higher the activity of the root system at the beginning of the growing season of the next year. Root buds awaken to active growth unevenly during the growing season. The speed and timing of their awakening depend on external conditions, hereditary characteristics, and the age of plants [6-8].

The increase of the utilization rate of fertilizers to the maximum possible value and get the return of fertilizers directly in the year of their application. This result is possible by ensuring that fertilizers are applied to the area where the central part of the active roots is located, without damaging them simultaneously, when the largest suction roots are active.

It has been established that the main factors of rotary machines that affect the quality of soil cultivation and energy indicators include kinematic parameters (the circumferential speed of the drum, the forward speed of the machine, feed to the knife, etc.), and design parameters (the diameter of the drum, the shape of the working body). Therefore, when developing a rotary working body for soil cultivation, it is necessary to select its optimal shape.

It is possible to improve the quality of the soil preparation process for applying fertilizers with their simultaneous incorporation at a given depth of the root system of fruit trees. The condition for this result is using a working body for soil cultivation in the form of a cut-out disk with working elements fixed on it, made in a parabola.

### 2. Materials and methods

The works review allows concluding that the curvature of the knife surface determines the nature of the deformation and movement of the soil under the action of the rotary working body. Therefore, for processing the soil with obtaining a particular structure for applying fertilizers, we proposed a working body (Fig. 1), made in the form of a cut-out disk, with teeth, one cutting edge of which is made along a straight line 4, and the other edge 3 – according to the law given by the formula (1). On edge, made in the form of a parabola, working elements are fixed in the form of knives with a cutting edge consisting of two parts: one 6, which is set along the periphery at an angle $\alpha_1 = 70 \ldots 65^\circ$ straight, 60 mm long, the other five is made curved along the entire length of the tooth to its curved edge [8].

![Figure 1. Rotary working body: 1 – disk; 2 – tooth; 3 – parabolic edge; 4 – straight cutting edge; 5 – the surface of the knife is curved; 6 – edge of the straight surface of the knife](image-url)
3. Results of the study of the rotary working body

Mathematical model of the shape of the working surface of the knife of the rotary working body

\[ y = \frac{x^2}{2p}, \]  

where \( p \) is the parameter of the parabola.

According to the mathematical model (1), the dependence of the working surface shape of the knife on the parameter of the parabola \( p \) is plotted (Figure 2). The range of variation of the parabola parameter \( p \) 2.5 ... 3.5 is determined based on exploratory experiments.

![Figure 2. Dependence of the shape of the working surface on the parabola parameter \( p \): p1 = 2.5; p2 = 3; p3 = 3.5.](image)

Analyzing the graphs (Figure 2), we can conclude that with an increase in the parameter \( p \), the curvature of the working surface increases.

To clarify the processes occurring in the soil during its processing by this rotary working body and assess its design parameters’ influence on the resulting structure, we carried out experimental studies.

The studies were carried out in a garden on tinned soil, with a 16 – 18% moisture content, a hardness of 32 kg / cm². Moisture was determined by drying hardness using a Revyakin hardness tester. The aggregate composition was determined by the method of N.I. Savinova. Repetition – 3-fold [7].

Figure 3 shows the dependence of the percentage of soil fractions in size from 10 to 0.25 mm and > 30 to 10 mm, depending on the parabola parameter \( p \).

The analysis of the dependence shows that with a decrease in the parameter \( p \) of the parabola, i.e., the radius of curvature, the number of soil particles of the required fraction with a size from 10 to 0.25 mm increases. So, with \( \alpha = 200 \) and \( p = 3.5 \), there were 56.8% of them, with \( p = 3 \), 61.8%, and with \( p = 2.5 \), the largest number of them was obtained 65.5%. However, with a further decrease in the radius of curvature, the opposite process was observed, i.e., the amount of this fraction decreased, so, at \( p = 2 \), they were 58.7%.
4. Conclusion

Thus, it follows that using a rotary working body when applying fertilizers can increase their efficiency by obtaining a structured soil of a particular granulometric composition. In this case, the number of soil particles of the fraction we need depends on the curvature of the surface of the knife of the rotary working body. So the quality of soil cultivation required by agricultural technology by this working body with a knife working surface made in a parabola was obtained with a parameter $p = 2.5$.

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