Technology and tools for strip tillage in the energy-saving system of agriculture in Volgograd region

I B Borisenko and M V Meznikova
Volgograd State Agrarian University, 26 University Avenue, Volgograd, 400002, Russia
E-mail: borisenivan@yandex.ru

Abstract. The article highlights the results of research in strip farming. The method of minimum soil tillage, a resource-saving working body ROPA and a soil tillage tool for strip ripping OMPO-5.6, which are designed to perform fine soil tillage with strip deepening, are proposed. Adjustment of loosening depth from bit is achieved within the range of 0.25-0.4 m and is selected taking into account the crop grown in the farm. Availability of undercutter tine allows to regulate parameters of continuous ripping zone. Parameters of treated and untreated strips are regulated by location of undercutter paw. The design of the tool provides a smooth adjustment mechanism by which the width of the cultivated strip can be changed within 0.25-0.35 m. This makes it possible to use the implement for different tilled crops. The technological process carried out by this working body helps to reduce the wounding effect on the soil through a simple technical solution. Installation of side undercutting discs allows cultivating the soil within a given strip, and the process of cutting the soil in a blocked environment improves the quality of treatment.

1. Introduction
One of the civilization development criteria is the state of natural resources. This aspect is especially pronounced in agriculture. In recent decades, a man uses soil, air and water too intensively. The cause of environmental problems is, among other things, the result of frequent continuous cultivation and numerous machine passages in the field [1, 2]. The agricultural production industry is an important area of science and technology development. At the same time, its products take a leading place in the development of the Volgograd region [3]. The main object of cultivation and means of production in crop production is soil. Soil is a living organism that needs to be treated with care. The impact of man and machinery on soil resources in recent decades is increasingly leading to the emergence of undesirable processes [4]. Therefore, studies in the field of soil fertility conservation, the use of technologies and technical means developed using scientific approach to resource conservation in crop production are very relevant [5, 6].

In recent years, the competent application of resource-saving technologies is not only resource-saving, but also economically beneficial, as they allow to reduce costs and achieve higher yields of crops. At present, the resource-saving approach is actively implemented through minimal-till, zero tillage technology (no-till) and Strip-till technology [7]. Minimal tillage consists of one or a number of small tillage operations with cultivators or disc harrows, and it is important to keep stubble residue mulch on the surface and on top of the soil for subsequent sowing under these conditions [8].
The result of the scientific approach to the development of strip farming technology is especially vivid. The technology provides for the treatment of soil within the lane where a cultivated plant grows and develops, and the technological operations help to create favorable conditions for their growth and development. The row spacing remains untreated, which allows to accumulate plant residues and thus reduce erosion processes, retain moisture, make the soil decompaction in the untreated strip naturally. Hoarse vegetation in the row spacing is in worse conditions than the cultivated plants in the treated strips, worse development and dying. The best results are achieved when growing in strip farming system of row crops, responsive to the depth of processing (sunflower, corn, soybean, sorghum, mustard and others). Good prospects in the application of strip farming technology in melon, vegetable and cotton crops. These directions show a positive effect in economic and energy aspects when growing these crops with row width of 0.9 and 1.2 m [4, 5]. On the territory of the Volgograd region strip farming is applied on the area of 914 thousand ha, and on the whole Russia - 14450 thousand ha. This emphasizes the prospects of developing the chosen research area.

2. Materials and methods
The possibility of minimizing soil tillage depends on the compliance of agroecological conditions of the land plot with the cultivated crop, and the intensity of cultivation - on the quality of soil itself [9]. Factors for selecting the minimum tillage system are significant deviations from the normative indicators of density, consistency, hydromorphism and salinity. The presence of other undesirable characteristics of the soil environment are also taken into account when choosing methods to regulate the condition of the arable horizon. This affects the development of necessary approaches to the formation of energy-saving principles and systems of soil treatment [3, 10].

In this regard, we developed a method of minimum soil tillage (RF Patent 2612798), resource-saving working body ROPA (RF Patent 2489826) and a soil tillage tool for strip loosening OMPO-5.6 (RF Patent for useful model №154634), which perform fine tillage of soil with strip deepening.

Figure 1 shows the OMPO-5.6 tool, the main components of which are: frame 1, chisel type working tools ROPA 2, bracket for attaching working tools 3, depth control mechanism for working 4, trailer 5, tilting console 6, stand 7.

Figure 1. OMPO-5.6 minimal strip processing tool: 1 - frame; 2 - working body; 3 - bracket; 4 - wheel mechanism; 5 - hitch; 6 - console; 7 – stand.

The central place in the working body of the ROPA (Figure 2) is occupied by a curved stand 1, made with an intra-soil bend. There is a blade on the stand 2. A shoe with an overhead bit 3 is fixed at the bottom of the working body. On the bend back side of stand 1 straight part with a pair of bolts 4 is fixed undercutting paw 5 of one-sided type, acting as a cutting knife. The paw has a technical
possibility to move along the rack 1 in height. For this purpose, there are holes 6, made in 50 mm increments. Chisel with bolt fixing is installed on the heel of the stand. During the movement of machine-tractor unit the technological process of loosening is carried out under the action of stretching and compressive forces, which are the cause of intensive destruction of internal soil bonds. With the help of bit, the cut layer of soil is lifted, bent and stretched in both planes. Necessary zone of continuous loosening is formed by undercutting the inner soil ridges with the help of undercutting paw, which has the ability to move vertically along the rack.

![Figure 2](image)

**Figure 2.** Working body ROPA: 1 - rack; 2- blade; 3- chisel; 4- fastening bolt; 5- paw; 6- attachment point of the trimming foot.

Cultivation of tilled crops has its own features. Pastoral crops are responsive to deep soil cultivation. Therefore, the depth of cultivation and the ability to regulate it is very important. In areas of risky agriculture, soil tillage should be aimed at extensive accumulation of precipitation and its retention in the soil. Therefore, it is recommended to use Strip-till tillage tools for tilled crops. A machine system is needed for Strip-till cultivation. For this purpose, working tools with chisel rack are produced in series. But in their design, there are front row cleaners, which remove part of the untreated soil. This is necessary to reduce the spread of the ripping zone from the bit. It also helps to keep constant sizes of the cultivated 0.25 m wide strip. Depth of the treated strips with serial working tools (for example, Orthman) is up to 0.25 m. If the depth of the treated strips is further increased, the volume of treated soil from the bit will go beyond the zone of cleaners work. This will lead to the disturbance of strip dimensions. Also, there is no possibility to regulate width of treated strips in serial working bodies.

Scientists from the Volgograd State Agrarian University developed a machine for deep strip cultivation. This machine has the ability to regulate the parameters of the treated strip [RF Patents 2533038 and 2544950]. The depth of cultivation is limited by the critical depth of loosening (up to 0.37 m), while foreign analogues allow to cultivate soil to a depth of 0.25 m. It is also possible to use this machine for tillage for different crops due to the adjustable width of the cultivated strip (0.25-0.3 m) [4, 5].

The central place in the construction is occupied by a chisel rack. Chisel has low metal consumption and high reliability, easy in construction, can be supplied with replaceable bits of different width, energy efficient. Chisel rack is designed for soil loosening operation. If a seed line is installed on the chisel rack, it is possible to sow simultaneously with the ripping operation (in case of single-phase stripping). When installing the tubing, it is possible to simultaneously apply mineral fertilizers and ameliorants to the root zone of cultivated plants. To undercut weed plants or improve the quality of the treated strip on the chisel can be installed undercutting paws with the possibility of
vertical movement. The working width of the undercutting tines does not exceed the width of the treated strip.

![Figure 3](image_url)

**Figure 3.** Tool for deep strip tillage: 1 - parallel linkage system; 2 - mouldboardless ripper with a fertilizer guide; 3 - central circular knife; 4 - circular knives; 5 - rolling roller; 6 - chisel; 7 - trimming paw.

### 3. Results and discussion

Parameters of working bodies were defined and clarified by calculation and experiment. The following recommended parameters have been defined for the ROPA working body.

The depth of loosening from bit is set with accent on grown crop within 0.25-0.4 m. With the help of undercutter paw it is possible to provide a zone of continuous ripping in the range of 0.13-0.23 m, step is 0.05 m. Maximum depth of bit loosening is 0.4 m. When setting the ripping depth with the minimum value of 0.25 m, the continuous ripping zone will be 0.08 and 0.03 m. The ripping zone can be adjusted by installing the tine.

The internal 45-degree bend of the post, which is oriented towards the field cut, is designed for continuous ripping. It reduces the number of work tools on the implement frame by half.

In terms of technology, when using chisel ploughs, it is necessary to perform a continuous cultivation of soil to a depth that provides the functional state and development of the root system of plants crop rotation. It is also important to consider the need for maximum preservation and accumulation of moisture in the autumn-winter rainfall for planning the size of the soil deepening. [10, 11, 12, 13]. At the same time, energy-saving issues are also relevant [14, 15, 16]

Technological analysis of chisel working bodies, which were developed with our participation, is shown in Figure 4.

The area of soil deformation and quality parameters determine the conditions for plant growth and energy costs of treatment. The ratio of heights $h_p$ and $h_r$ affect the area of the inner soil ridge. The zone of continuous loosening is formed at $h_r < h_d$, the value of which is formed as a difference $h_m = h_r - h_d$.

At $h_r > h_d$ there is an exit of intrasoil ridge and the zone of untreated soil surface is formed (strip treatment). Let us denote the ratio of $h_r / h_d = K_r$ - the yield factor of the inner soil ridge.

When designing the working device for strip deep soil tillage the improved technological process of strip soil tillage was taken as a basis, which consists of the process of cutting the soil layer with cutting discs and simultaneous loosening with a chisel working device.

Analytical dependencies were obtained revealing the relationship between the parameters of the working body for deep strip tillage and the indicators of the technological process of strip deep soil tillage and physical and mechanical properties of the treated medium. As a result of theoretical
research and clarification of design parameters of the proposed working device, taking into account the requirements of the technological process of strip deep soil tillage, the optimal parameters of the disk knife were established.

Figure 4 - Schemes of loosening the soil from the chisel with chisel working bodies with different configurations of racks: a - straight rack; b - inclined rack; c - X-shaped rack; d - ROPA; e - profile of the bottom of the furrow.

4. Conclusions
The results of the conducted researches testify to the identity of transverse profiles of soil deformation as a result of application of straight and inclined props after chisel working bodies, which is straight, which is inclined (at an angle of 45°) props. When using the working device ROPA shape of the lower part of the profile is different. The area of soil deformation and quality parameters determine the conditions for the growth of plants and energy costs for its treatment. The ratio of height \( h_d \) and \( h_r \) effect the area of the inner soil ridge. The zone of continuous loosening is formed at \( h_r < h_d \), the value of which is formed as a difference \( h_m = h_d - h_r \). At \( h_r > h_d \) the ridge of the soil inside the ridge comes out and zone of untreated soil surface is formed (strip treatment).

The concept of the yield coefficient of the intrasoil ridge \( K_{ir} \), equal to the ratio \( h_r/h_d \), is introduced. In the study of the dependence of the yield factor of the intrasoil ridge on the depth of loosening at different widths of the interlaceration for the bit width of 0.06 m yield of the intrasoil ridge occurs at
h_r > 1, forming a strip of uncultivated soil. Therefore, to perform the adopted technological process of soil treatment, taking into account its minimization, at the stage of design or selection of a plough, it is necessary to set its specific design parameters (M, B, h_d).

When using strip autumn tillage for tilled crops with a row spacing of 0.7 m, you should take into account the required depth of loosening and technology of autumn weed control. At a ripping depth of less than 0.32 m for mechanical destruction of weeds on the working body ROPA should be installed undercut paw.

It is possible to combine the advantages of the chisel rack and serial working tools for stripping with the possibility of increasing the working depth up to 0.37 m, adjustable strip width can be used when using the working tool for strip deep soil treatment. On the basis of theoretical calculations and regularities, specified in the field conditions, it is necessary to set the following design parameters.

Diameter of discs taking into account the diameter of the axis should be not less than 0.696 m. To comply with technological requirements when processing strips to a width of 0.25 m, the center of the axis of disk blades should be on the vertical, carried out from the chisel bit to the soil surface, and the axis of discs should be located higher by 0.08 m from the soil surface. For a strip width of 0.35 m the disc axis should be extended forward by 0.025 m and lowered by 0.07 m.

The proposed technical solution allows for an adjustable volume bandwidth of the arable horizon while reducing the overall energy intensity of the ripping process. In addition, the use of the developed tool allows you to save on the material and technical equipment of the machine and tractor fleet, as it is possible to use it for various agricultural crops. At the same time, the quality of cultivated soil is improved while reducing the anthropogenic impact.

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