**Nargiza Toshpulatovna Nabikhujaeva**
PhD, Lecturer
Jizzakh Polytechnic Institute,
Jizzakh, Uzbekistan

# WIDE –COVERAGE CHISEL CULTIVATOR FOR PRE-SOWING SOIL PREPARATION

**Abstract:** This article analyzes the positioning and technological processes of the working elements of a wide-coverage chisel cultivator. The chisel cultivator is designed as a mounted structure, consisting of central and side sections. Hydraulic cylinders enable the transition from working to transport positions. The working elements are arranged in a staggered two-row configuration on the frame: the sweep width of the first row is reduced, while the second row's sweep width matches that of the ChKU-4 chisel cultivator. Both working elements are set to operate at the same working depth. This setup allows for energy savings and efficient resource use.

The findings contribute to research aimed at improving soil processing efficiency, advancing agricultural machinery, and optimizing production processes. Based on experimental results, the fourth variant of working elements is recommended for highly effective soil processing. This chisel cultivator is expected to meet agrotechnical requirements and reduce energy intensity. The scientific conclusions and recommendations presented in this article are essential for modernizing technical processes in agriculture.

**Keywords:** Wide-coverage chisel cultivator, sweep blade, right side section, left side section, wing opening angle, sweep width.

**Набихужаева Нагиза Тошпулатовна**
PhD, Преподаватель
Джизакский политехнический институт
Республика Узбекистан, г. Джизак,

# ШИРОКОЗАХВАТНЫЙ ЧИЗЕЛЬ- КУЛЬТИВАТОР ДЛЯ ПРЕДПОСЕВНОЙ ОБРАБОТКИ ПОЧВЫ

**Аннотация:** В статье анализируются расположение и технологические процессы рабочих элементов широкозахватного долотового культиватора. Культиватор разработан как навесная конструкция, состоящая из центральной и боковых секций. Гидроцилиндры обеспечивают переход из рабочего положения в транспортное. Рабочие элементы расположены в шахматном порядке в двух рядах на раме: ширина захвата первого ряда уменьшена, в то время как ширина захвата второго ряда соответствует ширине захвата культиватора ЧКУ-4. Оба рабочих элемента настроены для работы на одинаковой глубине. Такая конструкция позволяет экономить энергию и эффективно использовать ресурсы.

Полученные результаты способствуют исследованиям, направленным на повышение эффективности обработки почвы, развитие сельскохозяйственной техники и оптимизацию производственных процессов. На основе экспериментальных данных рекомендуется четвертый вариант рабочих элементов для высокоэффективной обработки почвы. Ожидается, что данный долотовый культиватор будет соответствовать агротехническим требованиям и снижать энергоемкость. Научные выводы и рекомендации, представленные в статье, важны для модернизации технических процессов в сельском хозяйстве.

**Ключевые слова:** широкозахватный долотовый культиватор, лемех, правая боковая секция, левая боковая секция, угол раскрытия крыльев, ширина захвата.

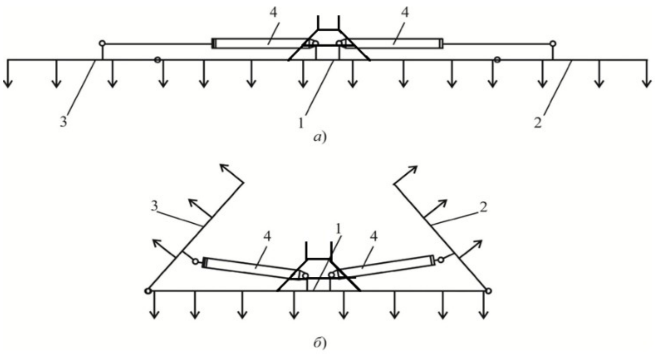
**Introduction** In agricultural production, it is essential to introduce modern technologies to improve efficiency and enhance soil processing procedures. This article provides information on the new design and technological processes of wide-coverage chisel cultivators. The wide-coverage chisel cultivator, with its central and side sections, reflects innovative approaches in agricultural machinery.

The features of this device, including the ability to transition from working to transport mode through hydraulic cylinders, and the staggered arrangement of working elements on the frame, play a critical role in efficient and economical soil processing. The working elements in the first row aid in soil loosening, while the second-row elements further expand the loosened zones created by the initial pass.

This article also analyzes approaches aimed at reducing energy consumption in the chisel cultivator's operation, assessing its efficiency in agricultural use. The research results support the implementation of new technologies, helping to conserve resources and optimize production in agriculture.

The wide-coverage chisel cultivator is constructed as a mounted structure, consisting of a central section (1) and two side sections (right 2 and left 3) (Figure 1). The side sections are connected to the central section by longitudinal hinges and can be shifted from working to transport mode and vice versa using hydraulic cylinders (4).

The working elements of the wide-coverage chisel cultivator are arranged in a staggered two-row configuration on the frame. Smaller-width sweeps are installed in the first row, while larger-width sweeps are used in the second row. For the chisel cultivator, the sweep width of the ChKU-4 chisel cultivator is set at 26 cm, and the sweep width of the working elements in the first row is set at 14 cm. The only difference between these elements is in sweep width; other parameters remain the same.




1 - central section; 2 - right side section; 3 - left side section; 4 - hydraulic cylinder.

**1-Figure. Diagrams of the wide-coverage chisel cultivator in working (a) and transport (b) modes.**

The technological process of the developed chisel cultivator proceeds as follows: the first-row working elements affect the intact soil, creating side-loosened zones for the second-row elements to operate in open-cutting conditions.

The second-row working elements then act on the clods surrounded by the loosened zones (created by the first-row elements), deforming these clods toward the loosened zones. As a result, energy consumption is reduced. [1].

**Methodology** The angles of the working organs are determined based on the following expression, which ensures that their resistance to pulling is low and the quality of soil clodding is high. [2]:

$$\alpha_{o'} = \arcsin\left\{\left\{\sqrt{\sin^2(\varphi_1+\varphi_2)+\left[2+\frac{1}{2}\cos(\varphi_1+\varphi_2)\right]\left[1+\cos(\varphi_1+\varphi_2)\right]}-\sin^2(\varphi_1+\varphi_2)\right\}:\left[2+\frac{1}{2}\cos(\varphi_1+\varphi_2)\right]\right\}, \qquad (1)$$

Here, $\varphi_1$ and $\varphi_2$ are the angles of external and internal friction of the soil, respectively, in degrees. By accepting $\varphi_1$= 30-35° and $\varphi_2$ = 40-45°, the calculations conducted based on expression (1) show that the clodding angles of the working organs should be in the range of 24-29°.

The opening angle of the wings of the working organs is determined according to the following expression, which ensures that they fracture the soil while consuming minimal energy during the working process. [3]:

$$2\gamma_{\breve{y}} = 2\,arctg\frac{\sqrt{9tg^2\phi_1+8}-3\,tg\,\phi_1}{2}\cdot ¿¿ \qquad (2)$$

By substituting the known values of $\varphi_1$ (30-35°) into this expression, it becomes clear that the opening angle of the working organs' wings should be in the range of 71-77°. Therefore, for the working organs to clod the soil while consuming minimal energy, their clodding angle should be in the range of 24-29°, and their opening angle should be in the range of 71-77°.

The width of the traces of working bodies $a_k$, their coverage widths $b_1$, $b_2$ and the longitudinal distance $L$ between them are the parameters determining their location in the frame.

We take the width of the traces of working bodies as 200-225 mm based on previous studies [1].

The coverage widths of the working bodies, first of all we determine the coverage width of the working bodies located in the second row of the chisel-cultivator. Taking into account that they work in open cutting conditions, we use the following condition [1]:

$$b_2 < \frac{2h\cos(\gamma_{o'} + \varphi_1)}{\cos\varphi_1 \cos\frac{1}{2}(\alpha_{o'} + \varphi_1 + \varphi_2)}, \quad (3)$$

Here, $h$ - is the working depth, in meters. When condition (3) is fulfilled, it ensures that the working organs operate in a fully open cutting condition, allowing for the soil to be broken down horizontally under the influence of their wings. This leads to the complete loosening of the treated layer and a reduction in energy consumption [1].

Taking $h=0.2$ m, putting the above values of $\gamma_{o'}$, $\varphi_1$, $\alpha_{o'}$ and $\varphi_2$ in (3), we determine that the coverage width of the working bodies located in the second row can be at most 32 cm. Based on the results obtained above ($\alpha_{o'}$=24-29°, $\gamma_{o'}$=71-77°) for installation in the second row of a comprehensive chisel-cultivator, the coverage width of the CHKU-4 chisel-cultivator is 26 cm, the grinding angle is 30° and the wings we can accept an arrow-shaped claw with an opening angle of 75°.

We determine the coverage width of the working bodies installed in the first row of a comprehensive chisel-cutivator, provided that the distance between them and the working bodies located in the second row is completely softened according to the following expression:

$$b_1 \geq 2a_k - b_2. \quad (4)$$

If we add the values of $a_k$ and $b_2$ determined above to this expression, it follows that the coverage width of the working bodies located in the first row should be at least 140 mm.

We determine the longitudinal distance between the working bodies by the following expression, based on the condition that soil, weeds and plant residues do not get stuck between them:

$$L \geq l + \frac{1}{2}\kappa_y b_2 tg\left(\gamma_{\breve{y}} + \phi_1\right), \qquad (5)$$

where $l$ is the length of the working body installed in the first row, m;

$k_y$ is a coefficient that takes into account the accumulation of soil, plant residues and weeds in front of the working bodies installed in the second row.

At the values of $l=20$ cm, $k_y$=2, $b_2$=26 sm, $\gamma_o$=37° and $\varphi_1$=30°, according to the expression (5) the longitudinal distance between the working bodies of the chisel-cultivator is at least 81.2 cm came out

We determine the coverage width of the chisel-cultivator according to the following expression [4]:

$$B \leq \chi \frac{R_N}{R_T^c}, \qquad (6)$$

where $\chi$– is the coefficient of use of the traction power of the tractor;

$R_N$ –is the tractor's nominal pulling power, N;

$R_T^c$ – resistance of the chisel-cultivator to traction, corresponding to one meter coverage width, N/m.

The traction resistance of the chisel-cultivator is mainly formed by the traction resistance of its working bodies. Therefore, its relative resistance to gravity can be found with sufficient accuracy according to the following expression:

$$R_T^c = \frac{R_1 + R_2}{2a_k}. \qquad (7)$$

Taking into account expression (7), expression (10) takes the following form:

$$B \leq 2\chi \frac{R_N \cdot a_k}{R_1 + R_2}. \qquad (10)$$

Taking $\chi$ =0,9 and putting the values of $a_k$, $R_1$ and $R_2$ determined above in the expression (10), the coverage width of the chisel-cultivator for aggregation with CLAAS AXION-850 and NewHolland T7060 tractors ($R_N$ = 40 kN) is greater with 6 m, and for "Magnum 8940", MX-255 tractors ($R_N$ = 50 kN) it should be 7,5 m was determined.

Knowing the coverage width of the chisel-cultivator and the transverse distance between the working bodies, we determine the total ny installed on it and the number of working bodies installed on its first ($n_1$ ) and second ($n_2$ ) rows:

$$n_y = \frac{B}{a_к} + 1 ; \tag{11}$$

$$n_1 = \frac{B}{2a_к} + 1 \tag{12}$$

and

$$n_2 = \frac{B}{2a_к} . \tag{13}$$

(The values of $B$ and $a_k$, as determined above, indicate that up to 39 working tools should be installed on the chisel cultivator, with 20 on the first row and 19 on the second row.

*a*) *b*)

**Figure 2. Views of the experimental model of the wide-coverage chisel cultivator in transport (a) and working (b) positions**

**Results**

Experiments on studying the types and arrangement schemes of working tools on the frame were conducted in the following five variants:

Variant 1. The working tools were arranged in three rows on the frame of the implement in a staggered pattern, as in the CHK-3.0 chisel cultivator, with loosening shovels installed in a stepped configuration across all rows (Figure 3a).

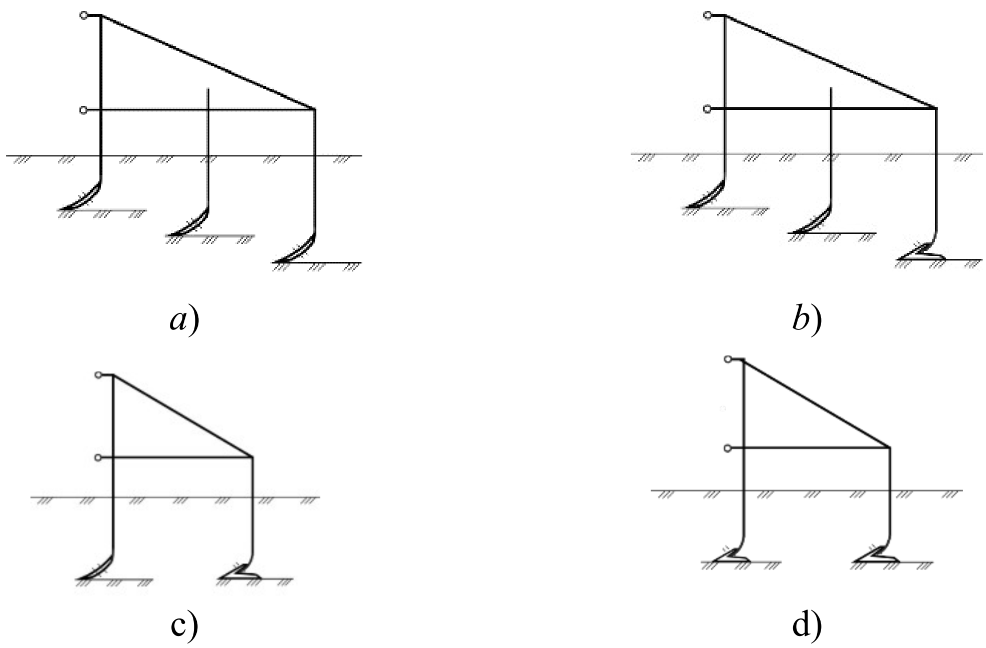
Variant 2. The working tools were arranged in three rows on the frame in a staggered pattern. Loosening shovels were installed in a stepped configuration on the first and second rows, while chisel-point shovels were installed on the third row (Figure 3b).

Variant 3. The working tools were arranged in two rows on the frame in a staggered pattern. Loosening shovels were installed on the first row, and chisel-point shovels, set at the same working depth, were installed on the second row (Figure 3c).

Variant 4. The working tools were arranged in two rows on the frame in a staggered pattern. The first row featured chisel-point shovels from the CHKU-4 chisel cultivator with a reduced working width of up to 140 mm, while the second row had chisel-point shovels with an unchanged working width of 260 mm, both set at the same working depth (Figure 3d).

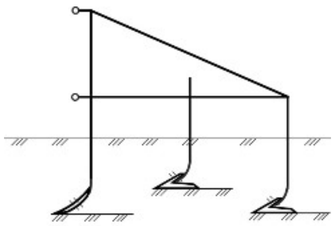
Variant 5. The working tools were arranged in three rows on the frame. The tools on the first and second rows were arranged in a staggered pattern, while those on the second and third rows were arranged in-line and in a stepped configuration. Loosening shovels were installed on the first row, and chisel-point shovels were installed on the second and third rows (Figure 3e).

In all variants, the longitudinal distance between working tools is 80 cm within a single row  the transverse distance between the positioned working tools was set at 40 cm.



*a*) *b*)

c) d)



e)

a, b, c, d, e - option 1, 2, 3, 4 and 5 working bodies, respectively

**Figure 3**. Types of work bodies and layout schemes

The experiments were conducted at operating speeds of 6 and 8 km/h.

**Discussion**

The results of the experiments are presented in Table 1. The following points can be noted:

- the working depth in the first and second variants was less than the designated 20 cm. The main reason for this is that, due to the staggered and stepped arrangement of the working tools in these variants, unloosened ridges (irregularities) form at the base of the tilled layer, which reduces the working depth;
- in variants 3, 4, and 5, the working depth matched the designated depth;

- the soil fragmentation quality met the requirements in all variants except the first, with over 80% of particles in the tilled layer being smaller than 50 mm;
- in the first variant, the percentage of particles smaller than 50 mm was 76.6%;
- the height of surface irregularities in the tilled layer was within the required limits, remaining below 10 cm in all variants;
- the height of irregularities at the base of the tilled layer met agronomic standards in all variants except the first, where it remained below 4 cm;

-the specific draft resistance was lowest in the fourth variant and highest in the fifth variant. For the other variants, this indicator ranged from 5.49–5.96 kN/m at a speed of 6 km/h and 5.81–6.28 kN/m at a speed of 8 km/h;

- increasing the speed from 6 km/h to 8 km/h improved soil fragmentation quality, reduced the height of surface and sub-surface irregularities in the tilled layer, and increased the specific draft resistance.

**Table 1**

**Effect of the Type and Arrangement Scheme of Working Tools on the Frame of the Wide-Coverage Chisel Cultivator on Its Agronomic and Energy Performance**

| Variants of the Type and Arrangement Schemes of Working Tools on the Frame of the Wide-Coverage Chisel Cultivator | Working depth and its mean square deviation, cm. | | The amount of size (mm) fractions, % | | | The height of irregularities formed on the surface of the tilled layer, cm | The height of irregularities formed at the bottom of the tilled layer, cm | Specific draft resistance, kN/m |
|---|---|---|---|---|---|---|---|---|
| | $M_{ur}$ | $\pm\sigma$ | >100 | 100-50 | <50 | | | |
| V=6 km/h | | | | | | | | |
| 1-variant | 16,40 | 1,61 | 8,52 | 14,88 | 76,60 | 3,7 | 5,5 | 5,75 |
| 2-variant | 18,10 | 1,56 | 6,55 | 12,61 | 80,84 | 4,5 | 3,9 | 5,96 |
| 3-variant | 19,66 | 1,22 | 6,03 | 12,62 | 81,35 | 4,2 | 3,6 | 5,49 |
| 4-variant | 20,47 | 1,21 | 5,71 | 12,28 | 82,01 | 4,4 | 3,1 | 5,28 |
| 5-variant | 20,93 | 1,25 | 4,70 | 10,55 | 84,75 | 4,6 | 3,7 | 6,23 |
| V=8 km/h | | | | | | | | |
| 1-variant | 16,46 | 1,57 | 8,56 | 13,38 | 78,06 | 3,4 | 4,6 | 5,94 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2-variant | 18,67 | 1,39 | 4,98 | 12,43 | 8<br>2,59 | 4,1 | 3,1 | 6,28 |
| 3-variant | 19,26 | 1,26 | 6,12 | 10,45 | 8<br>3,43 | 3,8 | 3,2 | 5,81 |
| 4-variant | 20,33 | 1,16 | 5,13 | 11,84 | 8<br>3,03 | 3,8 | 2,5 | 5,61 |
| 5-variant | 20,60 | 1,21 | 4,25 | 10,28 | 8<br>5,47 | 4,2 | 3,0 | 6,73 |

## Conclusion

In this study, the types and arrangement schemes of the working tools on the frame of a wide-coverage chisel cultivator were examined. Based on the results of the experiments, the efficiency and working depth of various variants were analyzed.

As highlighted above, the fourth variant of working tools was selected for installation on the wide-coverage chisel cultivator. In this configuration, the working tools are arranged in two staggered rows on the frame: the first row is equipped with chisel-point shovels with a reduced working width of up to 140 mm, while the second row has chisel-point shovels with an unchanged working width of 260 mm, both set to the same working depth.

Based on the results, it is recommended to adopt the fourth variant of working tools arranged in a staggered pattern on the frame of the wide-coverage chisel cultivator. This approach enables effective soil tillage and achieves outcomes that meet agronomic requirements. The findings from this study are expected to be useful for improving agricultural machinery and optimizing production processes.

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