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Improvement Of The Working Parts Of The Wide-Row Chisel Cultivator

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Abstract: The article is dedicated to improving the working components of wide-row chisel cultivators, which play a significant role in soil preparation before planting in Uzbekistan's agriculture, directly impacting crop yield and resource efficiency. It analyzes the influence of the fourth variant of working components (arranged in a staggered pattern, with a coverage width of 140 mm in the first row and 260 mm in the second row) on agrotechnical and energy performance indicators. The study experimentally examines the effects of different working component arrangements on soil tillage depth, fraction distribution, surface and subsurface irregularities of the tilled layer, and traction resistance. The research results highlight key directions for developing resource-efficient chisel cultivators with minimal soil impact, compatible with modern high-power tractors. The article contributes to the advancement of scientific and practical approaches aimed at modernizing soil tillage technologies in Uzbekistan's agricultural conditions.

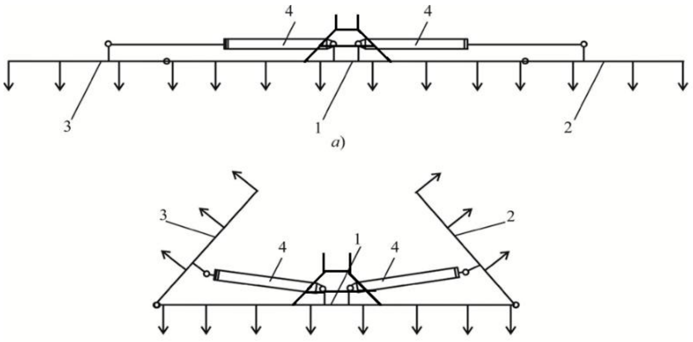
Keywords: Wide-row chisel cultivator, arrow-shaped tines, coverage width, tillage depth, resource-efficient, agrotechnical and energy performance indicators.

Introduction: Agriculture is one of the key sectors of Uzbekistan's economy, and its efficiency largely depends on the quality of pre-planting soil preparation. Chisel cultivators play a significant role in this process, as they are effective in loosening soil, processing crop residues, and maintaining water balance. In Uzbekistan, chisel cultivators such as the ЧКУ-4 and ЧК-3.0 are widely used; however, their designs, largely unchanged for the past 30–40 years, do not meet modern agrotechnical requirements, particularly in terms of minimal tillage and resource efficiency. These machines have high material and energy consumption and limited coverage width (3–4 meters), making them incompatible with modern high-power tractors such as the Magnum 8940, ARION-630C, AXION-850, and others. As a result, excessive fuel, labor, and time are expended during tillage, reducing the economic efficiency of agricultural production [1].

Currently, the need to modernize agricultural technologies and align them with international standards is becoming increasingly urgent in Uzbekistan. International experience demonstrates the successful use of wide-row chisel cultivators, such as the LD-100 or EUROPAL 8, which achieve high results in resource-efficient soil tillage and increased crop yields. However, such wide-row machines are neither imported nor sufficiently developed in domestic production in Uzbekistan. This forces farmers to rely on outdated or makeshift chisel cultivators. This article is dedicated to improving the efficiency of soil tillage, optimizing energy and resource consumption, and fully utilizing the power of modern tractors through the enhancement of wide-row chisel cultivators. The study explores the development of a new, efficient chisel cultivator model tailored to local agricultural needs through innovative design solutions, automated control systems, and parameters adapted to local soil conditions [2].

METHODS

The developed wide-row chisel cultivator is designed in a mounted form, consisting of a central (1) and two side (right 2 and left 3) sections (Figure 1).



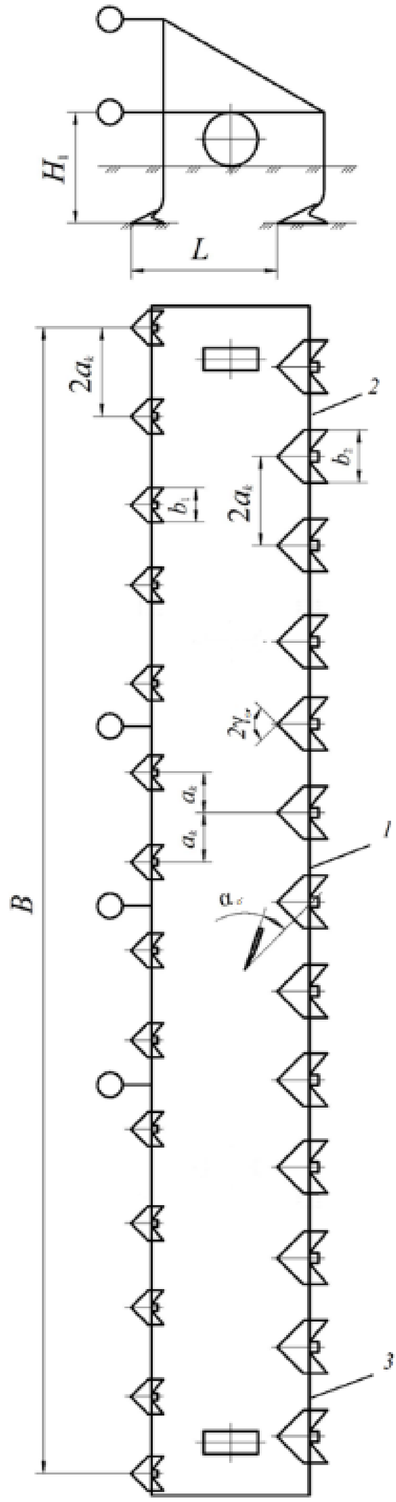
1 - central section; 2 - right side section; 3 - left side section; 4 - hydraulic cylinder.

Figure 1. Schematics of the wide-row chisel cultivator in working (a) and transport (b) positions

The side sections are connected to the central section via longitudinal hinges and are transitioned from the working position to the transport position and vice versa using hydraulic cylinders (4).

The working components of the wide-row chisel cultivator are arranged in a staggered pattern in two rows on the frame (Figure 2). The first row is equipped with arrow-shaped tines with a smaller coverage width, while the second row has tines with a larger coverage width. These tines differ only in their coverage widths, with all other parameters being identical [3].

The technological process of the developed wide-row chisel cultivator operates as follows: the working components in the first row interact with undisturbed soil, creating loosened zones on the sides to enable the second row's working components to operate under open cutting conditions. The second row's working components then act on soil clods that already have loosened zones on both sides (created by the first row's components). As a result, the soil clods being processed are deformed toward the loosened zones, leading to reduced energy consumption.



1 - central section; 2, 3 - side sections Figure 2. Structural schematic of the wide-row chisel cultivator

To study the impact of the types and frame arrangement schemes of the wide-row chisel cultivator's working components on its agrotechnical and energy performance indicators, field experiments were conducted. The experiments, investigating the types and arrangement schemes of the working components, were carried out in the following five options:

Variant 1: The working components are arranged on the device's frame in a staggered pattern in three rows, as in the CHK-3.0 chisel cultivator, with loosening tines installed stepwise across all rows (Figure 3,a).

Variant 2: The working components are arranged on the device's frame in a staggered pattern in three rows. The first and second rows have loosening tines, while the third row has arrow-shaped tines, all installed stepwise (Figure 3,b).

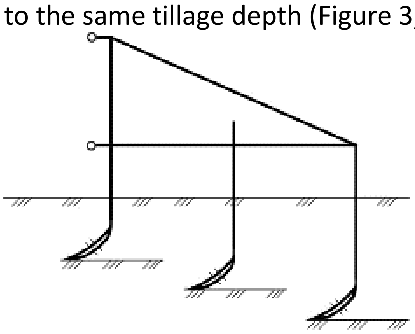
Variant 3: The working components are arranged on the device's frame in a staggered pattern in two rows. The first row has loosening tines, and the second row has arrow-shaped tines, both set to the same tillage depth (Figure 3,c).

Variant 4: The working components are arranged on the device's frame in a staggered pattern in two rows. The first row has arrow-shaped tines with a reduced coverage width of up to 140 mm (as in the CHKU-4 chisel cultivator), while the second row has arrow-shaped tines with an unchanged coverage width of 260 mm, both set to the same tillage depth (Figure 3,d).

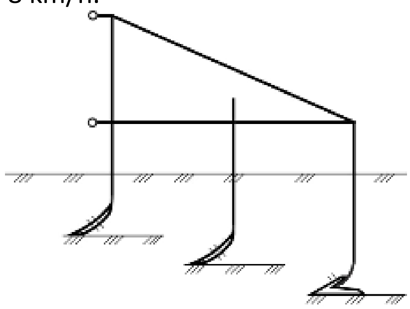
Variant 5: The working components are arranged on the device's frame in three rows. The first and second rows' components are in a staggered pattern, while the second and third rows' components are aligned in sequence and stepwise. The first row has loosening tines, and the second and third rows have arrow-shaped tines (Figure 3,e) [4].

In all options, the longitudinal distance between working components was set at 80 cm, and the transverse distance between working components in a single row was set at 40 cm.

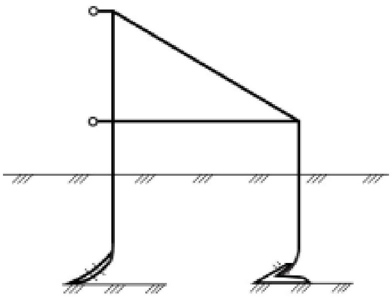
The experiments were conducted at operating speeds of 6 and 8 km/h.



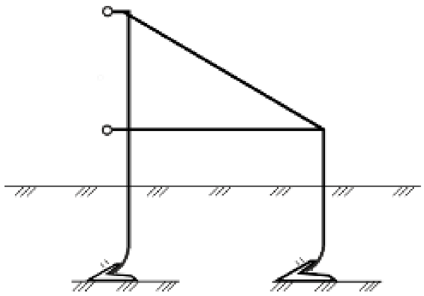
a)



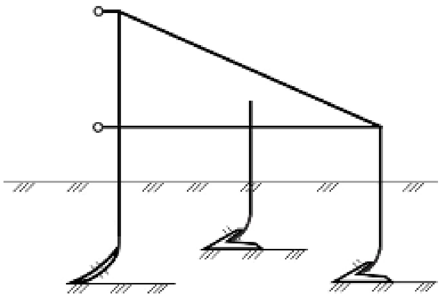
b)



c)



d)



e)

a, b, c, d, e **– correspond to the working component arrangements for option 1, 2, 3, 4, and 5, respectively.**

Figure 3. Types and arrangement schemes of working components

RESULTS AND DISCUSSION

The results of the experiments are presented in Table 1. The following points can be highlighted based on these results:

The tillage depth in the first and second options was less than the designated 20 cm. The main reason for this is that the working components in these options were installed in a stepwise and staggered pattern, leading to the formation of unloosened ridges (irregularities) at the bottom of the tilled layer, which reduces the tillage depth.

In the third, fourth, and fifth options, the tillage depth matched the designated value. The soil crumbling quality was at the required level in all options except the first, with the proportion of fractions smaller than 50 mm in the tilled layer exceeding 80%.

1-table

Influence of the type and frame arrangement schemes of wide-row chisel cultivator working tools on its agrotechnical and energy performance indicators

Options of the type of working bodies of a wide-row chisel-cultivator and their arrangement on the frame	Depth of machining and its root mean square deviation, cm		Amount of fractions with the following sizes (mm), %			Height of irregularities formed on the surface of the machined layer, cm	Height of irregularities formed at the bottom of the machined layer, cm	Specific tensile resistance, kN/m
	M_{av}	$\pm\sigma$	>100	100-50	<50			
V=6 km/h								
1-option	16,40	1,61	8,52	14,88	76,60	3,7	5,5	5,75
2-option	18,10	1,56	6,55	12,61	80,84	4,5	3,9	5,96
3-option	19,66	1,22	6,03	12,62	81,35	4,2	3,6	5,49
4-option	20,47	1,21	5,71	12,28	82,01	4,4	3,1	5,28
5-option	20,93	1,25	4,70	10,55	84,75	4,6	3,7	6,23
V=8 km/h								
1-option	16,46	1,57	8,56	13,38	78,06	3,4	4,6	5,94
2-option	18,67	1,39	4,98	12,43	82,59	4,1	3,1	6,28
3-option	19,26	1,26	6,12	10,45	83,43	3,8	3,2	5,81
4-option	20,33	1,16	5,13	11,84	83,03	3,8	2,5	5,61
5-option	20,60	1,21	4,25	10,28	85,47	4,2	3,0	6,73

In the first variant, the proportion of fractions smaller than 50 mm was 76.6%.

The height of irregularities on the surface of the tilled layer was within the required level in all options, less than 10 cm.

The height of irregularities at the bottom of the tilled layer met agrotechnical requirements in all options except the first, less than 4 cm.

The specific traction resistance was lowest in the fourth variant and highest in the fifth variant. In the other options, this parameter ranged from 5.49–5.96 kN/m at 6 km/h and 5.81–6.28 kN/m at 8 km/h.

Increasing the speed from 6 km/h to 8 km/h improved the soil crumbling quality, reduced the height of irregularities on the surface and at the bottom of the tilled layer, and increased the specific traction resistance.

Based on the above, the working components of the fourth variant were selected for installation on the wide-row chisel cultivator. In this configuration, the working components are arranged on the cultivator's frame in a staggered pattern in two rows: the first row is equipped with arrow-shaped tines with a reduced coverage width of up to 140 mm, and the second row with arrow-shaped tines with an unchanged coverage width of 260 mm, both set to the same tillage depth [5].

2-table

Technical characteristics of a wide-row chisel cultivator

№	Name and unit of measurement of indicators	The value of indicators
1.	Type	Suspension
2.	Tractor with aggregate	3-5
3.	Coverage width, m	6,4
4.	Working speed, km/h	6-8
5.	Productivity during the main period, ha/h	3,8-5,1
6.	Mass, kg	1400
7.	Depth of machining, cm	12-24
8.	External dimensions, mm:	
	width	6420
	length	1060
	height	1400

a)

b)

1-central section; 2, 3-left and right side sections; 4-base wheel; 5-suspension device

Figure 4. Chisel-cultivator in working (a) and transport (b) positions

CONCLUSION

This study focused on improving the working components of a wide-row chisel cultivator for pre-planting soil preparation in Uzbekistan’s agricultural conditions. The fourth variant of working components, arranged in a staggered pattern with arrow-shaped tines having a coverage width of 140 mm in the first row and 260 mm in the second row, was found to provide the most optimal agrotechnical and energy performance indicators. Experimental results showed that this variant achieved a tillage depth of 20.47 cm at 6 km/h and 20.33 cm at 8 km/h, with the proportion of fine fractions (<50 mm) ranging from 82.01–83.03%. Additionally, the fourth variant demonstrated superior performance compared to other options in terms of the height of irregularities at the bottom of the tilled layer (2.5–3.1 cm) and traction resistance (5.28–5.61 kN/m). The technical specifications of the chisel cultivator, including a 6.4 m coverage width, productivity of 3.8–5.1 ha/h, and tillage depth of 12–24 cm, were designed to be compatible with modern high-power tractors (Class 3–5). The study results confirmed that the staggered arrangement of the wide-row chisel cultivator’s working components enhances soil tillage quality, reduces resource consumption, and enables efficient use in Uzbekistan’s agricultural conditions. These solutions serve as a significant step toward modernizing local agricultural machinery and implementing minimal tillage technologies.

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