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ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

БАЯНДАМАЛАРЫ

ДОКЛАДЫ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

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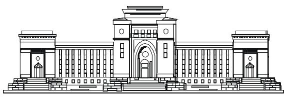

ALMATY, NAS RK

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
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SELECTION AND JUSTIFICATION OF PARAMETERS OF WORKING BODIES OF THE COMBINED TOOLS FOR THE BASIC AND PREPLANT PROCESSING OF SOIL IN THE CULTIVATION OF ROW CROPS IN THE CONDITIONS OF SOUTH KAZAKHSTAN

Abstract. In the southern zone of Kazakhstan, agricultural crops are cultivated, both on irrigated and rain-fed lands. The main technology used for tillage is traditional, which accounts for 90% of all cultivated crops. This technology provides for multiple passes of machine-tractor units (MTU) across the field, which causes a large load on the soil, leading to the destruction of its structure.

In the South of the Republic, combined tools supplied from neighboring countries (Russia, Belarus, Ukraine) are mainly used for pre-sowing tillage. They do not correspond to the soil and climate conditions and technologies used. To ensure the required quality of soil preparation, it is necessary to use machines adapted to zonal conditions.

To develop a combined tool for pre-sowing and basic tillage, the parameters of its working bodies were justified. Based on the conducted research, a prototype of the combined OKP-4,0 machine was manufactured at the experimental plant of "SPC of agricultural engineering " LLP, and its acceptance tests were carried out during the operation of pre-sowing soil preparation for corn sowing, according to which the quality of soil treatment corresponded to agricultural requirements. There were no breakdowns or failures in operation.

Keywords: combined tool, selection of the ripping working body, ring-bar roller, interaction of the roller with the soil, justification of the parameters of the sealing element (ring), distance between bars, length of bars, angle of installation of the roller, prototype of the combined tool, acceptance tests.

Introduction. In the southern zone of Kazakhstan, agricultural crops are cultivated, both on irrigated and rain-fed lands. The main technology used for tillage is traditional, which accounts for 90% of all cultivated crops. A special feature of this technology is the use of dump plowing in the autumn or spring periods. In addition, this technology is used for early spring harrowing operations with tooth harrows, disking or cultivation in order to decompress the top layer of soil and destroy weeds. This technology provides for multiple passes of machine-tractor units (MTU) across the field, which causes a large load on the soil, leading to the destruction of its structure. Currently, the main task facing farmers in the South of Kazakhstan is to reduce the cost of agricultural production and preserve soil fertility, the main wealth of the country. Therefore, measures aimed at introducing resource-saving soil protection technologies and developing technical means that provide optimal conditions for plant development, low energy intensity of soil treatment and protection from destruction are of particular relevance. One of the ways to reduce the load on the soil and the energy intensity of its processing is to replace single-operation machines with combined machines that combine operations for loosening, leveling and rolling the soil.

In the course of research, a comparative analysis of traditional and resource-saving technologies for soybean cultivation using combined tools was carried out in terms of operational and energy indicators. According to the data obtained, operating costs, specific capital investment and energy costs for performing technological operations of pre-sowing tillage using resource-saving technologies were 50-70% lower.

In the South of the Republic, combined tools supplied from neighboring countries are mainly used for pre-sowing tillage: KPP-4, KPP-8 "Red Aksay "(Russia); Polaris-4" Elvorti "(Ukraine); KPM-4, KPM-8" Techmash " (Belarus). They are mostly equipped with cultivator legs, levelling devices and rolling rollers.

The working elements installed on these machines do not meet the soil conditions and recommended tillage technologies . For example, flat-cutting cultivator feet with a crumbling angle of 8-100 and spring harrows do not provide the required crumbling and leveling of the soil. Also, the processing depth of 5-10 cm is insufficient . In the southern zone of Kazakhstan, the period of spring field work is prolonged due to repeated frosts. They begin with the closing of moisture with tooth harrows in the 20th of March and end in the first decade of may with the sowing of row crops (soy, corn, sugar beet). Therefore, it is recommended to carry out the first cultivation for spring soil decompression and provoking weed shoots to a depth of 14 cm and the second pre-sowing to a depth of 8 cm to destroy weeds.

Thus, there is a need to develop a combined tool that will ensure that the quality of loosening, leveling and rolling of the soil, as well as the formation of a compacted bed for sowing seeds, meets the agricultural requirements for technological operations.

In the process of developing a combined tool for pre-sowing and basic tillage, the parameters of its working bodies were justified and a prototype was made and its acceptance tests were conducted on the basis of theoretical and field tests of the mock-up and experimental sample.

Research methods. When conducting scientific research on type selection and justification of parameters of working bodies of the combined instruments used in classical theoretical mechanics, theory of mechanisms and machines, continuum mechanics, agricultural mechanics. When conducting acceptance tests of the prototype, the following GOST Standards were used: GOST 20915-2011 "Testing of agricultural machinery. Methods for determining test conditions". Interstate standard; GOST 33736-2016 "agricultural Machinery. Machine for deep soil cultivation. Test method". Interstate standard; GOST 33687-2015 " machines and tools for surface tillage. Test method». Interstate standard; GOST 33677-2015 " Machines and tools for inter-row and row tillage. Test method». Interstate standard; GOST 24055-2016 " agricultural Machinery. Methods of operational and technological assessment". Interstate standard; GOST R 52777 " agricultural Machinery. Methods of energy assessment". National standard of the Russian Federation; GOST 12.2.111-85 " System of labor safety standards. The agricultural machine is mounted and trailed. General security requirements".

Interstate standard.

Research results and their discussion. Selection of the type and parameters of the arrow legs of the combined machine.

The main loosening and leveling effect when the machine is working is achieved by using pointed paws. When working in front of the paw, a soil roller is formed, the size of which will be constant on a perfectly aligned field. In real conditions, when the foot meets the ridges, the roller size increases and the soil is transported for some distance due to internal friction and then part of it moves to the furrow. Then this process is repeated, so the soil is loosened and leveled with pointed paws.

The zone of deformation propagation around the paw working organs is quite well studied by Trufanov V. V. and Kapustin A. N.[1,2]. According to the results of the research performed on loamy soils of heavy and medium mechanical composition for high-quality loosening and leveling of the soil, it is recommended to use universal pointed paws with a crumbling angle of 26-28°;

In the developed combined machines for basic tillage for sowing grain and pre-sowing-for sowing row crops, a universal pointed paw with a grip width of 330 mm, with a crumbling angle of 26-280, which was previously developed with the participation of KAZSRIMEA for tools for pre-sowing soil treatment on stubble backgrounds OP-6 (OP-8), is used as a working body for loosening the soil.

Pointed paws with a width of 330 mm loosen the soil to a depth of 6 to 14 cm and prune weeds, and can also carry out non-shaft flat-cutting processing of stubble backgrounds. Due to the significant crumbling angle, they have a good leveling ability. The results of their use in technologies of pre-sowing tillage in the southern zone of Kazakhstan gave positive results.

To improve the quality of crumbling and leveling of the soil during pre-sowing treatment, a ring-bar roller was introduced into the design and technological scheme of the combined tool, the optimal parameters of which were selected and justified in the course of theoretical research and field tests (figure 1).

Justification of parameters of the ring-bar roller of the combined tool.

A number of researchers have studied the interaction of different types of rinks with the soil. Ring-shaped, spiral-shaped, bar-shaped rollers and their other varieties were studied[3-8]. We conducted theoretical studies to determine the diameter of the roller and its rings, taking into account the features of light chestnut soil[9]. The optimal diameter of the ring roller according to the research results was 510 mm and was determined at the values of internal soil friction coefficients f_n = 0.4 and soil friction on steel f_c = 0.5, with the size of the soil lump h = 50 mm.

According to the test results, the low efficiency of using bar and ring rollers was established. They do not provide sufficient crumbling of the soil, bar rollers also did not create a compacted layer at the depth of sowing. To ensure the necessary fractional composition of the soil in its upper layer, changes were made to the design of the ring roller - bars were installed between the rings along their inner diameter (Figure 1). The roller was installed at an angle of 15-250 to the transverse plane in the direction of movement of the unit. When performing the technological process, the rings move with a side slide to seal the soil at the depth of sowing seeds. The soil shifted by the rings falls under the influence of rods and they produce additional crumbling.

The compacted layer is created by the roller rings. Since the bars are located along the inner diameter of the rings, their sealing effect is not taken into account in this case.

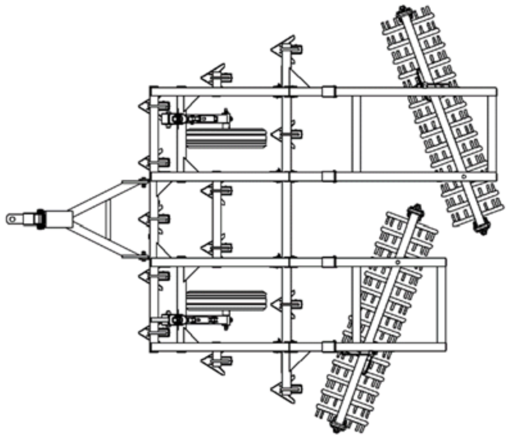

Figure 1 – Layout diagram of a combined machine with a ring-bar roller

The distance between the rings of the roller was determined from the condition of creating a solid compacted soil layer at the depth of sowing seeds h_1. When a circular ring is inserted into the soil (figure 2), a soil wedge will form on the AB arc, bounded by a Central angle equal to $2\varphi_1$.

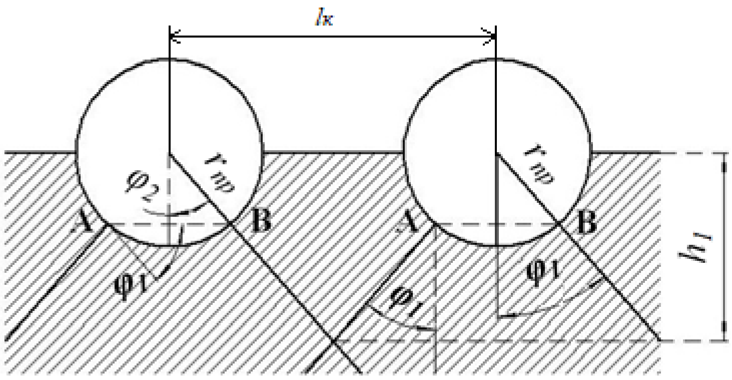

Figure 2 – Diagram of the introduction of a circular ring into the soil

The maximum soil density in the ring compaction zone is achieved when it is sunk to a depth equal to the radius. Its further deepening leads only to an increase in the depth of the seal propagation.

The depth of the compacted layer formed is determined depending on the distance between the roller rings l_K and the angle of deformation propagation φ_1

$$h_1 = r_{\text{пр}} cos\varphi_1 + (\frac{l_{\text{к}}}{2} - r_{\text{пр}} sin\varphi_1) ctg\varphi_1 \quad (2)$$

where r_{np} – the radius of the rink ring adjusted to the direction of movement

Hence the distance between the rings of the rink that provides the specified condition will be equal to:

$$l_к = \frac{2(h_1 - r_{пр} cos\varphi_1 + r_{пр} sin\varphi_1 ctg\varphi_1)}{ctg\varphi_1} \quad (3)$$

The radius of the ring of the roller r_{np} is assumed to be 10 mm. The distancel_k between the rings will be 150 mm.

To determine the size of the processed strip depending on the angle of installation of the roller, the trajectory of its movement in the coordinate system is considered (Figure 3):

$$x = R\left[\frac{\theta}{(1-\varepsilon)\cos\alpha} - \cos\alpha\,\sin(\theta+\tau) + \theta\sin\alpha\right];$$

$$z = R\,[\sin\alpha\,\sin(\theta+\tau) + \theta\cos\alpha]\,;$$

$$y = R\,[1 - \cos(\theta+\tau)] \quad (4)$$

where R – radius of the rink ring, m; θ – angle of rotation of the roller before the start of removal of soil particles, rad; α - angle of attack of the rink, rad; τ – the angle that characterizes the position of the point *M* on the ring from the beginning of the removal of the soil particle at point *K*, rad; $\varepsilon = (r_{np} - R)/ r_{np}$ – the coefficient of friction;

Trajectory of movement in the soil at$y = 0$:

$$x = R\left[\frac{\theta}{(1-\varepsilon)\cos\alpha} - \theta\sin\alpha\right];$$

$$z = -R\,\theta\cos\alpha \quad (5)$$

Excluding the parameter from expression (5) θ, we obtain the equation of the trace of the ring, the angle of attack of which is formed by its rotation relative to the frontal position:

$$z = \frac{(1-\varepsilon)}{1 + tg^2\,\alpha - (1-\varepsilon)\,tg\,\alpha}\,X = -X\,tg\,\alpha \quad (6)$$

Equation (6) shows that the trace of the ring is a straight line that makes up the angle α with the direction of movement of the axis *OX* (figure 3).

To analyze the moving soil lateral surface of the ring with the rod consider the motion of the ring in one revolution of the rink, laying it on the movement parallel to the axis of the rink *O'O'* and perpendicular to it (figure 3).

To determine the movement patterns of ring rod (geometric place of points), it is sufficient to analyze the motion of the point M the beginning of the removal of soil particles and points *N'* end of removal. The distance between the rings *MN'= 2πRtgα*

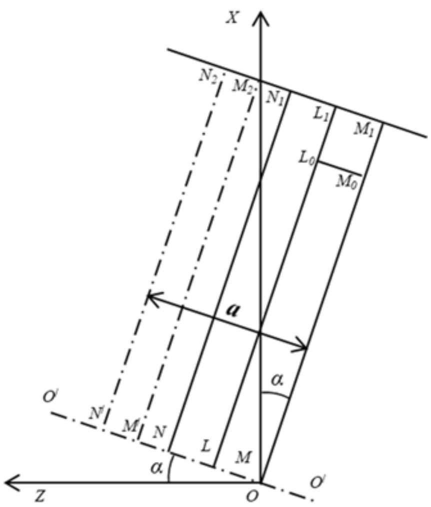

Figure 3 – Scheme of movement of ring ring-the rink bar and displacement of the soil side surface of the ring, the angle of attack which is formed by its rotation relative to the frontal position

When rolling the ring with the bar in the direction perpendicular to the axis of the roller, the point M of the ring will move to the point M_0 by a distance of $MM_0=2\pi R$ due to pure rolling, and from the point M_0 – to the point M_1 by a distance $M_0M_1 = \frac{2\pi R\varepsilon}{1-\varepsilon}$ as a result of sliding. The displacement of the point M in the direction perpendicular to the axis of the rink is $MM_1 = \frac{2\pi R}{1-\varepsilon}$. In the direction parallel to the roller axis, the M point will move a distance $M_1M_2 = \frac{2\pi R tg\alpha}{1-\varepsilon}$.

As a result of adding the displacement components, the point$M$ will take its final position at the point M_2, located on the axis OX. The total movement of point M is $MM_2 = \frac{2\pi R}{1-\varepsilon\cos\alpha}$.

It is obvious that the displaced point N of the end of the soil particle removal is equal to the displacement of the point M of the beginning of the soil particle removal. Therefore, the line connecting points M and N_2 is a trace of the movement of the ring with the rod at the soil surface, and the parallelogram connecting the points MM_1N_2N' is the surface area of a ring with a bar on the ground for one turn with the slide..

The size of the strip processed by one ring of the roller

$$a_к = l \cdot \sin\alpha \tag{7}$$

where: l – the chord of the circle of the diameter of the roller D, passing over the surface of the soil, when the roller is sunk into the soil to a depth h_k (3).

Taking into account the length of the bar l_{np} processed area on the length of the chord l will be:

$$a = a_k + a_{np} = l \cdot \sin\alpha + l_{np} \cdot \cos\alpha \tag{8}$$

The rings of the roller when moving with a side slide create a compacted bed for seeds, the rods crumble lumps and also compacts the soil. Taking into account the angle of deformation propagation φ_1, the impact area of the roller is sufficient-80% of the width of the grip.

The results of theoretical research are confirmed by the results of field tests.

The results of field tests. Comparative tests of various types of rollers: ring and ring-bar were carried out. It was found that for soils having low moisture content, high hardness and komkovatost promising type of the roller is a ring-bar with the following values of its parameters: the roll diameter 510 mm; distance between кольцами150 mm; ring diameter 20 mm; the mounting angle of the rings to the direction of movement (15...250); profile of the rod (the deformer) - round, rod length of 70 mm and the distance between the bars 70-110 mm.

In the course of research tests, the following were clarified: the angle of installation of the rings to the direction of movement of the unit; the optimal distance between the bars. Based on the research carried out, a prototype of the combined OKP-4,0 machine was made at the experimental plant of the «SPCAE» LLP (figure 4), which has the following parameters of the working bodies: universal pointed paws with a crumbling angle of 28°; the roll diameter 510 mm, distance between rings of 150 mm, a ring diameter of 20 mm, the installation angle of the rings to the direction of movement 200, the profile of the bar round, bar length 70 mm and the distance between bars is 70 mm.

Figure 4 – Experimental combined machine with a ring-bar roller

Acceptance tests of the prototype were carried out on the operation of pre-sowing soil preparation for corn sowing. In one pass, the machine performed operations for crumbling the soil with pointed paws, leveling it, and forming a compacted bed for sowing seeds with a ring-bar roller.

The test results are shown in table 1.

Table 1 – Functional performance indicators and OKP-4.0 for operations on pre-sowing tillage for corn sowing

Indicators	Value of indicator	
	by agricultural requirements	based on the results of acceptance tests
Unit (power machine + tool)		Belarus 2022 + OKP-4.0
Unit speed, km / h		10
Depth of tillage, cm:	–	
- setting:		14,0
- actual:		
$\overline{X}$, cm		13,7
±σ(cm)		2,1
γ (%)		15,3
Soil density, g/cm^3 by layer, cm		
0-5	Up to 1,0	0,79
5-10		1,0
10-20		1,0
Soil hardness, MPa, by layer, cm		
0-5		0,80
5-10	Up to 1,0	0,95
10-20		1,1
The crumbling of the soil, % of fractions, mm		
>50	The content of soil fractions up to 20 mm in size should be at least 70%	2,9
50-20		20,2
20-10		39,3
<10		37,6
Ridgeness of field surface, ± cm	No more than 5	2,7

The quality of tillage by the machine was satisfactory and met the agricultural requirements for the technological operation. After passing OKP-4.0, the soil density in the 0-20 cm layer was 0.93 g/cm^3, respectively, and the hardness was 0.95 MPa. At a depth of 5-10 cm, a compacted bed was formed for sowing seeds with a density of 1.0 g/cm^3. The depth of tillage was stable at 13.7 cm, and deviations from the set depth were insignificant: coefficient of variation; 15.3%; mean square deviation; 2.1 cm. The content of the fine-grained fraction after passing OKP-4.0 was 78.7%. The content of the fraction larger than 50 mm was within the acceptable values of 2.9%, as well as the ridges of the soil surface of 2.7 cm. From the above data, it follows that the combined OKP-4.0 tool provided a good quality of pre-sowing tillage. There were no breakdowns or failures in operation.

Conclusion. For soils with low moisture content, high hardness and komkovatost promising type of the roller is a ring-bar with the following values of its parameters: the roll diameter 510 mm; distance between кольцами150 mm; ring diameter 20 mm; the mounting angle of the rings to the direction of movement (15...250); profile rod - round, rod length of 70 mm and the distance between the bars 70-110 mm.

In the process of research test have been refined: the installation angle of the rings to the direction of movement of the unit; the optimal distance between the rods and manufactured at the pilot plant of LLP "SPCAE" prototype combined weapons OKP-4,0, having the following parameters of working bodies: universal Lancet paws with a chopping angle of 28°; roll diameter 510 mm, distance between rings of 150 mm, a ring diameter of 20 mm, the installation angle of the rings to the direction of movement 200, the profile of the rod (the deformer) - round, rod length of 70 mm and the distance between bars is 70 mm.

Acceptance tests of the prototype were carried out for the operation of pre-sowing soil preparation for corn sowing, according to which the quality of soil treatment was satisfactory and met the agricultural requirements for the technological operation. The depth of tillage was stable 13.7 cm, deviations from the set depth were insignificant: coefficient of variation; 15.3%; average square deviation; 2.1 cm; the Content of small-lumpy fraction after passing OKP-4.0 was 78.7%; the content of a fraction larger than 50 mm - 2.9%; ridges of the soil surface.

There were no breakdowns or failures in operation.

А.С. Рзалиев, Ш.Б. Бекмухаметов, В.П. Голобородько

«Агроинженерия ғылыми-өндірістік орталығы» ЖШС, Алматы, Қазақстан

ҚАЗАҚСТАННЫҢ ОҢТҮСТІГІ ЖАҒДАЙЫНДА ОТАМАЛЫ ДАҚЫЛДАРДЫ ӨҢДЕУ КЕЗІНДЕ ТОПЫРАҚТЫ НЕГІЗГІ ЖӘНЕ СЕБУАЛДЫ ӨҢДЕУ ҮШІН ҚҰРАМА ҚҰРАЛДЫҢ ЖҰМЫС ОРГАНДАРЫНЫҢ ПАРАМЕТРЛЕРІН ТАҢДАУ ЖӘНЕ НЕГІЗДЕУ

Аннотация. Қазақстанның оңтүстік аймағында суармалы да, тәлімдік жерлерде де ауылшаруашылығы дақылдары өсіріледі. Топырақ өңдеудің негізгі технологиясы дәстүрлі болып саналады, оған барлық өңделетін дақылдардың 90%-ы тиесілі. Бұл технология машина-трактор агрегаттарының (МТА) танап бойымен бірнеше рет өту жағдайын қарастырады, әрі топыраққа құрылымының бұзылуына әкелетін үлкен жүктеме тудырады.

Республиканың оңтүстігінде негізінен таяу шетелден (Ресей, Беларусь, Украина) жеткізілетін құрама құралдар топырақты себу алдында өңдеу үшін қолданылады. Олар топырақты-климаттық жағдайларға және қолданылатын технологияларға сәйкес келмейді. Топырақты дайындаудың қажетті сапасын қамтамасыз ету үшін аймақтық жағдайларға бейімделген машиналарды пайдалану қажет. Егістік дақылдарға (қопсыту, тегістеу, тығыздау, себу табанын қалыптастыру) және аңыздықты негізгі өңдеуге арналған құрама құралдарды әзірлеу үшін оның жұмыс органдарының параметрлері негізделді.

ОКП-4,0 құрама құралының тәжірибелік үлгісі жасалды. Топырақты жүгері егуге дайындау алдындағы операцияларға тәжірибелік үлгіні қабылдау сынақтары жүргізілді, оған сәйкес топырақты өңдеу сапасы қанағаттанарлық және технологиялық операцияға арналған агроталаптарға сәйкес келді. Оны өндіріске қою үшін тәжірибелік үлгіге техникалық құжаттама әзірленді.

Түйін сөздер: құрамдастырылған құралдар, қопсыту жұмыс органын таңдау, сақиналы-шыбықты тығыздауыш, тығыздауыштың топырақпен өзара әрекеттесуі, тығыздау элементінің (сақинаның) параметрлерін негіздеу, шыбықтар арасындағы қашықтық, шыбықтар ұзындығы, тығыздауышты орнату бұрышы, құрама құралдың тәжірибелік үлгісі, қабылдау сынақтары.

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ВЫБОР И ОБОСНОВАНИЕ ПАРАМЕТРОВ РАБОЧИХ ОРГАНОВ КОМБИНИРОВАННОГО ОРУДИЯ ДЛЯ ОСНОВНОЙ И ПРЕДПОСЕВНОЙ ОБРАБОТКИ ПОЧВ ПРИ ВОЗДЕЛЫВАНИИ ПРОПАШНЫХ КУЛЬТУР В УСЛОВИЯХ ЮГА КАЗАХСТАНА

Аннотация. В южной зоне Казахстана возделываются сельскохозяйственные культуры как на орошаемых, так и богарных землях. Основной применяемой технологией обработки почвы является традиционная, на долю которой приходится 90% всех возделываемых культур. Данная технология предусматривает многократное количество проходов машинно-тракторных агрегатов (МТА) по полю, что обуславливает большую нагрузку на почву, приводящую к разрушению ее структуры.

На юге республики в основном применяются для предпосевной обработки почвы комбинированные орудия, поставляемые из ближнего зарубежья (Россия, Беларусь, Украина). Они не соответствуют почвенно-климатическим условиям и применяемым технологиям. Для обеспечения требуемого качества подготовки почвы необходимо использовать машины, адаптированные к зональным условиям.

Для разработки комбинированного орудия для предпосевной и основной обработки почвы были обоснованы параметры его рабочих органов. Был изготовлен опытный образец комбинированного орудия ОКП-4,0. и проведены его приемочные испытания в ходе операции предпосевной подготовки почвы к посеву кукурузы, согласно которым качество обработки почвы соответствовало сельскохозяйственным требованиям. Никаких поломок или сбоев в работе не было. Разработана техническая документация на опытный образец для постановки его на производство.

Ключевые слова: комбинированное орудие, выбор рыхлительного рабочего органа, кольчато-прутковый каток, взаимодействие катка с почвой, обоснование параметров уплотняющего элемента (кольца), расстояние между прутками, длина прутков, угол установки катка, опытный образец комбинированного орудия, приемочные испытания.

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