N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF AGRICULTURAL SCIENCES
ISSN 2224-526X
Volume 3, Number 57 (2020), 51 – 58 **https://doi.org/10.32014/2020.2224-526X.25**

UDC 631.319.06

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COMBINED TOOLS FOR PRE-SOWING TILLAGE TO TRACTORS OF THE CLASS OF 14, 20 AND 30 KN

Abstract. In the conditions of the irrigated zone of the South of Kazakhstan, when cultivating crops using traditional technology, multiple tillage is carried out with single-operation methods, which leads to soil compaction, delaying the timing of spring field work, and as a result, to soil drying. These disadvantages of the technological process of tillage in traditional technologies predetermined the feasibility and necessity of developing a combined tool that simultaneously performs several technological operations. To develop combined tools adapted to work on the soils of the southern zone of the Republic, studies were conducted to select the optimal types and parameters of their working bodies. Various types of rollers were studied for additional crumbling, leveling the soil and forming a compacted bed for seeding. It was found that the ring-bar (ring-spur) roller meets the agricultural requirements for soils with high hardness and lumpiness. In farms with small-contour fields, with humidity in the range of 14-18%, satisfactory results were obtained when using a slatted roller as part of a mounted combined tool, which in this arrangement has greater maneuverability, as well as lower energy capacity and cost. Experimental samples of combined tools CMT-3,6 for tractors of 14-20 kN traction class with a slatted roller and CST-4,0 for tractors of 30 kN traction class with a ring-bar roller were made. Research tests of experimental samples showed that the quality of technological operations, characterized by the following main indicators: crumbling, hardness, density, leveling on the pre-sowing tillage of the dump background and subsurface (main) processing of the stubble background corresponded to agricultural requirements. No structural breakdowns or failures were detected. The results of the research will be used in the design and manufacture of experimental samples of combined tools.

Key words: combined tools, pre-sowing soil preparation, main processing of the stubble background, ring-bar roller, slatted roller, parameters of the roller, experimental samples.

Introduction. The most important condition for obtaining high yields and preserving soil fertility, as the main wealth of the country, is a rational system of agriculture based on soil protection technologies of tillage [1-2]. In the conditions of the irrigated zone of the South of Kazakhstan, the following operations are performed when cultivating crops using traditional technology: spring soil cultivation (end of March - beginning of April) for a depth of 6 to 12 cm, smoothing in order to level the field surface, followed by pre-sowing cultivation to destroy weeds (if necessary, twice). This technology requires multiple passes of machine-tractor units (MTU) with single-operation tools across the field, which leads to compaction of the soil, delaying the start of spring field work, and as a result, to the desiccation of the soil, increasing the cost of labor and material resources for production. These disadvantages of the technological process of tillage in traditional technologies predetermined the feasibility and necessity of developing combined tools that simultaneously perform several technological operations [3-8]. The complexity of choosing the design and technological schemes of combined tools is compounded by the peculiarity of the soils of the southern region of the Republic, which have different mechanical composition and are subject to drying and significant compaction by the time of sowing. The choice of a working body for loosening the soil to a depth of 6-12cm is not particularly difficult. From their large number of types, universal and flat center hoe or disks can be adopted, the parameters of which are sufficiently fully justified for different types of soils. The choice is also simplified due to the fact that the following working bodies (leveler, rollers) allow to eliminate the shortcomings of the loosening working body. In connection with the above, the aim of the research was to select the types and parameters of rollers for additional crumbling, leveling the soil and forming a compacted bed for sowing seeds [3-8].

Research methods. When conducting scientific research on the choice of the type and parameters of working bodies of a combined tool, the classical provisions of theoretical mechanics, the theory of mechanisms and machines, continuum mechanics, and agricultural mechanics are used.

For field tests, a laboratory installation, breadboards of rollers and experimental samples of combined tools were made. Tests were carried out on the station fields in "Kazakh Research Institute of agriculture and crop production" LLP according to the following normative documentation: GOST 20915-75 "Agricultural machinery. Methods for determining test conditions"; ST RK 1559-2006 "Machines and tools for surface tillage".

Research results and their discussion. To create optimal conditions for seed growth, it is necessary to bring the content of the soil fraction with a size of less than 20 mm to at least 70%, ensure a surface ridgeness of no more than 3 cm, create a soil density in the zone of seed occurrence of no more than 1.0 g/cm^3 and form a compacted bed for their sowing. In this regard, the ripping hoe should work together with the roller, the type and parameters of which will provide the indicators of pre-sowing tillage set by agricultural requirements for the South of Kazakhstan.

In previous years (2015-2017), tests of bar and slatted rollers were carried out. It was found that the bar roller did not provide the necessary quality indicators of crumbling and leveling of the soil, while the bar roller showed satisfactory results. In farms with small-contour fields, satisfactory results are obtained when using a slatted roller with humidity in the range of 14-18 % as part of a mounted combined tool, which has high maneuverability, lower energy consumption and cost. However, for large farms, it is advisable to use a ring-bar roller. The trailer combined tool with such a roller has a high productivity and provides better quality of crumbling and leveling of the soil.

In this regard, research on the ring-bar roller was launched in 2018. The ring-bar roller for improving the quality of soil crumbling is installed at an angle to the direction of movement of the unit. The working bodies of the roller are rings installed with a certain step on the axis of the roller. Bars are attached to the inner surface of the disks (figure 1). When working with a ring-bar roller, the rings when moving, rotating with a side slide, pinch clumps of soil and crumble them, comb out and throw out weeds on top, create a compacted bed for seeds and a loosened surface layer of soil that prevents loss of moisture. Bars installed on one side of the rings along the inner diameter and in the direction of their sliding produce additional crumbling of the soil shifted by the roller rings.

To create a ring-bar roller adapted to work on the soils of the South of Kazakhstan, it is necessary to justify its parameters, including the diameter of the roller rings, the pitch of their installation on the shaft. For this purpose, theoretical studies were conducted to determine the area of its impact on the soil (figure 1).

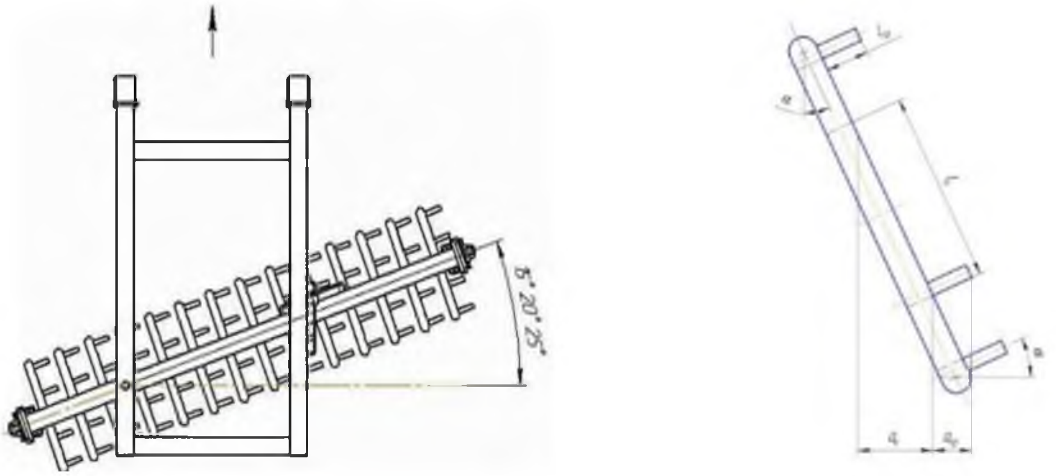


Figure 1 – To determination of the impact area of a ring-bar roller

The magnitude of the strip processed by one ring of the roller is determined by the formula

$$a_r = l \cdot \sin\alpha \quad (1)$$

where l - the chord of the circle between the points of entry and exit of the ring, passing along the soil surface, deepening of the roller into the soil to a depth of h_k.

Taking into account the length of the bar l_b, the processed width of the strip on the chord length l will be:

$$a = a_r + a_b = l \cdot \sin\alpha + l_b \cdot \cos\alpha \quad (2)$$

When moving the rollers with lateral sliding, a compacted bed for seeds is created, the bars crumble lumps and also compacts the soil. Considering the angle of the distribution of deformation φ_2, the impact area of the roller is sufficient - 80% of the working width.

From the condition of jamming of soil lumps up to 50 mm in size, the optimal diameter of the roller rings was determined.

Determination of the diameter of the roller and its rings.

The ring-bar roller moves along an uneven field surface. To identify the effect of the roller rings on this surface, we consider their interaction with a separate roughness (lump) of soil. From the action of the force N on the soil lump, friction forces F_2 arise (figure 2) between the roller ring and the lump, as well as the friction forces F_1 between the lump and the soil surface, which are directed in the direction opposite to the direction of movement of the roller.

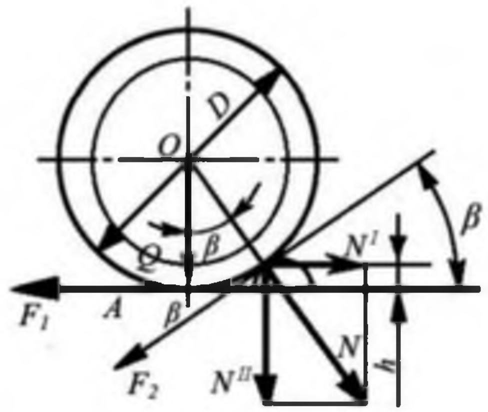


Figure 2 – Scheme of the impact of the roller on the lump of soil. h - the height of the lump or clod; D - the diameter of the roller; α - the angle between the horizontal and the tangent to the circumference of the roller, drawn at the point of contact with an obstacle (lump); N - force, normal to the surface of the roller at the point of contact with the lump of soil

Jamming of the soil lump between the roller ring and the field surface occurs under the condition [9]

$$F_1 + F_2 cos\beta > N' \quad (3)$$

Based on the conditions of jamming the lump of soil by the surface of the roller, the diameter of the roller at which it will roll through the soil lump without moving it forward can be selected [10]

$$D_r \leq hctg^2 \frac{\varphi_1 + \varphi_2}{2} \quad (4)$$

where D_r - the diameter of the roller, m; h- size (height) of the lump, m; φ_1, φ_2 - the angle of external and internal friction of the soil, rad.

To reduce the longitudinal movement of the soil, which destroys its structure, the angle of β - grip of the roller ring by the soil should not exceed 15-20°.

The impact of rollers on the soil is determined by the formula:

$$q = 2Q / bl \quad (5)$$

where q – specific pressure of the roller, N/cm^2; b and l – width and length of the roller footprint on the ground, cm; Q - the force of gravity of the roller and the machine falling on the roller

Since l is the chord of a circle with a diameter D_r its value can be determined by the formula:

$$l = 2\sqrt{h_t(D_r - h_t)}, \quad (6)$$

where h_r - track depth, cm.

The depth of the track is determined by the depth at which it is necessary to create a compacted bed for seeds, i.e., the depth of seeding.

The optimal rolling pressure is $q = 3 - 4$ N/cm^2 [11].

From expression (4) it is possible to determine the diameter of the roller and its rings based on the physical and mechanical properties of the soil.

The diameter of the roller for manufacturing the experimental sample was determined at the values of internal soil friction coefficients f_2 = 0.4 and soil friction on steel f_1 = 0.5, the size of the soil lump h = 50 mm and is 510 mm.

The article presents the results of research to clarify the angle of installation of the roller relative to the movement of the tillage unit, the length of bars and their arrangement on the rim of the roller rings, which provide quality indicators of tillage corresponding to agricultural requirements.

To conduct research on a laboratory installation, a breadboard of a ring-bar roller was tested (figure 3), on which bars with a length of 40 to 90 mm were installed, with a distance between adjacent bars on the circumference of the ring of the roller from 50 to 140 mm. The angle of installation of the roller rings relative to the movement of the unit varied from 13 to 25^0. The distance between the rings of the roller, determined from the conditions of continuous tillage according to dependence (2) and with a ring diameter of 40 mm, was 150 mm.

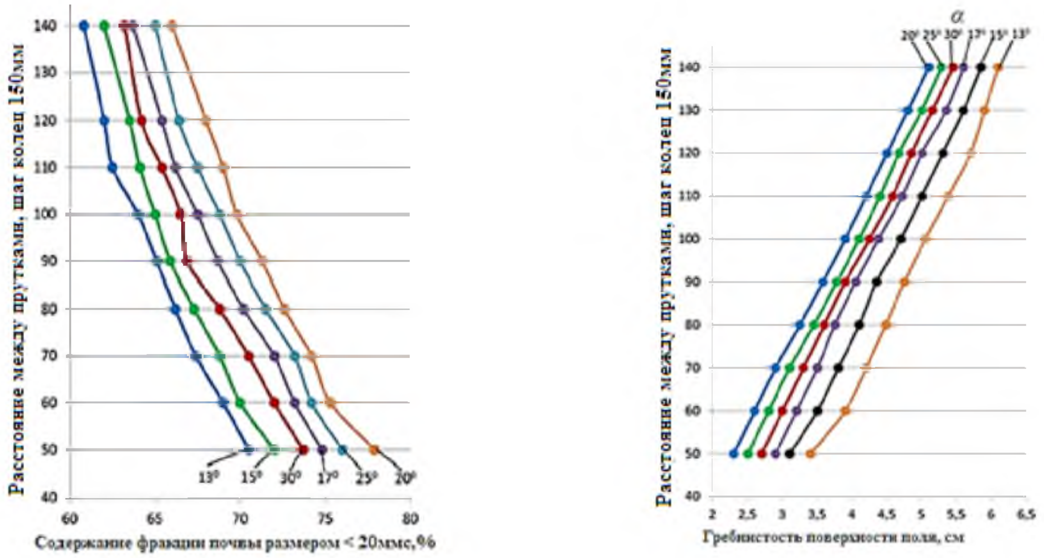
Figure 3 – Ring-bar roller on testing

The optimal crumbling of the soil and the leveling of its surface were observed at a minimum distance between adjacent bars of 50-70 mm. With an increase in this distance to 140 mm, the quality of the tillage did not correspond to the agricultural requirements for the technological operation. With increased humidity and lumpiness of the soil and the presence of a large number of plant residues with a distance between adjacent bars of less than 70 mm, clogging of the rings of the roller with soil was noted (figure 4).

The impact of the length of bars on the quality of tillage was studied. It was found that increasing the length of the bars from 60 to 90 mm increased the content of the soil fraction less than 20 mm in size and had a minor effect on the field surface leveling (figure 5).

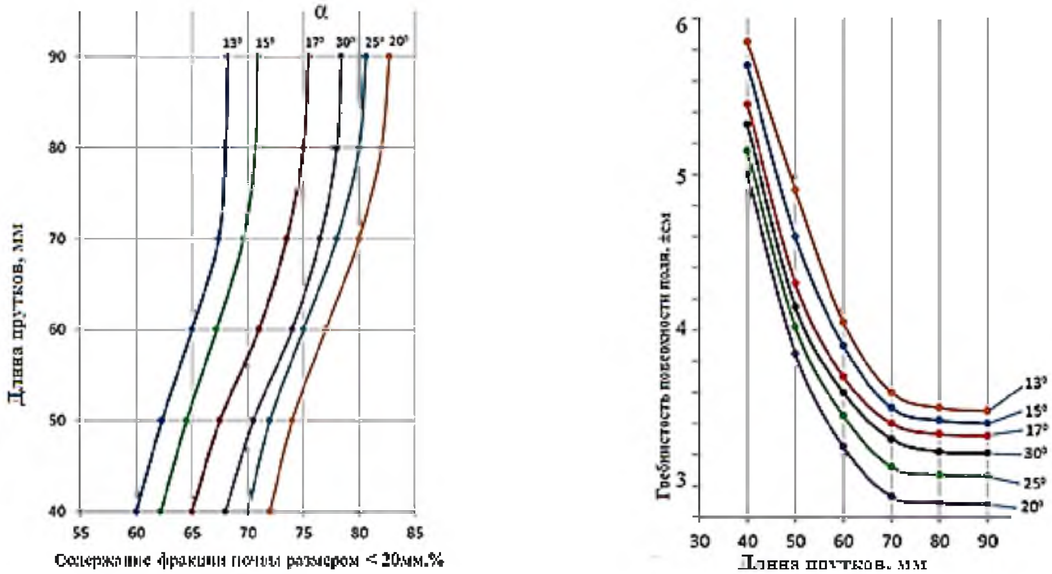
The study of the impact of the roller installation angle on the quality of tillage showed that the optimal angle is 20^0 (figures 4-5).

Thus, on the basis of the conducted research, the parameters of rollers of combined machines were clarified. In the manufacture of the experimental sample it was composed with ring-roller bars having a diameter of rings 510 mm, distance between rings of 150 mm, the step between bars on the rim of the rings of 70 mm, a bar length of 70 mm. The angle of installation of rollers relative to the movement of the unit equal to 20^0 provided better quality of tillage.



a *b*

Figure 4 – Dependence of soil crumbling *a*) and field surface ridgeness *b*) on the distance between the adjacent bars on the circumference of the ring and the angle of installation of the roller to the direction of the unit movement



a *b*

Figure 5 – Dependence of soil crumbling *a*) and field surface ridgeness *b*) on the length of the bar and the angle of installation of the roller ring to the direction of the unit movement

Experimental samples of combined tools were made at the experimental plant of “SPC Agroengineering” LLP: CST-4,0 to tractors of class 30 kN in a complete set with center hoe and a ring-bar roller; CMT-3,6 to tractors of class 14-20 kN in a complete set with center hoe, a leveler and a slat roller. CMT-3.6 (figure 6). Due to the relatively low cost, weight, dimensions and energy intensity, the CMT-3.6 is planned to be used in farms with a small area and the most widespread tractors of the 14-20 kN class in Kazakhstan. The manufactured combined tools are intended for pre-sowing tillage of the dump background for sowing row crops and for main surface processing of the stubble background for sowing grain crops.

Research testing on the dump background was conducted on the fields of LLP “KazRIACP". On operations for pre-sowing preparation of the soil for sowing row crops from April 20 to May 15.

CST-4,0

CMT-3,6

Figure 6 – Experimental samples of combined tools

Before testing, the humidity, density and hardness of the soil in the 0-20 cm layer, respectively, were: 16.3%, 1.17 g/cm, 2.0 MPa; surface ridgeness ± 6.7 cm; the content of soil lumps larger than 20 mm 50.1%. Thus, the soil had increased hardness and lumpiness.

In the course of research tests, failures in operation and breakdowns of structures of combined tools were not observed. Functional indicators of their work were determined (table).

Functional indicators of the work of CMT-3,6 and CST-4,0

Indicators	The value of indicators	
	Research test results	
Unit (power machine + tool)	MTZ-82 + CMT-3,6	Belarus 2022 + CST-4,0
Velocity of unit, km/h	10	10
Depth of tillage, cm:		
- set:	14	14
- actual:		
$\overline{X}$, cm	13,5	14,3
±σ (cm)	2,0	2,3
γ (%)	14,8	16,1
Density of soil, g/cm^3 by layers , cm 0-5	0,80	0,75
5-10	0,90	0,80
10-20	1,25	1,27
Hardness of soil, MPa, by layers, cm 0-5	0,69	0,75
5-10	0,72	0,82
10-20	0,95	0,90
Soil crumbling, % by fractions, mm >50	4,7	2,2
50-20	25,0	21,1
20-10	35,6	39,3
<10	34,7	37,4
Ridgeness of soil surface, ± cm	3,8	2,2

The quality of the tillage by tools was satisfactory and consistent with the agricultural requirements for the technological operation. After the passage of CMT-3,6 and CST-4,0, the soil density was 0.98; 0.95 g/cm^3, hardness 0.73; 0.70 MPa, respectively. The depth of tillage was stable, deviations from the set depth were insignificant: the coefficient of variation was 14.8; 16.1%; the average square deviation was 2.0; 2.3 cm. The content of the small-lumpy fraction of the soil after the passage of CMT-3,6 was 70.3%; after the passage of CST-4.0 - 76.7%. The content of a fraction larger than 50 mm was within acceptable values (respectively, for machines: 4.7%; 2.2%), as well as the ridgeness of the soil surface (3.8; 2.2 cm). From the data provided, it follows that CST-4,0 provided somewhat better crumbling and leveling of the field surface. There were no breakdowns or failures in the operation of combined tools on the dump background.

From August 20 to September 1, experimental samples of combined machines were tested on operations for main, surface tillage for spring sowing of spring crops on bogar in a layout with pointed flat hoe without a leveler and rollers.

The soil conditions during the tests were typical for this zone and gray-earth soils. In the 0-20 cm soil layer, the humidity was 12.3%, the density was 1.20 g/cm^3, the hardness was 2.5 MPa, and the ridgeness was 6.5 cm, i.e. the soil had an increased hardness.

The quality indicators of tillage of CMT-3,6 and CST-4,0 were satisfactory. The actual depth of tillage was stable and slightly different from the established depth (14 cm). During the work of CMT-3,6 it was 13.7 cm with the coefficient of variation of 12.8%; for CST-4,0 - 13.3 cm with a coefficient of variation of 14.3. Significant differences in the quality of tillage of CMT-3,6 and CST-4,0 are not detected, failures and breakdowns estate related tools for stubble background was observed. Soil spraying was not observed at CMT-3,6 working with the slatted roller.

On the basis of the conducted research, the technical specification and design documentation for prototypes of the combined tools are being developed and their production is planned.

Conclusion. For soils of South-Eastern Kazakhstan agrotechnical requirements are satisfied by ring-bar roller with the following settings: diameter of the roller rings - 510mm, distance between rings - 150 mm, the installation angle of the rings to the direction of movement - 20^0, the profile of the bar (the deformer) - round, bar length - 70 mm and the distance between bars - 70 mm.

Experimental samples of combined tools CMT-3.6 for tractors of 14-20 kN traction class and CST-4.0 for tractors of 30 kN traction class were made. Research tests of experimental samples showed that the quality of technological operations for pre-sowing and surface tillage corresponded to agricultural requirements. No structural breakdowns or failures were detected.

The results of the research will be used in the design and manufacture of a prototype of the combined tool.

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ТАРТУ КЛАСЫ 14, 20 ЖӘНЕ 30 КН ТРАКТОРЛАРЫНА ТОПЫРАҚТЫ СЕБУАЛДЫ ӨҢДЕУГЕ АРНАЛГАН ҚҰРАМА ҚҰРАЛДАР

Аннотация. Қазақстанның оңтүстігіндегі суармалы аймақ жағдайында дәстүрлі технология бойынша ауылшаруашылық дақылдарын өсіру кезінде топырақты бір операциялық құралдармен бірнеше рет өңдеу жүргізіледі, бұл топырақтың тығыздалуына, көктемгі егіс жұмыстарыныц мерзімдерінің созылуына және соның салдарынан топырақтың құргауына экеп согады. Дәстүрлі технологиялардағы топырақты өңдеудің технологиялық процесінің бұл кемшіліктері бір мезгілде бірнеше технологиялық операцияларды орындайтын құрама құралды әзірлеудің орындылыгы мен қажеттілігін анықтады. Республиканың оңтүстік аймагының топырақтарында жұмыс істеуге бейімделген құрама құралдарды әзірлеу үшін олардың жұмыс органдарының оңтайлы типтері мен параметрлерін таңдау бойынша зерттеулер жүргізілді. Дәндерді себуге қосымша топырақты ұсақтау, тегістеу және тығыздалған бет қалыптастыруга арналган катоктардың әртүрлі түрлері зерттелді. Жогары қаттылыгы мен кесектілігі бар топырақтар үшін агротехникалық талаптарды сақиналы-шыбықты (сақиналы-шпорлы) катоктар қанағаттандыратыны анықталды. Шағын танаптары бар шаруашылықтарда ылгалдылыгы 14-18% шегінде қанағаттанарлық нәтижелер осындай құрастыруда үлкен маневр, сондай-ақ энергия сыйымдылыгы мен құны төмен аспалы құрама құрал құрамында планкалы катокты пайдалану кезінде алынды. Тарту класты 14-20 кН тракторларга планкалы катокты ОКН-3,6 және тарту класы 30 кН тракторларга сақиналы-шыбықты катокты ОКП-4,0 құрама құралдарының тәжірибелік үлгілері дайындалды. Технологиялық операцияларды жүргізу сапасы эксперименттік үлгілердің зерттеу сынақтарының негізгі көрсеткіштермен сипатталатынын көрсетті: қайырмалы және аңыздық фондарда топырақты себуалды өңдеуде ұсақталу, қаттылық, тығыздық, тегістік агроталаптарга сай болды. Конструкцияда сыну және жұмысындагы ақаулар болган жоқ. Жүргізілген зерттеулердің нәтижелері құрама құралдардың тәжірибелік үлгілерін жобалауда және дайындау кезінде пайдаланылатын болады.

Түйін сөздер: құрама құралдар, топырақты себуалды дайындау, аныздық фонның негізгі өңдеуі, сақиналы-шыбықты каток, планкалы каток, каток параметрлері, эксперименттік үлгілер.

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КОМБИНИРОВАННЫЕ ОРУДИЯ ДЛЯ ПРЕДПОСЕВНОЙ ОБРАБОТКИ ПОЧВ К ТРАКТОРАМ КЛАССА ТЯГИ 14, 20 И 30 КН

Аннотация. В условиях орошаемой зоны юга Казахстана при возделывании сельскохозяйственных культур по традиционной технологии проводятся многократные обработки почвы однооперационными орудиями, что приводит к уплотнению почвы, затягиванию сроков весенних полевых работ, и как следствие, к иссушению почвы. Эти недостатки технологического процесса обработки почвы в традиционных технологиях предопределили целесообразность и необходимость разработки комбинированного орудия, одновременно выполняющего несколько технологических операций. Для разработки комбинированных орудий, адаптированных к работе на почвах южной зоны республики, проводились исследования по выбору оптимальных типов и параметров их рабочих органов. Исследовались различные типы катков для дополнительного крошения, выравнивания почвы и формирования уплотненного ложа для посева семян. Установлено, что для почв, имеющих высокую твердость и комковатость, агротехническим требованиям удовлетворяет кольчато-прутковый (кольчато-шпоровый) каток. В хозяйствах, имеющих мелкоконтурные поля, при влажности в пределах 14-18 % удовлетворительные результаты получены при использовании планчатого катка в составе навесного комбинированного орудия, которое в такой компоновке имеет большую маневренность, а также меньшую энергоемкость и стоимость. Изготовлены экспериментальные образцы комбинированных орудий ОКН-3,6 к тракторам класса тяги 14-20 кН с планчатым катком и ОКП-4,0 к тракторам класса тяги 30 кН с кольчато-прутковым катком. Исследовательские испытания экспериментальных образцов показали, что качество проведения технологических операций, характеризующееся следующими основными показателями: крошение, твердость, плотность, выровненность на предпосевной обработке отвального фона и плоскорезной (основной) обработке стерневого фона, соответствовало агротребованиям. Поломок конструкции и сбоев в работе обнаружено не было. Результаты проведенных исследований будут использованы при проектировании и изготовлении опытных образцов комбинированных орудий.

Ключевые слова: комбинированные орудия, предпосевная подготовка почвы, основная обработка стерневого фона, кольчато-прутковый каток, планчатый каток, параметры катка, экспериментальные образцы.

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