EurAsian Journal of BioSciences
Eurasia J Biosci 13, 609-617 (2019)

Types and parameters of combined tool implements for perspective soil-saving technologies

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Abstract

The article presents the results on the comparative efficiency of technological complexes of machines in traditional and minimum tillage soil-saving technologies, according to which the replacement of single-function machines with universal and combined staffed with a certain set of implements reduces the load of machine-tractor units on the soil and thereby reduces the negative impact of machines on the soil structure. In the development of universal and combined tools for minimum soil-saving technologies, implements were selected, and their layout schemes ensure the formation of the minimum number of erosion-hazardous particles and high-quality tillage. The design and technological scheme of the universal tool provides for the possibility of its layout with various types of loosening, leveling implements and packer rollers depending on the type of operations and soil moisture.

Keywords: soil erosion, soil-saving technologies, erosion-hazardous particles, implements of tillage machines, layout schemes of tillage machines, experimental sample

Rzaliyev A, Bekmukhametov S, Goloborodko V, Begaly D (2019) Types and parameters of combined tool implements for perspective soil-saving technologies. Eurasia J Biosci 13: 609-617.

INTRODUCTION

The soil cover of South Kazakhstan includes mainly sierozem and light chestnut soils. Their mechanical composition is represented by light, medium and heavy loam. Soils are characterized by ash structure, a tendency to overcrust, crust formation, compaction after rain and watering, the presence of various types of erosion.

A distinctive feature of the development of erosion processes in the South of Kazakhstan is the simultaneous manifestation of water and wind erosion (Alimbayev et al. 1998, Dzhamalbekov and Beldibayeva 1999, Ecological condition of lands of the Republic of Kazakhstan, Faizov and Asanbayev 1998, Land degradation in Kazakhstan, Mirzakeyev and Saparov 2010, State and use of the land fund of the Republic of Kazakhstan 2008). Wind erosion destroys soil aggregates, and the remaining fine earth is washed away by water while the wind and water act simultaneously and the soil most actively loses nutrients.

One of the determining factors in the development of erosion processes is a violation of agricultural practices in the cultivation of agricultural crops. To reduce the negative impact of tillage effects on its structure, it is necessary to minimize the number of passes of agricultural equipment through the fields by replacing single-function implements with combined tools. The study of erosion processes and the development of technological methods in order to preserve soil fertility is relevant for our country and the countries of near and far abroad (Ryken et al. 2018, Obour et al. 2018, Zhao et al. 2018).

In the southern zone of Kazakhstan, agricultural crops are cultivated both on irrigated and bogharic lands. The main applied tillage technology is traditional, which accounts for 90% of all cultivated crops. A feature of this technology is the use of moldboard plowing in the autumn or spring period. In addition, according to this technology, early spring harrowing operations are carried out with toothed harrows, disking or cultivation in order to loosen the topsoil and weed control. It is recommended to carry out 2 cultivations: the first one for decompression of the soil to a depth of 12-14 cm, the second pre-sowing for the destruction of weeds to a depth of 6-8 cm. Spring tillage is performed for a long period of time - from March 20 to April 25. This is due to repeated spring frosts. After March 10-15, there is a sharp increase in air temperature, which leads to the drying of the surface layer of soil. As a result, clumps of soil in the upper layer harden, their hardness reaches 3 MPa or more. Later on, when performing pre-sowing tillage operations, they are poorly crumbling. This technology provides a multiple number of passes of machine-tractor units (MTU) across the field, which causes a large load on the soil, leading to the destruction

Received: November 2018
Accepted: March 2019
Printed: May 2019

Table 1. Qualitative indicators of tillage in the cultivation of winter wheat and soybean using traditional technologies used in the South of Kazakhstan

Technological operations	Type of tools	Terms of operations	Agrophysical indicators of soil						
			Soil pulverization, %						
			>50	50-20	20-10	<10			
						10-1.0	1.0-0.5	0.5-0.25	<0.25
Winter wheat (predecessor cereal)									
Scuffling	Disk mounted harrow DMH-2.4	05.08-15.08	-	-	-	-	-	-	-
Plowing	Reversible semi-mounted plow RSMP 4+1	1.09-10.09	12.1	26.1	21.8	27.7	3.3	6.1	2.9
Disking in 2 tracks	DMH-2.4	1.09-10.09	6.2	30.9	22.9	27.9	3.30	6.5	2.3
Field layout	Soil equalizer shredder SES-5.6	10.09-15.09	5.7	31.1	22.0	28.0	3.6	6.9	2.7
Pre-sowing cultivation	Mounted high-speed cultivator MHSC-4	15.09-20.09	4.8	31.3	21.8	28.1	3.8	7.2	3.0
Soybean (predecessor cereal)									
Scuffling	DMH-2.4	15.09-20.09	-	-	-	-	-	-	-
Plowing	RSMP 4+1	20.09-25.09	15.9	32.8	19.0	22.6	3.5	3.9	2.3
Moisture closure in 2 tracks	Medium toothed harrow MTH-1	20.03-1.04	12.7	35.8	21.0	24.9	3.3	1.4	0.9
1st cultivation	MHSC-4 + MTH-1	1.04-15.04	8.4	33.8	21.4	28.1	5.3	1.8	1.2
Field surface layout	SES-5.6	15.04-20.04	4.0	34.2	22.4	29.0	5.0	3.4	2.0
2nd cultivation with 2 track harrowing	MHSC-4	20.04-1.05	5.3	33.7	22.0	28.4	5.7	3.3	1.6

of its structure. Based on the analysis of research conducted on the development of tillage technologies (Harper et al. 2018, Jena 2019, Rusu 2014, Schneider et al. 2017, Tagar et al. 2017, Upadhyay and Raheman 2019, Zhang et al. 2018). An alternative to the traditional technology is zero, which, due to the peculiarities of the soils of the South of Kazakhstan (draining, high hardness and density), has not been applied and the minimum soil-saving technology developed by «Kazakh Research Institute of Agriculture and Crop Production» LLP (KazRIACP LLP), which accounts for about 10% treated areas (Obour et al. 2018, Ryken et al. 2018). The introduction of this technology makes it difficult to lack tillage machines capable of replacing moldboard plowing with periodic deep loosening of soil and to combine the execution of a number of technological operations for pre-sowing tillage in one single pass of machine.

PURPOSE OF THE RESEARCH

In connection with the above, the need arises to develop a universal tillage machine using minimum soil-saving technology and a combined tillage machine on Strip-till technology, providing high-quality tillage with minimum negative impact on its structure.

METHODS OF THE RESEARCH

When conducting scientific research on the type choice, parameters and operating modes of the compacting implement of combined tool for pre-sowing tillage, the classical concepts of theoretical mechanics, theory of mechanisms and machines, continuum mechanics, and agricultural mechanics were used. Experimental studies of the leveling implement and the packer rollers were carried out on specially developed laboratory-field installations and on experimental tool sample using appropriate measuring instruments and equipment. Technical documentation for the manufacture of samples of rollers and a combined tool was developed in accordance with GOST 2.001-93 “Unified system for design documentation. General Provisions”; ST RK 4.8-2003.

RESULTS OF THE RESEARCH AND DISCUSSION

Comparative tests of the quality of tillage in the cultivation of winter wheat and soybean using the traditional and minimum soil-saving technology have been carried out (Guidelines for the application of …, Minimizing tillage for winter wheat on boghara: Recommendations 2008). In addition, «KazRIACP» LLP together with «Research and Production Center of Agroengineering» LLP, proposed a project for the cultivation of tilled crops using Strip-till technology (**Tables 1**, **2**), which allows 2/3 of the soil to remain untreated. Preservation of crop residues between the strips and the preservation of most of the soil with undisturbed addition and structure.

The complex of machines for the traditional technology included the machines used in the farms of the South of Kazakhstan.

In the process of conducting experiments, the quality indicators of the machines operation were determined: soil pulverization (including the content of erosion-hazardous particles), ridgeness (**Tables 1**, **2**).

For the minimum soil-saving technology of tillage, «Research and Production Center of Agroengineering» LLP (RPCAE LLP) developed an experimental sample of the universal tillage tool UTT-4 that performs stubble cleaning, cutting plowing with disk implements; soil loosening with lancet and flat-cutting paws and leveling the field surface; soil chiseling in order to destroy the plow soles and moisture accumulation in the soil.

Table 2. Qualitative indicators of tillage of various types of implements in the cultivation of cereal crops and soybeans using minimum soil-saving technology and Strip-till technology

Technological operations	Type of tools	Due date	Agrophysical indicators of soil. Soil pulverization, %. Size of fractions, mm						
			100-50	50-20	20-10	<10			
						10-1.0	1.0-0.5	0.5-0.25	< 0.25
Winter wheat (predecessor cereal)									
The main flat-cutting processing on 10-12cm	Universal tillage tool UTT-4 (module with flat-cutting paws)	10.08	3.0	43.9	24.4	19.2	5.5	3.1	0.9
Chiseling (1 time in 3 years) on 35cm	UTT-4 (module with chisel rippers)	10.09	4.0	37.6	27.7	20.0	6.0	3.7	1.0
Pre-sowing processing (loosening, leveling, rolling)	UTT-4 (module with lancet paws)	22.09	-	28.9	30.4	28.9	6.2	3.9	1.7
Soybean Strip-till technology (predecessor cereal)									
Formation of strips 30 cm wide, chiseling with fertilization to a depth of 35 cm	Combined tool	25.09	5.0	16.0	37.6	32.3	5.4	2.4	1.3
Restoring the band edges, loosening the rolling bands, sowing seeds	Combined tool	25.04	-	16.8	39.0	35.5	5.6	2.0	1.1

Table 3. Soil pulverization with loosening implements

Implements	Fraction content, %. Fraction size, mm			Surface ridgeness, ±cm
	More than 50	50-20	Less than 20	
Universal lancet paws	16.5	42.8	40.7	6.2
Flat-cutting paws	18.6	44.0	37.4	5.3
Spherical disks	24.5	42.3	33.2	6.5
Chisel rippers with raking prop	33.7	40.9	25.4	6.0
Chisel rippers with straight prop	32.9	42.3	24.8	5.5

For the cultivation of tilled crops by the Strip-till technology, an experimental sample of a combined tool was developed that performs operations for loosening, fertilizing, forming a strip and sowing seeds into it.

According to the obtained data in the cultivation of winter wheat and soybeans, according to the traditional content of fine-grained fraction of soil less than 20 mm in size should be 70% and above. The actual content of this fraction before sowing of winter wheat was 63.9%, soybeans - 61.8%. At the same time, it took 6 passes of machine-tractor units (MTU) across the field to prepare the soil for sowing winter wheat, and 8 passes for sowing soybean. The fraction content of erosion-hazardous particles less than 0.5 mm in size on the main tillage with a dump plow in traditional technologies of cultivating winter wheat and soybeans, respectively, was 8.9 and 6.2%. As a result of subsequent crumbling and leveling of the soil with single-function tools before sowing soybean, the content of this fraction reached 7.4%, and that of winter wheat 10.2%. The increase in the concentration of erosion-hazardous particles before sowing winter wheat was promoted by significant drying of the soil in the autumn period.

Thus, at tillage according to perspective technologies, its quality has improved and the content of erosion-hazardous particles has decreased.

However, despite the fact that the quality of tillage using an experimental sample of a universal tillage tool in soil-saving technologies has improved significantly, it did not meet the agro-requirements for pre-sowing processing, according to which the content of the soil fraction less than 20% should be 80% or more, soil surface ridgeness more than ± 3 cm is not permissible, and the content of erosion-hazardous particles less than 0.5 mm in size should not increase after the tool passage. During soil chiseling, the content of fraction less than 50 mm in size should not be less than 60%.

In connection with the above, when developing experimental samples of universal tools for minimum soil-saving technology and combined tools for Strip-till, it is necessary to choose the optimal layout schemes of implements, which provide, apart from the minimum formation of erosion-hazardous particles, high quality of tillage.

For universal tillage tool, the lancet paws, flat-cutting paws, spherical disks, chisel rippers with straight and raking prop were tested as a loosening implement. Testing the effectiveness of the implements were conducted from 15 May to 25 August. The previous operation is plowing and disking. According to the obtained data, soil moisture during the testing of loosening implements in the 0–20 cm layer averaged 12.5%, density 1.09 g/cm^3, hardness 1.5 MPa, surface ridgeness 7.5 cm, which is typical of the soils of South Kazakhstan.

Analysis of the work quality of loosening implements for surface tillage (**Table 3**) shows that, compared with the disks, the lancet and flat-cutting paws provided a greater degree of crumbling and leveling of soil and a lower concentration of erosion-hazardous particles. Implements for deep loosening of soil - chisel rippers with raking and straight prop formed an insignificant

Fig. 1. Experimental equalizer

Table 4. Qualitative indicators of the work of various types of equalizers

Indicators	Experience options		
	Leveling board	Toothed spring-actuated harrow	Experimental equalizer
Soil moisture 17%			
Soil pulverization, % by fractions:			
>50mm	5.0	5.5	4.3
50-20	44.2	43.2	40.3
<20	50.8	51.3	55.4
Surface ridgeness, ±cm	5.4	5.7	4.0
Soil moisture 14%			
Soil pulverization, % by fractions:			
>50mm	4.8	6.0	4.5
50-20	42.8	44.0	39.5
<20	52.4	50.0	56.0
Surface ridgeness, ±cm	5.0	6.0	4.8
Soil moisture 10%			
Soil pulverization,% by fractions:			
>50mm	5.8	6.5	6.0
50-20	41.5	47.9	41.6
<20	52.7	45.6	52.4
Surface ridgeness, ±cm	5.2	6.7	5.0

number of erosion-hazardous particles, while the chisel ripper with raking prop better loosened the soil. According to the obtained data, only with the work of loosening implements it is impossible to achieve satisfactory indicators of soil pulverization and leveling of surface. In this regard, multifunctional tools must be equipped with leveling devices and rollers.

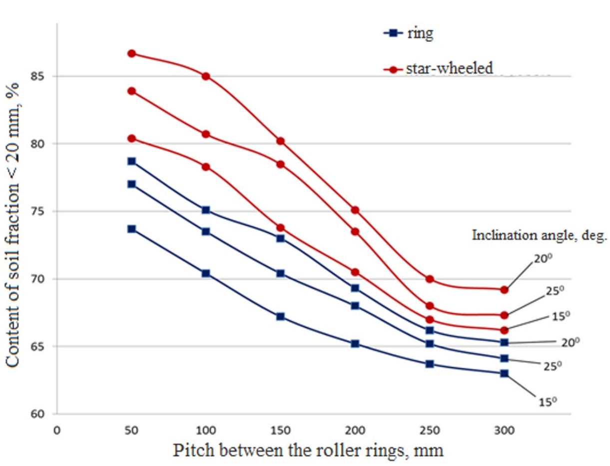
An experimental equalizer developed by «RPCAE» LLP (**Fig. 1**) was tested as a leveling device; its performance indicators was compared with the indicators of the most common leveling tools on farms: leveling board and toothed spring-actuated harrow. As previous studies show, the qualitative indicators of soil equalizers depended on soil moisture. In this regard, tests of the leveling devices in the layout with lancet paws were carried out at three levels of moisture (**Table 4**). If take the fraction of less than 20 mm in size as qualitative indicator of soil pulverization, as follows from agro-requirements, then the experimental equalizer provided the best degree of crumbling and leveling of the soil compared to the leveling board and the toothed spring-actuated harrow. However, as follows from the data of **Table 7**, with low soil moisture, it has formed a larger number of erosion-hazardous particles compared with a toothed harrow (**Table 7**). According to the results of the studies performed, the allowable moisture range was determined when various types of equalizers were operating. When operating an experimental equalizer in soil-saving technologies, soil moisture should be in the range of 17-14%; toothed spring-actuated harrows 17-10%. When soil moisture is below 10 - 7% in the soil layer 0-20cm, the use of all types of equalizers is not effective.

Leveling devices have improved tillage qualitative indicators. However, to create optimal conditions for seed germination, it is necessary to increase the content of the soil fraction less than 20 mm to 80%, reduce the surface ridgeness to 3 cm and form a compacted bed for sowing seeds. In this regard, loosening implements and leveling devices in a tillage tool should work together with a roller, the type and parameters of which will ensure the quality indicators specified by agro-requirements. To perform this operation, rollers of various types and parameters are widely used. As a result of analysis of domestic and foreign sources of information, patent research of existing rollers for study, the most perspective for the soils of South Kazakhstan were selected: rod, ring, and star-wheeled roller

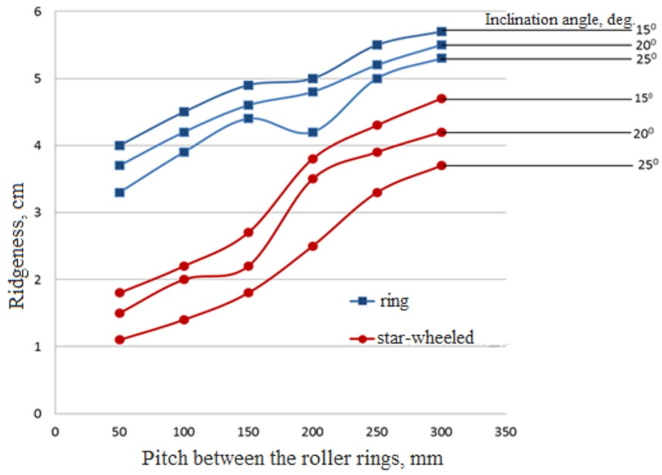
ring roller

star-wheeled roller

Fig. 2. Field studies of various types of rollers



(a)



(b)

Fig. 3. Dependence of the quality of soil pulverization a) and ridgeness b) of the surface on the distance between the roller rings and the angle of its installation to the direction of movement

designed by us that works as follows: when rings are moving with side slip, they create a packed bed for seeds, spurs (rods) loosen the surface layer and crush clumps of soil.

As a result of theoretical studies of the laws of motion and interaction of star-wheeled roller with the soil, an equation describing the trajectory of their movement during the technological process and the conditions of soil compaction by them was obtained. Theoretical studies (Golubev 2004, Kapustin 2013, Kruk et al. 2015, 2016, Shubin 2001, 2010) made it possible to consider the processes: the interaction of ring and spurs of the roller with soil clumps; force impact of ring on the soil and select the ranges of acceptable values: the diameter of ring (500-550 mm); the distance between the rings (50-300mm); installation angle of rings to the direction of motion (15-25^0).

To confirm the results of theoretical studies, field studies of various types of rollers were carried out (**Fig. 2**). For this purpose, a laboratory installation was made, which was assembled with lancet paws, leveling implement and various types of rollers.

The test results showed that the quality of crumbling and leveling of soil when using the rod roller did not satisfy the agro-requirements. In this regard, the rod roller was replaced by a ring one in which the ring spacing was regulated and, in addition, a star-wheeled roller was made based on it. On the inner circumference of the ring, which on one side were installed rods with a length of 70-80 mm. This design of the roller improves the conditions of crushing the soil clumps and crumbles them better.

The soil pulverization and the surface ridgeness of the field depended on the layout of these rollers: the pitch between the roller rings; installation angle of the roller relative to the direction of movement; distances between spurs, and their parameters (**Fig. 3**).

Table 5. Density change in the upper layers of soil (g/cm^3) under the influence of ring and star-wheeled rollers (distance between the roller rings 150mm; between spurs 100mm)

Layer of soil, cm	Ring			Star-wheeled		
	Installation angle of the rings to the direction of movement					
	15^0	20^0	25^0	15^0	20^0	25^0
0-5	0.85	0.70	0.77	0.80	0.68	0.70
5-10	1.2	1.25	1.22	1.22	1.27	1.25
10-15	1.0	1.1	1.15	0.98	1.15	1.15
15-20	1.4	1.42	1.47	1.42	1.43	1.46

When exposed to the soil of a ring roller without rods, regardless of the distance between the rings, the quality indicators of its processing was lower - the ridgeness ranged from 3 to 5.7 cm and the soil fraction less than 20 mm from 58 to 78%. During the operation of the roller with spurs, these indicators improved and accordingly amounted to: ridgeness from 1.1 to 4.7 cm; the content of soil fractions less than 20 mm in size from 68.2 to 88.7%.

When the installation angle of the roller rises to the direction of movement, the quality indicators of soil pulverization reach the optimum value at 20^0 (**Fig. 3a**), and the field surface alignment at an angle of -25^0 (**Fig. 3b**).

The maximum content of soil fraction of less than 20 mm in size was formed when the distance between the roller rings was 50 mm. However, with such a pitch between the roller rings with high soil moisture (more than 16% in the 0-20cm layer), it was sticking with soil, and if there were large clumps of soil and plant residues and clogging. Increasing the pitch to 100-150 mm reduced the quality of soil pulverization, however, the content of the soil fraction less than 20 mm corresponded to the agro-requirements and the operation of tool was stable at all levels of its moisture. With a further increase in the pitch between the roller rings to 250 and 300 mm, the quality of soil pulverization decreases. The minimum ridgeness was provided with a distance between the rings of 50-100 mm, and the maximum at 250-300 mm, both during the operation of ring and star-wheeled roller.

The distance between the spurs and their length also had an impact on the quality indicators of tillage. The maximum crumbling of soil and the levelness of its surface were observed with a minimum distance between the roller spurs 50-70 mm. As this distance increases to 140 cm, the quality of tillage deteriorates dramatically. With increased moisture and lumpiness of the soil and the presence of a large amount of plant residues when the distance between the spurs was 50 mm, the roller rings were clogged with soil and plant residues. Thus, the distance between the roller spurs 100mm should be considered optimal.

In the process of testing, the influence of the spur length (60 and 85 mm) on the crumbling and ridgeness of the soil surface was determined. It has been established that an increase in the spur length to 85 cm increased the content of a soil fraction of less than 20 mm in size by 15%, and had almost no effect on the levelness of field surface.

One of the main indicators of the quality of the roller performance is the formation of a compacted seed bed under their influence (**Table 5**). In this connection, the change in the soil density in its upper layers after the passage of the laboratory installation with various types of rollers was determined.

Regardless of installation angle of the ring to the direction of movement, the compacted seed bed (layer 5-10 cm) was formed by ring roller both without spurs and with spurs. The density in the area of seed occurrence was sufficient to restore the capillaries of the soil and moisture to them.

Thus, the agrotechnical requirements for surface pre-sowing tillage in the conditions of the South of Kazakhstan are satisfied by a star-wheeled roller with the following parameters:

- the installation angle of the roller relative to movement of the unit 20-250;
- the distance between the roller rings 100-150mm;
- the distance between the spurs 70-100mm;
- the spur length 85mm.

To develop effective layout schemes for universal tools for tillage technologies, it is necessary to consider the process of their implement impact on the formation intensity of erosion-hazardous particles in the soil.

The experiment was conducted on light chestnut soil of medium loam texture in the spring (May 15) and summer-autumn period (August 25) 2018. For testing was made laboratory installation. Loosening implements (lancet paws, flat-cutting paws, spherical disks, chisel rippers), leveling implements (leveling board, toothed spring-actuated harrow, leveling implement of experimental equalizer, as well as various types of rollers (ring, star-wheeled). In the spring period (May 15), the soil moisture was optimal for processing and in the 0-20cm layer was 17%. In the summer-autumn period (August 27) the soil was dry. Its moisture content in the 0-20cm layer was 10%, what is typical for the soils of the South Kazakhstan. Soil sampling to determine the concentration of erosion-hazardous particles was carried out after 0.5; 24; 48 and 72 hours after tillage (**Table 6**).

For study in a soil sample, sifted through a 1mm sieve, the concentration of soil fraction of less than 0.5 and less than 0.25 mm was determined.

Table 6. Content of the erosion-hazardous soil fraction at different moisture

Experiment options	**Content, %**											
Fraction size, mm	**1-0.5**				**0.5-0.25**				**<0.25**			
Soil sampling time, hour	0.5	24	48	72	0.5	24	48	72	0.5	24.0	48.0	72
Testing due date, soil moisture, %	May 15, soil moisture 17%											
Previous operation	Early spring harrowing of fall plowing											
The content of erosion-hazardous particles before the tool passage (control)	12.7	12.7	12.7	12.7	20.4	20.4	20.4	20.4	66.9	66.9	66.9	66.9
Loosening implements:												
- universal lancet paws;	5.2	6.8	8.1	9.6	24.4	22.1	21.3	20.2	70.4	71.0	70.6	70.2
- flat-cutting paws;	7.9	9.1	11.2	12.4	23.7	21.9	21.0	20.4	68.5	69.0	67.8	67.2
- spherical disks;	3.4	5.1	5.2	5.5	26.6	23.4	23.0	23.5	71.8	71.5	71.8	71.0
- chisel ripper with straight prop;	7.3	7.7	9.7	12.0	23.4	21.8	21.0	20.0	69.3	70.5	69.3	68.0
- chisel ripper with raking prop;	6.1	8.0	7.2	8.9	23.8	22.0	22.6	21.6	70.1	70.0	70.2	69.5
Leveling implements:												
- leveling board;	10.4	11.6	12.1	12.3	21.7	21.0	20.5	20.7	67.9	67.4	67.4	67.0
- toothed spring-actuated harrow;	11.6	12.0	12.4	12.6	21.0	20.8	20.6	20.4	67.4	67.2	67.0	67.0
- experimental equalizer;	7.4	9.2	10.8	11.3	22.6	21.9	21.6	21.4	70.0	68.9	67.6	67.3
Roller implements:												
- ring roller;	10.2	11.1	11.7	12.4	21.8	21.6	21.1	20.6	68.0	67.3	67.2	67.0
- star-wheeled roller;	9.1	9.9	10.7	11.5	22.1	21.9	21.4	21.0	68.8	68.2	67.9	67.5
Testing due date, soil moisture, %	August 27, soil moisture 10%											
Previous operation	Cereal stubble cleaning											
The content of erosion-hazardous particles before the tool passage (control)	5.4	5.4	5.4	5.4	14.5	14.5	14.5	14.5	80.1	80.1	80.1	80.1
Loosening implements:	3.5	5.4	5.5	5.7	13.3	13.5	13.6	13.8	83.2	81.1	80.9	80.5
- universal lancet paws;	1.8	3.6	5.9	6.4	12.9	12.8	13.0	13.2	85.3	83.6	81.1	80.4
- flat-cutting paws;												
- spherical disks;	1.2	1.2	5.4	5.5	11.8	12.0	12.3	12.7	87.0	86.8	82.3	81.8
- chisel ripper with straight prop;	1.7	4.4	5.4	6.6	12.5	12.6	12.9	12.9	85.8	83.0	81.7	80.5
- chisel ripper with raking prop;	1.3	3.3	6.0	6.7	12.7	12.9	12.9	13.1	86.0	83.8	81.1	80.2
Leveling implements:												
- leveling board;	5.1	5.5	5.6	5.8	13.8	13.5	13.7	13.9	81.1	81.0	80.7	80.3
- toothed spring-actuated harrow;	5.3	5.4	5.5	5.6	14.1	14.2	14.3	14.3	80.6	80.4	80.2	80.1
- experimental equalizer;	3.6	4.0	4.9	5.3	13.9	14.0	14.1	14.2	82.5	82.0	81.0	80.5
Roller implements:												
- ring roller;	5.0	5.2	5.3	5.5	13.2	13.4	13.5	14.0	81.8	81.4	81.2	80.5
- star-wheeled roller;	4.2	4.5	5.0	5.2	13.5	13.7	14.0	14.1	82.3	81.8	81.0	80.7

The criterion for effectiveness evaluating of the machine implements are agro-requirements for technological operations in the anti-erosion system of farming, according to which the amount of erosion-hazardous soil fraction after the passage of tools should not increase.

After tillage with various types of implements, the content of erosion-hazardous particles increased. From loosening implements, the maximum number of them at all levels of moisture formed disk implements. Next on the intensity of the formation of erosion-hazardous particles are lancet paws. Minimal spraying of the soil was observed when it was processed with flat-cutting paws and chisel implements. Moreover, chisel implements with straight prop did not turn soil clumps to the surface and, as a result, formed the minimum amount of erosion-hazardous fraction of soil in the experiment.

The study of the impact on the soil leveling devices showed that the minimum amount of soil fraction of less than 0.5 mm in size was formed by a toothed spring-actuated harrow.

The types of rollers did not have a significant impact on the formation of an erosion-hazardous fraction of soil. However, during the operation of the star-wheeled roller, the content of erosion-hazardous particles slightly increased. At the same time, it provided the best soil pulverization (content of the agronomical valuable fraction was maximum) and, unlike other rollers, formed compacted bed for sowing seeds.

Soil moisture had a significant impact on the content of erosion-hazardous particles in the soil both in the control and after the passage of all types of implements. At the optimum moisture content in spring period (17%) before the tillage tools pass, the concentration of soil particles less than 0.5 mm was 87,3%, including the fraction less than 0,25-66,9%. With soil moisture of 10%, the initial amount of these fractions was 94,6 and 80,1%, respectively. After 0.5 hours after the passage of the implements reached a maximum value. Over time, sticking of small particles of soil and their transition into an agronomical valuable fraction occurs. So, 72 hours after the soil was loosened by various types of implements, the content of erosion-hazardous particles significantly decreased and, at the optimum soil moisture of 17%, basically came to its original state. At low soil moisture when it is processed by disk implements after 72 hours, the soil did not come to equilibrium. Thus, during the passage of heavy rainfall immediately after disking dry soil or when watering is carried out simultaneously with or immediately after sowing, these leaks of erosion-hazardous particles from the soil can occur.

On the basis of the above data, the optimal layout options of the combined tool for strip tillage and universal tillage tools when performing technological operations at

Table 7. Layout schemes of combined tool for cultivating row crops by Strip-till technology

Technological operations	Layout schemes
Formation of strips with a width of 30 cm, chiseling with fertilizer application to a depth of 35 cm	Chisel rippers with straight prop + spherical disks + star-wheeled roller
Restoring the band edges, loosening the strips, rolling, sowing seeds	Spherical discs + cultivating paws + section for sowing seeds

Table 8. Layout schemes of UTT-4 tool when processing soils with different levels of moisture

Technological operations	Technological modules UTT-4	Soil moisture in the layer 0-20cm, %		
		minimum	maximum	optimal
Soil chiseling to a depth of 35cm	Chisel rippers + star-wheeled roller	10	18	14-17
Pre-sowing processing of waste background	Lancet paws + experimental equalizer + star-wheeled roller	10	19	14-17
Pre-sowing loosening of stubble background	Flat-cutting paws + toothed spring-actuated harrow	7	19	14-17
Plowing	Spherical disks + experimental equalizer + star-wheeled roller	14	18	14-17
Stubble cleaning	Spherical disks	10	18	14-17

different levels of soil moisture in soil-saving technologies (**Tables 7**, **8**).

The results of field tests of the combined and universal tools showed that they qualitatively performed the technological process of tillage, and when performing technological operations at the optimum level of moisture, the concentration of erosion-hazardous particles 72 hours after processing came to its original state.

CONCLUSIONS

Existing technologies of cultivation of agricultural crops do not provide for protective measures from soil degradation under the influence of erosion processes.

The most perspective are the minimum technologies for the cultivation of cereal, as well as the cultivation of row crops using Strip-Till technology. Dump tillage contributes to the enhancement of erosion-hazardous processes on dry soils of the South-East of Kazakhstan and should be replaced with a flat-cutting and chisel processing.

In soil-saving technologies in the conditions of the South of Kazakhstan, the best option is the main flat-cutting and chisel processing, as well as pre-sowing soil loosening with combined and universal tools.

Depending on the moisture content of the cultivated soil, the constructive-technological scheme of the implements should provide for the possibility of their arrangement by various types of loosening, leveling implements and press rollers. Disk implements in comparison with the lancet paws provide a greater amount of erosion-hazardous particles, and therefore can be used on cutting plowing on soils with sufficient moisture and on operations for stubble cleaning, which protects the soil from spraying. The optimal arrangement for pre-sowing processing is the layout of combined tool with lancet paws on dump background or flat-cutting paws on stubble background, toothed spring-actuated harrow and star-wheeled roller. To replace the dump plowing tool must be composed of chisel rippers and star-wheeled roller.

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