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Experimental Study of Different Methods of Soil Treatment with the Purpose of Maximum Preservation of Stubble and Pruning of Weeds

In Northern Kazakhstan, the main task of agrarians is to accumulate and retain the maximum amount of moisture. In this regard, effective agrotechnical moisture conservation methods are high-quality autumn non-moldboard processing of stubble backgrounds with maximum preservation of stubble on the surface and a mechanical method of weed control in a fallow field. The obvious disadvantages of existing tillage machines are the poor deepening ability of flat-cutting working bodies, embedding stubble into the soil, and incomplete cutting of weeds. Machine-tractor units with single-operational specialized machines and their multiple passes over the field recompact about 60% of the cultivated area. The most promising for the implementation of these technological operations are combined tools. However, the technical process of the joint interaction of lancet, disk, and bar working bodies with the soil in the conditions of Northern Kazakhstan has not been sufficiently studied so far. In this regard, the work aims to study the effect of technological schemes of a combined tool on agrotechnical and energy indicators and to test an experimental sample under production conditions.

Keywords: *combined tool, fallow, stubble, soil crumbling, depth of processing.*

1. INTRODUCTION

The right choice of technology for the main tillage in a particular crop rotation field is an important reserve for increasing crop yields. The criterion for the need for tillage can be the difference between the natural density of the soil on the field and the optimum allowable density for a particular crop. If these indicators are close, then additional processing of the root layer is optional. The existing system of technologies and mac–hines [1] for the main tillage against various back–grounds recommends several machine technologies that provide for moldboard or non-moldboard culti–vation of the root layer to a depth of 16–20 cm [2,3]. Such treatments regulate the density of the soil, provide better absorption of meltwater, embedding weed seeds in the surface layer. However, machine-tractor units with single-operational specialized machines and multiple passes over the field compact about 60% of the cultivated area. In addition, single-operational machines often do not allow the total loading of high-speed energy-saturated tractors. Combined units and machines reduce the number of MTU passes across the field and reduce labor and material costs [4,5,6,7, 8]. The high efficiency of combined implements or the introduction of new technologies for the cultivation of crops contributes to an increase in their use in the USA, Canada, European countries, and Russia [9].

The analysis of scientific and technical literature allows concluding that with a soil-protective system of agriculture, for the main processing of fallow and stubble backgrounds, it is most effective to use wide-cut combined tools capable of performing at least three technological operations in one pass of the unit (Smaragd, Pegasus, APK-7.2). The use of these mac–hines will increase the productivity of the units, reduce to a minimum the gap between technological opera–tions and the impact of tractor propellers on the soil, which will make it possible to retain moisture in the soil, prevent the process of spraying the upper and over consolidation of the lower soil layers on cultivated areas [10-12]. Reducing or eliminating the use of che–micals to control weeds will allow us to obtain envi–ronmentally friendly agricultural products and pre–serve the health of consumers of our products [13, 14]. Similar research results have been achieved (Sarkar P, Upadhyay G and Raheman H. 2021) and found that various passive-passive combinations of combined imp–lements are superior to traditional tillage methods in ter–ms of fuel consumption, time, and cost of operation [15].

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Along with the listed positive performance indi–cators of the combined units developed in Germany and Russia, they all have significant drawbacks. The tools Smaragd and Pegasus qualitatively perform the technological process on the processing of a fallow field, while on the non-moldboard cultivation of stub–ble fields, there is almost no stubble on the surface of the field; it is all embedded in the soil, which does not meet the agrotechnical requirements for the techno–logical operation "non-moldboard tillage" [16]. The APK-7.2 tool qualitatively performs the technological process in processing stubble fields. In contrast, the processing of fallow fields leaves from 5-12% of weeds, which does not meet the agrotechnical requi–rements for the technological operation "Millboardless tillage" [16].

The layered cultivator mixes the soil in the upper soil layer and loosens the deeper layers. Its use in the organic farming system contributes to the high-quality pruning of weeds, contributing to increased yields. However, after the passage of a layered cultivator, almost all of the stubble is embedded in the topsoil [17]. In the conditions of Northern Kazakhstan, such tillage contributes to the occurrence of wind erosion. This conclusion was reached by researchers Paul Mayer and Alfred Bester from the University of Basel Library.

In the North-Eastern region of the European part of Russia, processing winter rye stubble on heavy loamy soddy-podzolic soil with its moisture content of 23.8% and hardness of 2.36 MPa is analyzed. A combined tool consisting of sequentially installed flat-cutting working bodies with a working width of 0.76 m and disk working bodies installed in one row at an angle to the direction of movement provides the required processing quality indicators (Andreev V L, Vasilyev S A, et al. 2019) [18]. However, with a high degree of probability, it can be assumed that with such a scheme of the tool, there will be practically no stubble on the surface of the field after the passage.

Y. Abbaspur-Ghilande, M. Fazeli, A. Roshani–anfard et al. [19], R. Horn found that as the moisture content in the soil decreases due to drying and harde–ning of the soil, the traction force increases. Therefore, soil strength increases by increasing the cone index [20]. With an increase in the soil's strength, the working bodies' deepening ability deteriorates, and a violation of the technological process occurs.

It is known that the soil and climatic conditions of Northern Kazakhstan differ significantly from the conditions of Siberia, Central Europe, and other coun–tries; therefore, to obtain the required quality of processing on medium and heavy soils with an average hardness of the treated layer of 3.0-3.5 MPa and a moisture content of 10 -12% with existing tillage implements is almost impossible.

To achieve the high-quality performance of the technological process in our studies, we should use a flat-cutting working body with slightly changed geometric parameters (width of grip and crumbling angle) compared to previous similar studies.

Therefore, the problem of developing a combined tool adapted to the zonal soil conditions of Northern Kazakhstan, capable of consistently performing the technological process of the main processing with the required quality, is relevant.

2. MATERIALS AND RESEARCH METHODOLOGY

Based on the analysis of scientific, technical, and patent literature, it has been established that four main technological schemes of a combined implement are used in the practice of world agricultural engineering. Therefore, four variants of the technological schemes presented in Figure 1 were tested when substantiating the technological procedure.

Scheme 1 - Flat-cutting working bodies with a working width of 500 mm installed in two rows, spherical disk working bodies □450 mm (installed in one row with an attack angle of 20 degrees), a press roller (bar, double drum).

Scheme 2 - Flat-cutting working bodies with a working width of 500 mm installed in two rows, spherical disk working bodies □ 450 mm (installed in pairs, at an angle of attack of 20 degrees), press roller (bar, double drum).

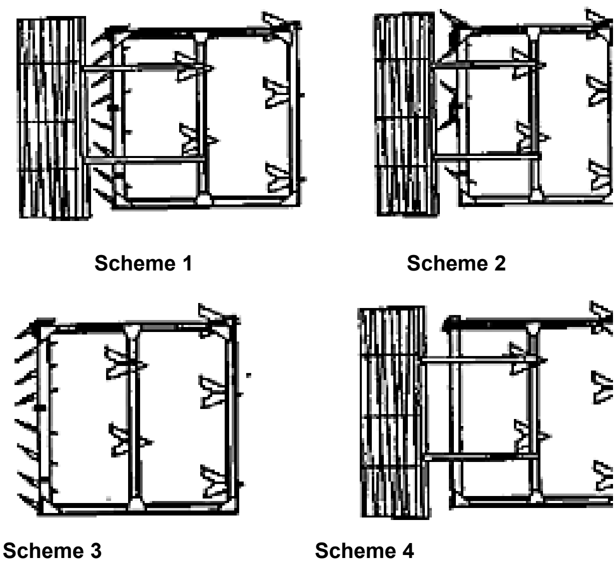


Figure 1. Variants of technological schemes

Scheme 3 - Flat cutting working bodies with a working width of 500 mm installed in two rows, spherical disk working bodies∅ 450 mm (installed in one row with an attack angle of 20 degrees).

Scheme 4 - Flat-cutting working bodies with a working width of 500 mm installed in two rows, a roller (bar, double drum).

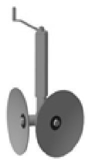
The main evaluation indicators in the agrotechnical assessment of technological schemes were the crushing of the treated layer, cutting weeds, keeping stubble on the surface, and stability of the course in terms of the depth of processing. The test conditions were determined according to State Standard 20915 [21], and agrotechnical indicators were evaluated by the requirements of State Standard 33687 [22]. Verification of options for technological schemes of the combined implementation for the main tillage was carried out on a laboratory-field installation shown in Figure 2.

Figure 2. General view of the laboratory and field installation

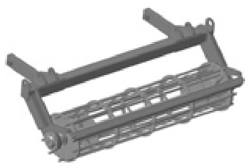
The laboratory and field installation had a working width of 3.9 m. It was equipped with 9 flat-cutting working bodies, five batteries of disk working bodies, and a double drum press roller. The working bodies used in the experimental studies are shown in Figure 3.

a

b



c



d

a – flat cutting tool;
b – battery of disk working bodies with variable working depth;
c –disk working bodies installed in pairs at an angle to the direction of movement.
d – double drum press roller.

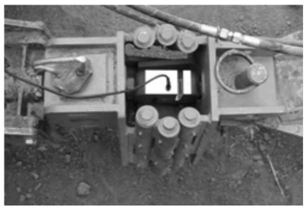
Figure 3. Working bodies

The flat-cutting working body of the presented design cuts weeds not worse than the lancet share. Still, it steadily and efficiently performs the technological process on dry and over-compacted soils (stubble background, main processing). The lancet share in such conditions no longer works. A double drum packer roller provides better soil crumbling on a stubble background than a single drum one.

Energy evaluation of agricultural machinery is carried out following State Standard R 52777 [23]. The energy evaluation is carried out simultaneously with the agrotechnical one. When conducting an energy evaluation, traction resistance, fuel consumption, distance traveled during the experiment, and the experiment's time is determined. The traction resistance of agricultural machinery is measured using tensometric equipment, including an S-shaped tensile force sensor UU with a measurement range of 3 and 5 tons and a tensometric station ZET017-T8 manufactured by ZETLAB. The equipment is shown in Figure 4. Electrical signals from the strain gauge link between the tractor and the agricultural machine are recorded by the strain gauge station ZET017-T8, which transmits the signal to a computer with a special program installed by ZETLAB.

In each repetition of the experiment, the recording of signals is carried out for at least 20 seconds. The repetition of the experiments is taken four times: two repetitions when moving forward, two - in the opposite direction. Before testing, the tension links are calib–rated on a special stand, by the method of stepped loa–ding and unloading, through a general-purpose spring-type tension dynamometer, of the second accuracy class.

a



b

c

a – tensor equipment; b – trailer dynamometer equipment; c – stand for calibration of tension links.

Figure 4. Strain gauge equipment

In calibration tests, the force values are recorded on the dynamometer. The corresponding readings of the tesozlink, are processed by the ZET017-T8 strain gauge station and displayed on the laptop monitor. The experiment was repeated four times.

The operational and technological evaluation of the experimental sample of the combined tillage tool was carried out according to State Standard 24055 [24].

The evaluation of the economic efficiency of the units was determined according to ST RK State Stan–dard R 53056 [25]. Direct operating costs of funds (I) per unit of operating time are calculated by the formula:

$$I = Z + G + R + A + F \quad (1)$$

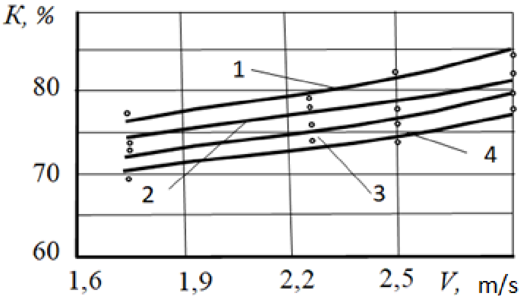
3. RESULTS AND DISCUSSION

Studies for substantiating the technological scheme of a combined tool for tillage were carried out in the Kostanay region, the Republic of Kazakhstan. Rese–arch dates: on the fallow background July 24 -August 10, on the stubble, August 25 - September 3.

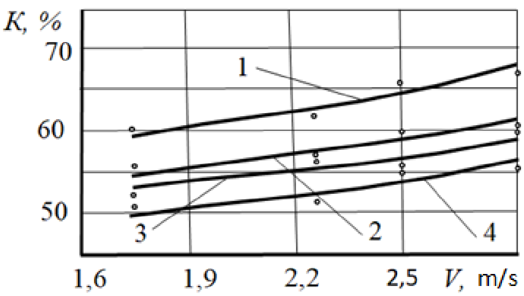
Field background – fallow. Average moisture values characterized soil conditions during the research period - 26.3%, hardness - 1.4 MPa, density - 0.9 g/cm3, in the layer 0-20 cm.

The background of the field is wheat stubble, the third crop after fallow. At a depth of 0-20 cm, the soil layer's state was characterized by average values of soil moisture 5.7%, hardness 4.1 MPa, and density 1.35 g/cm3.

The stroke depth of the lancet working bodies per pair is 15-16 cm; the working disk bodies are 7-8 cm; on the stubble, the stroke depth of the lancet working bodies is 13-14 cm, the working disk bodies are 5-6 cm.



a) Background – fallow



b) Background – stubble

Figure 5 - The influence of the speed of movement of the unit and the technological scheme of the tool on the crumbling of the soil (fractions: up to 25 mm - fallow; up to 50 mm - stubble)

Studies have shown that with an increase in the movement speed within 1.7–2.8 m/s, by Figure 5a (background of fallows) and 5b (background of stubble), the crumbling of the treated layer increases in all variants of technological schemes.

On the studied modes of movement of the unit, the maximum crumbling, on a fallow background, 76-84% of fractions smaller than 25 mm in size was obtained using technological scheme 1. The somewhat lower crumbling of the cultivated soil layer (74-79%) was obtained using technological scheme 2. Minimum soil crumbling Scheme 4 provided 70-76%. The results of studies of technological schemes 3 and 4 showed that under these soil conditions, they provide 72-78 and 70-76% of soil crumbling, respectively, depending on the speed of movement.

Studies on the stubble background showed that with an increase in the unit's speed from 1.7 to 2.8 m/s, soil crumbling increases according to all the studied schemes. However, the quality of soil crumbling, compared with the fallow background, decreased. The highest quality of crumbling of the treated layer 59-68%, by Figure 5b, is provided by scheme 1. The minimum quality of crumbling 49-56% is provided by scheme 4. All other schemes provide soil crumbling within 53-61% of fractions less than 50 mm.

Thus, the required quality of soil crumbling, by the initial requirements [16], presented for fallow treatment, at least 80% of fractions up to 25 mm, is provided by scheme 1 at a unit speed of 2.2–2.8 m/s. When processing stubble backgrounds, at least 60% of a fraction up to 50 mm is provided by scheme 1 at a movement speed of 1.8-2.8 m/s, and scheme 2 at a movement speed of 2.7-2.8 m/s.

The evaluation of the running stability indicators by the depth of processing was carried out in the same areas as crumbling. It has been established that with an increase in the speed of movement of the unit from 1.7 to 2.8 m/s, the change in the standard deviation of the processing depth in absolute value, by Figure 6, for all schemes is 0.2-0.3 cm and is within experience errors.

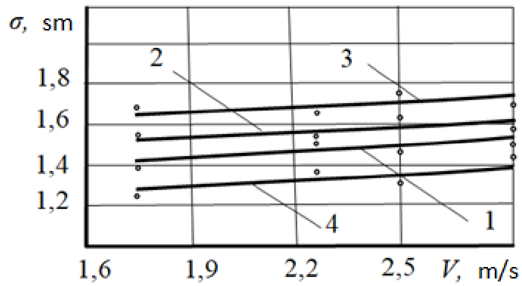


Figure 6. Influence of the speed of movement of the unit and the technological scheme of the tool on the standard deviation of the working depth (Background - fallow)

The minimum value of the standard deviation of ±1.2-1.4 cm has scheme 4, and the maximum value of ±1.6-1.7 cm is shown in scheme 3. It should be noted that all schemes for the stability of the stroke of the working bodies meet the initial requirements for a given depth processing.

Studies conducted on a stubble background showed that with an average depth of working bodies (14.8 cm), the standard deviation of the working depth with increasing speed increases in all the studied arrangements of working bodies. The largest standard deviation of the processing depth was obtained using scheme 3, and the minimum - scheme 4 (Figure 7).

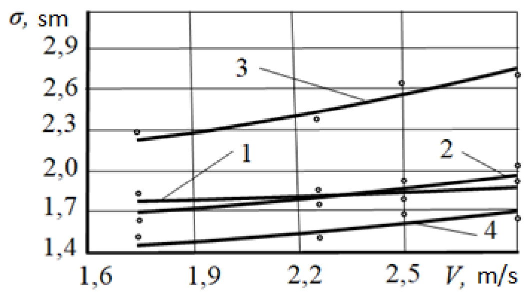


Figure 7. Influence of the speed of movement of the unit and the technological scheme of the tool on the standard deviation of the depth of processing (Background - stubble)

An increase in the speed of movement of the unit from 1.7 to 2.8 m/s increases the value of the standard deviation, for scheme 3, from 2.2 to 2.7 cm, and for scheme 4 from 1.5 to 1.7 cm. the root-mean-square deviation of the processing depth from the speed of movement is linear, which is preserved in all the studied schemes.

The initial requirements for the basic technological operation (non-moldboard tillage) established that the standard deviation of the tillage depth should not exceed ± 2 cm.

Thus, it was found that in the processing of stubble backgrounds, schemes 1, 2, and 4 in terms of the standard deviation of the depth of processing corres–ponding to the initial requirements for basic machine technological operations, "non-moldboard tillage".

When conducting laboratory and field studies to determine the effect of the technological scheme on cutting weeds, the average depth of processing with lancet paws on a fallow background was 15.2, on stubble 14.8 cm, and with working disk bodies - 7.2 and 6.4 cm, respectively. At the same time, the speed of movement of the unit was in the range of 2.3-2.5 and 2.6-2.8 m/s. The research results showed that the quality of cutting weeds varies depending on the technological scheme. It has been established that in the treatment of fallow, the best quality of cutting weeds, by Figure 8, is provided by scheme 1. Continuous tillage with lancet working bodies installed on the tool frame with an overlap of 50 mm between adjacent working bodies makes it possible to cut all weeds located at a depth of processing. Disc working bodies are installed behind the lancet paws in one row with a distance between the discs of 175-180 mm and an angle of attack of 20-22 degrees. They cut weeds at a depth of 6-7 cm and break the connection between the plant's root system and the soil.

The double-drum press roller partially combs out the weeds in the surface layer, in the zone of action of the bar working bodies, while the roller creates a loose surface, up to 5 cm deep, at which the survival rate of plants is zero. Therefore, a technological scheme with such an arrangement of working bodies ensures 100% destruction of weeds at a given processing depth.

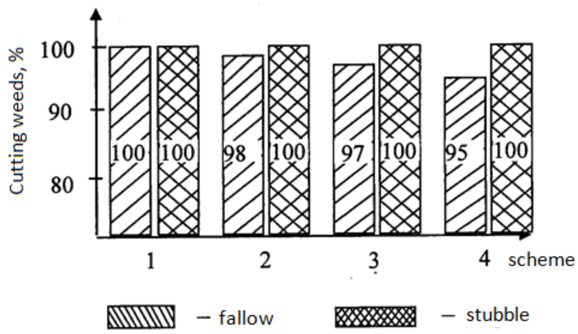


Figure 8. Influence of the technological scheme of the tool on the quality of cutting weeds

Technological scheme 2 provides cutting of 98% of weeds. The deterioration of the quality of cutting weeds, in scheme 2, is facilitated by the paired arrangement of disk working bodies. As in Scheme 1, the disk working bodies are located behind the lancet paws; however, they are installed in pairs on a stand with an angle of attack of 18 degrees each. The distance between the racks of disk pairs was within 750-760 mm, which contributed to the fact that between the sections of the disks, there were untreated areas, strips 200-250 mm wide, on which the soil was discarded by the disk working bodies were laid. This contributed to the preservation and survival, in the treated area, of 2% of weeds.

The decrease in the quality of cutting weeds in other schemes can be explained by the absence of one or two types of working bodies included in the combi–nation of working bodies of scheme 1. The absence of a press roller in the technological scheme contributes to a decrease in the stability of the tool stroke and the depth of processing, which also affects the reduction in the quality of cutting weeds. Confirmation is the percentage of cutting weeds when using schemes 3, 4.

Researching a stubble background showed that all the studied schemes ensure the destruction of weeds. Thus, the research results show that the complete cutting of weeds, on a fallow background, in one pass of the unit is ensured when the working bodies are arranged according to the technological scheme 1. All the studied schemes ensure the destruction of weeds on the stubble background.

An assessment of the significance of the difference in sample means by t-criterion was carried out. It sho–wed that at the 5% significance level, the difference between the mean values of schemes 1 and 4 is greater than the least significant difference, d > HSR0.5 (3.9 > 0.7). When the difference between the average values falls into significant differences, it is considered necessary.

One of the elements of the soil protection system of agriculture in areas prone to wind erosion is the preservation of crop residues on the field's surface. According to the existing recommendations for carrying out the main non-moldboard tillage, the content of crop residues on the treated surface should be at least 60% of the original. Checking the influence of technological schemes on the safety of stubble showed that, depending on the scheme, the indicator of stubble safety varies from 48 to 69%. Increasing the unit's speed from 1.7 to 2.8 m/s reduces the amount of stubble on the field surface by 5-16%.

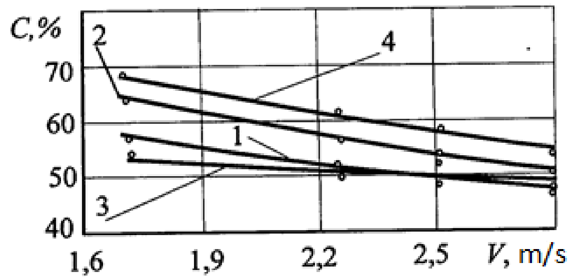


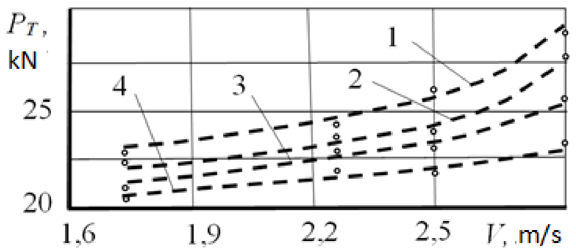
Figure 9. Influence of the speed of movement of the unit and the technological scheme of the tool on the presser–vation of stubble after the passage of the tool (Backg–round - stubble)

The research results showed that the maximum amount of stubble on the field surface, by Figure 9, remains after the passage of the tool with technological scheme 4. Depending on their arrangement 1 or 2, the use of disk working bodies reduces the content of stubble on the field surface by 5 -10% compared to scheme 4.

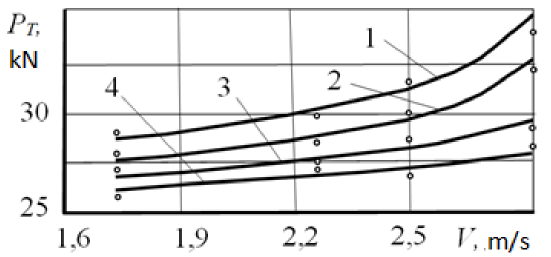
The traction resistance of the variants of technological schemes was determined simultaneously with the evaluation of functional indicators on the fallow and stubble backgrounds. It has been established that with an increase in the speed of movement of the unit within 1.7 - 2.8 m/s, the traction resistance of technological schemes increases; against the stubble background, it was in the range of 20.6-29.4 kN.

It was 26.1-39.5 kN on a fallow background. The obtained dependencies are shown in Figure 10. Scheme 1 has the highest traction resistance. movement 2.8 m/s - 39.5 kN. On the stubble at a speed of 1.7 m/s, the traction resistance was 23.0 kN, and at 2.8 m/s, it was 29.4 kN. Scheme 4 has the minimum traction resis–tance. On the fallow background, the indicators are 26.4-28.0 kN, on the stubble - 20.6-23.1 kN. The standard deviation of the traction resistance is 2.4 - 5.0 kN with a coefficient of variation from 5 to 12%.

Thus, according to the results of the studies, it was found that in the processing of fallow and stubble, the arrangement of working bodies on the frame of the laboratory installation according to the technological scheme 1, in comparison with other schemes, qualitatively performs the technological process and provides the indicators laid down in the initial requirements for basic machine technological operations. The required amount of stubble on the field surface after the pass is provided by scheme 4.
Mathematical statistics processed the obtained experimental data, and the significance of the difference in sample means was assessed according to Student's t-test [26].



Background – stubble



Background – fallow

1 – scheme 1; 2 – scheme 2; 3 – scheme 3; 4 – scheme 4

Figure 10. Change in traction resistance of variants of technological schemes depending on the speed of the unit

The main factors affecting the unit's productivity include the width of the tool, its traction resistance and speed, and the direct operating costs are the unit's productivity, specific fuel consumption, the price of the tractor, tools, fuels, and lubricants. Only with the optimal working width of the tool in combination with a tractor of a given traction class in specific soil conditions is it possible to ensure maximum produc–tivity at minimal material and labor costs. The main method for justifying the tool's width and the unit's speed is the method of mathematical modeling. The minimum direct operating costs and maximum pro–ductivity were taken as the main criteria for choosing the working width and speed of the unit [27,28].

Knowing the components of power losses in the tractor's engine, transmission, and running system, the traction power can be expressed in terms of the engine's maximum power and the degree of its load in terms of power and losses in the engine transmission and running system. Then the optimization problem is reduced to finding the maximum of the function:

$$W_{sm} = 0{,}36(N_{e_н}\xi \cdot \eta_d \eta_{m_o} \eta_{x.c_o} / P_y) \rightarrow max \qquad (2)$$

As can be seen from expression (2), the unit's productivity is proportional to the engine's rated power, its load in terms of power, the conversion of power into wheel traction, and is inversely proportional to the specific traction resistance of the implement.

Taking into account equation (2), the optimization of the width of the tool grip according to the criterion of operating costs is reduced to finding the minimum of the function:

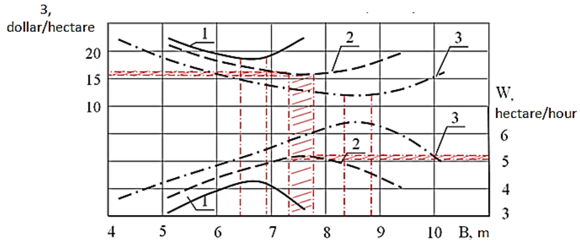
$$\begin{aligned} Z_{pr} &= G + Z + [(B_{tr}/t_{tr}) \cdot (a_{CRM_{tr}} + a_{Ov_{tr}} + r_{tr}) + \\ &+ (B_i/t_i) \cdot (a_{CRM_i} + a_{Ov_i} + r_i)] / 0{,}36 \cdot \\ &\cdot \tau_{of} (N_{e_н} \xi \eta_d \eta_m \eta_{xc} / P_y) \rightarrow min \end{aligned} \qquad (3)$$

According to expressions (2) and (3), productivity and direct costs were calculated using the results obtained in laboratory and field studies of a laboratory installation of a combined implement for basic tillage and data on the traction characteristics of wheeled tractors of traction class 5 with an engine power of 200 kW against a stubble background. The calculations took into account that fluctuations in the values of traction resistance within one experiment changed by an average of 5%.

The results of the calculations (Figure 11) show that when the MTU is used as part of a wheeled tractor of traction class 5 with an engine power of 200 kW and a combined implement, the optimal capture width of the combined implement, depending on the physical and mechanical properties of the soil, should be: for heavy ones within 6, 5-6.9 m, for medium 7.3-7.7 m, for light 8.4-8.8 m. In this case, the performance of the unit will be 4.1-4.2, 5.0-5.1, and 6.4-6.5 ha for one hour of main time, and direct operating costs will be 18.3-18.9; 15.2-16.1 and 11.8-12.0 $ (US)/ha, respectively.

Thus, the optimal working width of the combined tool for the main tillage should be 7.3-7.7 m, which corresponds to the maximum productivity of the unit and the minimum operating costs on average soils in terms of physical and mechanical properties.

When the unit is operating on heavy soils, it is necessary to reduce the unit's speed or the tool's width to 6.5-6.9 m by removing the extreme working bodies for the main and surface tillage. When working on light soils, it is necessary to increase the unit's speed by switching to a higher gear, while the operation of the MTU will not correspond to the optimal mode. The rate of movement of the unit should be in the range of 8.2-9.7 km / h.

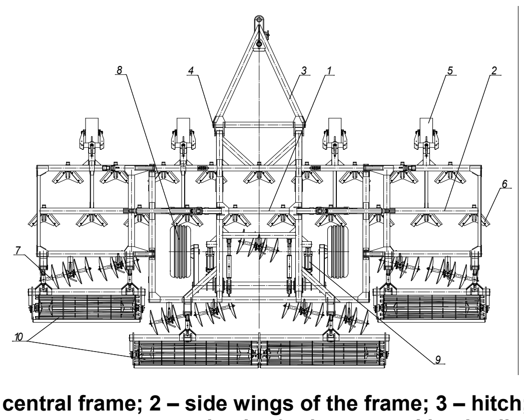


1 – heavy soils, at V = 8.2 km/h; 2 – medium soils, at V = 8.9 km/h;3 – light soils, at V = 9.7 km/h.

Figure 11. Influence of the working width of the implement on productivity and direct costs (for a tractor with an engine power of 200 kW)

Drawing documentation was developed based on the research results, and an experimental sample of a combined tillage tool was made. The experimental sample consists of a central frame and two side wings, a mechanism for transferring the side wings from the working position to the transport position, a towing device, support wheels, transport wheels, a mechanism for transferring the transport wheels from the working position to the transport position, flat-cutting and disk working bodies, a press roller.

The central frame 1 and the side wings of frame 2, according to Figure 12 are welded rectangular structures consisting of longitudinal spars and transverse bars. A towing device 3 is attached to the front beam and connected to the frame with the help of fingers 4. Support wheels 5 with a mechanism for step-less adjustment of the working depth are installed on the transverse spars of the central frame and side wings. Next, the lancet working bodies 6 are arranged in two rows. Sections of disk working bodies 7 are installed behind the lancet working bodies; each section contains four working bodies located at an angle to the direction of movement. Transport wheels 8 are pivotally attached to the longitudinal spars, and with the help of hydraulic cylinders, 9 can change their position.



1 – central frame; 2 – side wings of the frame; 3 – hitch; 4 – fingers; 5 – support wheels; 6 – lancet working bodies; 7 – disk working bodies; 8 – transport wheels; 9 – hydraulic cylinders; 10 – press rollers

Figure 12. Scheme of the experimental sample of the combined tool for the main tillage (top view)

The developed combined tool can process a fallow field to a depth of up to 18 cm by cutting weeds and creating a mulching layer on the surface, a stubble field by cutting weeds and crumbling the treated layer with flat-cutting working bodies to a depth of 18 cm while maintaining the stubble on the surface or with incorporation weed seeds and straw into the surface layer.

The technological process for processing the fallow field is carried out as follows. Flat-cutting working bodies, installed according to a two-row scheme, cut weeds and crumble the treated layer. Disc working bodies, installed in one row behind the lancet shares at an angle of attack of 20 degrees, loosen the surface layer and destroy weeds. The double-drum bar packer roller is installed behind the disc's levels and compacts the treated surface while creating a wind-resistant ribbed surface.

Diameter of disk working bodies - 450 mm. The tool is made trailer; the grip width is 7.3 m, the width of the flat-cutting working body is 500 mm, and the paws are located with an overlap of 80 mm. The press roller consists of outer and inner bar drums with 420 mm and 330 mm, respectively.

Tests of the experimental sample under production conditions were carried out on fallow treatment at «Sheminovska» LLP and stubble background treatment at «Sever-Ptitsa» LLP. The unit in operation is shown in Figure 13. Testing dates, on a fallow background June 28-July 12, on the stubble September 6-14, Kostanay region.

Field background - fallow. Average moisture content values characterized soil conditions during the research period - 21.3%, hardness - 1.8 MPa, density - 1.1 g/cm3, in the layer 0-20 cm.

The background of the field is wheat stubble, the third crop after fallow. At a depth of 0-20 cm, the soil layer's state was characterized by average soil moisture values of 16.8%, hardness of 3.7 MPa, and density of 1.33 g/cm^3.

According to the test results, it was established that the working width of the tool was 7.1 m, the average working depth for a fallow was 16.3 cm, and for stubble, it was 14.5 cm.

The agrotechnical assessment showed that during fallow treatment, the crumbling of the treated layer after the passage of the tool at a speed of 8.6 km/h amounted to 81% of fractions up to 25 mm. The content of fractions less than 1 mm did not exceed 8.4%, and after the passage of the gun, it decreased by 1.3% compared to the initial state, after the passage of the combined tool, complete cutting of weeds.

In the processing of the stubble field, the crumbling of the treated layer after the passage of the tool at a speed of 8.4 km/h reached 71%. The safety of stubble after the passage of the unit is 61%.

The traction resistance of the combined tillage tool against the fallow background was 56.3 kN, and against the stubble background, 54.6 kN.

According to the operational and technological assessment results, it was found that in the processing of fallow and stubble, the operating speed of the unit was 8.4-8.6 km/h, while its productivity per hour of the main time was 5.9-6.1 ha. The specific fuel consump–tion for the processing of fallow and stubble was 8.3 and 8.0 kg/ha, respectively.

a) – on the processing of the fallow field

b) – in the processing of stubble field

Figure 13. An experimental sample of a combined implement in an aggregate with a K-701 tractor

Comparative tests have shown that using an experimental sample combined for tillage can increase productivity by 1.2 times, reduce fuel consumption by 13.5%, and labor costs by 12%. At the same time, the operating prices of the combined tool are 14% lower than those of the existing analog.

It has been established that combined use for processing ensures the high-quality performance of the technological process at a hardness of 3.7-4.1 MPa. Using an experimental sample combined for soil cultivation increases productivity by 1.2 times reduces fuel consumption by 13.5%, and labor costs by 12%. At the same time, the operating expenses of combined consumption are 14% lower than those of the existing analog.

The research results were used by research organi–zations, developers, and manufacturers of agricultural machinery to design and develop combined tillage tools of a similar purpose developed combined tools that can freely work in agricultural production (crop production).

4. CONCLUSION

Field experimental studies have shown that at a speed of 2.2-2.7 m/s, technological schemes 1 and 4 ensure the fulfillment of quality indicators, in particular, soil crumbling, field surface ridges, stubble preservation, weed cutting by agrotechnical requirements.

The obtained research data made it possible to substantiate the design and technological parameters, the technological scheme, and operating modes of the exp-erimental sample of the combined tool. Drawing documentation and an experimental sample were developed based on the data obtained.

Tests in production conditions showed that with a working width of 7.1 m and a processing depth on the stubble - 14.5 cm, on a fallow background - 16.3 cm, the unit's speed was 8.4-8.6 km/h, respectively. The quality indicators of the combined implement correspond to agrotechnical requirements; the traction resistance is in the range of 54.6-56.3 kN, which ensures optimal traction capabilities of the tractor. The unit's productivity per hour of the main time was 5.9-6.1 ha.

The use of a combined tool provides a 1.2-fold increase in productivity, a reduction in fuel consumption by 13.5%, and a reduction in labor costs by 12%. At the same time, the operating prices of the combined tool are 14% lower than those of the existing analog.

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NOMENCLATURE

Z	the cost of funds for the wages of service personnel, in US dollars per 1 hectare;
G	expenses for fuels and lubricants, gas, electricity, in US dollars per 1 hectare;
R	expenses for repairs and maintenance, in US dollars per 1 hectare;
A	depreciation expenses, in US dollars per 1 hectare;
F	other direct expenses for basic and auxiliary materials (wire, twine, containers), in US dollars per 1 hectare.
$N_{e_н}$	rated motor power, kW
ξ	engine load coefficient by power;
η_d, η_{mo}, $\eta_{x.co}$	Coefficient of efficiency, respectively, taking into account power losses from fluctuations in traction load, transmission, and running system under the action of a deflecting moment;

P_y	specific resistance of the gun, N/m.
G, Z	costs for fuel and lubricants and wages, respectively, US dollars per hour;
B_{tr}, B_i	book value of the tractor and implement, respectively, US dollars per hour;
t_{tr}, t_i	annual load of the tractor and implement, respectively, hour;
a_{CRMtr} a_{CRMi} a_{Ovtr} r_{tr} r_i	deduction coefficients, respectively, for current repairs and maintenance, overhaul and renovation of the tractor and implement;
τ_{of}	operating time utilization factor.
APK-7.2	combined soil-cultivating unit.

ЕКСПЕРИМЕНТАЛНО ПРОУЧАВАЊЕ РАЗЛИЧИТИХ МЕТОДА ТРЕТМАНА ЗЕМ–ЉИШТА У ЦИЉУ МАКСИМАЛНОГ ОЧУ–ВАЊА СТРНИШТА И ОРЕЗИВАЊА КОРОВА

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У Северном Казахстану, главни задатак аграра је да акумулирају и задрже максималну количину влаге. С тим у вези, ефикасне агротехничке методе очувања влаге су висококвалитетна јесења неокална обрада подлоге стрништа са максималним очувањем стрништа на површини и механичка метода сузбијања корова на угару. Очигледни недостаци постојећих машина за обраду тла су слаба способност продубљивања равнорезних радних тела, уграђивање стрништа у земљиште и непотпуно сечење корова. Машинско-тракторске јединице са једнооперативним специјализованим машинама и њиховим вишеструким преласком преко њиве поново збијају око 60% обрађених површина. Најперспективнији за имплементацију ових технолошких операција су комбиновани алати. Међутим, технички процес заједничке интеракције ланцета, диска и шипки радних тела са земљом у условима Северног Казахстана до сада није довољно проучен. С тим у вези, рад има за циљ проучавање утицаја технолошких шема комбинованог алата на агротехничке и енергетске показатеље и испитивање експерименталног узорка у условима производње.