УДК 631.31

4.3.1. Технологии, машины и оборудование для агропромышленного комплекса (технические науки)

ЭКСПЕРИМЕНТАЛЬНЫЙ АНАЛИЗ ТЯГОВОГО СОПРОТИВЛЕНИЯ И РАСХОДА ТОПЛИВА ПОЛОСОВОГО ПОЧВООБРАБАТЫВАЮЩЕ-ПОСЕВНОГО ОРУДИЯ

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4.3.1. Technologies, machinery and equipment for the agro-industrial complex (technical sciences)

EXPERIMENTAL ANALYSIS OF TRACTION RESISTANCE AND FUEL CONSUMPTION OF A STRIP TILLAGE AND SOWING IMPLEMENT

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Целью данной работы является энергетическая оценка разработанного полосового почвообрабатывающе-посевного орудия в полевых условиях. Для полосовой обработки почвы с одновременным внесением минеральных гранулированных удобрений и посева семян кукурузы обоснована конструктивно-технологическая схема и изготовлено почвообрабатывающе-посевное орудие. Энергетическая оценка проводилась по данным полевых экспериментов по тяговому сопротивлению почвообрабатывающе-посевного орудия и расходу топлива трактора. Тяговое сопротивление орудия изменяется от 9365,56 до 3467,40 Н, расход топлива – от 9,5 до 14,1 л/га. Тяговое сопротивление почвообрабатывающе-посевного орудия для почвы среднесуглинистого механического состава минимально при влажности 17 … 21 %. На основании полученных результатов подобран тяговый класс трактора для агрегатирования разработанного полосового почвообрабатывающе-посевного орудия, который позволит провести технико-экономическую оценку

Ключевые слова: ПОЛОСОВАЯ ОБРАБОТКА ПОЧВЫ, ПОСЕВ, ПОЛОСОВОЙ КУЛЬТИВАТОР, РЫХЛИТЕЛЬ, ЛАПОВЫЙ РАБОЧИЙ ОРГАН, ВЛАЖНОСТЬ ПОЧВЫ, ТЕНЗОМЕТРИРОВАНИЕ

http://dx.doi.org/10.21515/1990-4665-203-030 ‘

The purpose of this work is an energy assessment of the developed strip tillage and sowing tool in the field. For strip tillage of the soil with simultaneous application of mineral granular fertilizers and sowing of corn seeds, a structural and technological scheme has been substantiated and a tillage and sowing tool has been manufactured. The energy assessment was carried out based on the data of field experiments on the traction resistance of the tillage and seeding implement and the fuel consumption of the tractor. The traction resistance of the implement varies from 9365.56 to 3467.40 N, the fuel consumption – from 9.5 to 14.1 l/ha. The traction resistance of the tillage and seeding implement for soil of medium loamy mechanical composition is minimal at a moisture content of 17 … 21%. Based on the results obtained, a tractor traction class was selected for the aggregation of the developed strip tillage and sowing implement, which will allow for a technical and economic assessment

Keywords: STRIP TILLAGE, SEEDING, STRIP CULTIVATOR, RIPPER, SHARP WORKING ELEMENT, SOIL MOISTURE, STRAIN MEASUREMENT

Introduction. Strip tillage is one of the types of energy-saving technologies that is being actively implemented in Russia. With this type of tillage, the soil is processed only in strips, the area of which is no more than 50% of the total area. This technology simultaneously combines the advantages of zero and minimum technologies. For example, strip technology can be used on lands subject to water and wind erosion [1,2,3]. In addition, a significant advantage of strip technology is that the processed strips heat up faster, thereby sowing can be done at an earlier date [4].

Shuxian Dou's research showed that strip tillage has certain advantages over no-tillage in increasing crop yields because it loosens the soil, increases soil temperature, and improves the soil environment in the crop strip, which in turn improves crop growth [5].

When using traditional technology for growing corn, about 57 l/ha of diesel fuel is used for soil cultivation [6]. Strip technology allows saving energy costs up to 75% by reducing the number of technological operations compared to traditional technology, while fuel consumption is reduced to 30 l/ha [7, 8]. Currently produced cultivators for strip cultivation are mainly equipped with working bodies that allow deep soil cultivation up to 0.25 m and simultaneously apply the main dose of mineral fertilizers to the cultivation depth in the fall, and then, in the spring, sow along the cultivated strips [9]. Such cultivators are mainly equipped with spherical disks or needle working bodies that clean the strip, then rippers of various designs are installed and targeted rolling rollers are installed for soil compaction.

This arrangement of working bodies prepares the soil for sowing quite well. However, the soil prepared in this way does not fully take into account the agrotechnical requirements for sowing and does not take into account the physiology of growth and development of the crop. In addition, existing cultivators do not allow combining two technological operations - soil preparation and sowing with the simultaneous application of mineral fertilizers. Combining two operations allows the creature to reduce operational indicators and comply with agrotechnical terms between soil cultivation and sowing, and this, in conditions of risky farming, is an important factor for the formation of the future harvest.

We propose a design scheme of a soil-cultivating and seeding tool, which includes the successive installation of loosening working organs with fertilizers and a paw working organ with a seed tube. This scheme, unlike existing designs, allows for simultaneous soil cultivation, the introduction of granulated mineral fertilizers into the lower soil horizon, and seeding to a specified depth. Due to the change in the design scheme compared to existing strip-till cultivators, it is necessary to conduct an energy assessment of the soil-cultivating and seeding tool in field conditions.

The purpose and objectives of the study.

The purpose of this study is to energy evaluate the developed strip soil-cultivating and seeding tool in field conditions. The objectives of the research:

- development of energy assessment methodology for strip tillage and seeding implement;
- analysis and interpretation of the obtained experimental data.

Material and research methods.

The experiments were conducted in the Blagovarsky district of the Republic of Bashkortostan on a field with typical chernozem soil, medium loamy mechanical composition, which for the full implementation of the experimental methodology with a combination of all selected factors was divided into 5 plots (No. 1, 2, 3, 4, 5) of 1 hectare each (Table 1).

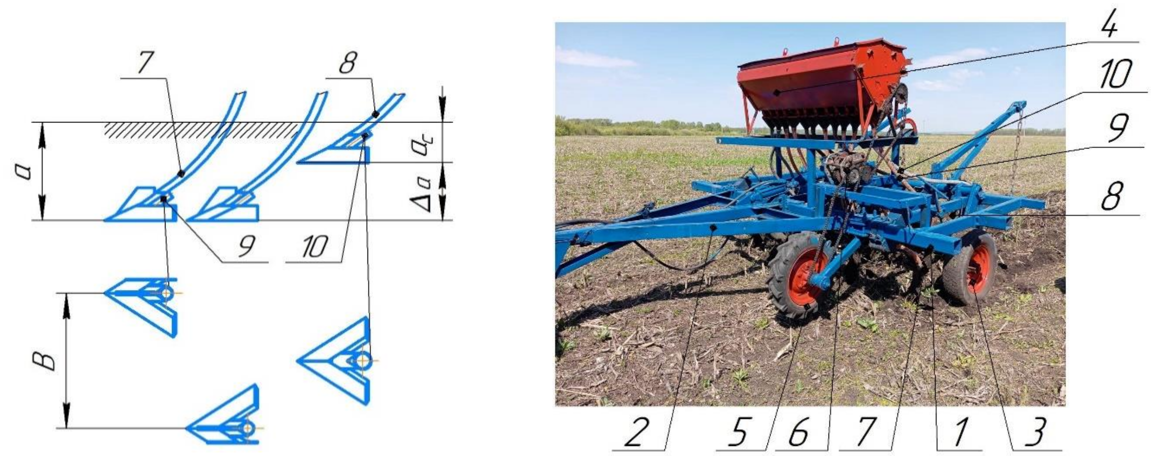
The characteristics of the experimental sites and test conditions indicating the type and mechanical composition of the soil, relief, determined according to the methodology of GOST 52777-2007 [10] are given in Table 1.

Soil characteristics were determined using the enterprise's soil maps, and soil moisture was determined using the thermostat-weight method in accordance with GOST 28268-89 [11]. For this purpose, soil samples were taken with a drill at depths of 0…100 mm; 100…200 mm; 200…300 mm, poured into heat-resistant cups (weighing bottles) and pre-weighed. For each sampling depth, the soil was collected in five replicates in different randomly selected areas of the field. Samples were dried in laboratory conditions in a thermostatic drying cabinet with a drying temperature of 105°C. The obtained soil moisture data are presented in Table 1.

Table 1 - Characteristics of the site during field tests

Soil type and purpose according to mechanical composition																typical chernozem, medium loamy fur composition				
Relief																smooth				
Indicator	Layer, mm															Average value for layer 0…300 mm				
	0…100					100…200					200…300									
Field No.	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Average soil moisture, %	18.3	18.7	19.6	19.3	19.1	19.2	19.5	19.8	20.1	19.3	19.8	20.8	20.4	20.1	20.2	19.1	19.7	19.9	19.8	19.5

The design diagram of the strip soil-cultivating and seeding tool and its manufactured appearance are shown in Figure 1.



1 – frame; 2 – towing device; 3 – support wheels; 4 – seed and fertilizer hopper; 5 – drive wheel; 6 – gearbox; 7 – rippers;
8 – coulter; 9 – fertilizer pipes; 10 – seed pipes
a – depth of the rippers; B – distance between the rippers; ac – sowing depth;Δa – distance from seed to fertilizer.
Figure 1 – Experimental strip tillage and seeding implement

The implement includes a frame 1 on support wheels 3 with a towing device 2. A hopper 4 for seeds and fertilizers is installed on the frame 1. A drive wheel 5 and a gearbox 6 are installed to set the seeding rate for seeds and fertilizers. In the front part of the frame, loosening working bodies 7 with fertilizer pipes 9 are installed, and behind them, for forming the seed bed, there are paws 7 with seed pipes 10.

The traction resistance of the developed strip tillage and seeding implement 1 was determined in accordance with GOST 34631-2019 [12] based on the readings of the 5-ton strain gauge 4 installed between two tractors - the tractor 3 and the aggregated tractor 2 (Figure 2) using the indirect determination method [13, 14, 15]. The readings from the strain gauge were recorded via the MIC-400D analog-to-digital converter in the WinRecorder program, then the obtained results were visually checked in the WinPos program and transferred to the Excel program for further statistical processing. The strain gauge calibration was carried out immediately before the experiments in laboratory conditions on the GRM-20 tensile testing machine. Statistical processing in the Excel program included determining the average values and the standard deviation of the traction resistance.

1 – cultivator; 2 – tractor-tractor John Deer 7000; 3 – aggregated tractor John Deer 7000; 4 – load cell

Figure 2 – Measuring traction resistance

Fuel consumption was determined based on readings from a fuel sensor installed on the aggregated John Deer 7000 tractor, via the Wialon system.

The traction resistance and fuel consumption were determined using the single-factor experiment method with a combination of two factors – the working speed of the implement V and the depth of the rippers a. The number of experiments for each repetition was thus 15. The experiments were carried out in triplicate. The depth of the coulter (seeding) ac for each experiment remained constant at 0.06 m.

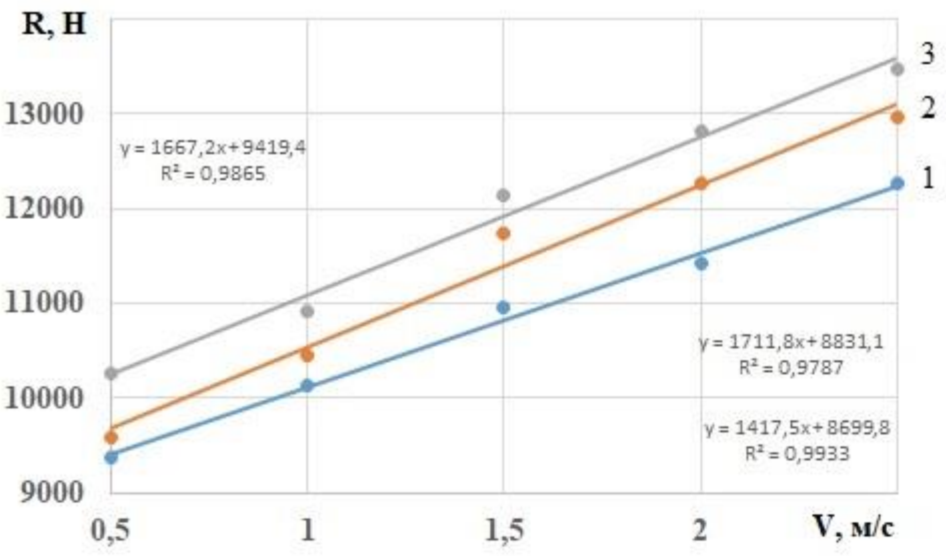
Research results and their discussion.

Traction resistance of a strip tillage and seeding implement obtained during field experiments under soil moisture φ=19.8%, presented in Table 2.

Table 2 – Traction resistance R, N of a soil-cultivating and seeding implement when changing the working speed and depth of the rippers

Ripper running depth a, m	Operating speed of the gun V, m/s				
	0.5	1	1.5	2	2.5
	Traction resistance R, N				
0.18	9365,56	10125,40	10958,74	11416,58	12263,70
0.22	9578,20	10458,70	11741,36	12257,40	12958,30
0.25	10253,54	10917,50	12136,52	12825,70	13467,40

The traction resistance of the tool varies in the range of 9365.56…13467.40 N with a change in the depth of travel a from 0.18 to 0.25 m and the speed V from 0.5 to 2.5 m and has a linear dependence on the speed (Figure 3).



1 – a= 0.18 m; 2 – a=0.22 m; 3 – a=0.25 m

Figure 3 - Dependence of the traction resistance R of the implement on the working speed V at different depths of the rippers a

The linear dependence of the traction resistance on the working speed of the implement slightly differs from the experimental data of other continuous tillage implements [16] and the well-known empirical dependence of V.P. Goryachkin [17] for determining the traction resistance, which have a polynomial dependence of the second degree. This may be due to the fact that the implement does not cultivate the soil in a continuous manner, but in strips, and the working bodies operate in a free mode. At the same time, with a change in speed from 0.5 to 2.5 m/s, the traction resistance of the tillage and seeding implement increases by 31...35.3% depending on the depth of the rippers.

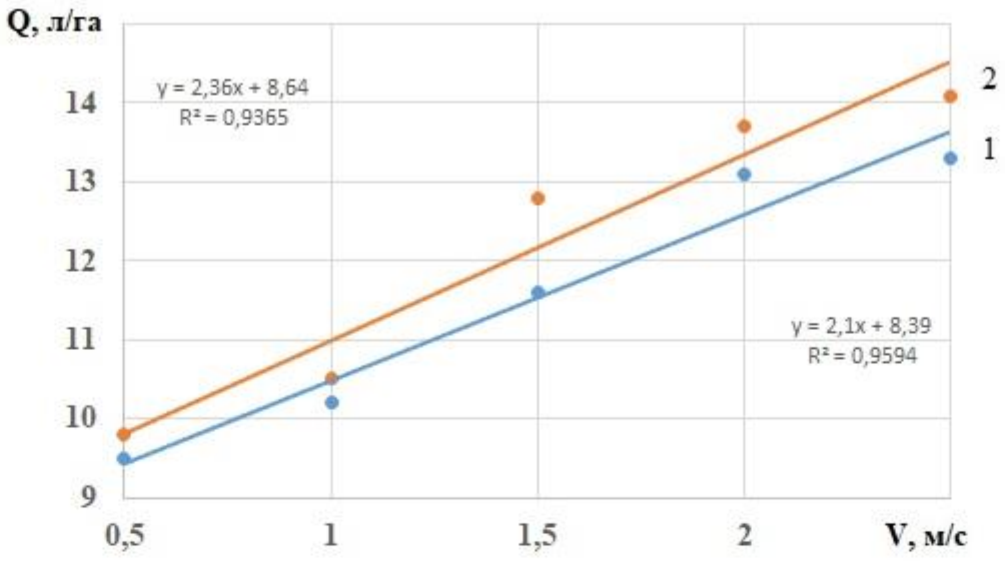
The maximum traction resistance of the strip soil-cultivating and seeding implement R=13467.40 N is observed at the maximum depth of the rippers a=0.25 m and the maximum working speed V=2.5 m/s. In this regard, to aggregate the implement with such design and technological parameters, a tractor of the traction class of 20 kN will be required.

Fuel consumption Q, l/ha by a tractor during the technological operation of strip tillage and sowing is presented in Table 3.

Table 3 – Fuel consumption Q, l/ha of a tillage and seeding implement during strip tillage

Ripper running depth a, m	Operating speed of the gun V, m/s				
	0.5	1	1.5	2	2.5
	Fuel consumption Q, l/ha				
0.18	9.5	10.2	11.6	13.1	13.3
0.25	9.8	10.5	12.8	13.7	14.1

Fuel consumption Q, l/ha also has a linear dependence on the operating speed of the unit V (Figure 4), as does the traction resistance.



1 – a= 0.18 m; 2 – a=0.25 m

Figure 4 - Dependence of fuel consumption Q on the operating speed V at different depths of the rippers a

According to the graph (Figure 4), when the speed of the unit changes from 0.5 m/s to 2.5 m/s, the fuel consumption of the tractor increases by 4.3...4.4 l/ha (31...35%).

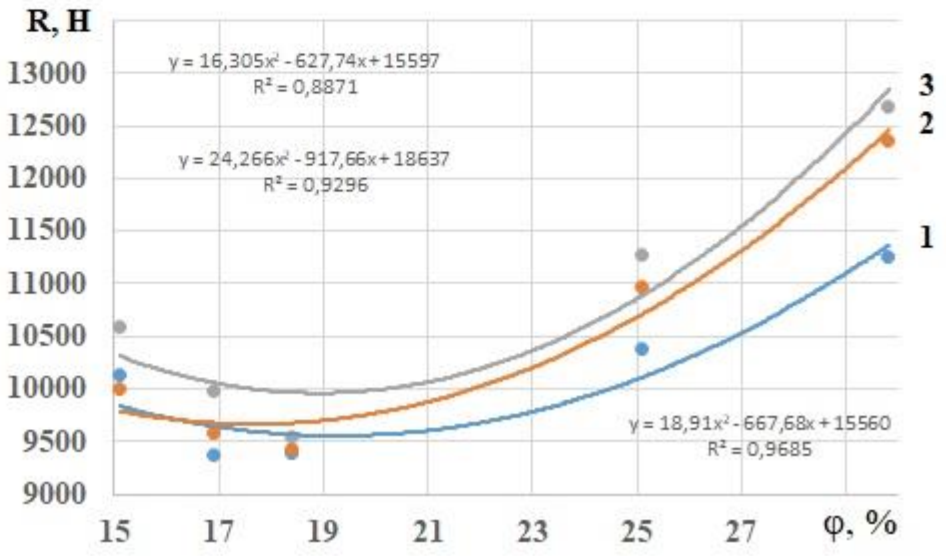
According to the developed experimental methodology, during the experiments the assessment. The influence of the initial soil condition – its moisture content on the traction resistance and performance of the developed soil-cultivating and seeding implement was also studied. The experiments were conducted on plots with soil moisture content φ=15.1, 16.9, 18.4, 25.1, 29.8%, at an average working speed of the unit of 2 … 2.2 m/s.

The traction resistance of tillage implements is determined by the initial state of the soil, for example, humidity. For most soils, there is a certain range of soil humidity at which the energy for its deformation and crumbling is spent the least. This range of humidity determines the physical maturity of the soil. To determine the range of humidity of the physical maturity of the soil, experiments to determine the traction resistance of the implement were carried out in different areas of the field, due to the different location relative to the edge of the field, forest plantations and terrain slope, they had different humidity in the range of 15.1 ... 29.8%. The traction resistance in these areas with different humidity is given in Table 4.

Table 4 – Dependence of the draft resistance of the implement on humidity

Ripper running depth a, m	Operating speed of the gun V, m/s				
	φ=15.1%	φ=16.9%	φ=18.4%	φ=25.1%	φ=29.8%
	Traction resistance R, N				
0.18	10124.38	9365,56	9399,40	10385,40	11256,40
0.22	9991,20	9578,20	9425,30	10964,50	12354,20
0.25	10587,10	9985,10	9541,20	11268,40	12687,40

According to the obtained data, with an increase in soil moisture from 15.1 to 29.8%, the traction resistance of the implement changes from 9365.56N to 12687.40N and has a second-degree parabolic dependence (Figure 5).



1 – 0.18 m; 2 – 0.22 m; 3 – 0.25 m
Figure 5 – Dependence of the traction resistance of a tillage and seeding implement on soil moisture at different depths of the rippers

The obtained dependence shows that the traction resistance of the implement is minimal when the soil moisture φ is in the range of 17...21%. When the soil moisture increases to more than 23%, it sticks to the surface of the paws (Figure 6) and the traction resistance associated with this phenomenon increases.

Figure 6 – Soil adhesion to the surface of rippers (soil moisture φ=29.8%)

Conclusion.

Energy assessment of the developed tillage and seeding implement for strip tillage. The analysis of the tractor's traction resistance and fuel consumption made it possible to establish their dependence on the operating speed of the unit and soil moisture.

According to experimental data, the traction resistance tillage and seeding equipment vary from 9365.56 to 3467.40 N, fuel consumption – from 9.5 to 14.1 l/ha at working speeds from 0.5 to 2.5 m.

The traction resistance of a tillage and seeding tool for soil with medium loamy mechanical composition decreases at a moisture content of 17...21%, which corresponds to the physical maturity of this type of soil.

The maximum traction resistance of the strip soil cultivation and seeding tool is 13467.40 N at a maximum ripping depth of a = 0.25 m and a working speed of V = 2.5 m/s. In this regard, to aggregate the developed soil cultivation and seeding tool for the strip soil cultivation system, it is necessary to use a tractor with a traction class of 20 kN.

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