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Improvement of the technological scheme of the implement for strip overseeding of grass seeds and selection of a combined tillage tool for leveling the soil in the strip and seeding

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Abstract

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Practice shows that strip overseeding increases the yield of grasses by 1.5-1.9 times. However, the existing combined implements do not provide the required quality of tillage or sowing. The aim of the work was to improve the quality of soil preparation in the strip for seeding and sowing grass seeds in the northern region of the Republic of Kazakhstan.

The strip overseeding implement (OPP-2) steadily performs the technological process, however, on soils with a hardness of more than 5 MPa, agricultural requirements for the width of the loosened strip and the uniformity of the incorporated grass seeds in depth are not fulfilled. This is due to the shortcomings in the technological scheme and design of the rolling-seeding tillage tool.

To achieve this aim, the technological scheme of the implement was improved and three variants of the combined tillage tool were developed. The obtained experimental data showed that the implement with an improved technological scheme performs a technological process with the quality corresponding to agricultural requirements.

Keywords: grass overseeding; laboratory setup; combined tillage tool; technological scheme; perennial grasses;nature meadows; pastures; tilling depth; sowing quality; traction resistance

Introduction

The amount of precipitation falling in Northern Kazakhstan is relatively small and varies greatly across its territory – from 300-350 mm in the north to 185-195 mm in the south and southwest (Morgun, 1977; Astafyevet al., 2021). More than half of the precipitation falls during the warm period of the year.

The limited area in moisture predetermined the types of grass stands. On sown cereals of perennial herbage, such crops as wheat grass, bromus, bluegrass, leymus racemosus have become widespread. From legumes-lucerne, melilot, sainfoin.

According to the yield of dry fodder, seeds, forage advantages, drought resistance, winter hardiness, durability and ease of cultivation, wheat grass takes the first place among forage grasses; 67% of sown forage lands fall to the share of this crop (Velichko al., 1981). High salt and salt resistance allows it to be cultivated on saline soils. Over time, the productivity of sown grass stands decreases. The rate of decline in yields depends mainly on the methods of processing, use and types of sown grasses. The maximum period for which the herbage yield approaches the level of virgin lands is 8-10 years (Postoyalkovet al., 1972;, Davy et al., 1996). On average, a sharp decrease in yield is observed already for

4-5 years of use (Grigoriev et al., 1996; Seguinet al., 1998). According to the data of many years of observations of the All-Union Grain Research Institute the yield of natural hayfields on average is 2-3 p/ha with an absolute maximum of 5.7 p/ha in wet years (Postoyalkovet al., 1976). The reasons for the decrease in productivity are the deterioration of the physical properties of the soil, water and air permeability. Soil compaction by the running systems of harvesting and transport units has a significant impact on this process. In the surface layer, the dense soil is covered with cracks, which contributes to an increase in evaporation. The ability to vegetative and seed renewal decreases. The oppressed valuable forage grasses are being replaced by weeds.

So, low-yielding seed and natural grass stands need to be improved, i.e., a set of measures should be taken to maintain yield at a certain level. Improvement is usually divided into root and surface. Radical improvement involves the complete destruction of the original vegetation and the subsequent sowing of grass seeds. The surface improvement is aimed at increasing the yield with a slight violation of the sod. The choice of the method of improvement depends on the state of the grass stand and the capabilities of the farms.

The use of a radical improvement allows increasing productivity by 4-5 times compared to natural grass (Postoyalkovet al., 1972). Its main disadvantage is the high cost of the process. Performing all operations involves numerous passes of guns across the field, the need to have a significant number of guns available, and the purchase of rather expensive seeds.

Superficial improvements include the aeration of the turf, the feeding of fertilizers, and the leaching of grasses and grass seeds.

Qualitatively different and much more favorable conditions for seed germination, survival and development of seedlings of sown grasses are created when sowing along strips on which the sod is intensively processed, the seeds fall into a well-prepared loosened soil, and the root competition of the grass stand as a result of sod processing is significantly weakened.

The conducted studies have established that due to the surface improvement by strip sowing of grasses, the yield increase for 3-4 years totals 25-30 p/ha of dry weight and costs 3-6 times less than with a radical improvement (Azarenko et al., 2005; Lazarev et al., 2001; Marchenko et al., 1987; Kormshchikov, 1999). The main advantages and disadvantages of existing machines for strip overseeding of grass seeds are presented in the table.

The strip overseeding implement (OPP-2) contains a frame with support wheels on which two sections of working bodies are installed, each of which consists of a milling chisel plough, a milling drum, a pre-sowing rolling roller, a disc coulter and a post-sowing rolling roller installed sequentially on the frame.

The results of field and production experiments on old-age crops of wheat grass showed that the use of the technology of strip overseeding of grasses with decompression of the root layer makes it possible to increase the yield of the herbage in the first year after processing due to decompression of the root layer, and in subsequent years due to the joint manifestation of decompression, growth and development of the sown grasses. The strip overseeding implement (OPP-2) steadily performs the technological process, however, on soils with a hardness of more than 5 MPa, agricultural requirements for the width of the loosened strip and the uniformity of planting grass seeds in depth are not fulfilled. This is due to shortcomings in the technological scheme and design of the rolling-sowing working body. The roller and the disc colter are rigidly fixed on common leashes, so copying the soil with a roller excessively deepens or deepens the disc coulter, which causes a deviation from agricultural requirements. The tool in the unit with a tractor (power 75 HP) has a capacity of 0.5-0.7 ha for one hour of shift time. Further increase in productivity, reduction of material consumption, labor and material costs is possible on the basis of the use of powerful tractors of class 5 and higher.

In foreign countries, studies are also being conducted on the influence of cultivated crops, equipment and technology on the yield of grasses and the quality of dry fodder (Barnhart et al., 2009).

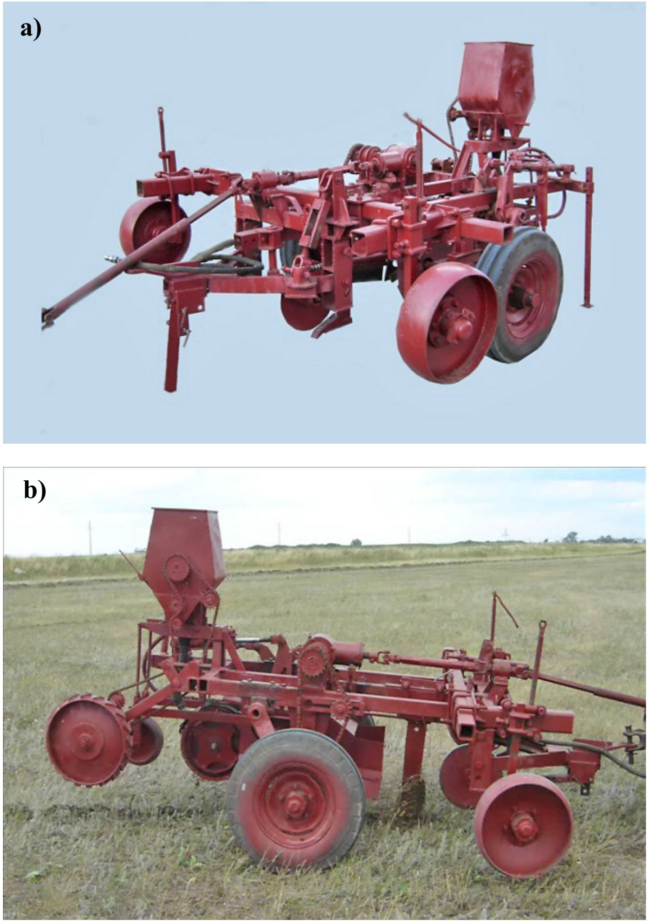
The research results show that the work carried out in this direction is relevant and has a high potential.

Materials and Methods

The laboratory-field installation (LFI) was used to conduct field studies on the choice of a combined working body for levelling the ground in the band and planting grass seeds. The design of the LFI consists of a frame with supporting wheels, a trailer and a seed bunker. One section of working organs is mounted on the frame for strip-compression, superficial processing of the strip, adjoining and sowing. The working bodies are set sequentially. The general type of installation is represented according (Figure 1).

A disc knife on a self-aligning support is used for cutting the turf layer. The design of the support allows you to change the depth of the stroke stepwise.

The milling chisel plough is a rack with a knife and a chisel placed in front of the rack. The thickness of the rack is 30 mm. The bit width is 50 mm, the bit crumbling angle is 25 degrees. The milling section is a shaft mounted



***a*) front view, side view; *b*) side view**

Fig. 1. Laboratory-Field Installation

on bearing supports. Hubs for fixing milling knives are welded on the shaft. Milling knives are L – shaped, with an additional cutting plate. The drive of the milling drum is carried out from the power take-off shaft by means of a gearbox, an intermediate support and a chain transmission. Variants of combined working bodies provide for the combination of operations of pre-sowing rolling and sealing of grass seeds.

The first option (in accordance with Figure 2a) is a coaxially mounted two-drum roller with a disc coulter. The roller is installed at an angle to the direction of movement equal to the angle of inclination of the disk. The second option is similar to the first, but the roller is made single-drum (in accordance with Figure 2b).

The third option is a single-drum roller made of composite, in the interval of which a spring coulter is rigidly fixed with the possibility of adjusting it according to the depth of seed embedding (in accordance with Figure 2b).

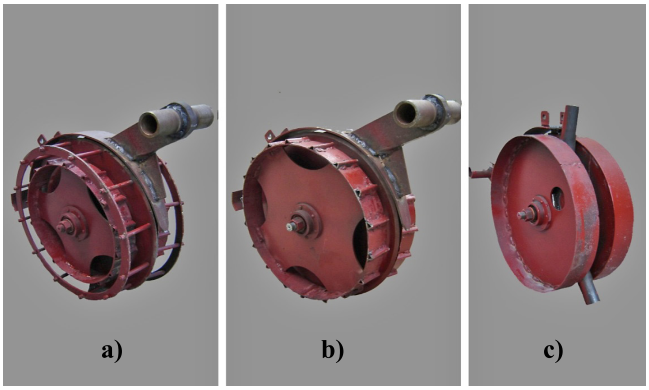


Fig. 2. Variants of combined working bodies for leveling the soil in the strip and sowing grass seeds

a) two-drum roller with a disc coulter, on the side; *b*) single – drum roller with a disc coulter; *c*) single-drum roller made of composite, in the interval of which a spring coulter is rigidly fixed with the possibility of adjusting it according to the depth of seeding-down

The basic option for comparison is to carry out separate operations of pre-sowing compaction and sealing of grass seeds with a two-drum roller and a disc coulter with a depth limiter. This design is used in the OPP-2 implement. The criterion for the comparative evaluation of the variants of working bodies is the qualitative indicators of the performance of the operations of rolling and sealing grass seeds.

Post-sowing rolling is carried out by a pneumatic roller of atmospheric pressure. The drive of the seeding machines is from the support wheel.

The main evaluation indicators for the agrotechnical assessment of technological schemes were the speed of movement, the depth of processing with a milling chisel plough, the depth of processing with a milling drum, the quality of crumbling of the surface layer, the ridge of the field surface, the density of the soil after the passage, the depth of seeding, the number of seeds at the depth of seeding and in adjacent 10 mm layers STANDARD GOST 20915-2011. (2013); STANDARD GOST 33736-2016. (2017); STANDARD GOST 33687-2015. (2016); STANDARD GOST 31345-2007. (2008); STANDARD GOST R 52777-2007. (2007).

The depth of embedding is determined by taking soil samples with a special device shown (Figure 3). The device is installed on the surface of the soil along the sown row until the lower frame comes into contact with the soil surface.

Opposite the cutout in the lower frame of the device, a recess is made in the soil to lower the scoop into it 20-30 mm below the level of the seeds most deeply embedded in the soil. After installing the device, the seeds located on the

Fig. 3. Device for determining the depth of seed embedding

soil surface in the strip, i.e. not embedded in the soil, are counted. Then, after removing the seeds from the surface, move the scoop from the recess along the device, carrying out layer-by-layer removal of the soil in a row.

The soil of each layer is sifted through two sieves, the cells of one of which are 1-3 millimeters larger than the size of the seeds of the sown crop, and the cells of the other one are 1 mm smaller than the size of the seed. The number of seeds located in each layer of soil is counted and recorded. Seeds located directly on the surface are recorded in a layer of 0-10 mm. The number of measurements of the depth of seed embedding should be at least 300 (STANDARD GOST 31345-2007. (2008).

According to the results of measurements of the depth of seed embedding, the indicators characterizing the total depth of seed embedding are determined: the average, the average square deviation, the coefficient of variation, the proportion of cases of seeds being found in 10 mm adjacent layers.

The energy assessment of agricultural machinery is carried out in accordance with (STANDARD GOST R 52777-2007. (2007).The energy assessment was carried out simultaneously with the agrotechnical one. When conducting an energy assessment, the torque on the PTO, the traction resistance, the distance traveled during the experiment and the time of the experiment were determined. The torque on the PTO and the traction resistance of the LPU were measured using strain gauge equipment, including a strain gauge, a tensile force sensor with a measuring range of 2 t and a strain gauge station ZET017-T8 manufactured by ZETLAB.

Electrical signals from strain gauges are recorded by the ZET 017-T8 strain gauge station, which transmits the signal to a computer with a special ZETLAB program installed.

Results and Discussion

An analytical review of the existing technological schemes for soil cracking in severe soil conditions showed that the required values of such indicators as the width of the loosened strip, the safety of cultivated plants and the combiness of the treated surface can be achieved if there is a disk knife installed in the technological scheme before the cutter.

The quality of seed sealing and the reduction of the material consumption of the structure can be achieved by combining technological operations of leveling the soil in the strip and sowing grass seeds. Based on the conducted research, the technological scheme of the tool for strip sowing of grass seeds was improved. The technological scheme of the tool is shown (Figure 4).

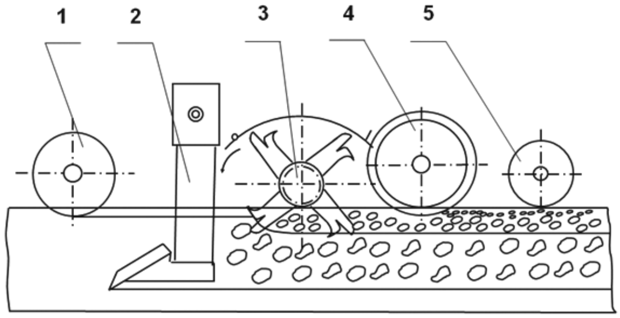


Fig. 4. Technological scheme of the implement for strip overseeding of grass seeds

1 – disk for cutting the turf layer; *2* – chisel tool; *3* – milling cutter; *4* – combined working body for levelling the soil in the strip and sowing the grass seeds; *5* – post-sowing rolling roller rolls

The tool for strip sowing of grass seeds with an improved technological scheme performs the technological process in the following sequence: a disk knife Ø 400 mm and a thickness of 6 mm, cuts the turf layer of the soil by 8-12 cm, a cutter installed behind the disk loosens the soil layer to a depth of 30 cm and forms a loosened strip up to 25 cm wide, a milling cutter Ø 450 mm and a rotation speed of 350 rpm, prepares the soil for sowing and forms a strip 15 cm wide and up to 10 cm deep, the combined working body levels the soil in the strip and sows grass seeds to a depth of 2-4 cm, the post-sowing rolling roller rolls the soil in the strip after sowing.

Experimental studies were conducted in the Kostanay region of the Republic of Kazakhstan in the period of September 15-25. The background of the field is an old-age mown grass stand. Average values of indicators at a depth of up to 30 cm: soil moisture-12.2%; soil volume mass-1.23 g/cm^3; soil hardness-4.2 MPa, hardness-2.55 g/dm^3. Air humidity-42%, air temperature-20.5°C, seed purity-84%, seed humidity-12%.

Variants of combined working bodies were installed behind the milling drum. The roller was reloaded by adjusting the spring rods. Variants of rollers with disc coulters steadily performed the technological process. The variant with tine coulters showed their inefficiency due to the rapid clogging of the surface of the coulter with root residues. At the same time, the residues were wedged between the gap of the skating pair. Further studies of this variant of the working organ were discontinued.

In terms of the quality of seeding, higher indicators were observed for a single-drum roller with a disc coulter (Figure 5). At a speed of 4.2-7.0 km/h, 80-90% of the seeds were located at the depth of embedding and in two adjacent ten-millimeter layers.

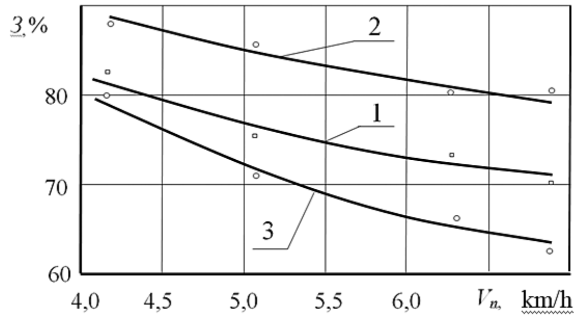


Fig. 5. Influence of the speed of movement on the quality of seeding by the combined rollers

The setting depth of sowing seeds h_z = 3 cm;
1 – combined working body with a two-drum roller; *2* – combined working body with a single-drum roller; *3* – basic variant with separate implementation of soil leveling in the strip and sowing

An increase in speed led to a decrease in this indicator. At a speed above 7 km/h, less than 80% of the seeds are located at the depth of embedding and in two adjacent ten-millimeter layers, which does not meet the requirements of the normative documentation (at least 80%). The variant of a combined working organ with a two-drum roller is inferior in absolute value by 8-10% to a combined working organ with a single-drum roller in terms of the quality of sealing. The combined working body with a two-drum roller provided the required quality of sowing seeds at a speed of up to 4.5 km/h.

The basic version with separate implementation of soil leveling in the field and sowing grass seeds in terms of the quality of sealing was inferior in absolute value by 10-19% to the combined working body with a single-drum cat and a disc coulter. The basic version provides the required quality of seed sealing at a speed of 4.2 km/h of the unit. With an increase in the speed of movement to 7.8 km/h, the quality of seed planting decreases to 65%.

The density of the strip after the passage of the roller in both variants was 0.91-1.05 g/cm^3. The reliable influence of speed on the change of this indicator was not revealed.

Thus, it is established that the use of a combined working body for combining the operations of pre-sowing rolling and seeding in the form of a single-drum roller and a two-disc coulter allows the technological process to be carried out with proper quality up to speed 7.0 km/h.

The traction resistance of a laboratory-field installation with a disk knife installed is reduced by 10 % compared to the scheme without a disk (Figure 6).

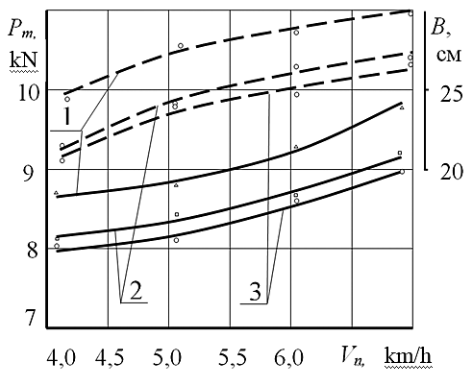


Fig. 6. Influence of speed of movement on the traction resistance and width of the tilling strip
- - - - - width of the tilled strip; ——— traction resistance;

1 – technological scheme without disk knife; *2* – technological scheme with disk knife, tilling depth of knife 8 cm; *3* – technological scheme with disk knife, tilling depth knife 12 cm; the depth of the chisel tool H_{sh} = 26 cm, deviation from the mean value σ = 2.1 cm

An increase in the depth of the disc stroke from 8 to 12 cm leads to a decrease in the drag resistance by 2.5 %, which is within the limits of the experimental error. The width of the loosened strip behind the milling chisel plough in the version with a disk knife is reduced. The permissible width of the loosened strip is not more than 25 cm. This parameter is provided at a speed of up to 6.0 km/h with a stroke depth of 12 cm of the disc knife.

With a stroke depth of 8 cm of the disc knife, the required width of the loosened strip is formed by the milling chisel plough rack at a speed of up to 5.4 km/h. An increase in the speed of movement leads to an increase in the traction resistance and the width of the loosened from 25 to 27 cm.

The torque on the power take-off shaft in the speed range of 4.2 - 7.8 km/h at a milling depth of 8.2 cm was 65-77 Nm. When removing the cutter and the disc knife, the processing depth decreased to 5.3 cm, and the torque was 180-230 Nm, which is 2.7-3.0 times higher. At the same time, the weight of the installation was not enough to overcome the pushing forces that occur when the cutter is working in a solid layer. All this indicates a favorable effect of the milling chisel ploughon reducing the cost of driving active working bodies and on the stability of the work of active working bodies in terms of processing depth.

The total power consumption for the movement of the laboratory installation and the drive of the milling drum, at a speed of 6.0 km/h, amounted to 21.3 kW.

The obtained research results will be used in the design of an experimental model of an implement for the strip overseeding of grass seeds. Testing of the functional parameters of the experimental model will be carried out in production conditions.

Conclusion

Thus, based on the research results being carried out, it was revealed:

– the technological scheme of the implement should contain a sequentially installed disk knife, milling knife-decompaction, a combined working body for leveling the soil in the strip and sowing grass seeds, a post-sowing roller rolls;

– the combined working body with a single-drum roller and a diskcoulter is 8-19% higher in the quality of seed placement than the basic variant with separate implementation of soil leveling in the strip and sowing grass seeds and a combined working body with a double-drum roller and disc coulter. The required indicator of the quality of planting grass seeds is provided at a speed of the unit up to 7.0 km/h;

– the permissible width of the tilled strip is not more than 25 cm is provided at a speed of up to 6.0 km / h with a tilling depth of the disk knife of 12 cm.

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