Artículo de investigación

Improving efficiency of primary tillage in the dry areas of the Russian Federation

Повышение Эффективности Основной Обработки Почвы В Засушливых Районах Российской Федерации

Mejora de la eficiencia del procesamiento básico del suelo en las zonas áridas de la Federación de Rusia

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Abstract

In the Russian Federation, large farmland areas are located in arid regions characterized by the sharply continental climate, strong winds, and insufficient rainfall. In such areas, the technology of basic nonmoldboard cultivation is widely used as a way of accumulating and preserving moisture in the soil. The specifics of this technology consists of continuous crumbling of the cultivated arable layer without soil overturning with the maximum preservation of stubbles and crop residues on the daylight surface of the field. In arid areas, subsurface tillage tools are widely used for continuous loosening of the arable layer: subsurface plows and moldboard plows with CibIME – LP-0,35 racks installed instead of housings. As a result of the conducted studies, the problem of improving the efficiency of the basic nonmoldboard cultivation in the fields in the arid

Аннотация

в Российской Федерации большое количество сельхозугодий расположено в засушливых районах, которые характеризуются резко континентальным климатом, сильными ветрами и недостаточным количеством атмосферных осадков. На таких территориях получила распространение технология основной безотвальной обработки, как способ накопления и сохранения влаги в почве. Специфика этой технологии заключается в сплошном крошении обрабатываемого пахотного слоя без оборота пласта с максимальным сохранением стерни и растительных остатков на дневной поверхности поля. В засушливых зонах для сплошного рыхления пахотного слоя стали широко применяться безотвальные

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agricultural regions has been solved through improving the operational and technological parameters of the plowing unit using noninversing plows PB-5, which are different from the known units with moldboard plows equipped with CibIME – LP-0,35 racks. The authors offer a plowing unit comprising a tractor of drawbar category 3 VT-100D and the new noninversing plow PB-5 for the technology of basic nonmoldboard cultivation in arid areas that ensures high productivity and reduction of energy consumption with equal performance quality, compared to serial plowing unit VT-100D+PLN-5-35+LP-0,35.

Keywords: Basic nonmoldboard cultivation, plow unit, noninversing plow, depth of tillage, preservation of stubbles, performance, fuel consumption.

почвообрабатывающие орудия: плоскорезы-глубокорыхлители и лемешно-отвальные плуги, на которые вместо корпусов устанавливаются стойки СибИМЭ – ЛП-0,35. В результате проведенных исследований решена проблема повышения эффективности основной безотвальной обработки почвы на полях, находящихся в засушливых районах земледелия, за счет улучшения эксплуатационно-технологических показателей пахотного агрегата с плугом-рыхлителем ПБ-5, отличающегося от известного агрегата с лемешно-отвальным плугом, оснащенным стойкой СибИМЭ - ЛП-0,35. Авторами статьи предложен пахотный агрегат в составе трактора тягового класса 3 ВТ-100Д и нового плуга-рыхлителя ПБ-5 для выполнения технологии основной безотвальной обработки почвы в условиях засушливого земледелия, обеспечивающего высокую производительность труда и снижение энергозатрат при равноценных показателях качества в сравнении с серийным агрегатом ВТ-100Д+ПЛН-5-35+ЛП-0,35.

Ключевые слова: Основная безотвальная обработка почвы, пахотный агрегат, плуг-рыхлитель, глубина обработки почвы, сохранность стерни, производительность, расход топлива.

Resumen

En la Federación de Rusia, una gran cantidad de tierras de cultivo se encuentra en regiones áridas, que se caracterizan por un clima continental fuerte, fuertes vientos y lluvias insuficientes. En tales áreas, la tecnología del procesamiento básico de vertederos, como una forma de acumulación y conservación de la humedad en el suelo, se ha extendido. La especificidad de esta tecnología radica en el desmoronamiento continuo de la capa cultivable cultivada sin recambio de la formación con la máxima preservación de los rastrojos y restos de plantas en la superficie del día del campo. En zonas áridas, para el aflojamiento continuo de la capa cultivable, los implementos de labranza que no son de vertedera se han utilizado ampliamente: cortadores planos, desgarradores profundos y arados de arado compartido, en los que se instalan bastidores SibIME - LP-0.35 en lugar de cascos. Como resultado de la investigación, el problema de aumentar la eficiencia de la labranza principal del vertedero en campos ubicados en áreas áridas de la agricultura se resolvió mejorando los parámetros operativos y tecnológicos de la unidad cultivable con el arado cultivador PB-5, que difiere de la unidad conocida con un arado de cuchilla equipado con un soporte SibIME - LP-0.35. Los autores del artículo propusieron una unidad de cultivo que consiste en un tractor VT-100D de clase 3 y un nuevo desgarrador de arado PB-5 para la implementación de la tecnología de cultivo básico de labranza en condiciones de cultivo en seco, que proporciona una alta productividad laboral y menores costos de energía con indicadores de calidad equivalentes en comparación con una unidad en serie VT-100D + PLN-5-35 + LP-0.35.

Palabras clave: Labranza básica del subsuelo, equipo cultivable, desgarradora, profundidad de la labranza, seguridad del rastrojo, productividad, consumo de combustible.

Introduction

The current economic, energetical and environmental situation in the country requires obtaining high yields, saving energy, preserving soil fertility, and protection from erosion. This has an essential effect on the modern state and development of tillage tools.

In the Russian Federation, large farmland areas are located in arid regions characterized by the sharply continental climate, strong winds, and insufficient rainfall (Azizov, 2004; Boykov et al., 1998; Borisenko, 2006; Lachuga, 2004; Mekhanizatsiya zashchity pochv ot vodnoi erozii v Nechernozemnoi polose, 1977, Spirin, 1995; Shabaev, 2003).

It is known that tillage is the most energy-consuming operation in agricultural production. Its share is up to 40 % of the energy used for crop production (Bobkov et al., 2001; Boykov 1998; GOST R 52778-200, 2008; Gribanovsky, Buidlingmeier, 1990; Zhuk, 1992; Lachuga 2004; Marchenko, 1991; Pavlov, 1995; Khalansky, Gorbachev, 2003). At the same time, the quality of basic soil tillage significantly influences the yield of agricultural crops (Puts, 2003; Putrin, 2000; Rumyantsev, 1964; Spirin, 1999; Shabaev, 2003; Capote et al., 2019). The need to improve the efficiency of basic cultivation in the dry areas of the Russian Federation resulted in the development of new technologies of soil cultivation performed by nonmoldboard tillage tools. The specifics of these technologies consists of continuous crumbling of the cultivated arable layer without soil overturning with the maximum preservation of stubbles and crop residues on the daylight surface of the field. Since the second half of the 20th century, nonmoldboard tillage tools have been widely used for basic soil cultivation in dry areas by the continuous crumbling of the arable layer: subsurface plows (Agricultural machinery: catalog, 1991; Khalansky, Gorbachev, 2003) and moldboard plows with CIBIME – LP-0,35 racks installed instead of housings (Agricultural machinery: catalog, 1991; Khalansky, Gorbachev, 2003).

This paper is aimed at improving the efficiency of basic nonmoldboard cultivation of the soil by improving operational and technological parameters of plowing units through the use of a noninversing plow.

Literature review

Subsurface plows are intended for basic nonmoldboard cultivation of soil with the maximum preservation of the stubble and other crop residues after cereals and intertilled crops. Analysis (Boykov, 1998; Gribanovsky, 1990; Kuipers, 1984; Lurie, Lyubimov, 1981; Ploskoreznaya obrabotka pochvy, 2015; Agricultural machinery: catalog, 1991) shows that for basic cultivation of soil in Russia, subsurface plows PG-3-5, GR-3,4; GR-4,3; PG-3-100, KPG-2,2; GUN-4; PRG-3,0; PRG-5,4, etc. have been used.

In our country, subsurface plows KPG-2,2; KPG-2-150; KPG-250A; GUN-4; PG-3,5; PG-3-100 are used. The working organs of these tools are made in the shape of symmetrical center hoes (Lurie, Lyubimov, 1981; Resursosberegayushchie tekhnologii vozdelyvaniya s.kh. kultur, 2001; Agricultural machinery: catalog, 1991; Khalansky, Gorbachev, 2003). The technical characteristics of the widely used tools are shown in Table 1.

Table 1. Technical characteristics of subsurface plows

Indicators	KPG-2,2	PG-3-5	PG-3-100	KPG-250A
Working width, m	1.1	1.1	1.1	1.1
The number of working organs, pcs	2	3	3	2
Working width, m	2.15	3.2;5.3	3.2	2.1
Tillage depth, cm	12…25	15…30	15…30	16…30
Working speed, m/s	Up to 2.77	Up to 2.77	Up to 2.77	Up to 2.45
Weight, kg	1030	1125	720	460
Attached to a tractor of drawbar category	3	5	3	3
Specific materials consumption, kg/m	479	343	225	219

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According to some authors (Boykov et al., 2009; Gribanovsky, 2004; Gureev, 1988; Mekhanizatsiya zashchity pochv ot vodnoi erozii v Nechernozemnoi polose, 1977; Pavlov, 1995; Revyakin, Prosvirin, 1990; Sokolova, 2014), the optimal geometric parameters of center hoes are the following: working width of center hoe – 1.1 m; plowshare angle – 1,000; plowshare angle to the plow sole – 23...250; furrow slice lift – 0.60...0.65 m.

It has been found that with the increase in the working width of the flat hoe, the degree of soil crumbling reduces from 78 % with the working width of 0.5 m to 66.3 % with the working width of 1.71 m (Gribanovsky, Buidlingmeier, 1990; Lurie, Lyubimov, 1981). The number of soil fractions with the size between one and 25 mm in the tilled topsoil with increasing the working width of the hoes also reduces. The hoes with the working width of 0.5 to 0.7 m ensure the presence of fractions with the size from one to 25 mm in the range between 45.5 and 47 %. With further increasing the working width, the percentage content of these factions reduces from 41.5 % to 33.1 % (Gribanovsky, Buidlingmeier, 1990; Lurie, Lyubimov, 1981).

According to (Boykov et al., 2009; Gribanovsky, Buidlingmeier, 1990; Gribanovsky, 2004; Lurie, Lyubimov, 1981; Gortuller, 2005; Putrin, 2000), one can note the following disadvantages of the used subsurface plows:

- Formation of compacted "sole" on the bottom of the furrow;
- Uneven loosening of the soil layer: lumpy on top, and disrupted structure on the bottom;
- Unleveled processed field surface;
- Deep backfurrow with the width of 20 cm and the depth of 15 cm;
- Soil crumbling quality ranges between 32 and 60 %;
- Degree of stubbles preservation with the use of subsurface plows does not exceed 73 %;
- With increasing the depth of tillage from 0.175 to 0.275 m, and the speed of tillage from 1.8 to 3 m/s, the specific traction resistance of subsurface plows increases from 36 to 25...61...72 kPa, i.e., by 70 – 180 % (Lurie, Lyubimov 1981); and
- Significant digging depth.

Given the shortcomings of using subsurface plows for improving the quality of basic cultivation in Russia, plowing tool PL-0,35 (SibIME rack) has been developed based on the known working organs of moldboard plows and subsurface plows. The SibIME racks are installed on the frame of general purpose plows instead of moldboard ones (Agricultural machinery: catalog, 1991). The hoe of LP-0,35 consists of a vertical rack with a shoe with a landside plate and a plowshare welded to the bottom. A plow equipped with an LP-0,35 hoe operates one-way, performing balk plowing. Technical characteristics of a SibIME rack are shown in Table 2.

Table 2. Technical characteristics of a SibIME rack

Indicators	LP-0,35
Working width, m	0.35
Tillage depth, cm	30…35
Working speed, m/s	Up to 2.77
Weight, kg	43

The experience gained during the use of SibIME racks required some adjustment of their geometric parameters. In particular, the plowshare angle to the plow sole had been increased from 25 to 300, which increased the degree of soil crumbling to 71.5 % (Gribanovsky, Buidlingmeier, 1990). The traction resistance increased only slightly.

SibIME racks minimize the removal of the natric horizon to the soil surface and retain 70 – 80 % of stubbles, which protects the soil and increases moisture accumulation (Gortuller, 2005; Rumyantsev, 1964; Spirin, 1995; Khalansky, Gorbachev, 2003; Shabaev, 2003).

Research studies (Spirin, 2005) showed that during the operation of plows with SibIME racks, the average fuel consumption was 21 kg/ha. With that, the tractive resistance in some cases was somewhat higher than in using general purpose moldboard plows: the specific traction resistance amounted to 106 kPa, and soil crumbling did not exceed 65 % (Goryachkin, 1965; Gureev, 1988; Dyakov, 1988; Revyakin, Prosvirin, 1990).

As follows from the above, the use of LP-0,35 does not completely solve the issue of improving soil quality and reducing the energy consumption during basic nonmoldboard cultivation either; therefore, the possibilities of improving the indicators basic nonmoldboard soil cultivation using traditional methods cannot ensure high efficiency of their implementation.

Methods

The methods of the research study included theoretical studying of materials disruption, the tilled soil layer in particular. Based on these studies, a noninversing plow for basic nonmoldboard cultivation was developed. They also involved experimental studies of the plowing unit with the developed noninversing plow. Theoretical studies of the tilled soil layer fracturing or crumbling are shown in the following papers (Goryachkin, 1965; Gureev, 1988; Dyakov, 1988; Lurie, Lyubimov, 1981; Revyakin, Prosvirin 1990). These papers state that reducing the energy consumption and improving the quality of tillage may be achieved through the implementation of pure shear and multidirectional deformations of the cultivated arable layer (Boykov, 1998; Gribanovsky, Buidlingmeier, 1990; Kuipers, 1984). Based on the obtained results of the theoretical studies, noninversing plow PB-5 for basic nonmoldboard soil cultivation has been developed.

The general view of noninversing plow PB-5 is shown in Figures 1 and 2.

Figure 1. Nonmoldboard noninversing plow PB-5. Front left view

Figure 2. Nonmoldboard noninversing plow PB-5. Rear right view

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On the frame of the PB-5 plow, working organs were installed with the possibility of moving along the main beam. The location of the working organs ensured the width of the noninversing plow of 2.25 m, 2.5 m, and 2.75 m. With that, the area of the surface tilled with the PB-5 noninversing plow (working width of 2.25 m, 2.5 m and 2.75) is shown in Figures 3, 4, and 5.

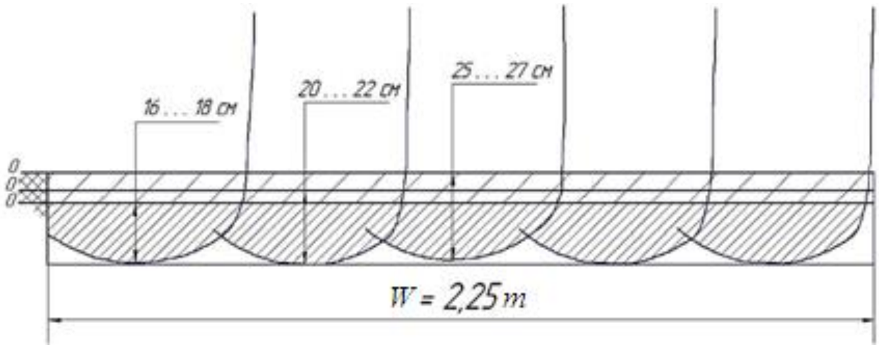

Figure 3. The area of the surface cultivated with the PB-5 noninversing plow with the working width of 2.25 m:
- with the average tillage depth a = 26 cm, S = 0.513 m^2;
- with the average tillage depth a = 21.3 cm, S = 0.4 m^2;
- with the average tillage depth a = 16.7 cm, S = 0.31 m^2

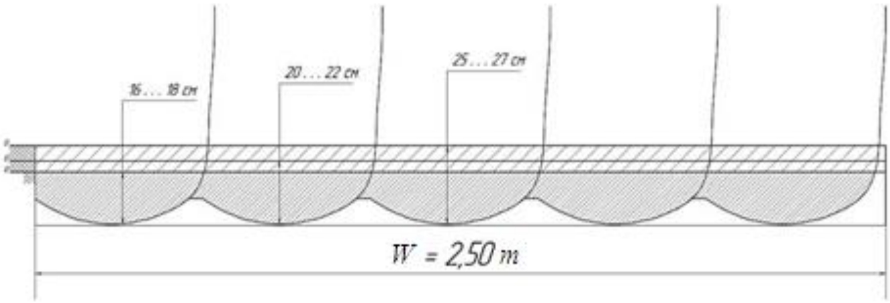

Figure 4. The area of the surface cultivated with the PB-5 noninversing plow with the working width of 2.5 m:
- with the average tillage depth a = 26 cm, S = 0.556 m^2;
- with the average tillage depth a = 21.3 cm, S = 0.431 m^2;
- with the average tillage depth a = 16.7 cm, S = 0.331 m^2

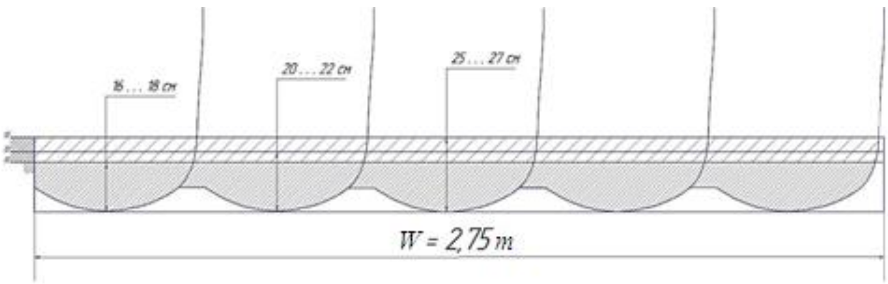

Figure 5. The area of the surface cultivated with the PB-5 noninversing plow with the working width of 2.75 m:
- with the average tillage depth a = 26 cm, S = 0.596 m^2;
- with the average tillage depth a = 21.3 cm, S = 0.459 m^2;
- with the average tillage depth a = 16.7 cm, S = 0.349 m^2.

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The technical characteristics of the PB-5 noninversing plow are shown in Table 3.

Table 3. Technical characteristics of the PB-5 noninversing plow

No.	Indicator	PB-5 plow
1	Product type	Hook-on
2	Aggregated into (tractor brand)	VT-100D, VT-175D, VT-100RM
3	Working speed, km/h	7.5....10.0
4	Transport speed, km/h	Up to 15
5	Working width, m: - designed - working	 2.25…2.75 2.23…2.74
6	Productivity per hour, ha: - effective time - operating time	 1.9…2.4 1.7…2.3
7	Overall dimensions, mm (in the position for storage): - length - width - height	 3,190 2,625 1,650
8	The overall weight of the unit in the working configuration, kg	810
9	The number of working organs, pcs	5

The methods of experimental research studies included the experiments in the field conditions according to GOST 20915-75 "Agricultural Machinery. Methods of determining test conditions", GOST 24055-88 "Agricultural Machinery. Methods of operational-technological evaluation. General", GOST 24057-88 "Agricultural machinery. Methods of operational-technological evaluation of machine complexes, special and universal machines at the stage of testing", and GOST 26025-83 "Agricultural and forestry machines and tractors. Measuring methods of constructive parameters" and (GOST 20915-2011 2013, GOST R 52778-200, 2008).

The object of the research study was the technological process of the basic nonmoldboard cultivation of fields using the PB-5 noninversing plow with a caterpillar tractor of drawbar category 3 VT-100D.

Results and discussion

Experimental studies were performed on the base of the FSBU "North-Caucasian Machine-testing Station".

The PB-5 plow was agronomically assessed by plowing the stubbles of winter wheat and late fall tillage in the fields of an experimental farm of the North Caucasus machine-testing station.

The tested PB-5 plow was aggregated into the commercially available tractor VT-100D. The reference was the serial plow PN-5U with SibIME racks. For autumn plowing, the test plots with cereals stubbles and tilled backgrounds had been tilled with disc harrow BTP-7,0 in a single track.

From the test conditions, it follows that the test plots on all backgrounds were level, and the microrelief of the field on stubbles and tilled backgrounds was 1.3...2.6 cm, which does not exceed the limit (up to three centimeters) allowed by the agrotechnical requirements (AR).

During summer plowing of cereals stubbles, the soil by humidity (19.3… 27.9 %) and hardness (1.12...3.5 MPa) was moist and solid (soil moisture – up to 28 %, hardness – up to 4 MPa). During autumn plowing of cereals stubbles, the soil by humidity (23.1...26.9 %) and hardness (1.04...2.35 MPa) was moist and less solid.

When plowing between rows, tilled soil layer by humidity (15.5... 24.8 %) and hardness (1.65...2.44 MPa) was consistent with AR.

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The parameters of vegetation and crop residues in all backgrounds were specific for the area of the machine-testing station; however, they were slightly higher than the limit allowed by the agrotechnical requirements (up to 25 cm) for cereals stubbles. This is due to the presence of tall and thin-stemmed weeds.

Thus, the testing conditions were characteristic for the area of the machine-testing station and were mainly compliant with the agrotechnical requirements.

During summer plowing of cereal stubbles with plow PB-5 aggregated into tractor VT-100D, slight sticking of the working organs was observed. This is explained by the fact that moisture content in the arable layer (7.9 %) corresponded to the maximum allowable AR value (up to 28 %).

Autumn plowing of winter wheat stubbles with plow PB-5 was made to the depth of 25 to 27 cm with the working width of 2.5 and 2.75 m, plowing of winter wheat stubbles with serial plow MON-5U with CibIME racks was also made to the depth of 25...27 cm. Plowing of winter wheat stubbles with serial plow PN-5U with chisel racks was made to the depth of 35 cm for the destruction of furrow bottom.

During autumn plowing of disked winter wheat stubbles, plow PB-5 aggregated into tractor VT-100D with the minimum working width (2.25 m) became clogged with plant and after-harvest residues, i.e., a violation of the technological process of machine operation occurred. This is explained by the fact that due to the small distances between the racks of the working organs of the plow, the plant mass has not time to pass through, and pilling-up of after-harvest and plant residues occurred.

Thus, when fields with undercut crop residues are tilled, plow PB-5 with the minimum working width (2.25 m) is inoperable.

With the working width of 2.50 and 2.75 m on the same background and on other backgrounds, the experimental plow and the reference plow satisfactorily withstood the speed operation mode, while meeting the AR (up to 12 km/h and 7...9 km/h, respectively).

By the depth and the working width, both plowing units met the AR (the average quadratic deviations did not exceed the AR). The quality of operation of the tested plow and the reference plow is equal in terms of these indicators. During the operation of the plowing units, high quality of preserving the stubbles on the soil surface was observed, except for the reference plow during summer plowing of cereal stubbles. Preservation of stubbles during the operation of the reference plow with tractor VT-100D was 51 %, meaning that by this indicator, plow PN-5U was inferior to the experimental plow PB-5. Soil layer crumbling by both units on all backgrounds satisfies the AR. However, for experimental plow PB-5, the percentage of lumps up to 50 mm was higher than that for the reference plow. Thus, by this indicator, plow PB-5 was slightly better than plow PN-5U.

During summer plowing of cereals stubbles, for both plowing units, the content of erosion-hazardous soil particles in the 0 to 5 cm layer did not increase, which met the AR.

The unevenness of the arable land surface after the experimental plow and the reference plow did not exceed the limit required by the AR for all backgrounds. Furrow sole ridge height after plow PB-5 aggregated into tractor VT-100D was 7.4 cm with the working width of 2.50 m; and 7.8 cm with the working width of 2.75 m.

A) Findings of the agricultural assessment

Plow PB-5 aggregated into a class 3...4 tractor consistently performs the technological process with the working width of 2.25, 2.50, and 2.75 m with the depth of soil tillage of 16...18, 20...22, and 25...27 cm without large amounts of vegetable and after-harvest residues. When processing fields with a medium and strong infestation, the plow consistently performs the technological process with the working width of 2.50 and 2.75 m; with the width of 2.25 m, clogging of the working organs occurs. When soil is tilled to the depth of 16... 18 cm, it is advisable to use the working width of 2.25 and 2.50 m, where unevenness of the furrow sole is 4.8 to 5.8 cm.

The tests also showed that in the area of the machine-testing station, during tillage of Ciscaucasian black soil, the plow steadily performed the technological process with the soil humidity of up to 26.9 %. With higher humidity (AR up to 28 %), sticking of the working organs occurs, and the working process is unstable.

In the conditions that ensure stable process, the structure of the soil tilled with plow PB-5 is less lumpy, the content of lumps smaller than 50 mm is higher by 6...10 % than with the reference plow.

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Operational and technological assessment of experimental plow PB-5 was performed on the same backgrounds and at the same time; therefore, the testing conditions are to be considered similar. An analog for comparison was plow PN-5U with CibIME racks. Both plows were aggregated with tractor VT-100D.

Plowing of winter wheat stubbles was made to the depth of 16... 18 cm with the working width of 2.75 m; to the depth of 20...22 cm with the working width of 2.75 m; and to the depth of 25...27 cm with the experimental plow working width of 2.50 m and 2.75 m.

With the working width of 2.25 m, operational and technological indicators were not determined due to the disruption of the working process. All racks of plow PB-5 were clogged with plant residues.

Plowing of sunflower stubbles was made to the depth of 25…27 cm, both the experimental and the reference units met the AR by the depth and the working width on all backgrounds; their operational quality was almost equal.

Analyzing the data of operational and technological assessment, one can note that when plowing winter wheat stubbles to the depth of 16...18 cm, productivity per hour of plow PB-5 exceeds that of the analog by 57 % due to the greater (by one meter) working width. With that, the working speed of the experimental unit was slightly below that of the basic one. The technological process was consistently performed by both units, as confirmed by the technological process reliability coefficients, which are 1.0 with the norm equal to 0.99.
The specific fuel consumption with the use of the experimental unit was lower than the reference by 87 %.

When plowing winter wheat stubbles to the depth of 20...22 cm, the productivity per hour of the experimental plow exceeded that of the reference by 55 % due to the greater (by one meter) width at the same operating speed. On this background, humidity (27.9 %) in the topsoil was the maximum allowed (up to 28 %). With that, sticking of the working organs of the plow was observed. In this regard, the technological process reliability coefficient for experimental plow PB-5 was 0.81 (with 1.0 for the reference). The specific fuel consumption with the use of the experimental unit was lower than that of the serial one by 48 %.

When plowing winter wheat stubbles to the depth of 25...27 cm, and the working width of the experimental plow of 2.50 m, the productivity per hour of the experimental unit was higher than that of the serial one with SibIME racks by 23 % at a lower (by 1.12 km/h) operating speed.

With that, the specific fuel consumption of the experimental unit was lower than that of the serial one by 29 %.

The productivity per hour of experimental plow PB-5 with the working width of 2.75 m and the tillage depth of 25...27 cm was higher than that of the reference plow with SibIME racks by 39 %. With that, the specific fuel consumption of the experimental unit was lower than that of the serial one by 32 %. The technological process during this type of work was steadily performed by both the experimental and the reference units, as confirmed by the technological process reliability coefficients, which were equal to 1.0. Thus, it should be noted that it is advisable to use plow PB-5, with the maximum working width of 2.75 m.

When plowing sunflower stubbles to the depth of 25...27 cm, which was performed only by the experimental plow, the productivity per hour was 2.10 ha/h, whic meets the AR (1.5 to 2.7 ha/h) at the unit operating speed of 7.8 km/h. The specific fuel consumption was 10.6 kg/ha.

Thus, for all types of works, experimental plow PB-5 by its main operational and technological indicators meets the AR and is superior to serial plow PN-5U.

B) Opinion on the results of operational and technological assessment
Plow PB-5 with tractor VT-100D in the conditions that provide for the normal technological process ensures the increased productivity (by 57 %) with the depth of tillering of 16... 18 cm (preset working width of 2.75 m), along with reduced fuel consumption (by 87 %) in case of tillering fall plowing to the depth of 25...27 cm; compared to the Siberian rack, productivity growth is 39 %, and fuel economy is 44 %.

Energy assessment of plow PB-5 was made with the aim of experimental determination of the energy-power indicators, their comparison to the corresponding indicators of similar plow PN-5U, and determination of the correspondence between the power consumption of the plow and the traction and power performance of tractor VT-100D.

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The tests were performed along with agronomic, operational and technological assessment in the field of the machine-testing station while tilling winter wheat stubbles to the depth of 26.0, 21.3, and 16.7 cm, and the working width of 2.75, 2.50, and 2.25 m.

Parameters of energy consumption of the compared plows PB-5 and PN-5U with CibIME racks were measured and recorded using a specially equipped tractor VT-100D. For a more accurate calculation of the specific traction resistance of plow PB-5, Figures 3, 4, 5 show the areas tilled with plow PB-5 with the working width of 2.25, 2.50, and 2.75 m, respectively, to the depth of 26.0, 21.3, and 16.7 cm.

With the plow working width of 2.75 m and the tillage depth of 26.0 cm, the traction resistance of plow PB-5 aggregated into tractor VT-100D was 37.0 kN at the speed of 7.6 km/h. In terms of traction resistance and traction power, plow PB-5 can be satisfactorily aggregated into tractor VT-100D. The load on the tractor relative to its nominal torque (48.0 kN) at the speed of 7.6 km/h was 77.0 %. With that, the tractive resistance of the experimental unit was by 23.3 % higher than that of the reference unit due to the greater working width of plow PB-5.

Caterpillar slipping of tractor VT-100D aggregated with plow PB-5 when working on a disk harrowed field was 3.0 %, which was within the norm for caterpillar tractors (3.0 %).

The specific resistance of plow PB-5 aggregated into tractor VT-100D at the speed of 7.6 km/h was 6.2 N/cm2, which was by 6.3 % less than that of the reference with CibIME racks. The specific energy consumption of the experimental unit at a speed of 7.6 km/h was 45.2 kW.h/ha, which was by 26.0 % less than that of plow PN-5U with CibIME racks.

With the working width of 2.50 m and the tillage depth of 26.0 cm, the specific resistance of the experimental unit was 6.47 N/cm2 and was almost equal to the specific resistance of plow PN-5U with CibIME racks (6.59 N/cm2). The specific energy consumption of the experimental unit at a speed of 7.7 km/h was 50.0 kWh/ha, which was by 18.2 % less than that of plow PN-5U with CibIME racks.

With the working width of 2.25 m and the tillage depth of 26.0 cm, the specific resistance of the experimental unit moving at the speed of 7.77 km/h was 6.62 N/cm2 and was almost equal to the specific resistance of plow PN-5U with CibIME racks (6.59 kN/cm). The specific energy consumption of the experimental unit at the speed of 7.77 km/h was 51.7 kW.h/ha, which was by 15.4 % less than that of plow PN-5U with CibIME racks.

The foregoing signifies that with decreasing the working width, its specific resistance increases.
In terms of specific power consumption, plow PB-5 with the working width of 2.75, 2.50, and 2.25 m, and the tillage depth of 26.0 cm is more efficient than reference plow PN-5U with CibIME racks.

In terms of power and traction, tractor VT-100D aggregated with plow PB-5 ensures sustainable performance of the technological process with all working widths.

The working engine power utilization factor with the working width of 2.75 m was 0.78 at the speed of 7.6 km/h; with the working width of 2.50 m – 0.76 at the speed of 7.7 km/h; and with the working width of 2.25 m – 0.73 at the speed of 7.77 km/h.

C) Opinion by the results of power assessment
In terms of power and traction, tractor VT-100D aggregated with plow PB-5 ensures sustainable performance of the technological process with all working widths. Specific energy consumption of the unit, compared to the analog (SibIME racks), with the tillage depth of 25...27 cm is lower: with the width of 2.25 m – by 15.4 %, with the width of 2.50 m – by 18.2 %; and with the width of 2.75 m – by 26 %.

An economic evaluation of the experimental nonmoldboard plow PB-5 was performed on the data obtained during the operational and technological assessment according to GOST 23729 "Agricultural machinery. Methods for economic assessment".

Analysis of the data shows that with the use of the experimental plow, labor consumption, compared to the analog, reduced by 29.7 % due to the fact that productivity of the tested plow in all types of works was higher than that of the serial one (by 31 to 58 %). Direct operating costs for the experimental plow are lower, compared to the reference, by 33 % due to higher productivity of plow PB-5 in all types of work (by 32 to 59 %), with slightly lower reported value of the experimental plow, and much lower fuel consumption (by 24 to 45 %). Specific capital costs of the experimental unit are lower, compared to the reference unit, by 33 %, and the sum of the integrated costs is also lower by 33 %.

Thus, the use of experimental plow PB-5 is economically advisable.

Conclusion

Using the results of the experimental studies of plowing unit VT-100D+PB-5, the following conclusion can be made:

- Reducing energy consumption and improving the quality of basic nonmoldboard cultivation may be achieved through the shape of the working organ, which, according to the theoretical studies, implements the pure shear condition in the tilled topsoil; and
- The use of the suggested noninversing plow with the optimal width for aggregation with a domestic or foreign tractor of the known power will greatly improve the efficiency of basic nonmoldboard cultivation in the arid regions of the Russian Federation.

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