

Artículo de investigación

Improving the technology and primary tillage plow

Совершенствование Технологии И Плуга Основной Обработки Почвы

Mejora de la tecnología y el arado de procesamiento básico de suelos

Recibido: 12 de julio del 2019

Aceptado: 24 de agosto del 2019

Written by:

Vasily M. Boykov²³⁶https://elibrary.ru/author_items.asp?authorid=277278

ORCID ID: 0000-0002-2014-1615

Sergey V. Startsev²³⁷https://elibrary.ru/author_items.asp?authorid=442568

ORCID ID: 0000-0003-3310-0035

Igor L. Vorotnikov²³⁸https://elibrary.ru/author_items.asp?authorid=291591

ORCID ID: 0000-0003-3631-8275

Abstract

The introduction of abandoned fields into crop rotation for obtaining agricultural product is an important economic problem today. The work is aimed at improving the technology of primary tillage of the soil and the moldboard plow for this purpose that would ensure embedding of tall-growing plants in abandoned fields at low energy costs and with good agronomic performance. The energetic and agronomic characteristics of the moldboard plow for primary moldboard tillage were studied using the basic provisions of classical and agricultural mechanics, mathematics, in accordance with the existing State Standards of the Russian Federation, Company Standard AIST, and the adopted scientific and practical methods. Ordinary medium loamy black soil was used as the physicomaterial properties of the soil. As a result of the studies, the problem of restoring abandoned fields has been solved through the use of advanced tillage technologies that are different from the existing moldboard tillage and performed using the designed working organ. The authors offer an advanced technology of primary moldboard tillage of abandoned fields and a plow that ensure embedding of tall-growing plants in the topsoil at low energy costs and with good agronomic performance.

Аннотация

ввод заброшенных полей в севооборот для производства сельскохозяйственной продукции является важной актуальной хозяйственной проблемой. Целью работы является совершенствование технологии основной обработки почвы и отвального плуга для её выполнения, обеспечивающего заделку высокорослых растений на заброшенных полях при низких энергозатратах и высоких агротехнических показателях. Исследования энергетических и агротехнических показателей плуга для основной отвальной обработки почвы проводились с использованием основных положений классической и земледельческой механики, математики, в соответствии с действующими ГОСТами РФ, СТО АИСТ и установленными в науке и практике методами. В качестве физико-механических свойств почвы использовали чернозем обыкновенный среднесуглинистый. В результате проведенных исследований решена проблема восстановления заброшенных полей, за счет применения усовершенствованной технологии обработки почвы, отличающейся от известной лемешно-отвальной обработки и выполняемой разработанным рабочим органом. Авторами статьи предложена усовершенствованная

²³⁶ Saratov State Agrarian University named after N.I. Vavilova, Theater Square, 1, Saratov, 410012, Russia, mtrushin@mail.ru²³⁷ Saratov State Agrarian University named after N.I. Vavilova, Theater Square, 1, Saratov, 410012, Russia.²³⁸ Saratov State Agrarian University named after N.I. Vavilova, Theater Square, 1, Saratov, 410012, Russia

Keywords: Primary tillage, plow, soil, depth of tillage, abandoned field, vegetation, embedding plants.

технология основной отвальной обработки почвы заброшенных полей и плуг, обеспечивающие заделку высокорослых растений в пахотный слой с низкими энергозатратами и при высоких агротехнических показателях.

Ключевые слова: Основная обработка почвы, плуг, почва, глубина обработки почвы, заброшенное поле, растительность, заделка растений.

Resumen

La introducción de campos abandonados en la rotación de cultivos para la producción agrícola es un importante problema económico urgente. El objetivo del trabajo es mejorar la tecnología del arado principal de labranza y vertedero para su implementación, lo que garantiza la plantación de plantas altas en campos abandonados con bajo consumo de energía y altos indicadores agrotécnicos. Las investigaciones de los indicadores energéticos y agrotécnicos del arado para la labranza principal del vertedero se llevaron a cabo utilizando los principios básicos de la mecánica clásica y agrícola, las matemáticas, de acuerdo con los GOST actuales de la Federación de Rusia, STO AIST y los métodos establecidos en la ciencia y la práctica. Como propiedades físicas y mecánicas del suelo, se usó chernozem ordinario medio arcilloso. Como resultado de la investigación, el problema de la restauración de los campos abandonados se resolvió mediante el uso de una tecnología mejorada de cultivo del suelo, que difiere del conocido cultivo de cuchillas de arado y lo lleva a cabo el cuerpo de trabajo desarrollado. Los autores del artículo propusieron una tecnología mejorada para la labranza principal del vertedero de los campos abandonados y un arado, que garantiza la incorporación de plantas altas en la capa cultivable con bajo consumo de energía y alto rendimiento agrícola.

Palabras clave: Labranza principal, arado, suelo, profundidad de labranza, campo abandonado, vegetación, incorporación de plantas.

Introduction

The agricultural census showed that the total area of unused agricultural lands in Russia had amounted last year to 97.2 million hectares, i.e., 44 % of all agricultural lands in the country. The census revealed huge areas that were officially considered arable land by the Federal Service for State Registration, Cadastral Records and Cartography, but in fact had not been plowed for a long time and became lealand.

The lands that were not claimed for agricultural production become junk lands and are characterized by the dynamics and processes of weeds dispersion. In the first stage, such lands pass the tall weeds stage with typical vegetation with annual dicotyledonous plants prevailing. The natural tendency is increasing the share of dangerous perennial weeds (perennial sow thistle, cursed thistle, trailing bindweed, a bindweed field, blue lettuce), rhizogenous (couch grass, sedge), and quarantine species (Russian knapweed, various types of hogweed, dodder and broomrape). Subsequently, dicotyledonous

plants are replaced by perennial grasses, and wasteland turns into natural lealand (Romanenko, 2008; Gornov, 2013; Vasiliev et al., 2016).

On the land withdrawn from agricultural turnover, a noticeable change of soil properties is noted (Bulinski, 2000; Technological properties of soil, n.d.; Mineev, 2004). All nutritional properties of lealands have poorer values than those of arable land. In the abandoned fields, along with a decreased content of nutrients in the soil, changes in the water and air conditions are noted (Skornyakov, 2013), which fact complicates the process of tillage (Golubeva, Nakvasina, 2015; Nikolaev, 2010a; Nuralin et al., 2017; Capote et al., 2019).

Thus, studying the agroecological state of the Russian lands withdrawn from agricultural turnover has shown that almost in all soil-climatic zones of the country, wastelands become overgrown with tall weeds and wild-growing

field vegetation within 10 – 15 years, with the increasing share of harmful perennial weeds, shrubs and woody thicket up to 1 – 1.7 m high (Gornov, 2013; Vasiliev et al., 2016). The presence of tall vegetation not only complicates mechanical tillage of the soil but also requires a lot of energy (Podskrebko, 2010; Tvorogov, 2008). It is evident that the introduction of abandoned fields into crop rotation for obtaining agricultural product is an important economic problem today.

Literature review

In the middle of the 20th century, tillage of virgin and fallow lands started in Russia (Osvoenie tseliny, n.d.). Fallow lands were mainly dominated by grass vegetation, with a maximum height of 25 cm and sod layer 10 – 12 cm deep (Matyuk et al., 2010). During that period, the technology of virgin lands tillage included sod disking and moldboard tillage of the soil with moldboard plows (Sitdikov, Safin, 2012). At the beginning of the 21st century as already mentioned (Agricultural machinery, 2018), many abandoned fields formed in Russia that were overgrown with weeds, shrubs and woody thicket up to 1 – 1.7 m high. To restore and use the abandoned fields, by analogy with the tillage of the virgin fields, a tillage technology was suggested, which included grinding and mixing the field vegetation with the soil, followed by plowing or subsoiling (Romanenko, 2008; Sitdikov, Safin, 2012). It is recommended to perform grinding and mixing using heavy disc harrows or disk headers, and the main tillage – with moldboard plows, chisel plows or subsurface cultivators – para plows of various brands. (Pleskachev, Borisenko, 2005; Churzin, Serebryakov, 2016; Pleskachev et al., 2013; Lepeshkin, 2015). It is also noted that it is rational to perform soil tillage using disc headers and moldboard plows (Trubilin et al., 2014; Labotsky et al., 2011; Mutikov et al., 2011). According to the studies of some authors (Burak et al., 2014, Kalinin, Ustroev, 2016; Nikolaev, 2010b), the energy intensity of tillage by disc

headers is on average 20 – 30 kW*h/ha, and by moldboard plows – 40 – 60 kW*h/ha. Accordingly, specific fuel consumption is 7 – 12 kg/ha and 16 – 22 kg/ha, respectively.

Therefore, from the technology point of view, tillage of abandoned fields includes initial grinding of the vegetation with disk harrows or disk headers (Pleskachev, Borisenko, 2005; Churzin, Serebryakov, 2016; Pleskachev et al., 2013; Lepeshkin, 2015), followed by plowing with general purpose plows or specialized plows (Trubilin et al., 2014; Labotsky et al., 2011; Mutikov et al., 2011; Weissbach et al., 2002; Lemken, n.d.; Kverneland plows, n.d.; The lineup of KUHN wide plows, n.d., GREGOIRE BESSON plow, n.d., Vogel Noot plows, n.d.). However, according to the agricultural requirements (Agrotechnical requirements to the main operations in adaptive technologies of cultivation of winter cereals and maize, and new tools for cultivation in the Krasnodar region, 2011), disc harrows and disc headers are efficient if the height of the vegetation and crops residues does not exceed 25 cm. In case of vegetation height reaching 1 – 1.7 m, disc harrows, and disc headers are inefficient. The existing plows also ensure high quality of tillage only if the height of stubbles and grass stand does not exceed 25 cm (Agrotechnical requirements to the main operations in adaptive technologies of cultivation of winter cereals and maize, and new tools for cultivation in the Krasnodar region, 2011). If the height of the grass stand exceeds 25 cm, the body of the plow gets clogged with the vegetation of the abandoned field. It means that the process of primary tillage stops.

In case of tillage with plows, energy consumption is almost twice higher than that of tillage with disc headers, with the processes performed almost equal fundamentally, the only difference being the depth of tillage.

The process of primary tillage with the existing moldboard plows is shown in the diagram below (Figure 1).

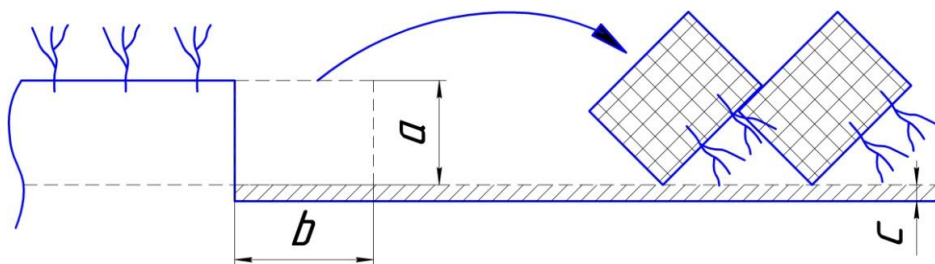


Figure 1. The diagram of primary tillage with the existing plows:
a – the depth of tillage; b – the working width of the plow; c – plow pan thickness.

On the one hand, tillage with plows includes undercutting, crumbling, turning the crumbled soil over and embedding stubbles and crop residues with the maximum height of 25 cm into the tilled soil layer (Pleskachev, 2013; Lepeshkin, 2015; Labyntsev et al., 2010; Sorochkin, Bryukhova, 2011). On the other hand, in case of tillage of abandoned fields with the vegetation height exceeding 25 cm, the existing process of primary tillage will be disrupted. This raises the scientific problem of developing a process for tillage of abandoned fields and a

working organ for performing it, which would perform tillage with the minimal energy consumption, high performance and will exclude soil disking.

Objects and Methods

The object of the research study was the process of primary tillage of abandoned fields using plows with new working organs. The technical characteristics of PBK-3 and PBK-5 moldboard plows for soil tillage are shown in Table 1.

Table 1. Technical characteristics of moldboard plows for moldboard plowing

No.	Characteristic	Plow	
		PBK – 3	PBK – 5
1	Aggregated with tractors of drawbar category	3 – 4	5
2	Working speed, km/h	up to 15	up to 15
3	Working width, m	2.4	4.0
4	Overall dimensions, mm		
	length	3,100	4,100
	width	2,800	3,800
	height	1,800	2,000
5	Weight, kg	845	1,440
6	The number of working organs, pcs	3	5
7	Working width of the organ, mm	800	800
8	The distance between working organs along the beam, mm	970	970
9	The distance between the toes of working organs in the direction of the plow, mm	670	670
10	The height from the bearing plane of the working organs to the frame, mm	720	720

The method of the research study included, according to Industry Standard 10 4.1-2001 and Industry Standard 10 2.2-2002 "Testing of agricultural machinery", GOST 20915-75 "Farm machinery. Procedure for 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", GOST 26025-83 "Agricultural and forestry machines and tractors. Measuring methods of constructive parameters", a field

check of the soil tillage process in abandoned fields, performed by the plow with new working organs with the aim of determining the quality and energy consumption of the new plow.

The depth of tillage was determined using the method of transverse profiling. The quality of embedding the vegetation on the surface of the field was determined by the weight.

Soil crumbling was determined by the samples taken at four points of the plot (two points in the direction of the unit movement, and two points in the opposite direction).

Soil hardness was determined by the Revyakin's hardness measuring machine. To determine the energy consumption, small-sized portable information-measuring system SP-238 was used, which is intended for measuring, analyzing, storing and displaying the parameters that determine the operating and technological parameters of tractors and agricultural machinery. The sensors of power parameters were resistance strain gages installed on the drive axle of tractor T-150K.

Results and discussion

For resolving the scientific problem, the technological process of primary soil tillage was improved (Pleskachev, Borisenko, 2005) (Figure 2). In the first stage, Figure 2, a) soil layer F is

loosened in cross-section axb . At the second stage, Figure 2, b) the loosened soil layer is divided into halves, i.e., $0.5F_1$, and a part of the layer by section $0.5F_1$ is moved from position 1 to position 2. After that, halves of layer sections F_2 and F_1 and tall plant residues of these four sections are moved simultaneously into the formed furrow 3 in the following sequence: first, $0.5 F_1$ is moved to position 5, then $0.5F_2$ is moved to position 6 (Figure 2, d).

After that, the process is repeated. Unlike with the existing technology (Pleskachev, Borisenko, 2005), Figure 1, dividing the initially loosened volume into two parts and the presence of ridges 7 (Figure 2, e) on the bottom of the tilled topsoil will ensure better turning of the topsoil and embedding of vegetation into the cultivated arable layer, and will also allow increasing the working width of the plow.

It is known (Podskrebko, 2010; Burchenko, 2001) that by implementing the stress-strain state of the arable layer, which is formed as a result of pure shear, it is possible to reduce the drag resistance of a working organ. This condition occurs in the arable layer upon the interaction of the conical working surface with the arable layer (Trubilin et al., 2014; Lobachevsky et al., 2000; Dyakov, 2009; Williams et al., 2000; Hill, Stott, 2000; Boykov, 1998), i.e., the working surface of the plow that interacts with the arable layer should have the shape of a conical surface.

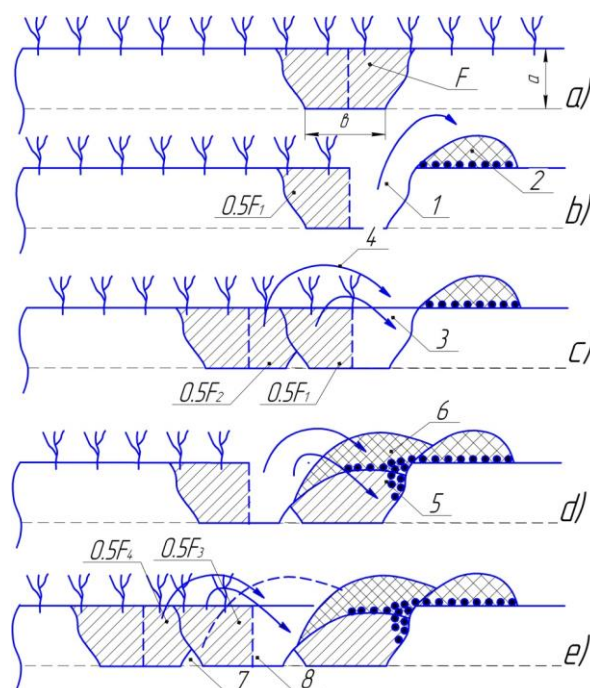


Figure 2. The diagram of the process of soil primary tillage in abandoned fields:

- Loosening soil layer F to depth a;
- 0.5 F moves from position 1 to position 2;
- Placing tall crop residues 4 into furrow 3, and sections 0.5 F₁ and 0.5 F₂ into furrow 3;

- Moving part of section F 0.5₁ to position 5 and sections 0.5 F₂ to position 6,
- Moving plant residues of layers sections 0.5 F₃ and 0.5 F₄ to position 8.

Using the diagram (Figure 2) of the soil tillage process in abandoned fields and the conditions of pure shear, a new working organ was developed, which is schematically shown in Figure 3.

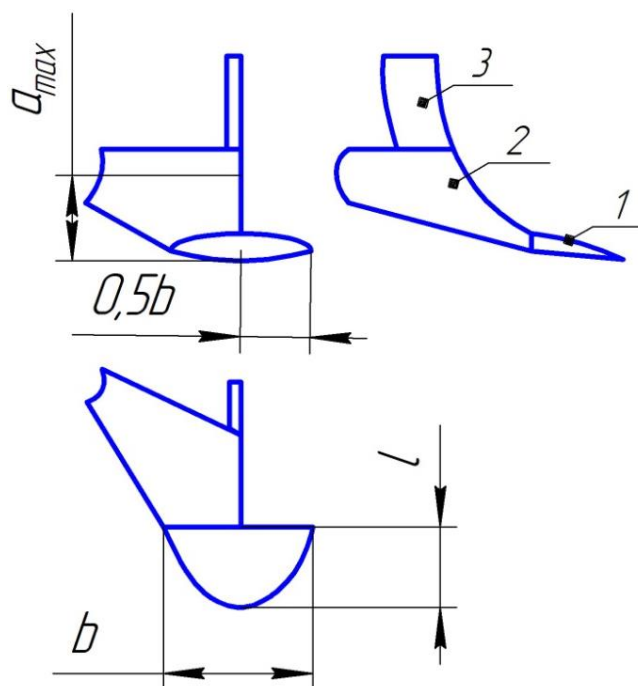


Figure 3. A diagram of the new working organ for tillage of abandoned fields:
1 – furrow opener; 2 – breast; 3 – rack

As a result of the theoretical studies, the basic parameters of the new working organ were determined: a_{max} – the maximum depth of tillage, $a_{max} = 35$ cm; b – the width of the furrow opener, $b = 0.5$ m; and l – the length of the furrow opener, $l = 0.5 b$. With that, two kinds of breasts were mounted on the working organ for studying the degree of abandoned field tall plants embedding. The conditional marking of the body with elongated breast is KBK-80, and of the body with a modified configuration of the breast field cut is KBK-80-01.

Based on the scheme of the new working organ, plows PBK-3 and PBK-5 were developed for aggregation with tractors of drawbar category 3 and 5 and the working width of 2.4 and 4.0 m. The technology and the plow for tillage of abandoned fields were studied in the fields of the Volga Research Institute of Seed Breeding in the Samara region in the area of activities of the

FSBE Volga Machine Testing Station (settlement Ust-Kinelsky, Kinel district, Samara region), on homogeneous plots by the type and the mechanical composition of the soil – ordinary medium loamy black soil. Their microrelief was weakly and medium manifested. The terrain of the abandoned field was flat, with the slope up to 4° . The vegetation height varied depending on the soil fertility from 9.5 to 83.8 cm. The weight of vegetation per one square meter ranged from 439 to 780 g. In the summer, the plowing units worked on the soil with the hardness of 2.7 – 3.8 MPa and the moisture content of 14.9 – 19.1 %. In the autumn, all arable layers: 0 – 10, 10 – 20, 20 – 30 cm featured high humidity content from 31.5 to 32.5 %, and hardness of 0.7, 1.0, 1.5 MPa, respectively.

Agrotechnical assessment of the efficiency of using plowing unit T-150K + PBK-3 and K-701 + PBK-5 was made at the depths of 23.2...28.7

cm. The mean square deviation of the depth from the preset depth was $\pm 1.3...1.6$ cm and did not exceed the allowed limits (± 2 cm). The deviation of the working width of the designed one of the units did not exceed $\pm 10\%$, even during tillage of soil with high moisture content. Based on the analysis of moldboard tillage of the soil with low humidity, it was found by the quality of crumbling that fractional composition with the size less than 50 mm had the range from 40.0 to 85.6 %.

The distinctive quality of units T-150K + PBK-3, K-701 + PBK-5 is the high degree of the vegetative mass. The vegetation was embedded to the depth of 12.7...19.0 cm by 95.1 – 97.6 %.

The ridgeness of arable land was 6.8 – 10.1 cm, which was not in line with the agricultural requirements – not exceeding 5 cm. No clogging of the working organs of plows with vegetation was observed in the process of plowing.

Figure 4 shows soil processing in the field overgrown with annual and perennial tall weeds with the height up to 1.2 m with plowing unit T-150K + PBK 3.

In general, tested plows PBK-3 and PBK-5 consistently performed the process of soil treatment in abandoned fields by the main agronomic indicators, except for ridgeness of arable land.



a)



b)

Figure 4. Moldboard plowing of an abandoned field with plowing unit T-150K + PBK-3: a – unit view from the field; b – unit view from the furrow

Figure 5 shows the dependence of the specific drawbar resistance of the studied bodies KBK-80 and KBK-80-01 on the speed of movement.

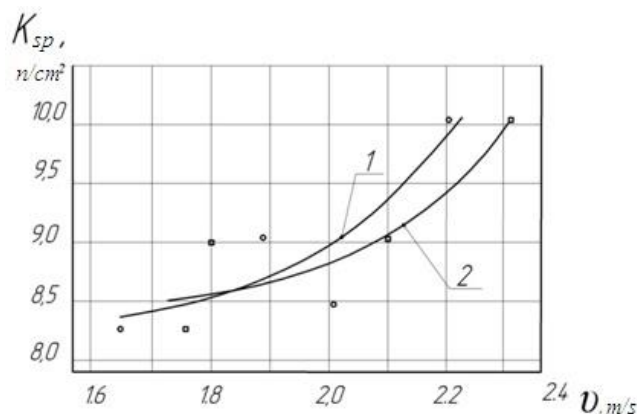


Figure 5. Dependence of the specific drawbar resistance K_{sp} of the studied bodies on the speed of movement v : 1 – KBK-80, 2 – KBK-80-01.

Analyzing the specific drawbar resistance of the bodies, a conclusion may be drawn that the pattern of changes in specific drawbar resistance has the same nature.

Energy assessment showed that the process moldboard tillage of the abandoned field with unit T-150K + PBK-3 with working body KBK-80-01 was less energy-intensive; the specific energy consumption amounted to 33.7...40.5 kWh/ha.

A distinctive quality of the unit with plows PBK-3 and PBK-5 was the high degree of plant mass

and crop residues embedding, the ability to embed all tall macropodal plant residues obtained during operation of K-701 + PBK-5. With the height of post-harvest stubbles from 47.6 to 100.4 cm, and high soil moisture content, the new unit embedded 98 % of those.

The results of the comparative operational assessment of the units consisting of tractor T-150K with serial plow PLN-5-35 and tractor T-150K with the developed plow PBK-3 are shown in Table 2.

Table 2. Operating characteristics of plows PBK-3 and PLN-5-35

No.	Characteristic	Characteristic value	
		PBK-3	PLN-5-35
1	Soil moisture content, %	32.3 – 35.9	32.3 – 35.9
2	Soil hardness, MPa	0.7 – 1.3	0.7 – 1.3
3	The height of post-harvest stubbles, cm	27.0	27.0
4	The depth of tillage, cm	26.6	25.5
5	Working width, m	3.2	1.9
6	Speed, km/h	8.2	7.8
7	The mean square deviation of the depth \pm cm	1.2	1.8
8	Soil crumbling, %, fraction size up to 50 mm	85.6	89.6
9	Stubble embedding degree, %	98.9	85.0
10	Stubble embedding depth, cm	7.4	12.6
11	Drawbar resistance, kN	21.4	20.6
12	Specific drawbar resistance, N/cm ²	4.15	4.19
13	Specific energy consumption, kWh/ha	33.7	43.0
14	Productivity per one hour, hectares:	1.8	1.6
15	Fuel consumption per hectare, kg/ha	13.5	15.0

Analysis of the table shows that reduction of the specific energy consumption of the plow unit equipped with plow PBK-3, compared to PLN-5-35, was by 21.7 %, of fuel consumption per hectare – by 10.0 %; with that, the hourly productivity of the plow unit increased by 11.1 %, and the quality of stubble embedding improved by 14.0 %.

Conclusion

The problem of restoring abandoned fields can be solved through the use of advanced technologies of soil tillage with the developed working organ, which is different from the existing technology of moldboard tillage with a moldboard plow. The developed working organ consists of a rack with a furrow opener and a breast. To reduce energy consumption during tillage, the furrow opener has a convex shape, which ensures the stress-strain state of the arable layer due to pure shear. Based on this working organ, plows PBK-3 and PBK-5 have been created, which ensure embedding of 98 % of the vegetation higher than 25 cm in abandoned fields to the depth of 7 – 10 cm, which removes the need for vegetation crushing with disk headers. It has also been found that by their working and technological characteristics, the suggested plows, compared to serial plows PNL-5-35, PNL-8-40, PNI-8-40, ensure higher performance and lower fuel consumption. With that, new plows do not get clogged with vegetation, and reduce the cost of plowing by 10.7 %. The developed technology of recovering abandoned fields, compared to the suggested one, allows reducing the energy consumption by 50 %, compared to moldboard tillage; however, according to the studies (Labotsky, 2011; Tiranova, Tiranov, 2011; Sorokin, 2011), the vegetation embedding depth of 7.0 – 8.0 cm ensures efficient decomposition of embedded plants.

References

Agrotekhnicheskie trebovaniya k osnovnym tekhnologicheskim operatsiyam pri adaptivnykh tekhnologiyakh vozdeleyvaniya ozimnykh kolosovykh i kukuruzy i novye tekhnicheskie sredstva dlya ikh vypolneniya v Krasnodarskom krae [Agrotechnical requirements to the main operations in adaptive technologies of cultivation of winter cereals and maize, and new tools for cultivation in the Krasnodar region]: Krasnodar. 2011.

Boykov V. M. (1998). Mechanical and technological substantiation of efficient methods and tools for primary tillage. Ph.D. Thesis. Saratov.

Bulinski J. (2000). Plugi do orki bezzagonowej. Wybrane zagadnienia budowy i uzytkowania. Przegl. Techn. roln. lesn, 8, 11-13.

Burak P. I., Pronin V. A., Prokopenko A. A. et al. (2014). Comparative tests of agricultural machinery: scientific edition. Moscow: FSBSI Rosinformagrotech.

Capote, Tania; González, Gonzalo; Perdomo, José (2019). El enfrentamiento al cambio climático en la especialidad forestal de la educación técnica profesional, Revista Científica del Amazonas, 2 (3), 5-16.

Golubeva L. V., Nakvasina E. N. (2015). Zarastanie drevesnoi rastitelnostyu postagrogennykh zemel na karbonatnykh otlozheniyakh v Arkhangel'skoi oblasti [Post-agrogeous lands overgrowing with woody vegetation on carbonate deposits in the Arkhangelsk region]. Bulletin of Saint-Petersburg Forestry Academy, 210, 25-36.

Gornov A. V. (2013). Osobennosti formirovaniya lesnykh soobshchestv na zabroshennykh senokosakh v Nerussko-Desnyanskom Polese (Bryanskaya oblast) [Peculiarities of forest communities formation in abandoned grasslands in the Nerusso-Desna woodland (Bryansk region)]. Forest Bulletin, 7(99), 92-96.

GREGOIRE BESSON plow. <https://ru.gregoirebesson.com/ru/gamme/mounted-plough>

Hill P.R., Stott D.E. (2000). Corn residue retention by a combination chisel plow. Soil Sc. Soc. America J, 64(1), 293-299.

Kalinin A. B., Ustroev A. A. (2016). Teoreticheskie predposylki i prakticheskie priemy ratsionalnoi sistemy obrabotki pochvy v tekhnologiyakh vozdeleyvaniya selskokhozyaistvennykh kultur [Theoretical prerequisites and practical methods of a rational system of soil tillage in the technologies of agricultural crops cultivation]. Technologies and tools for mechanized crop production and livestock breeding, 90, 70-78.

Labotsky I. M., Makut A. D., Kovaleva I. M. (2011). Rezultaty issledovaniya, provedennykh vo vremya ispytaniya agregata dlya lushcheniya zhnivya, doizmelcheniya i zadelki pozhnivnykh ostatkov selskokhozyaistvennykh kultur [Results of the studies performed during testing of a unit for stubble peeling, regrinding and embedding afterharvest residues of agricultural crops]. In collection: Mechanization and electrification of agriculture. Interdepartmental thematic collection. Minsk, pp. 88 – 94.

Labyntsev A. V., Sivachev V. Y., Tseluyko O. A. et al. (2010). Normativy i metodika primeneniya pobochnoi produktsii selskokhozyaistvennykh kultur dlya polucheniya bezdefitsitnogo balansa gumusa organicheskogo veshchestva v pochvakh

- na zemlyakh selskokhozyaistvennogo naznacheniya [The standards and methods of using byproducts of agricultural crops for obtaining a non-deficit balance of humic organic matter in the soils on agricultural lands]. Rostov region: SSU Donskoy Scientific Research Institute of Russian Agricultural Academy settlement Rassvet.
- Lemken. The agrovision company. (n.d.). Attached full-turn plows LEMKEN. <https://lemken.com/ru/obrabotka-pochvy/vspashka/>
- Lepeshkin N. D., Tochitskii A. A., Kozlov N. S. (2015). Izmelchenie i zadelka pozhnivnykh ostatkov vysokostebelnykh kultur [Crushing and embedding afterharvest residues of tall-growing crops]. In collection: Scientific and technical progress in agricultural production Materials of International scientific-technical conference: in 2 volumes, pp. 81 – 86.
- Lobachevsky Y. P., Panov A. I., Gentry I. M. (2000). Perspektivnye napravleniya sovershenstvovaniya konstruktssii lemeshno-otvalnykh plugov [Promising areas of improving the design of moldboard plows]. Tractors and agricultural machinery, 5, 12-18.
- Matyuk N. S., Rassadin A. Y., Polin V. D., Soldatova S. S. (2010). Obrabotka i okulturivanie zaleznykh zemel v Tsentralnom Nechernozemye. [Processing and cultivation of fallow land in the Central Nonblack Soil Zone]. Agriculture, 4, 26-29.
- Mineev V. G. (2004). Agrokimiya [Agricultural Chemistry]. Moscow: Publishing house of MSU; Moscow: Publishing house "Kolos".
- Mutikov V. M., Khoroshavin V. A., Grigoriev B. N. (2011). Vozvrat zabroshennykh zemel v pashnyu i osvoenie resursoberegayushchikh tekhnologii [Returning abandoned lands into cultivation and development of resource-saving technologies]. Machinery and equipment for rural areas, 4(166), 9-12.
- Nikolaev V. A. (2010a). Sovershenstvovanie tekhnicheskikh sredstv obrabotki pochvy [Enhancement of soil tillage tools]. Yaroslavl: Publishing House of FSEI HPE YSAA.
- Nikolaev V. A. (2010b). Zatraty energii na oborot plasta pochvy [Soil turnover energy cost]. Tractors and agricultural machinery, 4, 29 – 32.
- Nuralin B. N., Oleynikov S. V., Murzagaliev A. J., Konstantinov M. M., Trofimov I. V. (2017). Energeticheskaya i agrotekhnicheskaya otsenka raboty plugov s rombovidnymi i seriinymi rabochimi organami. [Energy and agronomic evaluation of plows with diamond-shaped and serial working organs]. Scientific methodical journal of the Omsk State Agricultural University, 81–83. <https://cyberleninka.ru/article/n/obosnovanie-shemy-korotkogabaritnogo-mnogokorpusnogo-pluga>
- Osvoenie tseliny [Development of virgin lands]. Encyclopedia. World History. https://w.histrf.ru/articles/article/show/osvoeniie_tseliny
- Pleskachev Y. N., Borisenko I. B. (2005). Sposoby osnovnoi obrabotki kashtanovykh pochv Nizhnego Povolzhya v zernoparovom sevooborote [Methods of primary tillage of the chestnut soils in the Lower Volga region in grain-and-fallow crop rotation]: Monograph. – The Lower Volga scientific research institute of agriculture. Volgograd: Peremena.
- Pleskachev Y. N., Koshcheev I. A., Kandybin S. S. (2013). Vliyanie sposobov osnovnoi obrabotki pochvy na urozhainost zernovykh kultur [The effect of the primary tillage methods on the yield of grain crops]. Bulletin of the Altai State Agrarian University, 1(99), 23-26.
- Podskrebko M. D. (2010). Zakonomernost izmeneniya soprotivleniya pochvy pri vspashke [Regularities of changing the soil resistance during plowing]. Machinery in agriculture, 2, 45–47.
- Romanenko G. A. (2008). Agroekologicheskoe sostoyanie i perspektivy ispolzovaniya zemel Rossii, vybyvshikh iz aktivnogo selskokhozyaistvennogo oborota [Agroecological status and perspectives of using lands withdrawn from active agricultural turnover in Russia]. Moscow: Rosinformagrotech.
- Sitdikov F. M., Safin H. M. (2012). Development of fallow and degraded land for long-term agrophytocenoses in the pre-Ural steppe zone of the Republic of Bashkortostan. Young Scientist, 5, 577-580.
- Skornyakov V. I., Bondarenko E. V., Belik M. A. (2013). Vlagosberegayushchaya effektivnost posleuborochnoi obrabotki pochvy [Moisture-saving efficiency of post-harvest tillage]. Machinery and equipment for rural areas, 9, 8-11.
- Sorochkin Y. P., Bryukhova Z. Y. (2011). Sideralni par i soloma elementy biologizatsii zemledeliya v usloviyakh Severo-Vostochnoi chasti TSCHR. [Green fallow and straw elements of biological agriculture in the North-Eastern part of the Central Chernozem region]. Agriculture, 3, 20-21.
- Sorokin A. B. (2011). Vozobnovlyaemye bioresursy povysheniya plodorodiya pakhotnykh pochv podtaezhnoi zony Zapadnoi Sibiri [Renewable bioresources for improving soil fertility of arable soils in the subtaiga zone of Western Siberia]. Ph. D. Thesis. Barnaul.
- Tekhnologicheskie svoystva pochvy [Technological properties of soil].

00https://vuzlit.ru/995467/tehnologicheskie_svoystva_pochvy

The lineup of KUHN wide plows.
<http://www.kuhn.ru/ru/range/ploughing/mounted-reversible-ploughs.html>

Trubilin E. I., Belousov V. S., Lapshina A. I. (2014). Osnovnaya obrabotka pochvy s oborotom plasta v sovremennykh usloviyakh raboty i ustroystva dlya ee osushchestvleniya [Primary soil tillage with layer turnover in modern working conditions, and devices for tillage]. Polythematic network electronic scientific journal of the Kuban State Agrarian University (Scientific Journal of KubSAU), 10(104), 1863-1883.

Tvorogov V. A. (2008). Tyagovoe soprotivlenie pluga i forma ego lemeshno-otvalnoi poverkhnosti [Plow drawbar resistance and the shape of its moldboard surface]. Tractors and agricultural machinery, 12, 29.

Vasiliev O. A., Vasiliev A. A., Chernov V. A., Ilyin A. N., Prokopyeva T. V. (2016).

Vosstanovlenie plodorodiya degradirovannykh serykh lesnykh pochv [Restoring fertility of degraded gray forest soils]. Proceedings of the international scientific-practical conference (dedicated to the 85th anniversary of the Chuvash State Agricultural Academy) «Scientific an educational environment as a basis for the development of the Agroindustrial complex and social infrastructure of the village». Chuvash State Agricultural Academy, 132-138.

Vogel Noot plows.
http://texagropark.ru/каталог-техники?field_mt_property_one_value

Weissbach M., Weiss J., Holz W. (2002). Krafte an unterschiedlichen Ausfuhrungen von Pflugscharen. H Landtechnik, 57(5), 270-271.

Williams J.D., Wilkins D.E., Douglas C.L. jr, Rickman R.W. (2000). Mow-plow crop residue management influence on soil erosion in north-central Oregon. Soil Tillage Res, 55(½), 71-78