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СОВРЕМЕННОЕ СОСТОЯНИЕ ТЕХНИЧЕСКИХ СРЕДСТВ МЕХАНИЗАЦИИ ДЛЯ УДАЛЕНИЯ НЕЖЕЛАТЕЛЬНОЙ РАСТИТЕЛЬНОСТИ

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В статье выполнены анализ, систематизация и оценка востребованности применяемых для удаления нежелательной древесно-кустарниковой растительности с территорий линейных инфраструктурных объектов машин, механизмов и оборудования. Проанализированы существующие технологические процессы, формирующие исключительно механические способы удаления нежелательной древесно-кустарниковой растительности. Систематизированы применяемые на территории линейных инфраструктурных объектов технические средства механизации работ по элементам технологического процесса. Показано преимущественное применение организациями-исполнителями работ конкретного ряда технических средств с указанием их характеристик и основных определяющих критериев востребованности. Установлено практически полное отсутствие как малых средств механизации, позволяющих уменьшить долю ручного труда при осуществлении работ по удалению нежелательной растительности в труднодоступных местах очищаемых территорий, так и специализированных подборщиков-погрузчиков порубочных остатков. Предложено и сформулировано определение технического средства сгребания нежелательной растительности: «грабли лесные». Раскрыто, что в ряде нормативных документов присутствуют некорректные названия моторизованных кусторезов ручного типа, приведены соответствующие рекомендации производству. Результаты работы могут быть использованы производственными предприятиями, занимающимися содержанием и эксплуатацией линейных инфраструктурных объектов.

Ключевые слова: линейный инфраструктурный объект, нежелательная растительность, удаление, механизация, техническое средство, характеристика, востребованность

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MODERN STATE OF TECHNICAL MEANS TO REMOVE UNCONTROLLED VEGETATION

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The article analyzes, systematizes and evaluates the demand for machines, mechanisms and equipment used to remove uncontrolled tree and shrub vegetation from the territories of linear infrastructural objects. The existing technological processes that form exclusively mechanical methods of removing unwanted tree and shrub vegetation are analyzed. The technical means of mechanization of work on the elements of the technological process used on the territory of linear infrastructure facilities are systematized. The predominant use of a specific number of technical means by implementing organizations is shown, indicating their characteristics and the main defining criteria of demand. It has been established that there is almost complete absence of both small means of mechanization, allowing to reduce the share of manual labor when carrying out work to remove unwanted vegetation in hard-to-reach places of the cleaned areas, and specialized pick-up loaders of felling residues. The definition of a technical means of raking up unwanted vegetation is proposed and formulated as a «forest rake». It was revealed that in a number of regulatory documents there are incorrect names for motorized hand-type brush cutters, corresponding recommendations for production are given. The results of the work can be used by enterprises engaged in the maintenance and operation of linear infrastructure facilities.

Keywords: linear infrastructure object, unwanted vegetation, removal, mechanization, technical means, characteristics, demand

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Currently, in the Russian Federation and in the world, new (and previously built) linear infrastructure facilities (LIFs) continue to be built, which include roads and railways, communication and power lines, gas, oil and product pipelines, and other facilities, length which significantly exceeds their width. According to the data provided in various statistical and information directories, as well as on the official websites of the respective joint-stock companies [1–5] in Russia alone as of 01.01.2019 the total length of power lines amounted to 2,35 million. km; trunk pipelines of 69080 km (including main oil pipelines of 52840 km, oil trunk pipelines of 16240 km); gas pipelines of 172,6 thousand km (as well as 746,3 thousand km of gas distribution networks); double-pipe heating networks of 183,3 thousand km; public roads 1498,7644 thousand km; public railways 85,554 thousand km. According to the instructions given in a number of regulatory documents ([6–9] and others), in order to maintain the indicated infrastructure facilities in a normative state on the LIF territory, work should be organized with a certain frequency to remove growing unwanted tree and shrub vegetation (UTSV). According to the results of our studies for 2012–2019 a general tendency towards an increase in the volume of work to remove UTSV from the territory of the linear parts of various infrastructure objects was revealed, while we set the average annual volume of unwanted vegetation removal at 57363,3 hectares, corresponding to the total length of the average annual UTSV removal

strip along the linear parts of infrastructure objects at 29 019 linear km. The indicated volumes of work (as well as the conditions for their implementation, a detailed consideration of which is not included in the goals and objectives of this article) impose certain requirements on machines and equipment that allow mechanizing the technological process of removing unwanted vegetation on LIF. However, our information search revealed insufficient knowledge of the issue of using universal and special forestry machines, mechanisms and equipment on the territory of linear infrastructure facilities, the parameters of which must comply with existing technical regulations (standards and other regulatory documents), ensure the reduction of material, energy and labor costs and comply with international standards ecology.

The purpose of the research

The purpose of the research is to analyze, systematize and assess the demand for the removal of unwanted tree and shrubbery vegetation in the territories of linear infrastructure objects of machines, mechanisms and equipment.

The tasks of the research:

1. To systematize the technical means of mechanization of work used in the territories of linear infrastructure facilities according to the elements of the technological process.
2. To identify the main representatives of domestic and foreign manufacturers of the considered technical means.

3. Determine the most popular technical means of mechanization among the organizations performing the work.

Materials and methods

Questions of mechanization of removal of unwanted tree and shrub vegetation at different times engaged both domestic [10–14] and foreign [15–18] scientists, however most researchers focused either on the combined method of removing UTSV from the LIF territory (providing for mechanized and subsequent chemical exposure to unwanted vegetation) [19, 20] or high-performance processes involving the removal of a significant amount of unwanted wood (including large stem diameter) [21, 22]. To achieve the above stated goal of the study, we examined existing technological processes (TP) that form exclusively mechanical methods for removing unwanted tree and shrub vegetation (by which we mean shrubs, light forests, undergrowths and overgrowth) from the territories of linear infrastructure facilities.

Our analysis of the existing technological processes for removing UTSV from the LIF territory (a detailed description of the results of which is not included in the purpose and objectives of this article) made it possible to establish that TP is implemented using universal and specialized machines, mechanisms, and equipment [23].

In general, the use of certain types and models of technical means of mechanization when removing vegetation is largely determined by the natural and geographical characteristics of the corresponding LIFs, climatic conditions, features of the vegetation

to be removed, and (to a large extent) financial component (namely, capital investments in the formation of appropriate machine system). Nevertheless, to achieve the purpose of the research we have identified the possibility of separating the technical means of mechanizing the work used to remove shrubs (light forests, undergrowth and overgrowth) by elements of the process into the following groups (fig. 1): Chainsaws, manual brush cutters, mounted mulchers, mounted brush cutters, forest rake, mounted pick-up loaders, shredders of chopping residues, pneumatic and / or tracked tractors, motor vehicles, multifunctional machines and self-propelled mulchers.

Results and discussion

An analysis of the machinery, mechanisms and equipment used to remove unwanted tree and shrubbery vegetation in the territories of linear infrastructure facilities showed the interest of domestic and foreign manufacturers of technical equipment in improving and developing this area, expressed in a large number of proposals, however we were among the implementing organizations certain preferences are revealed both by brands and by models of the corresponding technical means.

So, we found that with the manual (exclusively) and combined (manual and mechanized) method of influencing of the UTSV in the LIF territory chainsaws are used mainly of the trademarks Husquarna, STIHL, Oleo-Mac, Makita, for example Husquarna-254 (power 2,9 kW/3,9 hp), STIHL MS260 (2,6 kW/3,5 hp), Oleo-Mac 952 (2,5 kW/3,4 hp) [10], and manual brush cutters are mainly of the STIHL trademarks (e.g. FS 490 C-EM) and Husquarna (e.g. 545F and 545FX). At the same time, we revealed a certain incorrectness in the names of manual brush cutters (fig. 2, a), appearing in a number of regulatory documents such as « petrol cutter», « petrol trimmer», « motorized cutter» etc., including «brush cutter» and «scissors brush cutter». Our information search [7, 14, 24], a detailed exposition of which is not included in the purposes and tasks of this article, which allows us to recommend the formation of technical tasks, technological cards, estimates and other regulatory documents on the removal of UTSV from the LIF territories, when assigning a manual method of influencing vegetation, adhere to the definition of «brush cutter» according to GOST R 51389–99 [7]. It should also be noted that in addition to the above technical means, we revealed the almost complete absence of other small mechanization means that would allow us to reduce the share of manual labor when working in hard-to-reach places (for example, near and inside metal poles of power lines, near pipe poles, etc.) cleared area LIF.

With the combined or mechanized (exclusively) method of influencing UTSV in the territory of the



Fig. 1. Visualization of groups of technical means of mechanization work removal of unwanted tree and shrub vegetation in the territory of linear infrastructure facilities



Fig. 2. Removal of unwanted trees and shrubs: *a* — in the security zone of the high-voltage line, Ryazan Region, April 2019; *b* — in the security zone of the high-voltage line, Moscow Region, June 2019; *c* — in the right of way of the road, Arkhangelsk Region, July 2016; *d* — forest rake EM 2200; *e* — forest rake GL-3000; *f* — in the security zone of the high-voltage line, Moscow region, February 2019; *g* — multifunction machine KGT-4RS with mulcher ORD; *h* — in the railway right of way, Republic of Buryatia, May 2020

LIF, attachments (on a tractor or a multifunctional machine) such as mulchers and brush cutters are used. As noted in [25], the main criteria for choosing a mulcher mounted on a tractor (fig. 2, *b*) are the characteristics of the shredded vegetation (for example, the prevailing breed composition, diameter, density, etc.) and compatibility with the base tractor. In accordance with [26], are currently represented on the Russian market mulcher manufacturers such as Italian Delta, Seppi M, Ferri, FAE Group, Orsi Group, Agrimaster, German AHWI Prinoth, Canadian Denis Cimaf, Spanish TMS Cancela, NIUBO, French Galotrax and others. The Russian companies that produce mulchers include Exmash, Chopper, TaigaMash, Industrial Meridian, TPI Impulse and others. At the same time, we found that when organizing work on the LIF, mounted mulchers mainly from Seppi M, FERRI, FAE Group,

Industrial Meridian and Agrimaster with a minimum base tractor engine power of 58...73 kW (80...100 hp), providing shredding of vegetation with a diameter of up to 250 mm. The mulchers of the middle class of power with the price from 500 thousand rubles to 1300 thousand rubles are most in demand among the organizations performing the work, while the total capital investments for the formation of the «tractor + mulcher» bundle can reach values from 1800 to 3700 thousand rubles and higher. Among the mulchers mounted on the end of the boom handle of multifunctional machines (fig. 2, *c*; selected according to such basic criteria as the characteristics of the crushed vegetation, compatibility with the base machine, and the mass of this machine), the most popular mulchers are mainly Seppi M, FERRI manufacturers and Denis Cimaf with the required mass of a multifunctional ma-

chine 15...30 tons, providing shredding of vegetation with a diameter of up to 400 mm and a price category in the range of 2...2,5 million rubles.

For mounted brush cutters, we have identified a preference for the purchase by the implementing organizations of the appropriate technical equipment from manufacturers from the Republic of Belarus (Amkodor, Blooming and Euromash), forming an acceptable (for these companies) price ratio of equipment (200...300 thousand rubles), its productivity (cutting vegetation with a diameter of up to 200 mm with a working tool width of 900...2000 mm) and general reliability (for example, BL-2, EM-1.3, K-78M brush-cutting mowers). In general, it should be noted the significant interest of the organizations involved in the removal of UTSV from LIF territories to Belarusian machines, mechanisms and equipment. So, for mechanized raking of chopped residues find application the forest rake EM 2200, GL-3000, Intatech, ZPI, the forestry harvesting equipment OUL-24 and the rake of forest branches SVL-2.1 of companies Euromash, Intatehgroup, Innovatek, MTZ and Techmash (fig. 2, *d, e*). At the same time, the executing organizations as the base vehicle, taking into account the main criteria for selecting a tractor (its traction class, engine power, ecological class, propulsion type — pneumatic or tracked, the possibility of mounting and driving additional equipment, the possibility of servicing and repairing compressed time periods, general reliability in operation, the reputation and reliability of the manufacturer, etc.) give much of the traditional preference to Belarusian-made equipment MTZ-HOLDING, and pneumatic-wheeled tractors with prices ranging from 1300 to 2400 thousand rubles are most in demand.

In our opinion, special attention should be paid to technical means raking the cut-off (cut down) UTSV during operations on the LIF territory. The traditional means for carrying out such work was the so-called «shrub rake», intended for raking in heaps of cut and uprooted shrubs, light forests and stumps with a diameter of up to 15 cm and aggregated with tractors of 6.0 thrust class. However, our studies have established that at present, other (more modern) technical means are often used to rake cut vegetation (including when working on the territory of linear infrastructure facilities), often referred to as «forest rake», although in some documents (for example, estimates for the performance of work) still often appear precisely «shrub rake». At the same time, we carried out an information search of numerous (encyclopedic, explanatory, forest, etc.) dictionaries, as well as technical literature (devoted to this topic), revealed the absence of a definition of what should be considered a technical tool with the name «Forest Rake». Based on the foregoing, we propose the following definition for introducing into the practice

of organizing work to remove unwanted vegetation: «Forest rake is a specialized mounted equipment designed to collect unshredded chopping residues in areas to be cleared of tree and shrub vegetation».

In the absence of opportunity loading and transporting chopping residues outside the territory of LIF by the technological process may include shredding (crushing into chips) of the cut-off / chopped UTSV (fig. 2, *f*). In general, we found that when performing work on the LIF territory, the implementing organizations, taking into account the main criteria for choosing a shredder for chopping residues [27], are the characteristics of the shredded vegetation (for example, the prevailing species composition, diameter, humidity, etc.), type of execution (stationary or mobile), power and speed of work, type of drive, compatibility with the base vehicle, etc., chopping residues are used mainly by manufacturers of Euromash, Mozyrmash, Rubmaster, Teknamotor and Farni Forest (for example, EM-160, MDR-0.8, Farni CH260 DF, BELARUS MPH-1, etc.), while shredders at the price of 200...300 thousand rubles, with the greatest demand among executing organizations use shredders at a price of 200...300 thousand rubles, providing processing of vegetation with a diameter of up to 260 mm with a chip output of 5...40 m³/hour.

If the technological process provides for the shipping of chopping residues, then this technological operation in the vast majority of cases is carried out by dump trucks (with the extremely rare use of specialized cars for transporting wood chips) of various (European, Asian, Russian) manufacturers, while we revealed the absence of any special preferences for brands (models) of the above vehicles. However, the greatest demand among organizations performing the work in question, dump trucks are used at prices from 3800 to 4800 thousand rubles, at the same time in the specified price category fall for example dump trucks such as KAMAZ 65115-50, URAL NEXT 6×4, MAZ-551626-580-050, FAW CA3250 6×4, etc. It should also be noted that we have established an almost complete absence of proposals from manufacturers of specialized pick-up loaders of chopping residues, as a result of which cut-off (cut down) UTSV is often carried out manually [28].

In addition to the above vehicles, when removing UTSV from the LIF territory, multifunctional machines and self-propelled mulchers are used. Multifunctional machines traditionally perceived in Russia as an «excavator» due to the presence of a number of design features that are actually similar to the signs of «... a self-propelled digging ground and loading machine designed to develop rocks and soils» [29], are used to remove unwanted vegetation on the root by grinding with a mulcher mounted on the end of the boom handle of the specified machine. We have identified the predominant use in the LIF

of multifunctional machines with an engine power of 108 ... 184 kW (147...246 hp) and a mass of 20...32 tons produced in Japan or South Korea (for example, Doosan DX 225, Komatsu PC200), the price of which varies between 5...7 million rubles. With this in mind, it is precisely with large capital investments in the formation of the «mulcher» + «multifunctional machine» bundle (the price of which, taking into account the mulcher, reaches 7...10 million rubles and above) and, in our opinion, a certain «unpopularity» of such technical means when removing UTSV from territories of linear infrastructure facilities. However, it should be noted that some large companies, acquiring such equipment, successfully operate it when removing unwanted vegetation from the LIF territory. As a positive example, we can note the experience of Russian Railways in operating (since 2011) multifunctional machines KGT-4RS on a combined (road and rail) course manufactured by Geismar (France) with the ORD mulcher (fig. 2, g), at the same time the introduction of one machine allows cleaning the railroad right of way «... to replace a whole crew of railwaymen with three or four chainsaws in the absence of the need to clean chopping residues» [30].

In terms of the use of self-propelled mulchers in LIF territories (fig. 2, h), we found that enterprises performing work that take into account the main criteria for their selection (characteristics of the shredded vegetation: prevailing species composition, diameter, density of growth; engine power and type of selection; ecological class; economy; the possibility of servicing and repair; general reliability in operation, the reputation and reliability of the manufacturer, etc.), there are no special preferences for brands (models). Nevertheless, it can be noted that when working on the LIF territory find limited use self-propelled mulchers TM-250 (Russia), PRIME TECH PT175 and PT300 (Italy), AHWI RT-400 (Germany), with an engine power of 127...294 kW (173...400 h.p.), providing cutting of vegetation with a diameter of up to 600 mm, while the specified restriction is associated, in our opinion, with such a nearly fundamental criterion for choosing a self-propelled mulcher as its price (11...14 million rubles, for some models reaching 25...30 million rubles).

Conclusions

1. We found that there was an almost complete absence of both small mechanization means to reduce the proportion of manual labor when removing unwanted vegetation in hard-to-reach areas of the LIF cleared area, and specialized pick-up loaders of chopping residues.

2. The main domestic and foreign manufacturers of technical means of mechanizing the removal of UTSV from the LIF territory, represented on the Russian market, were identified, at the same time, the

primary use by the organizations-executors of works of a number of technical means is shown, indicating their characteristics and the main determining criteria for demand.

3. It is established that the main reason for the unpopularity of use in the territories of linear infrastructure facilities the «mulcher» + «multifunctional machine» bundles are large (compared to the «tractor + mulcher» bundle: 3...8 million rubles and more) capital investments in the formation of the machine system.

4. To introduce the practice of organizing the removal of UTSV proposed and formulated definition such technical means of raking undesirable vegetation as the «Forest rake».

5. It is disclosed that in a number of regulatory documents on the organization of the removal of UTSV from the LIF territory there are incorrect names for motorized hand-type brush cutters. It is recommended to executing and contracting organizations when drafting technical tasks, work design projects, technological cards, estimates and other regulatory documents on the removal of UTSV from LIF territories, when defining a manual method for influencing vegetation, adhere to the definition of «brush cutter» according to GOST R 51389–99.

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