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RESEARCH AND DEVELOPMENT OF UNIT FOR CUTTING BRANCHES WITH CROPPING AND MIXING THEM WITH SOIL

Lyudmila SHVETS, Candidate of Technical Sciences, Associate Professor
Daryna PAVLYUK, Recipient of the First Educational and Qualification Level
Vinnytsia National Agrarian University

ШВЕЦЬ Людмила Василівна, к.т.н., доцент
ПАВЛЮК Дарина Олеексіївна, здобувач першого освітньо-кваліфікаційного рівня
Вінницький національний аграрний університет

Modern technologies in agriculture are actively aimed at increasing the efficiency of processing garden plantings, which provides optimal conditions for the growth and development of plants. One of the key operations in tree care is regular pruning of branches, which helps to rejuvenate the garden and increase productivity. However, traditional pruning methods are time-consuming and require significant investment of time and resources. In addition, after cutting a branch, there is a need for further processing of the cut material, which adds additional operations.

In order to increase productivity and reduce labor costs, there is a need to develop universal mechanisms capable of performing several operations simultaneously. This work presents the development of an innovative unit that provides simultaneous cutting of garden branches, grinding of material and its incorporation into the soil. This approach not only simplifies the process of disposal of organic waste, but also increases soil fertility by enriching it with organic substances. Thus, the use of this unit can significantly increase the effectiveness of agrotechnical measures in horticulture.

The article presents the development and research of a unit for cutting garden branches with simultaneous grinding of material and its incorporation into the soil. The structural features of the mechanism and the principle of its operation are described. The main advantages of using the unit are analyzed, including increasing the efficiency of pruning, reducing the cost of manual labor and improving the condition of the soil thanks to the use of crushed organic material as fertilizer. The unit's performance was evaluated based on experimental studies and recommendations for its use in horticulture were given.

By integrating branch pruning, grinding, and soil incorporation into a single process, it minimizes the environmental impact of traditional methods. Furthermore, the unit's design prioritizes energy efficiency and ease of use, making it a practical solution for both small-scale and large-scale horticultural enterprises.

Key words: *shredding, cutting branches, wrapping in soil, soil enrichment, nutrient residues.*

Eq. 4. Fig. 5. Ref. 15.

1. Problem formulation

One of the main measures for the care of the above-ground part of trees in garden plots is crown pruning in accordance with the peculiarities of biology, growth and development of plantations. Tree pruning is carried out to remove dry, damaged branches, preserve the previously formed shape and size of the crown, and rejuvenate it.

One of the problems when pruning fruit trees is the disposal of cuttings.

One of the oldest and most primitive technologies involves manually loading cut wood onto vehicles moving along a nearby lane, taking the branches to piles where they are burned. In adverse weather conditions, instead of self-unloading trailers, you should choose a transport sled. In this case, unloading is also done manually. This technology is poorly mechanized and requires extensive use of unproductive manual labor. The coefficient of utilization of the carrying capacity of vehicles is very low, since it is impossible to place the collected wood tightly under load. Currently, it is used in small farms.

For quick decay of the cuttings, it is necessary to dig immediately after grinding to a depth of 7...12 cm in the most biologically active layer of the soil. The simultaneous introduction of wood chips into the soil with organic and mineral fertilizers only accelerates the process of wood decay.

2. Analysis of recent research and publications

The situation with additional costs for manual labor can be corrected by applying the technology of forming the so-called "windows". The effect is achieved by modernizing the design of the contour cutter of the segment type.

In addition to the vertical frame, several short frames with a separate fastening system and adjustment of their position are installed for cutting "windows" in the tree crown.

Adjusting the position and angle of inclination of the external (contour) frame, the number of additional frames and their angle of inclination, as well as carrying out pruning at different times allows the gardener to choose settings for each variety and site. [1-4].

By changing the place of cutting the "windows" on the crown over the course of three seasons, this technology ensures the rejuvenation of the branch system, which in its effectiveness is not inferior to the rejuvenation achieved after traditional manual pruning by skilled workers. Thanks to the mechanization of this process, on each hectare gardeners will be able to save 50-80 hours of labor compared to completely manual pruning of trees and 30-40 hours compared to a complex of traditional mechanical contour pruning and manual additional.

The machine can be used in three modes: [5-6]:

1. as a traditional contour trimmer, with the principle of operation of which Ukrainian gardeners are already familiar;
2. as a machine for separate cutting of "windows";
3. as a complex device that makes contour cutting and forming "windows" in one pass.

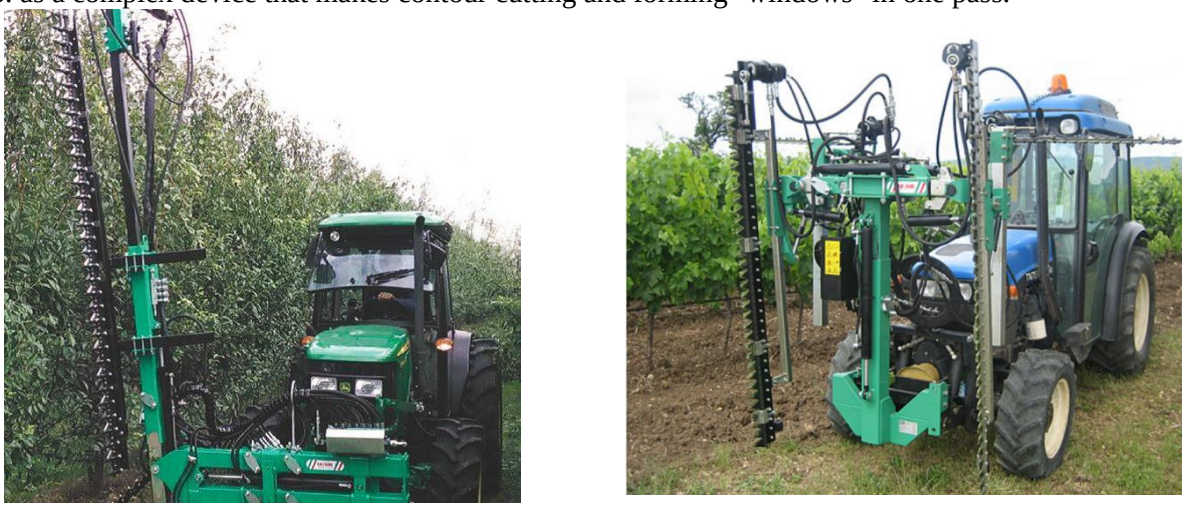

Fig. 1. Scheme of mechanized tree pruning in conditions of intensive horticulture.
Source: grouped by author based on [6]

About technology

Such a mechanism makes it possible to maximally mechanize the process of crown formation in the form of a slender spindle in an intensive garden, at the same time allowing for well-thought-out selective pruning according to a pre-developed program. Such pruning ensures fruiting of branches at the optimal age of 2-4 years.

The frequency with which the gardener will return to pruning the same spot in the crown of the tree with additional frames will regulate the fruiting cycle of the branches. We recommend doing such pruning in the same place once every 4 years.

The variability of this technology allows the gardener to choose the necessary number of additional frames for cutting "windows" in each specific case and to decide in which part of the tree to make them. For example, you can cut "windows" only in the middle and upper part of the crown, and leave the lower branches uncut. [7-9].

The technology of forming "windows" involves cutting up to a third of the branches on the tree at one time. Only a short knot 10-30 cm long remains at the cut site. One or more replacement branches grow from its bud, which grow perpendicular to the trunk. In this way, the peculiarities of the physiological development of seed plants are used: after pruning, new branches form generative buds in the second year and continue to bear fruit effectively, starting from the third year, for another 2-3 years.

Manual work in this case is needed only to remove competitive shoots growing upwards, dry branches outside the "window", etc.

One of the oldest and most primitive technologies involves manually loading cut wood onto vehicles moving along a nearby lane, taking the branches to piles where they are burned. In adverse weather conditions, transport sleds are used instead of self-unloading trailers. In this case, unloading is also done manually. This technology is poorly mechanized and requires extensive use of unproductive manual labor. The coefficient of utilization of the carrying capacity of vehicles is very low, since it is impossible to place the collected wood tightly under load. Currently, it is used in small farms. [10-13].

Technologies used in horticulture are known and more widespread:

1) shredding of cut branches directly between the rows of the garden by mobile shredders with the loading of chips into a hopper, their removal from the garden, the use of wood for making compost, followed by spreading it in the garden;

2) collecting branches with winnowers, loading them on vehicles, taking them to stationary shredders, loading branches into the shredder with grapple loaders and shredding with the following technological operations: preparation of organic composts and spreading them in the garden;

3) collecting branches with rakes, taking them outside the garden and burning them;

4) shredding wood with mobile shredders directly between the rows of the garden with simultaneous spreading of the mass over the soil surface.

The technologies by which cut branches are used to prepare composts are interesting in their own way. The first scheme of this technology involves shredding cut branches with mobile shredders directly between the rows of the garden with the collection of chips in a container. This wood is then transported by means of transport to storage areas, where it is composted. According to the second scheme, the whole cut branches are taken outside the garden to the places of processing. Grinding takes place at the hospital with subsequent composting. For more intensive rotting of the remains, wood is mixed with a number of other organic substances and catalysts. The mixture is laid in pits or trenches. After the compost is fully ready, it is loaded into vehicles and applied to the garden as an organic fertilizer [14].

3. The purpose of the article

The purpose of the study is to develop and substantiate the design of the unit for cutting garden branches with further grinding and working the material into the soil. The task of the research is to study the technological parameters of the unit, to evaluate its effectiveness in the conditions of field tests, as well as to determine the impact of the use of crushed material on the condition of the soil and the fertility of gardens.

4. Results of the researches

Analyzing the state of the solved scientific and technical problem, we can say that the most common technology in Ukrainian farms is the technology that involves the manual formation of a swath from cut branches in the middle of the row. Later, this wood is collected by SV-1 garden wheelbarrows and transported to the burning sites. At the collection sites, the branches are burned, using a bulldozer unit to turn them over, and an additional 5 l/ha of diesel fuel is used to activate the burning process. All this leads to environmental pollution, additional material and labor costs. In addition, it is known that in order to accumulate and burn collected branches from 100 hectares of garden, it is necessary to allocate 1.5...2 hectares of land and spend a significant amount of liquid fuel to activate the burning process. In places where branches are burned, useful soil microflora and vegetation are destroyed. The soil, for a long time, becomes unusable and may be subject to wind or water erosion.

When removing wood from the rows with the help of garden trowels, the branches often go beyond their dimensions and partially damage the trees. As a result of this, a decrease in the yield of apples by 250 or more kg of fruit from each hectare of the garden was noted.

There are many ways to use branches cut in the garden. Collected wood, after appropriate processing, can be used to prepare composts, in the woodworking industry - for the production of wooden boards; in the hydrolysis industry - for the production of fodder yeast, which is used as an additive in animal rations. Therefore, from the point of view of economy and environmental safety, the most widespread technology, both abroad and in our country, is the technology that involves grinding the cut branches directly between the rows and scattering their particles on the surface, followed by wrapping them in the soil as organic fertilizers or using them as mulch in tree trunk strips. [15].

For quick decay of the cuttings, it is necessary to dig immediately after grinding to a depth of 7...12 cm in the most biologically active layer of the soil. The simultaneous introduction of wood chips into the soil with organic and mineral fertilizers only accelerates the process of wood decay.

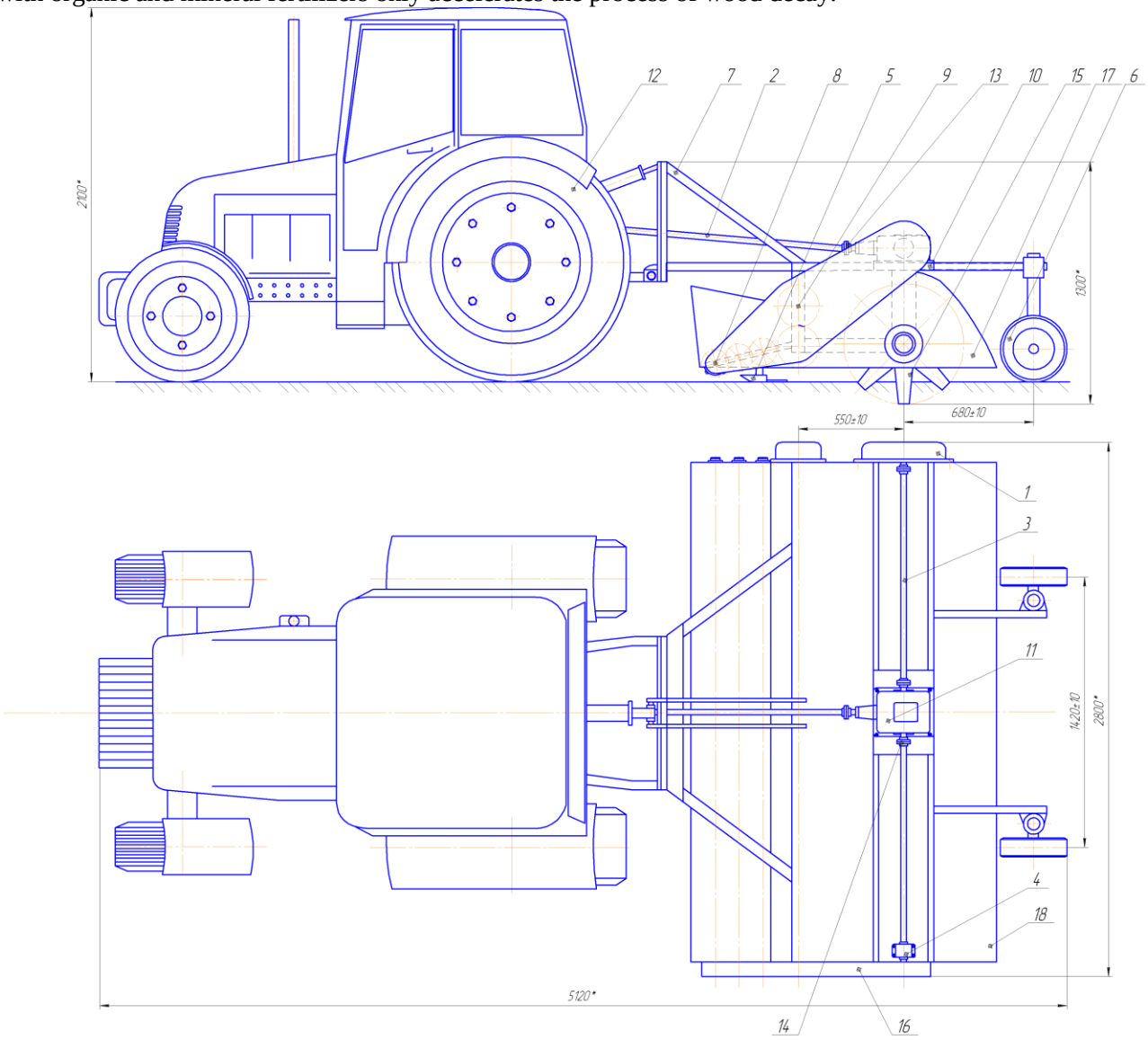

Fig. 2. Design machine:

1 – On-board gearbox; 2 – cardan shaft; 3 – transverse shaft; 4 – bearing assembly; 5 – skiing; 6 – support wheel; 7 – attachment device; 8 – feeding rollers; 9 – shredder; 10 – frame; 11 – conical reducer; 12 – tractor; 13 – safety clutch; 14 – connecting clutch; 15 – cutter; 16 – protective shield; 17 – side shield; 18 – chop shield

Every garden owner is faced with the need to dispose of plant waste. The best way to get rid of fallen leaves, dry grass and cut branches is provided by a garden shredder. Since this type of auxiliary equipment is still gaining popularity among farm owners.

We offer a design universal garden machine designed for collecting and grinding the cut branches of the garden with the simultaneous incorporation of the crushed material into the soil between the rows of garden plantings

The project machine consists of a frame 10 (Fig. 2), on which the working bodies of the machine are mounted. The machine is hinged and is attached to the tractor with a hinged device 7, the cut tops of trees are picked up by feed rollers 8, two skis are installed on the frame to adjust the height of lifting and soil copying - copying machines 5, the cut wood is shredded by a two-roller chopper 9. The crushed material is thrown outwards on the surface of the soil, then it is worked with a milling cutter 15 to a depth of 7-18 cm, the depth of soil treatment is regulated by support wheels 6. The detailed principle of operation of the design machine is shown in figure 2.

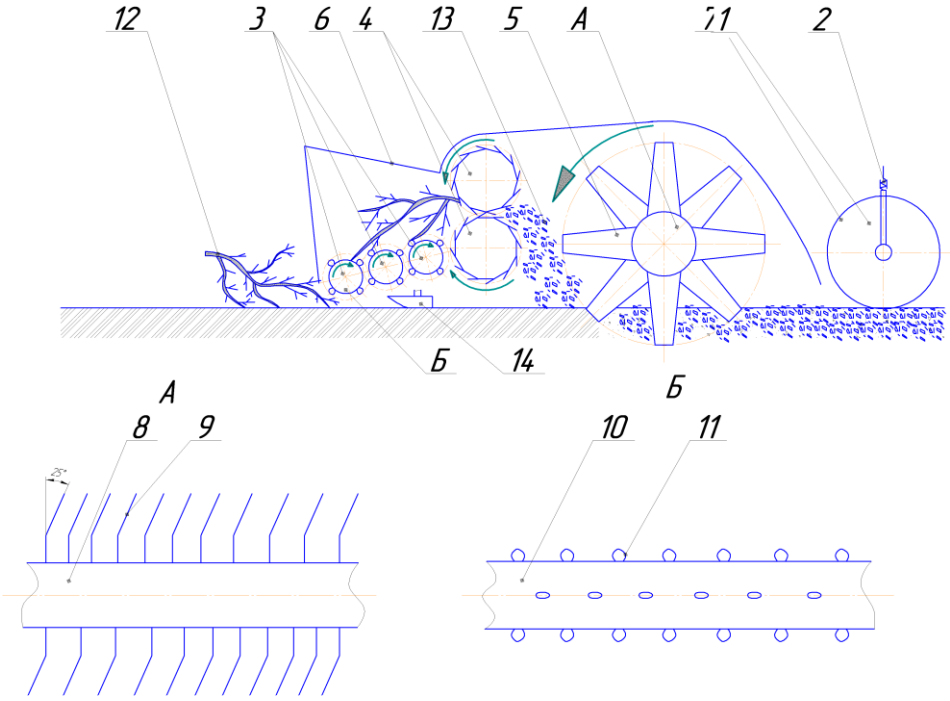

Fig. 3. Structure and operation of the design machine:
1 – Support wheel; 2 – Adjusting screw of tillage depth; 3 – feeding rollers; 4 – grinding device; 5 – cutter; 6 – receiving shield; 7- reflective shield; 8 – cutter shaft; 9 – a knife; 10 – feed roller shaft; 11 – scraper; 12 – wood scraps; 13 – chopped scraps; 14 – a copy of the soil relief

Figure 3 shows the operation of the design machine. Top 12 feed rollers 3 lift cuttings from the soil and send them to the shredder 4. Feed rollers (Fig. 2) consist of a tubular shaft 10 and scrapers that capture the cut wood. The shredding device (Fig. 3) consists of two combing rollers on which knives are attached. When feeding the material under the rollers, during their rotation, wood particles are combed by the counter movement of the rollers. When grinding the material according to the design of the grinder, the work can be performed at minimum revolutions of the grinding rollers

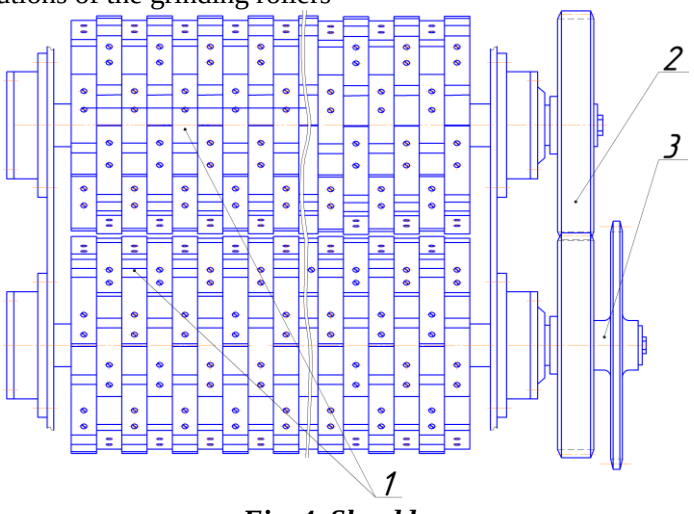

***Fig. 4. Shredder*:**
1 – Grinding shafts; 2 – gear transmission; 3 – shaft drive sprocket

After hitting the crushed mass on the soil, it is worked with a milling cutter (Fig. 3), which consists of bent knives for improved grinding of the soil. After milling between the rows of the garden, the soil is enriched with oxygen and nutrients, which will give crushed wood particles during its decomposition.

The drive of the working bodies of the machine is carried out from the GDP of the tractor (Fig. 4).

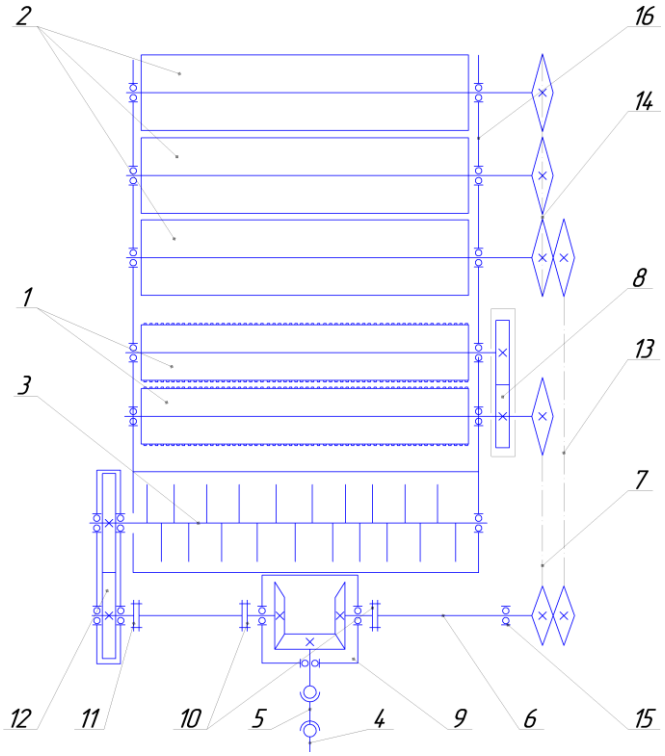

Fig. 5. Kinematic diagram of the drive of the working organs of the machine:
1 – Roller grinder; 2 – feeding rollers; 3 – cutter; 4 – tractor GDP; 5 – cardan shaft; 6 – drive shaft of the shredder and feed rollers; 7 – chain transmission of the shredder drive; 8 – cylindrical gear; 9 – conical reducer; 10 – safety clutch; 11 – connecting clutch; 12 – on-board gearbox; 13 – chain transmission of the drive of the feeding rollers; 14 – chain transmission of rollers; 15 – bearing assembly; 16 – housing

The calculation of the productivity of the feed rollers is determined by the formula [6]:

$$q = 47{,}1 \cdot [(D + 2 \cdot \delta)^2 - d^2] \cdot S \cdot K \cdot n \cdot \gamma \cdot C, \quad (1)$$

where D – is the diameter of the roller winding, D = 0.320 m.; d – the diameter of the roller shaft, d = 0.05 m.; δ – radial gap between the outer edge of the winding and the inner surface of the casing δ = 0.004 m.; S – winding step, S = 0.20 m.; K – is the filling factor, K = 1.0; n – rotation frequency, n = 620 min^{-1} = 10.4 s^{-1}; C – is the coefficient that takes into account the reduction of the capacity of the roller from the angle of inclination to the horizon, at β = 0, C = 1; γ – volumetric weight of cargo, γ = 0.74 t/m^3.

We substitute the value in the formula and perform the calculation.

$$q = 47{,}1 \cdot [(0{,}32 + 2 \cdot 0{,}004)^2 - 0{,}05^2] \cdot 0{,}2 \cdot 1 \cdot 10{,}4 \cdot 0{,}74 \cdot 1 = 6{,}87 \text{ t/h},$$

The required power for the drive is determined by the formula [6]:

$$N = \frac{q}{367 \cdot 10^3 \cdot \eta} \cdot (L_2 \cdot \omega + H) \cdot К_1, \quad (2)$$

where η =0.96 – efficiency factor of the drive; L_2 = horizontal projection of the cargo movement path, L_2 = 1.2 m.; H = 0 – the height of lifting the load; ω – coefficient of resistance of the material crossing, ω = 4; K_1 = 1.2 is a coefficient that takes into account friction losses in bearings.

We substitute the value in the formula and perform the calculation.

$$N = \frac{6{,}87}{367 \cdot 10^3 \cdot 0{,}96} \cdot (1{,}2 \cdot 4 + 0) \cdot 1{,}2 = 1{,}2 \text{ kVt},$$

The circular speed is determined by the formula:

$$\vartheta = \frac{\pi * D * n}{60}, \quad (3)$$

where D =0.32 m – is the winding diameter; n=620 min^{-1} – rotation frequency.

We substitute the value in the formula and perform the calculation:

$$\vartheta = \frac{3.14 \cdot 0{,}32 \cdot 620}{60} = 10{,}3 \text{ m/s},$$

The torque on the shaft is determined by the formula [8]:

$$T = \frac{P}{\omega} = \frac{30P}{\pi \cdot n}, \quad (4)$$

We substitute the value in the formula:

$$T = \frac{30 \cdot 1{,}2 \cdot 10^3}{3.14 \cdot 620} = 18{,}5 \cdot 10^3 \text{ Nmm.}$$

5. Conclusions

To ensure the highly efficient use of machines for garden plots, it is necessary to modernize existing units and develop new units and machines. The publication proposes the development of a design of a hinged universal garden machine for collecting and grinding trimmings with simultaneous fertilization of the soil between the rows of the garden by the milling method, which can be used in small garden farms of agricultural enterprises. That makes it possible to significantly facilitate manual work or even eliminate it. This technology in gardens and vineyards not only simplifies the process of disposal of organic waste, but also increases soil fertility by enriching it with organic substances. The use of such an aggregate significantly increases the efficiency of agrotechnical measures in horticulture.

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ДОСЛІДЖЕННЯ ТА РОЗРОБКА АГРЕГАТУ ДЛЯ ЗРІЗАННЯ ГІЛОК ІЗ ПОДРІБНЕННЯМ І ЗМІШУВАННЯМ ЇХ ІЗ ҐРУНТОМ

Сучасні технології в сільському господарстві активно спрямовані на підвищення ефективності обробки садових насаджень, що забезпечує оптимальні умови для росту та розвитку рослин. Однією з ключових операцій у догляді за деревами є регулярна обрізка гілок, що сприяє омолодженню саду та підвищенню врожайності. Однак, традиційні методи обрізки є трудомісткими, потребують значних затрат часу та ресурсів. Більш того, після обрізки виникає необхідність у подальшій обробці зрізаного матеріалу, що додає додаткових операцій.

З метою підвищення продуктивності та зниження витрат робочої сили виникає потреба в розробці універсальних механізмів, здатних виконувати кілька операцій одночасно. У цій роботі представлено розробку інноваційного агрегату, який забезпечує одночасне зрізання гілок саду, подрібнення матеріалу та його заробку в ґрунт. Такий підхід не тільки спрощує процес утилізації органічних відходів, але й підвищує родючість ґрунту за рахунок збагачення його органічними речовинами. Таким чином, застосування цього агрегату може суттєво підвищити ефективність агротехнічних заходів у садівництві.

У статті представлено розробку та дослідження агрегату для зрізання гілок саду з одночасним подрібненням матеріалу та його заробкою в ґрунт. Описано конструкційні особливості механізму та принцип його роботи. Проаналізовано основні переваги використання агрегату, включаючи підвищення ефективності обрізки, зниження затрат ручної праці та поліпшення стану ґрунту завдяки використанню подрібненого органічного матеріалу як добрива. Проведено оцінку продуктивності агрегату на основі експериментальних досліджень та наведено рекомендації щодо його застосування в садівництві.

Завдяки об'єднанню обрізання гілок, подрібнення та внесення ґрунту в єдиний процес мінімізується вплив традиційних методів на навколишнє середовище. Крім того, у конструкції пристрою пріоритетом є енергоефективність і простота використання, що робить його практичним рішенням як для малих, так і для великих садівничих підприємств.

Ключові слова: *подрібнення, зрізання гілок, загортання в ґрунт, збагачення ґрунту, поживні решетки.*

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INFORMATION ABOUT THE AUTHORS

Ludmila SHVETS – Candidate of Technical Sciences, Associate Professor, Department of Agricultural Engineering and Technical Service Vinnytsia National Agrarian University (Sunny str., 3, Vinnytsia, Ukraine, 21008, e-mail: shlv0505@i.ua, https://orcid.org/0000-0002-4364-0126).

Daryna PAVLYUK – Recipient of the First Educational and Qualification Level bachelor's degree in mechanical engineering Vinnytsia National Agrarian University (Sunny str., 3, Vinnytsia, Ukraine, 21008).

ШВЕЦЬ Людмила Василівна – кандидат технічних наук, доцент кафедри агроінженерії і технічного сервісу Вінницького національного аграрного університету (ВНАУ, вул. Сонячна, 3, м. Вінниця, Україна, 21008, e-mail: shlv0505@i.ua, https://orcid.org/0000-0002-4364-0126).

ПАВЛЮК Дарина Олексіївна – здобувач першого освітньо-кваліфікаційного рівня бакалавр з агроінженерії (вул. Сонячна, 3, м. Вінниця, 21008, Україна).