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CURRENT STATUS IN MECHANIZED HARVESTING OF NUT CROPS

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Abstract: *The article provides a review of technologies, machines and equipment for harvesting nuts, within which existing technologies for harvesting nuts and the main promising designs of machines and equipment for harvesting nuts were studied, presenting their classification and the main characteristics of the process of harvesting nut crops.The article identifies the current status in mechanized harvesting of nut crops, some current problems of walnut cultivation technology and analyzes of existing technologies and machines for harvesting fruits, including nut crops. As a result this review makes it possible to identify the main directions for improving the design of machines for harvesting nut crops in the conditions of the Republic of Moldova, and based on the above analysis, the main criteria for their classification were established.*

Key words: *Mechanized harvesting, Nut, Technology, Shaker, Vibrator.*

INTRODUCTION

The mechanized harvesting of nuts is a technological operation, as a result of which the collection is carried out in a constantly changing range of fruit ripening periods. This is often the most serious problem with mechanized harvesting, which has already been solved for many crops. For stone fruit crops, that problem is solved with the help of drugs that increase the rate of ripening without having negative consequences on the development of fruit color and at a given fruit hardness (Tyson, B., Dull, G., Webb, B., 1975). In addition, for nut crops, which also have great unevenness in ripening, the use of specific preparations will not be able to solve the problem, since we are primarily talking not about the nut kernel, but about its pericarp (Sims, E., Gambrell, C., T. McClary, J., 1971).

EXPOSITION

The analysis of existing technologies for growing nuts show that in the chain of technological operations, harvesting is the most complex and labor-intensive process and creates great problems for agricultural producers incomparable with such technological operations as pruning walnut trees, soil cultivation and spraying of the plantation (Melnic, Iu. Melnic, A.,

Tkachuk, V., Zârnescu, C., 2023). Usually these problems are associated with the mechanization of technological processes in agriculture, and the harvesting of nuts is directly related to the commercial processing of fruits, which involves quite large costs (Kiktenko, N., 2023). This is mainly due to the high costs of using manual labor.

Analysis of the latest research and publications

Moldovan scientists have developed many valuable varieties of walnuts, but the problem is that there is no guarantee they will give high yields when growing walnuts in large gardens, because of these varieties have still been studied very little (Zhadan, V., 1973).

Director of the Walnut Academy of Ukraine E. Ivchenko and ukrainan scientist A. Negovsky argue that at the moment cultivation and processing of walnuts is a highly profitable business all over the world (Ivchenko, E., 2016).

In recent years, increased attention has been paid to the development of the walnut business in the Republic of Moldova and neighboring countries such as Ukraine and Romania, however, despite the high profitability, existing technologies for growing and industrial processing of walnuts are still largely based on manual labor. This situation is due to the peculiarities of walnut cultivation, as well as a great desire to obtain as a result of processing the largest possible percentage of the whole walnut kernel, at a higher price on the market (Suvac, M., 2012).

In addition, for the production of nuts in the conditions of the Republic of Moldova, there are risks associated with climate, as well as economic risks, which often force farmers to think carefully before starting the production of nut crops. Therefore, only after analyzing the existing advantages and disadvantages of cultivation can be made a final decision on the production of walnuts.

The production of agricultural crops constantly requires significant production costs, and with an increase in the level of mechanization of technological processes, costs are significantly reduced.

The issue of mechanization of fruit harvesting of walnut crops is primarily related to the improvement of existing designs of fruit harvesting machines used in fruit-bearing walnut orchards, due to its morphological features: the rather large size of the trunk, crown and branches of the tree. Therefore, the problem of mechanized harvesting the fruits of large-standard walnut trees is relevant and requires a solution, which will, first of all, increase labor productivity, ensure the completeness of the harvest, raise the overall level of mechanization in the cultivation of walnuts, and also solve the social problem of work safety when harvesting fruits (Turcanu, I., 2004).

Mechanized harvesting methods provide a partial solution to this problem by effectively removing fruit from trees, reducing harvesting costs by 35-45% of the total cost of production and helping to increase the efficiency of nut production (Melnic, Iu. Melnic, A., Tkachuk, V., Zârnescu, C., 2023). In order to make labor-intensive and repetitive tasks easier, there is a need to develop more efficient and intelligent machines, thereby increasing their productivity. In existing technologies for growing nuts, harvesting begins after the fruits have fully ripened. This is the moment the green pericarp begins to crack. The nut harvesting process includes the following main technological operations:

- shaking the fruits;
- selection;
- loading fruits into vehicles;
- transportation of harvested fruits to the warehouse.

Depending on the fruit harvesting technology used, one or another set of machines is required to carry out nut harvesting work. So, depending on the volume of production and the level of mechanization, the following methods of harvesting nuts are distinguished: manual, semi-mechanized and mechanized (Varlamov, G., 1978).

The manual method of harvesting nuts is a method in which the nuts are knocked from the tree with a long stick or involves manually shaking the branches and then collecting them by

hand. This method is unproductive, requires huge labor and financial costs, and is even more unsafe.

The semi-mechanized harvesting method involves shaking the trees, which is carried out by mechanized tree shakers, and the collection is done manually or by nut collectors. This method is more productive and safe compared to manual, and does not have a large negative impact on the trunk, branches and root system of the tree. The disadvantage is that there is no significant number of nit harvesters.

With *the mechanized harvesting method*, not only the shaking process is mechanized, but the collection of nuts is also mechanized and automated. This harvesting method significantly reduces the number of nut pickers and increases the productivity and safety of workers. Therefore, in industrial orchards, special tools and harvesting equipment are used to harvest fruits, which allows you to quickly and cost-effectively harvest fruits.

Rezults and discussions

Of all the listed methods of harvesting nuts, the most promising and economically profitable in the conditions of the Republic of Moldova, with a constant reduction in the number of workers involved in agriculture, is mechanized, providing an increase in labor productivity in the range of 5 - 12 times.

There are two possible methods of mechanized harvesting:

- single-phase method;
- two-phase or separate method.

With the single-phase method, the shaking installation is equipped with a fruit catcher or a shaker-catcher is used in tandem, and then additional selection of nuts is eliminated. The two-phase method consists of a phase of shaking the fruits on the ground, and then picking up the nuts using special picking machines.

The first group of machines for harvesting nuts using a single-phase method includes such machine like, for example, the Maja Weremczuk (Poland) fruit harvester (Fig. 1) (Melnic, Iu. Melnic, A., Tkachuk, V., Zârnescu, C., 2023).

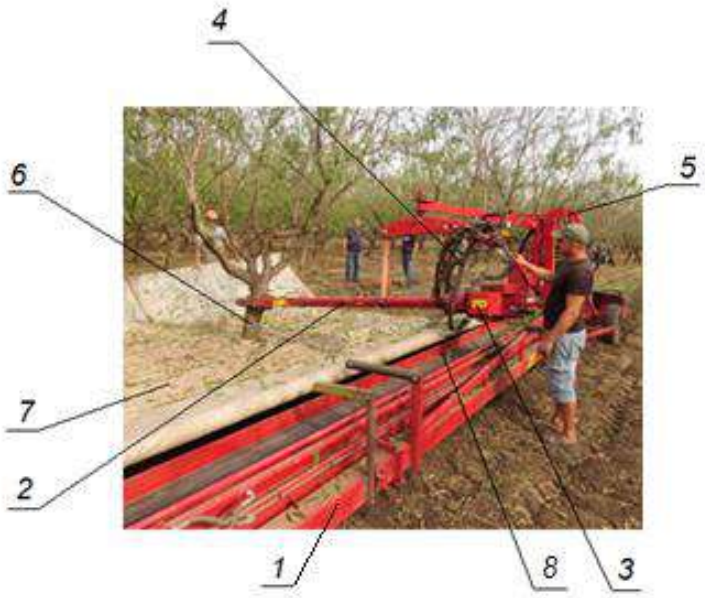

Fig. 1. Maja WEREMCZUK harvester:
1 - machine frame; 2 - movable rod with a device for clamping the barrel; 3 - vibrator; 4 - hydraulic system for controlling mechanisms; 5 - fan; 6 - trunk; 7 - catching device; 8 - longitudinal conveyor.

The following machines can be mentioned among the modern nut shakers: hydraulic shaker Tornado (Italy) (Fig. 2), parallelogram hydraulic shaker VHP AMB Rousset (France)

(Fig. 3). They are used for harvesting of nuts, almonds, hazelnuts as well as cherries, plums and apricots and work on any type of nut crops, and field topography.

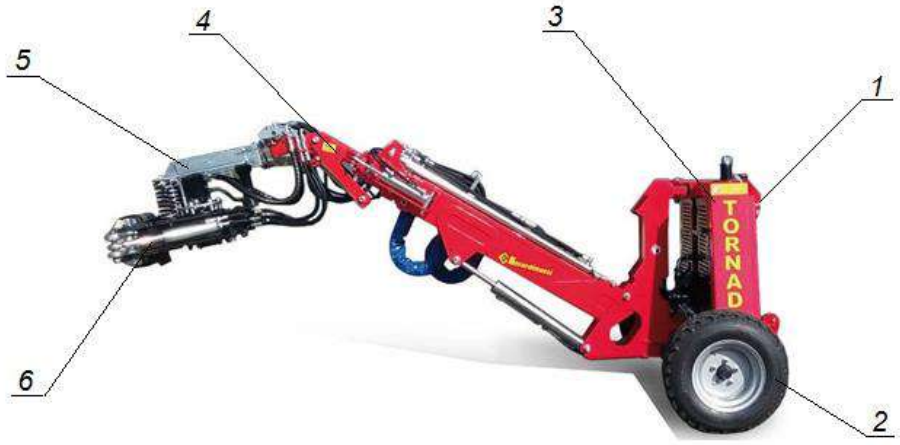

Fig. 2. Shaker Tornado (Italy):
1 - shaker frame; 2 - support wheels; 3 - hydraulic system with piston vibration pump; 4 - telescopic boom; 5 - vibrator (hydraulic motor on a vibrating head); 6 - device for clamping a tree trunk.

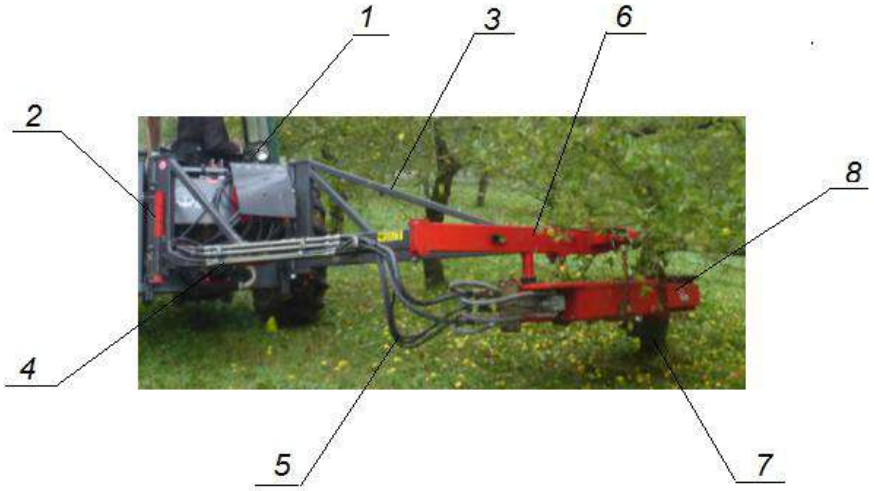

Fig. 3. Parallelogram hydraulic shaker VHP AMB Rousset (France):
1 - tractor; 2 - shaker frame; 3 - parallelogram mecanism; 4 - hydraulic system; 5 - hydraulic hoses; 6 - frame of clamping device; 7 - tree trunk; 8 - tree trunk clamping device with vibrator.

Existing nut harvesting machines are mainly created on the basis of fruit harvesters for apple, plum, cherry, etc. orchards (Bradu, N., Bychkov, V., 1981).

Studying the design of these machines and other technical means for harvesting nuts, they are divided according to the following established classification criteria:

1) According to the method of connection to the tractor - trailed, mounted and self-propelled;

2) By purpose - for shaking, for collection from the ground or trees and for shaking and collecting;

3) By level of automation - semi-automated and automated;

4) According to the principle of operation - vibration, rotary, using air flows and using combinations of various mechanisms.

The study of scientific literature, analysis and theoretical research in order to improve the design of shakers and machines for harvesting nuts made it possible to determine the following

basic requirements for the fruit harvesting process, machines and technological harvesting equipment:

- the number of fruits remaining on the tree should not exceed 50 pieces per skeletal branch;
- the number of damaged fruits should not exceed 1%;
- minor local damage to tree bark is allowed, which generally does not affect the life of plants;
- the vibrating rod must have a rise and fall in a vertical plane, and the lower position of the grip center must be at least 0.5 m from the ground level;
- the time of continuous oscillations should not exceed 10 seconds/tree or branch;
- raising and lowering the boom should be smooth and, in general, not damage the trees;
- the machine's catching device must catch at least 95% of the nuts.

There are also certain requirements for the soil when harvesting nuts. Thus, 10 - 14 days before the start of harvesting work, the soil should be flat and rolled, and if a lawn is planted in the garden, it should be cut short. For this purpose, special tillage implements are used that combine the operations of leveling and compacting the soil or high-performance mowers with a very low cut.

It should be noted that modern technologies involve the use of entire complexes of machines for mechanized harvesting of walnuts, combining both mechanisms for shaking walnut trees onto the ground and mechanisms for collecting fruits into special bins of the machine or directly from the ground using powerful vacuum cleaners. They have their advantages and disadvantages, but we can say with confidence that these machines are not advisable to use in the conditions of the Republic of Moldova, primarily due to the high initial investment in purchasing combines and a set of special technological equipment for harvesting and subsequent additional processing of fruits.

From an analysis of the main designs of existing fruit harvesting machines, it was found that one of the most common disadvantages of shakers is the transmission of vibrations to the tractor or the frame of a trailed combine (Melnic, Iu. Melnic, A., Tkachuk, V., Zârnescu, C., 2023). A device for clamping the trunk or skeletal branches of a walnut tree is also important for the shaking process and the future life of the fruit tree, as this is due to the impact of vibration intensity on the bark and root system of the tree. Therefore, to improve the design of a machine for shaking nut crops, it is also necessary to study the shaking process itself.

The main indicators characterizing the quality of work of a fruit harvesting machine include the completeness of fruit removal, loss and damage to fruits and trees and depend on many factors such as:

- biological in nature - degree of fruit maturity, size and mass indicators of fruits and trees, location of fruits, strength of connection between fruits and trees, fruit weight, yield on the tree, crown features, etc.;
- design and kinematic parameters of the working bodies - type of gripping device and its covering of the working surface, type of catching device, frequency and amplitude of vibrations of the vibrator, vibration time, pressure on the tree bark from the gripping pads, fixation of the closed position of the gripping device, maneuverability of the machine, terrain microrelief and etc.

The completeness of fruit removal is one of the main indicators that determine the effectiveness of the mechanized harvesting method. At a constant amplitude and other equal conditions, the completeness of fruit removal increases with increasing oscillation frequency. Thus, to ensure complete fruit removal within the limits of agrotechnical requirements (95% or more), the optimal frequency of oscillations when harvesting plums, apricots and almonds is a frequency within 650-900 cycles/min and an amplitude of 20-30 mm, when harvesting cherries and sweet cherries - within 900-1200 cycles/min and amplitude 15-20 mm, when harvesting apples - within 500-600 cycles/min and amplitude 20-25 mm. These modes of operation of the vibrator of the fruit harvesting machine provide the necessary modes of oscillation of the fruit's suspension point for its separation.

As can be seen from the experimental data, the larger the fruit, the lower the oscillation frequency and the greater the amplitude. Hence, for a nut, the limits of oscillation frequency and amplitude should be 600-800 cycles/min and 25-30 mm, respectively.

The vibration time of trees, which affects the completeness of fruit harvest, is relatively short for nut species and averages 2.0-3.5 s for almonds, 4-7 s for hazelnuts and up to 10 s for walnuts. It should be noted that the vibration time of trees has the closest connection with the characteristics and density of the crown.

The number of knocked down fruit formations also depends on the operating modes of the vibrator of the fruit harvesting machine and on the biological characteristics of the fruit and fruit wood (the degree of ripeness of the fruit, the strength of the connection between the stalk and the branch and the fruit, the yield on the tree). The vibration time of trees greatly influences the number of knocked down fruit formations of all types, and this, in turn, affects the further fruiting of the tree.

Previously, scientists found that the number of knocked-down fruit formations during mechanized harvesting is slightly lower than during manual harvesting. Of course, this is data for stone fruit crops, but for nut crops this is also an important indicator, since knocked down fruit formations mean a decrease in crop yield next year. Experimental studies show that the specified amplitudes of the vibrator, reduced by 1.5-2.0 times, provide the necessary amplitude oscillations of the fruit's suspension point due to the wave motion of parts of the tree when it oscillates by trunk 1 (Fig. 4).

The completeness of fruit removal also depends on the distance of the gripping point of the trunk to the ground or the distance of gripping the branch from the place of attachment to the trunk by a vibrator or vibrator grip. Experimental studies of the influence of the height of the trunk gripping site on the completeness of fruit removal showed that the greater the height of the trunk gripping site 1 and higher to the skeletal branch 2 and higher to other branches, the lower the number of fruits removed (Fig. 4).

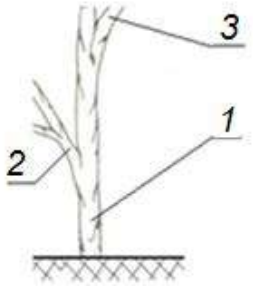

Fig. 4. The main gripping points for the action of the vibrator on the walnut tree:
1 - trunk; 2 - skeletal branch; 3 - branch.

The completeness of fruit removal from a tree is influenced by the weight of an individual fruit. Moreover, the greater the mass of the fetus, the easier and faster the fetus is torn away from the place of attachment due to significant inertial forces that arise when it oscillates.

The diameter of the branch to which the stalk is attached also has a significant influence on the completeness of fruit harvest. With branch diameters of 5 mm or less, the completeness of removal is extremely insignificant. The best results are observed when removing fruits whose stalks are attached to branches with a diameter of 15-20 mm or more.

When mechanized harvesting of fruits from trees, some disadvantages of machine operation have been identified; as a result of obtaining a heap, the heap includes:

- healthy and damaged fruits;
- fruits harvested with and without stalks;
- rotten fruits (natural marriage);
- downed fruits and fruit formations;
- leaves and various insects.

The quality of harvested fruits is determined to a large extent by their quality at the time they are on the tree. Since the harvesting machine is deprived of the selective principle of harvesting fruits, when the tree vibrates, all the fruits fall off, including green, rotten and diseased ones, the fruits of which ultimately need to be discarded, which requires additional labor. The number of damaged fruits depends on the size and design of the catching device, the degree of ripeness of the fruit during the harvesting period, the yield on the tree, the weight of an individual fruit, the characteristics of the crown, the size of the tree and the operating modes of the vibrator of the fruit harvesting machine.

Therefore, the operating modes of the vibrator of a nut harvesting machine must subsequently be given additional attention and experiments must be conducted to establish optimal modes for the main nut crops grown in the Republic of Moldova such as walnuts, almonds and hazelnuts.

It should be noted that modern technologies use agricultural machinery for mechanized harvesting of walnuts, combining both mechanisms for shaking off trees and mechanisms for collecting fruits in special machine bunkers or directly from the ground using powerful vacuum cleaners. They have their advantages and disadvantages, but we can say with confidence that these machines are not fully suitable for use in the conditions of Moldova, primarily due to the high initial investment for the purchase of combines and a set of special technological equipment for harvesting and subsequent additional fruit processing.

From an analysis of the designs of fruit harvesting machines, it was established that one of the main technical disadvantages of shakers is the transmission of vibrations to the tractor, and technological ones - a negative impact on the root system of the tree.

Vibrator 5 (Fig. 2) and its drive mechanism are the main elements of the shaker design. The device for clamping the trunk of the movable rod 2 (Fig. 1) is also of great importance for the shaking process and the future life of the fruit tree, since this is due to the effect of vibration intensity on the bark and root system. Therefore, to improve the design of a machine for shaking nut crops, it is also necessary to further study the process of shaking nuts. Improving the design and operating modes of vibrator 5 (Fig. 2) or 8 (Fig. 3) should solve the identified shortcomings in mechanized nut harvesting. So, the study of the theoretical background of the technological process of shaking walnut fruits with the justification of the main parameters influencing the process of tearing off the fruits and their falling to the ground is one of the most important elements affecting the productivity of the machine and the quality parameters of its operation.

Since collecting nuts involves mandatory shaking, this method can have an extremely negative impact on the fruit-bearing tree itself, which leads to damage to the bark, causing the death of trunks, the development of diseases and, as a result, a drop in yield in subsequent years. In order to minimize injury to the tree, it is necessary to study how the magnitude of the vibration amplitude and its duration affects the tree itself, depending on the age of the tree, the diameter and height of the trunk grip.

CONCLUSIONS

1. The study and analysis of existing technologies for growing nuts showed that in the chain of technological operations for growing nut crops there are problems associated with harvesting, which is one of the most important and most labor-intensive technological operations, in which the costs of collecting and commercial processing of fruits are at least 50-60% of the total costs of growing fruits.

2. The proposed classification of machines for harvesting nuts indicates an area in which further research is planned to develop and improve the design of machines and technological equipment.

3. As a result of studying the existing designs of fruit harvesting machines and special scientific literature, the basic requirements for the process of mechanized harvesting of nut crops were determined.

4. Vibration transmission to the tractor has been found to be one of the most common problems with shaking off walnut trees.

5. Further study of the theoretical background of the technological process of shaking of nuts with justification of the main parameters influencing the process of the fruit being torn of and falling to the ground, is one of the most important elements affecting the productivity of the machine and the quality indicators of its operation.

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