Current problems of walnuts growing technology

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Abstract: *The article identifies the main current problems of walnut cultivation technology and analyzes of existing technologies and machines for harvesting fruits, including nut crops.*

As a result of the research, the main directions for improving the technology of growing walnuts by improving the technological and technical parameters of the design of machines and equipment for harvesting walnuts were proposed and hypotheses were put forward for their improvement, in particular, a machine equipped with a bar for shaking fruits and a catcher, which is designed to collect fruits and partial destruction of the green pericarp of the walnut fruit.

KEY WORDS: *GROWING TECHNOLOGY, WALNUT, HARVESTING, MACHINERY AND EQUIPMENT, PERICARP, FRUIT SHAKING, SHELL, WALNUT KERNEL, PARAMETERS.*

Introduction

The agricultural sector has been and remains one of the main pilar of the national economy in the Republic of Moldova. Fertile soil and temperate continental climate give Moldova a competitive advantage in agricultural production. Although the main place in the economy of Moldova is occupied by the service sector, according to the data of 2018, agriculture continues to play a very important role: it accounts for 12% of GDP and more than 30% of all jobs [1]. In particular, Moldova's agricultural potential is a strong asset for the food industry. The Republic of Moldova has competitive advantages in agriculture, namely in the cultivation of fruits and vegetables, while respecting the 3 main elements of competitiveness - price, quality and models.

Walnut plantations began to be established in Moldova in the 1990s, but before that, walnut cultivation was practiced in individual, peasant farms and along forest belts and roads. The walnut culture in the Soviet Union, and even in Moldova, did not receive due attention, since low purchase prices made the industry deliberately unprofitable and unattractive for walnut producers. It should be noted that the products of the walnut garden are quite price-intensive, and one kilogram of walnut kernels, in monetary terms, is equivalent to 40-50 kg of wheat and does not require huge warehouses for storage and transportation costs [2].

A significant role in the transformation of walnut growing from a secondary industry (amateur) into the main, basic sector of agriculture in Moldova was played by the adoption of the "Law on walnut crops" adopted by the Parliament of the Republic on October 29, 1999 [3]. According to the National Program for the Development of Nut Crops, by 2020, the area of plantations occupied by walnut crops should be at least 14 thousand hectares, while the harvest of nuts in shell should be 60,000 tons. Over the past five years, production in this sector of walnut crops has increased by 55%, which positions the Republic of Moldova among the world's leading producers [4].

The Ministry of Agriculture and Food Industry notes that while the share of value added and employment in the country's agriculture has declined over the years, the nut sector continues to be an engine of economic growth through export potential, as well as a means of reducing poverty.

According to the National Bureau of Statistics of the Republic of Moldova, there are a total of 34.7 thousand hectares of walnut crops, of which 20.9 are fruit-bearing orchards. Compared to 2018, there is an increase in walnut areas, by about 4 thousand hectares. According to the latest data, the gross moldovan production of nuts in 2020 was 14.7 thousand tons, which is 5 thousand tons less than in 2019, due to the climate effects of natural disasters and severe drought. Of the total volume of nut crops harvested in 2020, about 12.7 thousand tons were exported and their total value was about 71.7 million US dollars.

About 79% of them went to such EU countries as France, Germany, the Netherlands, Romania, Austria, etc. In the period from January to August 2021, about 4 thousand tons of nut products were exported. According to experts, in 2021 the gross harvest of nut crops obtained from orchards, as well as purchased from citizens, will be more than 25 thousand tons [4].

The main nut crop in the Republic of Moldova is the walnut, and its cultivation is of great economic and social importance. The walnut kernel is a food product that is used both fresh and as a raw material in the food industry. A study of prices for this product abroad demonstrates the profitability of this industry: 1 kg of nuts costs an average of 10-12 euros abroad, while on the domestic market of the Republic of Moldova it is sold for only 4-5 euros. The local walnut kernel is higher in quality than that obtained in other countries, with a much better taste and a much richer biological composition.

The production and export of nuts brings significant profits to the state. Since the 2000s, the Republic of Moldova has ranked 5th-9th in the world in terms of the export of walnut kernels. At the same time, the walnut growing business requires patience and large investments, since the beginning of fruiting takes place only 5-6 years after planting, and the phase of stable fruiting occurs only after 12-15 years.

Formulation of the problem

The walnut, under certain technological conditions, can have a significant longevity, with a beneficial effect on the environment, and, as noted, at the same time of great economic and social importance.

The development of zone-differentiated technologies, depending on more difficult climatic conditions, should become an important area of activity for specialists in this field of research, education and production. In this regard, it is also necessary to take into account the relationship between tradition and innovation, as well as the many years of experience accumulated by local walnut producers. The scientific and practical support of the walnut industry in the Republic of Moldova has been accompanied for many years by the following scientists and practitioners such as Dorofeev P.P., Rybin V.A., Turcanu I.P., Komanich I.G., Zhadan V.M. and others [2].

The study and analysis of existing technologies showed that quite big problems can be identified in the chain of technological operations for growing walnuts. Such important operations as pruning and spraying tall walnut trees, tilling the soil around them due to the large crown and harvesting fruits are current problems in walnut cultivation technology. For the most part, these problems are associated with the mechanization of technological processes in agriculture.

Harvesting is one of the most important operations in fruit crop cultivation technology. Moreover, harvesting and commodity processing of fruits are the most labor-intensive operations in fruit growing, the costs of which, even in the advanced specialized horticultural farms of the world, average 50–60% of the total cost of growing fruits [2]. In our conditions, this also applies to the harvesting of walnuts and is associated with rather high costs, primarily for the use of manual labor.

Analysis of recent research and publications

In general, in Moldova and Ukraine, scientists have bred quite a lot of valuable walnut varieties, but the problem is that there are no guarantees that they will produce high yields in massive orchards, since these varieties have very poorly studied flowering biology, compatibility pollen, etc. Such scientists as Zhadan V. et al. recommend that before a detailed study of walnut varieties, create, for now, walnut plantations along the boundaries of land use, around orchards and vineyards, along canals, in the protective zones of reservoirs, and most importantly - along the borders and on household plots of the population, where the bulk of commercial nuts are produced [5, 6]. However, walnut producers, as always, are ahead of science, so the creation of modern competitive walnut orchards on an industrial basis has already begun [7].

Ukrainian scientists A. Negovsky and V. Pakhno argue that the cultivation and processing of walnuts is a highly profitable business all over the world. In recent years, increased attention has been paid to the development of this business in a number of CIS countries. However, despite the high profitability of the walnut business, the existing technologies for the cultivation and industrial processing of walnuts in these countries largely use manual labor, especially to pick up the nuts. This is due to the peculiarities of growing, as well as the desire of processors to obtain the largest possible volume of the whole walnut kernel, which has the highest value on the market [7, 8].

One of the main distinguishing features of the walnut business in Moldova is the insignificant area of cultivated walnut plantings (ie walnut orchards) and rather high diversity of walnut varieties. The difference in the shape, size and physical and mechanical properties of walnuts of various varieties entering for processing does not make it possible to create an “ideal” technique for harvesting and processing them.

It should be noted that the production of agricultural crops constantly requires production costs, and the mechanization of technological processes in agriculture facilitates work and reduces these costs. To ensure the stability of production, it is necessary to analyze the trends and opportunities of crop production well enough.

According to the last experience of several producers and scientific researchers in this field, the walnut is a promising agricultural crop for the Republic of Moldova and Ukraine, since the volume of nuts produced in Europe is insufficient for the European market. That is why problems in the production of nuts and their marketing should not arise in the coming years, since the quality of Moldovan walnuts is good, and in composition they even surpass nuts produced in other countries of the world. However, Moldova's climate has somewhat negative and economically risky consequences for walnut cultivation. Consideration of the cultivation technology and conditions for the production of walnuts revealed the main risks in this area, such as:

- spring frosts, especially late ones;
- low average annual rainfall;
- less productive local varieties of walnuts;
- short duration of exploitation of grafted walnut plantations.

The risks presented often make farmers and large agricultural producers wonder if they can take such risks.

Another problem is that agricultural enterprises are in the form of associations, and the land is owned by members of the local association, which enters into a short-term lease by the manager (usually for 3-5 years), after which the exit from the association is free. Thus, it can be concluded that in order to plant a walnut orchard, the land must be leased for a long-term lease (for example, at least 50 years) or the land must be owned.

Therefore, in order to decide on the production of walnuts, it is necessary to take into account all the risks, advantages and disadvantages of cultivation.

Rezults and discussions

The existing nut harvesting machines are mainly based on fruit harvesters for apple, plum, cherry, etc. orchards. According to the harvesting method, these machines can be divided into harvesters with a catching device for direct harvesting of fruits and harvesters that perform a separate harvesting method.

The old harvesters MPU-1A and VUM-15A were mainly intended for harvesting fruits of stone fruit crops (plums, cherries, etc.), in which the size of trees is small compared to walnut ones [9]. More modern designs of such machines include the GACEK cherry and plum harvester, JAGODA JPS Agromachines is designed to harvest cherries, as well as other stone fruits such as plums [10]. An innovative solution is the use of a reversible "umbrella", which is hydraulically unfolded under the tree, before shaking the fruit. Harvesting takes place by shaking the fruit, then the impurities are removed with a fan, and the fruit is poured into boxes or pallets. Such a combine is recommended to be used for orchards up to 5 hectares. To service the combine, 2 people are required: a tractor driver and an equipment operator. The GACEK cherry and plum harvester, under optimal conditions, can pick fruit from 50 to 60 trees per hour, and the distance between trees in a row is from 2.2 to 2.5 m.

Due to the use of an "umbrella" unfolding under the tree in the design the listed combines are not suitable for further modernization of the design. Given that the diameter of the crown of walnut trees is at least 6-8 m, the technological scheme of work is not suitable.

Fruit harvester KPU-2 is designed for mechanized harvesting of stone fruit, seed and nut crops [9, 11]. The fruits are harvested for fresh production and processed. Combine KPU-2 works under the following conditions:

- in all industrial zones for the production of fruit crops;
- on horizontal fields and on slopes up to 6°;
- tree crown diameter up to 7 m;
- landing pattern 6x3 m and much more.

Combine design features:

- the harvester contains a special device for clamping the trunk;
- the clamping device of the inertial vibrator eliminates the transmission of vibration to the harvester;
- rubber shock absorbers prevent damage to the case;
- a layer of cushioning material prevents damage to fruits when falling;
- the harvester is equipped with a device for adjusting the height of falling fruit into a container or box.

The harvester has high productivity (removes 60 trees/hour), provides harvesting quality at the level of 95%, fruit harvesting quality - 97%, harvesting area - 46-54 m^2. The harvester is aggregated with the T-16 tractor, the transport speed is 15 km/h.

Among the existing machines, there is one which is the Balkan-3 fruit harvester, aggregated with two tractors MTZ-80 (82) and is designed for harvesting stone fruit and nut crops in orchards located on a slope of up to 5°, with a planting pattern of 6x4 m by shaking with simultaneous cleaning and collection of fruits in containers or boxes [12].

Figure 1. Maja WEREMCZUK harvester

Source: *https://weremczukagro.com/ru/products/maja-2/*

Similar in principle of operation, but more modern, are the designs of the Maja WEREMCZUK harvester, which provide a fairly good harvest of stone fruit crops (Fig.1) [13]. The Maja trailed unit is a machine that combines the functions of shaking and

peeling fruits ready for direct sale. This group of combines contains:

- two axle shafts with a clamping device;
- two cloth-catchers of fruits;
- vibrator, for shaking off trees with coverage of trunks of different diameters;
- cross conveyor;
- loading conveyor with fan to remove leaves and other impurities;
- platform for containers (boxes);
- hydraulic system.

Therefore, from the analysis of fruit harvesters with a catching device, it can be concluded that the technological scheme of structures with a catching device for harvesting fruits in the form of umbrellas is not fully suitable for harvesting walnuts, whose trees have large crowns and trunks. However, trailed harvesters with a spreading catcher are more suitable for design improvement in relation to the harvesting of walnuts.

Most growers use split harvesting, where after shaking off the trees, the nuts are picked from the ground by hand. The existing technology for harvesting walnuts involves the use of shakers of various types from companies such as Bosco (Italy), Sommier and AMB ROUSSET (France) and others [7]. Mechanisms for shaking trees can be made in the form of autonomous units or as attachments to a tractor chassis.

It should be noted that modern technologies use agricultural equipment for mechanized harvesting of walnuts, which combine both mechanisms for shaking off trees and mechanisms for collecting fruits in special bunkers of the machine, or directly from the ground using powerful vacuum cleaners. They have their advantages and disadvantages, but we can confidently say that they are not fully suitable for use in the conditions of the Republic of Moldova, primarily because of the high initial costs for the purchase of a set of harvesters and special technological equipment for further fruit processing.

In addition, the complication of the harvesting and processing process increases the production costs for growing walnuts, reducing the quality of the kernel [7].

One of the most common drawbacks of shakers is the transfer of vibrations to the tractor or the frame of the trailed harvester. Therefore, the vibrating device 5 of the shaker (Fig.2) should solve this main problem.

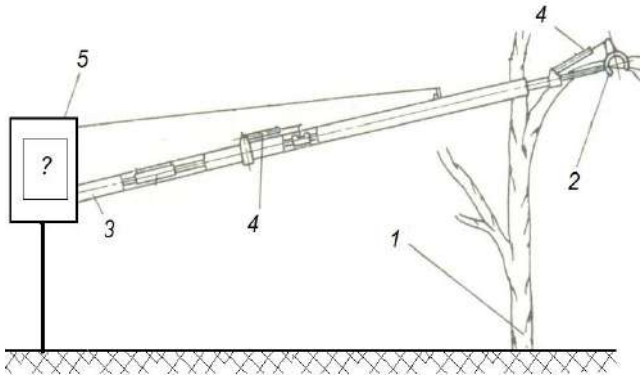

Figure 2. Trunk (branches) shaker:
1 - tree; 2 - fixture for clamping the trunk (branches);3 - movable vibrating rod; 4 - hydraulic cylinder; 5 - vibrator (unknown).

Vibrator type 5 and its drive mechanism are the main elements of the design being developed (Fig.2). Device 2 for clamping the trunk (branch) is also important for the process of shaking and the further life of the fruit tree, as this is due to the effect of vibration intensity on its root system.

Therefore, in order to improve the design of a machine for shaking nuts and solving the problems of theoretical research, it is necessary not only to study the various mechanisms of machines and their designs, but also to study the shaking process itself. So, the study of the theoretical prerequisites for the technological process of shaking off walnut fruits with the justification of the main parameters affecting the process of tearing off the fruit and its fall to the ground is the most important element affecting the productivity of the machine and the quality parameters of its operation.

In the case of harvesting using machines with vibrators, the walnut fruits are torn off the branch due to the vibrations of the tree (branch). The theoretical aspects of the process of tearing off the walnut fruit from the stalk is based on the following statement:

- detachment occurs under the condition that the inertial forces acting on the fruit exceed the force of connection between the fruit and the branch [14,15].

Normal force F_n is determined from the following relationship [14,15]:

$$F_n = N = \frac{Ma^2\omega^2}{l} \cdot \cos^2 \omega t \quad (1)$$

where: M - weight of the fetus, kg;
a - amplitude of the generating force, cm;
l - length of the physical pendulum, cm;
ω - circular frequency of the generating force, s^{-1}.
t - oscillation time, s.

The tangential force F_t is directed perpendicular to the normal force N and is equal to:

$$F_t = Ma\omega^2 \sin \omega t \quad (2)$$

At the last the force of inertia F is determined from relation (3):

$$F = \sqrt{F_n^2 + F_t^2} \quad (3)$$

However, these formulas do not fully reflect the process of walnuts shaking off and falling to the ground, because it differs from the same process, for example, stone fruits.

Figure 3. Walnut fruit on the twig:
1- walnut fruit; 2 - stalk; 3 - twig of walnut tree.

This is due to the shape, length, thickness and stiffness of the stalk of walnuts and other nut crops (Fig.3).

Research in this area is more related to shaking fruits from crops such as plums, cherries, sweet cherries and apples [14]. However, as noted earlier, walnut crops have some biological features that should be taken into account during mechanized harvesting.

The shaking process is greatly influenced by the time of the beginning of harvesting, the parameters of the walnut stalk, since in the cracked protective shell (green pericarp) the nut (fruit) settles a little and it forms angle a of deviation of the nut from the axis of the fruit (Fig.4).

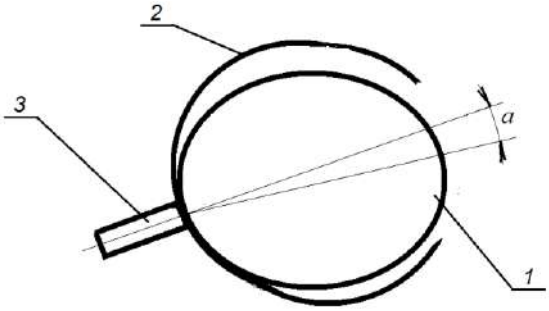

Figure 4. Deviation of the nut inside the cracked protective shell from the axis of the fruit: *1- walnut in the late stage of ripening; 2 - cracked protective shell (green pericarp);3 - stalk; a - angle of deviation of the nut from the axis of the fruit.*

Moreover, depending on the angle *a* of the deviation of the nut from the axis of the fruit, several different cases can be obtained: a=0; a=1-5^o; a=6-10^o, etc., which need additional research.

As a result of studying the designs of harvesters, scientific literature and preliminary theoretical studies in order to improve the design of vibrating machines for harvesting nuts, it is necessary to identify the area of requirements for them:

- the number of damaged fruits should not exceed more than 1%;
- local damage to the bark of trees that does not affect the vital activity of plants is allowed;
- the number of fruits remaining on the tree should not exceed 50 pieces per skeletal branch;
- vibrations (oscillations) should not affect the vital activity of trees and their further productivity;
- the time of continuous oscillations should not exceed 10 seconds;
- the catching device must catch at least 95% of the fruit; if the nuts are shaken off to the ground, then either manual labor or picking machines are used for the subsequent selection;
- the vibrating rod must have a rise and fall in a vertical plane; the lower position of the capture center should not be less than 0.50 m from the ground;
- lifting and lowering of the bar must be smooth;
- the vibrating rod must not cause damage to the trees.

Conclusions

1. The main nut crop in the Republic of Moldova is the walnut, and its cultivation is of great economic and social importance.

2. The study and analysis of existing technologies showed that quite big problems can be identified in the chain of technological operations for growing walnuts. Such important operations as pruning and spraying tall walnut trees, tilling the soil around them due to the large crown and harvesting fruits are current problems in walnut cultivation technology.

3. Harvesting is one of the most important operations in fruit crop cultivation technology. Moreover, harvesting and commodity processing of fruits are the most labor-intensive operations in fruit growing, the costs of which, even in the advanced specialized horticultural farms of the world, average 50–60% of the total cost of growing fruits. In our conditions, this also applies to the harvesting of walnuts and it is associated with rather high costs, primarily for the use of manual labor.

4. One of the most common drawbacks of shakers is the transfer of vibrations to the tractor or the frame of the trailed harvester.

5. The study of the theoretical prerequisites for the technological process of shaking off walnut fruits with the justification of the main parameters affecting the process of tearing off the fruit and its fall to the ground is the most important element affecting the productivity of the machine and the quality of parameters of its operation.

6. The main directions for improving the technology of growing walnuts by improving the technological and technical parameters of the design of machines and equipment for harvesting walnuts were proposed and hypotheses were put forward for their improvement, in particular, a harvesting walnuts machine equipped with a rod for shaking fruits and a catcher, which is designed to collect fruits and partial destruction of the green pericarp of the walnut fruit.

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