ISSUES OF MECHANIZATION OF HARVESTING IN FRUIT ORCHARDS

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Presented by the Institute of Agriculture of the Tskhum-Abkhazian Academy of Sciences

Abstract. Among the time-consuming operations of maintenance and harvesting of fruit crops, harvesting stands out, which is done manually or with the use of small mechanized technical means. Labour costs for harvesting operations of this or that culture make up about 30-40% of the total costs of harvesting. Mechanization of the harvesting process will significantly reduce labour costs and make the fruit growing industry profitable. The main direction of perfection of fruit-picking machines is to increase productivity, the damage to fruits and trees should be reduced as much as possible, fruit-picking machines should have high off-road and manoeuvrability in parallel with simple construction, reliable lifting of working bodies and guarantee of safety.

The article "Issues of Mechanization of Harvesting in Fruit Orchards" discusses the mechanical technologies of fruit harvesting in fruit orchards. The constructions of a new modern machine for blowing fruits from the plant with impact vibrations and the fruit holding device aggregated to it are presented. The article discusses the advantages of the mentioned machine technologies, compared to the already existing machine technologies for harvesting in orchards. The theoretical foundations of the working organs of the fruit-holding device are also discussed.

Keywords: *Shock vibrations, vibrating, stamp, spherical body, modulus of elasticity.*

The method of harvesting from fruit crops (apples, pears, plums, peaches, citrus fruits, walnuts, etc.) is known, by the method of forcing the fruits from the plant. For this purpose, machines working on different principles have been created in advanced agricultural countries abroad. Among them, the vibration type machines, whose main working body is a vibrator and a fruit holding device, have found a wide distribution. To carry out the technological process of picking with such machines, it is necessary to stop the fruit-picking machine for a certain time at each plant, connect the vibrator to the stalk of the plant and make it vibrate.

In order to eliminate the mentioned shortcomings, the scheme of the machine for blowing fruits from the plant with shock vibrations (vibrator) was developed.

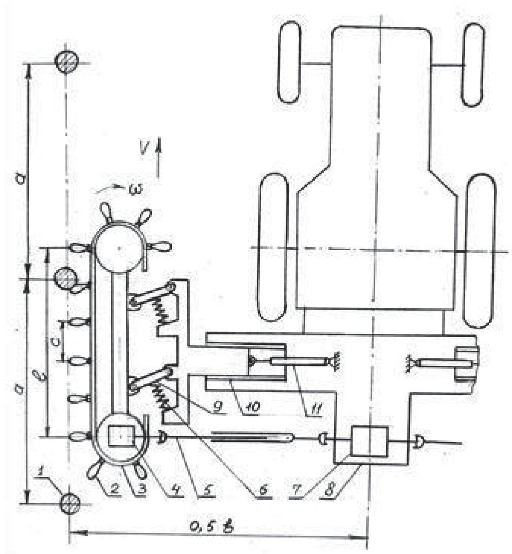

Fig. 1. Scheme of the machine for blowing fruits from the plant with impact oscillations

1 - stamp of the plant; 2 - long-element hammer; 3 - chain transmission; 4 - conical reducer; 5 - cardan transmission; 6 - spring; 7 - distribution reducer; 8 - supporting body; 9 - suspension mechanism; 10 - guiding groove; 11 - hydraulic cylinder.

It is possible to adjust the width of the machine modes by means of the guide groove (10) and hydraulic cylinders (11). It is also possible to adapt the hammers to the plant stem, in case of small deviations in the arrangement of the plants in the row, which is ensured by the suspension mechanism and springs (6).

During the movement between the rows, the machine makes several blows on the stem of the plant with flexible elastic hammers and causes it to vibrate. The speed of movement of the machine V, the angular speed of the hammer chain, as well as the frequency and force of the blow should be selected taking into account the physical and mechanical properties of the plant and the fruit so that the fruits are completely beaten without damaging the plant stem.

The advantage of this method is the continuous movement of the machine, the elimination of the rigid attachment of the vibrator to the stem, and a short period of vibration.

In case of implementation of the construction of a fruit press machine with shock vibrations according to our proposed scheme (Fig. 1.), it is necessary to make a suitable fruit catching device, which ensures perfect collection of the fruits that have fallen as a result of shock vibrations. In this direction, a device for holding fruits of fruit trees was developed, which is aggregated on a device for pressing fruits (Fig. 2.)

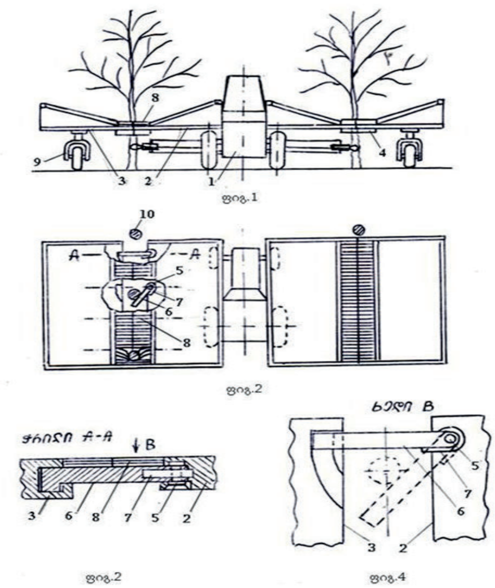

Fig. 2. Device for holding fruits of fruit trees

Compared to other existing devices, the mentioned fruit pressing device has certain advantages: there is no need to prepare the work process for blowing the fruit, to stop at each plant, since this device is aggregated with a continuous action fruit pressing device, which moves between rows of plants without stopping, and the presented fruit pressing device collects fruits without stopping the machine; In particular, it is mounted on the frame of the baler (2, 3). In this way, the fruit press and the fruit holding devices are a single unit that ensures a continuous work process of picking fruits from the plant.

In fruit orchards, the efficiency and quality of the machines used in mechanized harvesting mainly depend on the main characteristics of the fruit harvesting device:

- On the completeness of pressing of forcibly dropped fruits;
- On the degree of injuries of forcibly dropped fruits.

One of the main efficiency indicators of the fruit-holding device is the number of damaged fruits, which depends on: fruit mass, fruit ripening quality, yield, diameter of individual branches, plant stem shape, fruit-holding device construction, fruit-pressing device operation mode, etc.

If we consider the basics of the theory of collisions of individual fruits: with branches, with each other, with the surface of the working organ of the fruit-holding device, it is possible to establish a general relationship between the physical-mechanical properties of the plant fruit and impacts on the surface of the fruit-holding device, as well as to establish a general regularity for the processing of the optimal fruit-holding device, which will subsequently minimize damage to the fruits.

With further extension of Hertz's theory, S.P. Timoshenko, B.S. Horsfield and R.B. Friedlin showed that, approaching the point of collision 1 in the collision of two spherical surfaces, the maximum deflection can be calculated by the formula:

$$\alpha_1 = \left(\frac{5v_\partial^2}{4nn_1}\right)^{\frac{2}{5}}, \tag{1}$$

where the relative velocity of two spherical bodies approach each other.

$$n_1 = \frac{m_1+m_2}{m_1 m_2}, \tag{2}$$

$$n = \sqrt{\frac{16R_1R_2}{9\pi^2(K_1+K_2)(R_1+R_2)}}, \tag{3}$$

where the mass of the first and second spherical bodies;

R_1 and R_2 Radiuses of spherical bodies.

$$K_1 = \frac{1+v_{\pi_1}^2}{\pi E_1}, \tag{4}$$

$$K_2 = \frac{1+v_{\pi_2}^2}{\pi E_2}, \tag{5}$$

where $v_{\pi_1}^2$ და $v_{\pi_2}^2$ accordingly, the first and second are the Poisson coefficients of spherical bodies;

E_1 and E_2 elastic modulus of spherical bodies.

The approximation of two spherical bodies with a certain pressure to the radius of the contact surface α can be calculated by the following equation

$$\alpha = (K_1 + K_2)P_0\frac{\pi^2 a_k}{2}, \tag{6}$$

where P_0 is the pressure, which originates near the center of the contact surface;

a_k - The radius of the contact surface of two spherical bodies, which can be calculated from the following image

$$a_k = (K_1 + K_2)\frac{\pi^2}{2}P_0\frac{R_1R_2}{(R_1+R_2)}. \tag{7}$$

By further solving the mentioned equation in relation to P_0 and if we insert the following values into equation (1.8), we get

$$\alpha = \alpha_K^2\frac{R_1R_2}{(R_1+R_2)}. \tag{8}$$

When $m_1 \geq m_2$ approach speed (impact speed) v_d and (1) member of the formula n_1 Accordingly, it is possible to change the height of the drop h and the weight of the body *G*. Accordingly, the impact speed and the mass of spherical bodies are calculated by the well-known formulas.

If we accept that, for the collision surface of two spherical bodies, the Poisson's coefficient is equal to 0.49, then we can calculate the radius of collision of the spherical body with the fruit-holding device and the pressure that occurs at the center of the contact surface and excludes the damage of the spherical body.

$$a_k = 2,74(Gh)^{1/5}\left(\frac{E_1+E_2}{E_1E_2}\right)^{1/5}\left(\frac{R_1R_2}{R_1+R_2}\right)^{2/5}, \tag{9}$$

$$P_0 = 0,34(Gh)^{1/5}\left(\frac{E_1E_2}{E_1+E_2}\right)^{4/5}\left(\frac{R_1+R_2}{R_1R_2}\right)^{3/5}. \tag{10}$$

When a spherical body (fruit) collides with a flat surface, the modulus of elasticity can be expressed by the formula

$$E = \frac{0,54GhR^2}{a_k^5}, \tag{11}$$

where R^2 is the radius of the sphere, (cm).

Experimentally, it was determined that the height, weight, ripeness of the fruit and the modulus of elasticity of the working surface of the clamping device have a significant influence on the damage to the fruit of the plant that has been forcibly dropped. It is very unlikely that the kinetic energy possessed by a plant fruit falling from a certain height (which causes its subsequent damage upon impact) is transformed into the energy of deformation of the surface of the holding device. Thus, in order to avoid injuries to the fruits that are forcibly dropped, it is important that the working surface of the holding devices is covered with a material that has a low modulus of elasticity.

During mechanized fruit tree harvesting, the forcefully dropped fruits are damaged, not only when they fall on the surface of the holding device, but in most cases they are damaged when they collide with each other.

If we use the assumptions made above, the injuries of the fruits that are forcibly dropped on a flat horizontal plane (if we consider that they are not likely to be damaged when they come into contact with the horizontal growth of the fruit-holding device) can be represented by the following image:

$$P_1 = 0, \tag{12}$$

$$P_2 = \frac{4d^2}{D_{\wp}^2}, \tag{13}$$

$$P_n = \frac{4(n-1)d^2}{D_{\wp}^2}, \tag{14}$$

where "d" is the diameter of the fruit;

$D_{დ}$ - The diameter of the surface of the clamping device.

The probability of encountering (collision) of forcibly dropped fruits can increase with arithmetic progression. Thus, the damage caused by the fruits falling from the tree for the next tree can be represented by the following image:

$$P_{ბ} = \sum_{i=0}^{n} P_i = \frac{2d^2 n(n-1)}{D_{დ}^2}. \tag{15}$$

This image can be simplified if we assume that (such an assumption is quite acceptable in the case of a large number of fruits on a plant) and consider that when two fruits collide, both are damaged, then

$$P_{dam} = 2P_{ბ} = \frac{4d^2 n^2}{D_{დ}^2}. \tag{16}$$

Damages from forcefully dropped fruits can be reduced by:

- When positioning the holding surface of the fruit holding device at a certain angle;
- When mounting the holder of the fruit-holding device from such a material that absorbs the potential energy of the fruits forcibly dropped from the height.

When the clamping device is placed at a certain angle to the stem of the plant, the damage to the fruits that are forcibly dropped can be expressed by the following formula

$$P_{holding/helping.} = 8\frac{d^2 nt}{D_{დ}^2 T_{რხ}}, \tag{17}$$

where t is the average time of fruit rolling;

T - The complete swing time of the plant.

In order to exclude the injuries of fruits that are forcibly dropped, which collide with the surface of a passive horizontal holding device, the kinetic energy of fruits falling from a certain height must be completely transferred to the energy of deformation of the surface of the holding device.

Energy transfer coefficient $\eta_{დამ}$, according to I.M. Fedotov's equation, has the following form

$$\eta_{დამ} = (1-K)^2 \frac{m_{ნ} m_{დამ}}{m_{ნ} + m_{დამ}}, \tag{18}$$

$$\eta_{დამ} = \frac{C\delta_{დ}^2}{m_{დამ} v_{ნაყ}}, \tag{19}$$

where K is the recovery coefficient;

$m_{ნ}, m_{დამ}$ - The surface mass of the fruit and the holding device;

C - Stiffness coefficient;

δ - Dynamic displacement of the collision surface.

It is very difficult to take into account all the factors that can take place when harvesting the fruit of a plant in a mechanized manner. But separate factors that have the important influence on the degree of fruit damage and the completeness of harvesting have been established. These are:

- Formation of plant stem. Creation of mechanized agrophone in gardens;
- Ripening of plant fruits and their mass;
- Amplitude of fruit oscillation;
- The type of working surface of the fruit-holding device and the structural adaptation of the device to the plant stem.

The analysis of the mentioned factors allows us to determine the general regularity for the processing of the optimal fruit-holding device, which will further minimize the damage and losses of the fruits.

References:

1. Dundua V. "Complex mechanization of work in orchards". Training University "Lampari" Kutaisi 2015.
2. Ebanoidze N. Dundua V. "Vibrator Fruit Picker Machine". “Sakpatenti”. Repair model patent U P5880 Tbilisi 2013.
3. Ebanoidze N. Dundua v. "Fruit Holding Device". “Sakpatenti”. Repair model patent U 13393/01 Tbilisi 2015.
4. Khrobostov S. "Operation of Car-Tractor Park". Publishing house “Education”. Tbilisi 1983.
5. Varlamov G.P. “Machines for harvesting fruits”. “engineering” Moscow 1978 (Russian).

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წარმოადგინა ცხუმ-აფხაზეთის მეცნიერებათა აკადემიის სოფლის მეურნეობის ინსტიტუტმა

აბსტრაქტი. ხეხილოვანი კულტურების მოვლა–მოყვანის და აღების შრომატევად ოპერაციებს შორის გამოირჩევა მოსავლის აღება, რომელიც უმეტეს შემთხვევაში სრულდება ხელით ან მცირე მექანიზაციის ტექნიკური საშუალებების გამოყენებით. ამა თუ იმ კულტურის მოსავლის აღების ოპერაციებზე შრომის დანახარჯები, მოვალ–მოყვანის სრული დანახარჯების დაახლოებით 30-40%–ს შეადგენს. მოსავლის აღების პროცესის მექანიზაცია მნიშვნელოვნად შეამცირებს შრომის დანახარჯებს და რენტაბელურს გახდის მეხილეობის დარგს. ნაყოფამღები მანქნების სრულყოფის ძირითად მიმართულებას წარმოადგენს მწარმოებლობის ამაღლება, მაქსიმალურად უნდა შემცირდეს ნაყოფებისა და ხეების დაზიანება, ნაყოფამღებ მანქანებს მარტივი კონსტრუქციის პარალელურად უნდა ჰქონდეთ მაღალი გამავლობა და მანევრულობა, სამუშაო ორგანოების საიმედო აძვრა და უსაფრთხოების გარანტია.

სტატია „ხეხილოვან ბაღებში მოსავლის აღების მექანიზაციის საკითხები“ განხილულია ხეხილოვან ბაღებში ნაყოფის აღების სამანქანო ტექნოლოგიები. წარმოდგენილია ახალი თანამედროვე, მცენარედან ნაყოფების დარტყმითი რხევებით ჩამოსაბერტყი მანქანისა და მასზე დააგრეგატებული ნაყოფდამჭერი მოწყობილობის კონსტრუქციები. სტატიაში განხილულია აღნიშნული სამანქანო

ტექნოლოგიების უპირატესობა, ხეხილოვან ბაღებში მოსავლის ამღებ, უკვე არსებულ სამანქანო ტექნოლოგიებთან. ასევე განხილულია ნაყოფდამჭერი მოწყობილობის სამუშაო ორგანოების თეორიული საფუძვლები.

საკვანძო სიტყვები: *დარტყმითი რხევები, ვიბრაციული, შტამბი, სფერული სხეული, დრეკადობის მოდული.*