Bulgarian Journal of Agricultural Science, 28 (No 5) 2022, 804–809

Method and technical means for picking oil-bearing roses

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Abstract

Bozhkov, S. (2022). Method and technical means for picking oil-bearing roses. *Bulg. J. Agric. Sci., 28 (5)*, 804–809

Harvesting flowers from oil-bearing rose plantations has been done by hand for centuries.

A method for mechanized picking of oil-bearing roses, based on a scheme for detachment of the flowers from the bush as a result of pneumatic suction with mechanical cutting of the peduncle under the ovary, is defined in the article. The design parameters of the technical means for application of the method are specified. As a result of a theoretical and experimental study, values were obtained for the air flow rate (80 – 100 m^3/h) and for the pressure below the atmospheric pressure, providing suction force (115 – 185 Pa), which allow mechanized execution of the technological operation "picking", regardless of how the vacuum is created in the technical means.

Keywords: oil-bearing rose; picking; method; technical means, air flow, parameters, test.

Introduction

Harvesting rose flowers is the final, most labor-intensive, but also the most delicate stage of the technological process in the cultivation of oil-bearing rose. The flowering of the rose bush is gradual, non-simultaneous, which requires daily harvesting of the flower for twenty or more days. The picking begins in the first minutes of the visible part of the day. It takes place in conditions of increased humidity from the fallen morning dew or from the rain typical for the period (mid-May – mid-June). Permanent contact with the thorns on the rose stems and insect stings accompany the work of the rose pickers (Nedkov et al., 2005; Doncheva, 2020). According to the established practice in rose production, the flowers are picked off whole, under the ovary, immediately after opening. In the morning it is permissible to pick flowers with 2-3 open petals, which subsequently bloom in the gathered, warmed flowers (Atanasova and Nedkov, 2004). Overblown flowers and faded petals should not be picked, as they contain a small amount of poor quality essential oil.

Although the beginning of the cultivation of the oil-bearing rose is centuries away from our time, its flowers are still picked by hand. The opinion of experts in the construction of agricultural machinery is that full automation of the harvesting process in rose production is possible, but it is economically unprofitable. The complexity of mechanizing the technological operation is related to the requirement of keeping the way of detachment of the flower from the oil-bearing plant and to the need to apply a differentiated approach to picking the rose flowers.

Research on the creation of technical means for mechanization of flower harvesting from oil-bearing rose plantations has been conducted at the Nikola Pushkarov Institute of Soil Science, Agrotechnologies and Plant Protection in Sofia for years. One-module and three-module variants of a farm implement for manual picking of roses have been developed. Their functional suitability has been proven in operational tests (Bozhkov et al., 2015; Bozhkov et al., 2017). In parallel, the first field experiments were carried out, in which the possibility of detachment of the flowers from the oil-bearing rose plant with the help of vacuum was tested and some design parameters of a pneumatic picking off system for its implementation were determined (Stanchev and Bozhkov, 2016). Research on pneumatic picking of roses continues with the use of compressed air for realization of the technological operation (Bozhkov, 2021).

The aim of the present study is to define a method for mechanized picking of oil-bearing roses, to specify design parameters and to determine the operational indicators of a technical means for its application.

Materials and Methods

The research on mechanization of oil-bearing rose picking combines theoretical studies with experimental tests.

The success, albeit partial, that was achieved during field tests at the detachment of rose flowers (using the edge of the suction hole as a support) led research to developing a method for mechanized picking of oil-bearing roses. The basis of the method is a scheme for detachment of the flower from the bush as a result of pneumatic suction and mechanical cutting. Conceptual design of a scheme for pneumo-mechanical detachment of the flowers from the rose plant, combining the potentials of the vacuum to "pull" and tilt the flower to the suction hole and the mechanical cutting to cut the flower peduncle under the ovary in contact with the sharp edge of the hole, is shown in Fig.1.

The method of mechanized picking of oil-bearing roses provides an opportunity for remote detachment of only the flowers that are subject to harvesting. The technical means for applying the method is designed to allow the detachment of flowers from rose bushes at any attempt, without or with minimal effort applied by the picker, without sucking the nearby buds and leaves and without unacceptable damage to the detached flowers when carrying them to the place for temporary storage.

The research on a method and technical means for mechanized picking of oil-bearing roses was carried out in two stages. For the first stage, aimed at refining the design parameters,

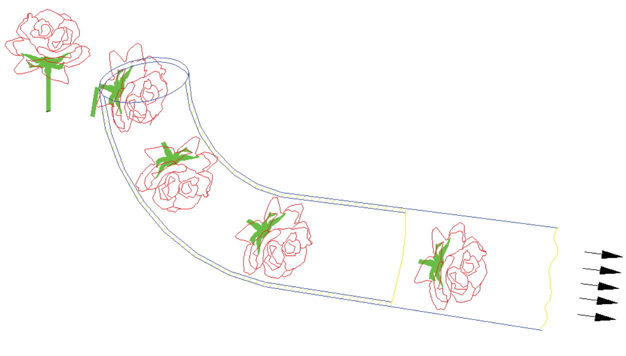

Figure 1. Principle scheme for pneumo-mechanical detachment of the flowers from the rose plant

a prototype (an experimental model) of a technical means using compressed air for realizing pneumo-mechanical picking of rose flowers was completed – the prototype of the earlier tests (Stanchev and Bozhkov, 2016) uses a vacuum created by a vacuum module. The prototype consists of: a receiving part with a cutting element located near the suction hole; middle part with dimensions allowing remote detachment of the rose flowers; flexible lead-out part for taking the detached flowers to the place of their collection; pneumatic fittings for connection to the source, providing the necessary conditions for detachment of the flowers and bringing them out of the prototype. One of its design differences compared to the prototype used in the first tests is the presence of a narrowing and widening of the cross-sectional size along its length. The aim is to create an organization of the movement of compressed air used as a driving agent, in which to provide underpressure in the receiving part of the prototype and absolute pressure at its outlet, higher than that at the inlet. Values are expected that are sufficient for the rose flower to be sucked in at the inlet, moved inside and taken out through the outlet of the technical means.

The dimensions of the elements used in the assembly of the prototype were determined as optimal in the earlier studies (Stanchev and Bozhkov, 2016; Bozhkov, 2021), as a result of which:

- the receiving part is made in an arcuate shape with an arc angle of 75° and a diameter of the suction hole Ø 46 mm;
- the cutting element is located on the periphery of the edge of the suction hole;
- the middle part is made with a length of 420 mm and a diameter of the cross section Ø 36 mm;
- the lead-out part is made of a flexible tube with an inner diameter of Ø 50 mm.

With the prototype of the technical means (hereinafter referred to as the „detachable module"), the dimensions of the structural elements were specified in laboratory conditions and the functional suitability of the two-component scheme for detachment of the flowers was checked. The test bench, in the complete set of which the detachable module was tested, is presented in fig. 3.

The second stage of the research is dedicated to determining the operating parameters of a technical means for mechanization of picking oil-bearing roses. Assuming that the issue of ensuring mechanical cutting of the rose peduncle under the ovary has been resolved, research has focused on the other element of the pneumo-mechanical scheme for detachment of the flower from the bush – the pneumatic component. To ensure the functionality and efficiency of the detachable module, the requirement for the parameters characterizing its operation is to allow not only suction of the flowers inside the receiving part, but also their transfer to the collection point after cutting. This directs the research towards determining the parameters of the working environment at the input and output of the module.

The parameters of basic importance for the operation of the detachable module are the pressure and the flow rate of the air passing through the suction and outlet holes. The determination of the values of the two parameters that would ensure the functionality of the detachable module was performed on the basis of theoretical dependences on „Fluid Mechanics“ (Guzhgulov and Petrov, 1992; White, 2011; Munson et al., 2006) and on the results of experimental tests.

The flow rate of the air providing the necessary conditions for the operation of the detachable module is calculated on the basis of the flow continuity equation (Pipko, 1992; Umrath, 1998; Yoshimura, 2008). For pipelines with a circular cross-section, the air flow rate in the i^{th} cross-section of the detachable module (Q_i) is calculated by the formula:

$$Q_i = V_i . S_i = V_i . \frac{\pi . D_i^2}{4}, \qquad (1)$$

where: S_i is the area of the i^{th} cross-section of the detachable module, m^2;

V_i – the speed of the air flow in the i^{th} cross-section of the detachable module, m/s;

D_i – the diameter of the i^{th} cross-section of the detachable module, m.

It is known from “Fluid Mechanics” that the energy balance along a streamline can be represented by the Bernoulli equation, known as the „Bernoulli integral for potential established flows of an ideal incompressible fluid“ (Antonov et al., 2010; Yurieva, 2012; Alexander, 2017). With an error permissible for practice, the detachable module, the area with the rose flowers in front of it and the area with the container for collecting the detached flowers behind it can be considered as lying in one plane, and as such in theoretical research can be considered as elements of a streamline. Assuming that the changes in height are insignificant, the gravitational member in Bernoulli‘s equation can be ignored. For the points of the sections in the area with the rose flowers “1-1”, at the input “2-2”, in the narrowest part “3-3” and at the output “4-4” of the detachment module from the streamline of fig.2 the general form of the equation will be the following:

$$\frac{\rho . V_1^2}{2} + p_1 = \frac{\rho . V_2^2}{2} + p_2 = \frac{\rho . V_3^2}{2} + p_3 = \frac{\rho . V_4^2}{2} + p_4, \qquad (2)$$

where: ρ is the density of air, kg/m^3. Its value varies depending on temperature, atmospheric pressure and other factors. In the Rose Valley region (average altitude 380 m) under the usual climatic conditions during the harvest period (air temperature between 10–20°C and atmospheric humidity around and above 60%) the air density changes insignificantly. Based on information available on the Internet[1], its value can be accepted within the limits 1.20 – 1.25 kg/m^3;

V_1 ... V_4 are the air flow speed in the defined in fig. 2 sections, m/s;

p_1 ... p_2 – the values of the air flow pressure in the defined in fig. 2 sections, Pa.

The method and the pneumatic unit for creating an organization of the air flow movement in the internal space of the detachable module are not relevant for the theoretical part of the research and in fig. 2 are not visualized.

The inlet pressure of the detachable module can be determined using the Bernoulli equation for the points of the streamline in the sections “1-1” and “2-2” in fig. 2. Given the fact that the section “1-1” is located far from the suction hole of the detachable module, it follows that $V_1 = 0$ (air is undisturbed) and the pressure is equal to atmospheric (p_a), i.e. $p_1 = p_a$.

The equation for calculating p_2 takes the following form:

$$p_2 = p_a - \frac{\rho . V_2^2}{2} . \qquad (3)$$

The second member of equation (3) shows the decrease in pressure below atmospheric and can be taken as an indicator assessing the potential of the detachable module to realize the first phase (pneumatic suction) of the two-component pneumo-mechanical scheme for detachment of the flowers from the rose plant.

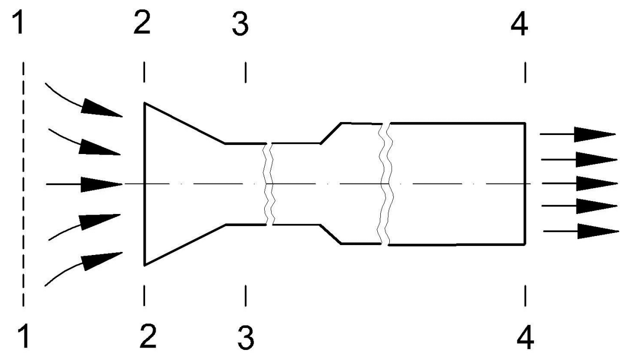

Figure 2. Scheme of a detachable module for determining the parameters of the working environment, ensuring its functionality

[1] https://optima-inv.ru/bg/vodoprovodnye/air-density-as-a-function-of-temperature-dependence-of-fluid-gas-and-porous-media-on-pressure/

The air flow pressure in the area with the smallest cross-sectional diameter along the detachable module (p_3) can be calculated using a dependence derived from the Bernoulli equation for the points of the streamline in the section "2-2" and the section "3-3". The speed of the air flow in the section "3-3" is derived by the formula for continuity of flow (1):

$$V_3 = \frac{4.Q}{\pi.D_3^2} \quad . \tag{4}$$

In the equation for the points of the streamline in the sections "2-2" and "3-3", replacing p_2 with the expression from equation (3) and V_3 with the expression from equation (4), for the air flow pressure in the narrowest zone of the detachable module is obtained:

$$p_3 = p_a - \frac{8.\rho}{\pi^2.D_3^4}.Q^2 \quad . \tag{5}$$

The information about the pressure p_3 and the air flow speed V_3 reveals what is happening inside the detachable module and can be used to optimize its design parameters in order to increase its efficiency during operation.

The dependence for calculating the air flow pressure at the outlet of the detachable module (p_4) is derived by applying the Bernoulli equation for two points on one streamline with respect to the sections „3-3" and „4-4":

$$p_4 = p_3 + \frac{\rho}{2} \, . \, (V_3^2 - V_4^2) \quad . \tag{6}$$

The value for p_4 is a reference for the fulfillment of the conditions for efficient operation of the detachable module. It must be higher than that at the inlet of the detachable module to allow the detached flowers to be carried away, and at the same time not too high so as not to damage them inadmissibly.

The formulas presented above show that to calculate the parameters characterizing the operating environment of the input and output of the detachable module, in addition to the values D_i, ρ, p_a (which can be considered constant for a particular case) it is enough to know the speed of the air flow at the inlet (V_2) and the outlet (V_4) of the module. The values of the two speeds, which will guarantee the functionality of the detachable module, were determined experimentally in laboratory conditions. For this purpose, a test bench (Fig. 3) is made, in which the vacuum is created inside the detachable module (3) by compressed air supplied by a pneumatic compressor (1).

The compressed air is released with a shut-off pneumatic device (4) equipped with a manometer (5). A portable anemometer (2) brand ALMEMO 2390-3 of the company AHLBORN (Belgium) with a measurement accuracy of 0.01 m/s was used to measure the air flow speed. The air flow speed is measured along the axis of the inlet and outlet holes of the detachable module (3) at different (after stabilization) pressure of the compressed air passing through the shut-off pneumatic device (4). Branches with rose flowers are served in front of the suction hole and the values of the air flow speed are fixed, at which the flower not only is sucked and directed inside the detachable module, but also allow it to be taken out of the module.

In order to recreate the working conditions of the real practice, the elements of the prototype are located in positions as identical as possible to the real ones. The experiments were performed by seven-fold repetition. The results of the measurements are registered in tabular form.

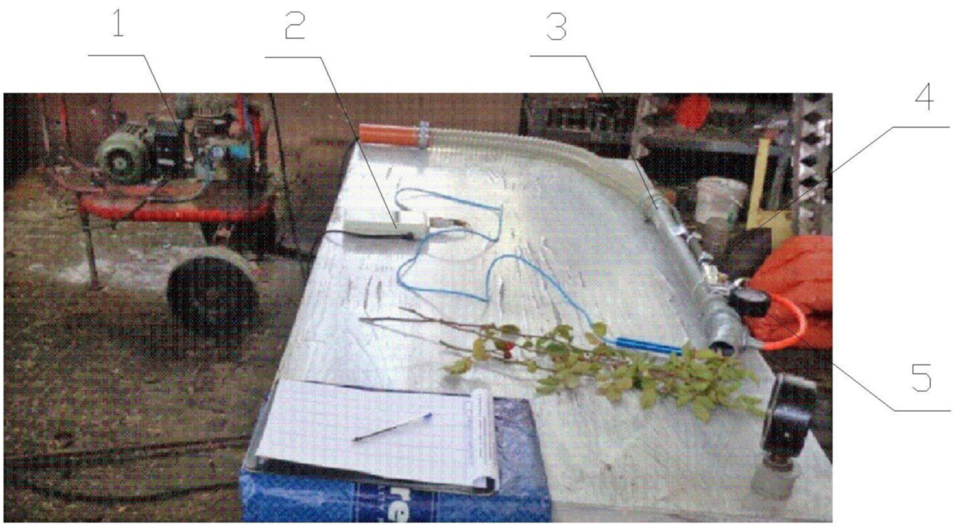

Figure 3. General view of a test bench for a pneumo-mechanical picking of oil-bearing roses 1 – pneumatic compressor; 2 – anemometer; 3 – detachable module; 4 – shut-off pneumatic device; 5 – manometer.

The determination of the values of the parameters of the working environment in the detachable module (flow rate and pressure of the air flow), which provide conditions for realization of the harvesting operation, is performed with the above dependences and the data obtained during the tests for the air flow speed at the inlet and outlet of the module. The analysis of the results seeks a balance between the two factors. Values which allow the rose flowers to be sucked into the detachable module and carried away after cutting to the collection point without unacceptable injury are considered appropriate.

Results and Discussion

Defining a method for mechanized picking of oil-bearing roses

Laboratory tests have shown that the pneumo-mechanical detachment scheme, combining the potentials of the vacuum to tilt the flower to the suction hole of the detachable module and the mechanical cutting to cut the rose peduncle under the ovary in contact with the sharp edge of the hole is functionally suitable. This gives grounds for defining a method for mechanizing the picking of oil-bearing roses, based on the two-component scheme as follows:

PNEUMO-MECHANICAL METHOD FOR MECHANIZED PICKING OF OIL-BEARING ROSES – *a method for mechanizing the picking of flowers in oil-bearing rose plantations, in which the rose flower is detached from the bush by pneumatic suction and mechanical cutting of the peduncle under the ovary and is carried by air flow to the place of its temporary storage.*

The expectations from the application of the method are to ensure quality realization of the harvesting operation, under improved working conditions and with increased productivity.

Parameters of a technical means for mechanized picking of oil-bearing roses

To determine the operating parameters of the detachable module, created on the basis of the pneumo-mechanical method, the speeds of the air flow at the inlet and outlet holes of the module at different pressure of the compressed air supplied to it were measured. The average test results are presented in Table 1.

When evaluating the functionality of the detachable module based on the speed of air flow, it is logical to use its value at the output of the module. In practice, the flow rate specified in the technical characteristics of pneumatic compressors, vacuum pumps, etc. pneumatic power supplies, refers to the air flow passing through their suction port. Pneumatic equipment dealers recommend that when choosing a source of this type, it should have about 30% more capacity.

The analysis of the results of Table 1 show the reduction between 29-34% of the speed of the air flow as it passes through the detachment module. Taking into account the recommendations from practice, for the needs of the analysis the results for the air flow speed, measured at the inlet of the detachable module, were used.

The tests performed showed that at speeds below 10 m/s the air flow is weak or insufficiently stable for the realization of pneumo-mechanical detachment of the flower from the rose plant, which confirmed the conclusion made in an earlier study (Bozhkov, 2021). The results obtained in the tests in the present research also confirmed the conclusion from the earlier study that performing the harvesting operation would provide an airflow speed between 13.75 – 17.4 m/s. This gives grounds to recommend the specified range of values for the airflow speed for use in the forthcoming calculations.

With the help of the derived dependences and the airflow speeds from the recommended operating interval, the values of the parameters of the working environment in the detachment module (flow rate and pressure of the air flow), which

Table 1. Results of the tests for determining the air flow speed at the inlet and outlet holes of the detachable module

Pressure of the compressed air, MPa . 10^{-1}			Air flow speeds at the inlet (V_2) and outlet (V_4) of the detachable module, m/s		Reduction of the speed of the air flow, %
from the compressor	in the shut-off pneumatic device				
	initial	stabilized	V_2	V_4	$(V_2-V_4)/V_2 . 100$
8	2.5	1.85	21.77	14.82	31.9
7	2.3	1.7	17.82	11.88	33.3
6	2.1	1.2	15.26	10.05	34.1
5	1.8	0.8	12.24	8.69	29.0
4	1.4	0.5	9.72	6.59	32.2
3	1	0.35	7.42	4.98	32.9
2	0.5	0.2	5.24	3.7	29.4
1	0.2	0.1	3.34	2.36	29.3

would provide conditions for flowers detachment and carrying to the place for their temporary storage, were calculated. For the version of the detachable module with a suction hole diameter of Ø46, a diameter in the narrowest cross-section of Ø36 and an inner diameter of the lead-out part Ø50, the air flow rate varies in the range of 80 – 100 m^3/h. The value by which the pressure of the inlet hole of the detachable module must be lowered below the atmospheric one in order to provide the necessary conditions for drawing the flowers to the inside of the module is in the range 115 – 185 Pa. The low suction values indicate that the determining factor for the realization of the rose flower detachment is not the force of the vacuum, but the flow rate of the air, ensuring the movement of the flowers through the module. The established fact is important in the selection of a pneumatic unit to create the necessary vacuum in the detachable module. Although determined for a specific design, the values calculated in the research are a guide good enough to find the right variant by looking for a balance between pressure and flow rate of the driving agent – the two main indicators characterizing the work of technical means for mechanized picking of oil-bearing roses.

Conclusions

The lack of technical means for picking an oil-bearing rose in modern rose production proves the complexity of mechanizing the most labor-intensive activity in its cultivation.

According to the results of the research, a method for mechanized picking of oil-bearing roses is defined, based on a scheme for detachment of the flower from the bush, combining pneumatic suction of the flower with mechanical cutting of its peduncle under the ovary. The technical means developed on its basis includes: an arcuate receiving part with a cutting element located on the periphery of its suction hole; middle part with a length allowing the rose flowers to be picked from a distance; flexible lead-out part for carrying the rose flowers to the place of their collection; pneumatic fittings for connection to the source, providing the necessary conditions for detachment of the flowers and bringing them out of technical means. The diameter of the inner section of each of its elements is consistent with their functional purpose and the requirement for free passage of flowers from the inlet to the outlet of the technical means.

The values obtained as a result of the theoretical and experimental study for the flow rate (80 – 100 m^3/h) and for the pressure below the atmospheric, providing suction force (115 – 185 Pa), allow mechanized execution of the technological operation "picking", regardless of the used way to create a vacuum in the technical means for detachment of the flowers from rose plant.

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Received:March,**25 2021**; *Accepted***: June, 25, 2021**; *Published*: **October, 2022**