MECHANISED HARVESTING OF INFLORESCENCES OF MEDICINAL AND AROMATIC PLANT SPECIES CULTIVATED ON A SMALL SCALE
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RECOLTAREA MECANIZATĂ A INFLORESCENȚELOR UNOR SPECII DE PLANTE MEDICINALE ȘI AROMATICE CULTIVATE LA SCARĂ REDUSĂ

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ABSTRACT
The quality of plant material obtained from cultivated medicinal and aromatic plants depends on several important factors, including harvesting, which must be carried out according to the requirements of each cultivation technology. Current producers, especially those who grow these species on small and medium-sized areas, face the high price of labour or its acute shortage, as well as limited access to specialized equipment. The paper provides a brief summary of current concerns about mechanised harvesting of inflorescences of medicinal species cultivated on a small-scale, with mechanisation generally being a guarantee of economic efficiency and quality.

REZUMAT
Calitatea materialului vegetal obținut din plantele medicinale si aromatice cultivate depinde de mai mulți factori importanți, printre care și recoltarea, ce trebuie efectuată conform cerințelor fiecărei tehnologii de cultură. Producătorii actuali, mai ales cei care cultivă aceste specii pe suprafețe mici și medii, se confruntă cu prețul ridicat al forței de munca sau cu lipsa acută a acesteia, precum și cu accesul limitat la utilajele specializate. Lucrarea prezintă o scurtă sinteză a preocupărilor actuale privind recoltarea mecanizată a inflorescențelor unor specii medicinale, cultivate la scară redusă, mecanizarea constituind în general o garanție în ce privește eficiența economică și calitatea.

INTRODUCTION
In the current conditions, of strong economic transformations, many generated by the pandemic, there has been an increase in the demand for medicinal plants worldwide *(Mirzoieva et al., 2021)*. Although the use of medicinal plants has a millennial tradition, they remain very important to 85% of the world's population, who use them as a first aid method in treating diseases. After processing, they can be raw material for the pharmaceutical industry, their bioactive principles being the basis for many drugs *(Fitzgerald et al., 2020; Salmerón-Manzano et al., 2020*). In addition, medicinal plants are also used for the production of teas, extracts, tinctures, food supplements, natural colours. They are also often used in the food industry, varnishes and paints, cosmetics, as well as for the ecological restoration of paintings *(Stan et al., 2018)*. Medicinal plants are increasingly being studied for veterinary use, being used in the daily diet of poultry and pigs, as growth promoters or as natural additives, in the form of powders, essential oils or in many other homogenized forms. (*Puvača et al., 2021; Oanh et al., 2021*).

Although cultivated medicinal plants are considered less effective than those derived from spontaneous flora, their cultivation is practiced all over the world. This method has several advantages because: it offers the possibility to use known, studied and improved species and varieties, with a high content of bioactive and productive substances; it allows the application of specific cultivation practices, which can ensure high and stable yields in terms of compounds; it supports the protection of natural sources of medicinal plants, the exploitation of which must be done sustainably; this method implicitly contributes to the protection of the environment; it favours the establishment of a reasonable level of the cost price of these products in the profile markets, etc. *(Chen et al., 2016; Moafa, 2020)*.

The cultivation of medicinal plants is considered in many countries a profitable niche for farmers, especially for those who grow them on small areas, possibly in an ecological system. In other countries, commercial cultivation and conservation of these species are addressed together. International experience shows that in order to encourage the cultivation of these species, efficient agricultural policies are needed, which could support potential producers, through their instruments *(Jeelani et al., 2018; Salamon et al., 2018; Nwafor et al., 2021; Mirzoieva et al., 2021).*

For the production of medicinal and aromatic plant crops, specialized knowledge is needed, possibilities for mechanisation of works, as well as for the capitalization of the plant material obtained, in conditions of quality and safety *(Ivanovic et al., 2014)*. In addition to the species, variety/population, environmental factors, the quality of the plant material obtained from medicinal plants depends to a large extent on the harvesting conditions and the post-harvesting condition *(Kiani et al., 2018; Segneanu et al., 2021)*.

The active compounds in medicinal plants are concentrated in certain organs or parts of them, only them being collected. It is therefore important that the harvesting operation be carried out in a short time, when the concentration of active principles is at its maximum *(Bai et al., 2020; Yeşil et al., 2021)*.

For collecting, each useful part is characterized by a certain method of harvesting, using: digging/displacing systems for the underground parts, cutting systems for the stem with leaves and possibly flowers, combing or cutting systems for inflorescences, etc. Thus, the harvesting equipment is classified according to the collecting method *(Martinov et al., 2007)*. There are many concerns worldwide about the equipment for harvesting medicinal plants, on small areas, because the technology of cultivation is also adopted according to the available mechanical means, the use of which offers the guarantee of profitable productions *(Mašán et al. 2016; Niemiec et al., 2018; Comparetti et al. 2022)*.

The paper presents a brief summary of the current state of research and achievements on harvesting equipment for some species of small-scale cultivated medicinal plants, from which the flowers or parts thereof (petals) are harvested.

MATERIALS AND METHODS

Chamomile *(Matricaria recutita* L.*)* is one of the most well-known medicinal plants, due to its calming, carminative, etc. properties, being widely used both as a natural remedy, but also in the cosmetics industry. From this species, the flower is harvested with a petiole as short as possible (max. 30 mm, for extra quality) *(Aćimović et al., 2021).* This medicinal plant is cultivated on important areas in many countries around the world, including Egypt, the crops being mostly organic *(Abbas et al., 2018)*.

Due to the characteristics of this species, the harvesting system used has a major effect on the productivity and quality of the collected plant material. Manual harvesting guarantees compliance with the quality conditions for the harvested flowers, but the productivity is 3-5 kg/day for an experienced picker. In the case of using some auxiliary tools (toothed metal dust pan type), the productivity can reach 10-15 kg/day *(Zimmer and Müller, 2004).* For the mechanized harvesting of chamomile, comb-type tools are mainly used, which can move linearly, with the additional cutting of the stems, or can have a circular movement, in the forward direction of the machine or in the opposite direction *(Martinov and Konstantinovic, 2007)*. Based on previous international experience regarding high-capacity chamomile harvesting machines (trailed or self-propelled) and taking into account the specific requirements for equipment intended for small areas, Egyptian researchers have designed an experimental model of small-capacity, portable and easy-to-manoeuvre chamomile harvesting equipment (Fig.1).

The principle of operation, shown in Figure 2, is based on cutting the stem of each inflorescence at a distance from the flower head. The combing system *(7)* whose fixed fingers are made of steel wire with a diameter and spacing of 4 mm, respectively, selects the Chamomile flowers *(1)* to direct them to the cutting device *(6)*. The cleaning drum *(3)* also participates in supporting the inflorescences to cut their petiole, as well as in directing them to the collecting box *(8)*.

The drum consists of 3 adjustable arms *(5)* equipped at the ends with brushes (brushes), fixed on its central axis. It rotates in the bearing housings fixed to the machine frame, being driven by a 12V electric motor, powered by a rechargeable battery. The frame is made of aluminium profiles, and the collecting box and the support handles right/left are made of plastic, so that the mass of the equipment is as small as possible (approx. 12 kg). The cutting device is located at an adjustable distance under the fingers of the combing system. It is of the double-knife type, with a cutting width of 0.70 m and is driven by a heat engine, with a power of 0.75kW, 1-cylinder, 2-stroke, air cooled *(Radwan et al., 2015).*

Fig. 1 – Chamomile harvesting equipment
(Radwan et al., 2015)

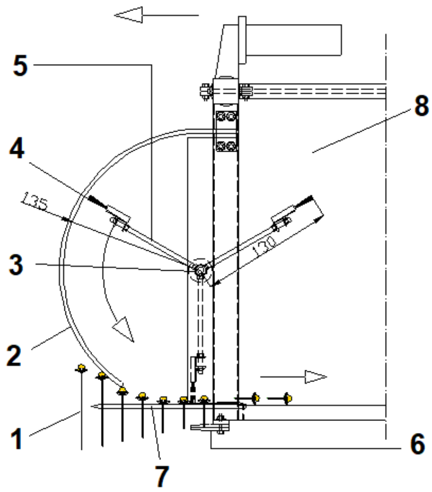


Fig. 2 – Operating principle scheme
(Radwan et al., 2015)

To evaluate the results obtained when testing the chamomile harvesting equipment on small areas, the weight-based procedure was used, according to *Beier and Ehlert (2014)*. The experimental plots had an area of 0.7m^2 (1 m long x 0.7 m working width). For each experiment, 5 plots and three checkpoints were used. The inflorescences on the control plot were hand-harvested, as well as those that fell on the ground or that were not harvested. Flower samples were compared by weighing, at the same water content. To determine the quality of the plant material, samples weighing 200 g were used *(Radwan et al., 2015).*

Marigold *(Calendula officinalis* L.*)* are one of the most common species of medicinal plants used in traditional medicine in China, India, Europe, USA, due to their immunostimulatory, antiseptic, spasmogenic, hepatoprotective properties, etc. *(Jan et al., 2017; Ak et al., 2021)*. From this species, the yellow/orange inflorescence with a peduncle of max 2 cm is harvested, for quality I. This species is also widely used and cultivated in Egypt, where a model of a Marigold harvester was designed (Fig. 3), intended to collect the flower heads of these plants, cultivated on small areas. Figure 4 shows the operating principle scheme of the equipment consisting of the Marigold inflorescence cutting system *(1)* and the collecting system, which includes: flexible tube *(2)*, blower *(3)*, heat engine *(4)*, Venturi tube *(5)* and collecting basket *(6)*. The blower generates an air stream of high pressure and speed. The vacuum effect is created by the Venturi effect, generated by using a tube of a special construction. The blower is driven by a heat engine of 5 HP power, being positioned together with the collecting basket in the backpack worn by the user. The mass of the whole equipment is approx. 12.2 kg *(Mohamed et al., 2020)*.

Fig. 3 - Marigold harvester
(*Mohamed et al., 2020*)

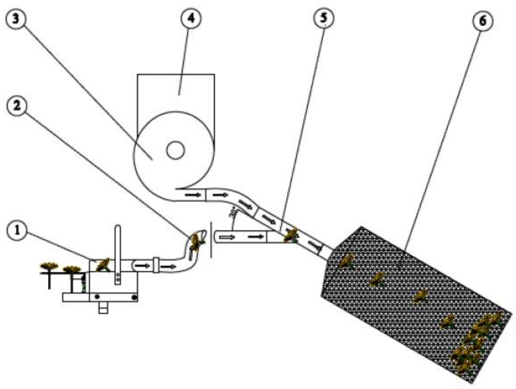


Fig. 4 - Operating principle scheme
(*Mohamed et al., 2020*)

The cutting system (Fig. 5) consists of: cutting device *(1)*, frame *(2)*, comb *(3)*, comb frame *(4)*, diverters *(5)*, handle *(6)*, pipe *(7)*, flexible hose *(8)*. The cutting device (Fig.6) consists of: frame *(1)*, cutting disc *(2)*, articulated plate *(3)*, butterfly nut *(4)*, plastic housing *(5)*, driven belt wheel *(6)*, disc holder *(7)*, safety coupling *(8)*, locking nut *(9)*, locking bolt *(10)*, bearing *(11)*, drive belt wheel *(12)*, adjusting plate *(13)*, adjusting washers *(14)*, direct current electric motor *(15)*, toothed V-belt *(16)*, cutting disc adjustment system *(17)*. The two systems, namely the cutting and the collecting one, are synchronized, so that the combing fingers select the plants, then the cutting discs cut the stem to the right length, and the airflow under pressure sucks the inflorescences thus detached, directing them to the basket *(Mohamed et al., 2020)*.

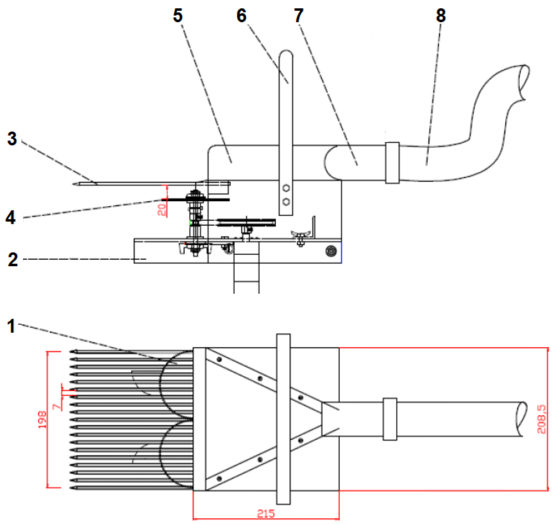


Fig. 5 - Cutting system
(*Mohamed et al., 2020*)

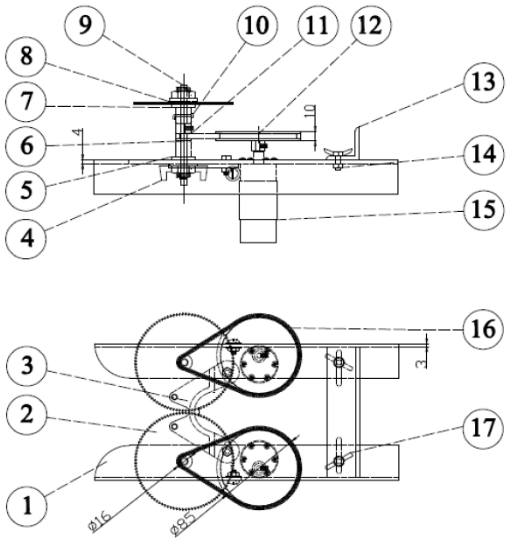


Fig. 6 - Cutting device
(*Mohamed et al., 2020*)

The same procedure, based on weight, was used for the evaluation of the results obtained when testing the equipment for harvesting marigolds cultivated on small areas, as in the case of the equipment for harvesting chamomile on small areas. Each experiment was carried out in 5 repetitions, each plot having the length of 1 m, and the width including 3 rows, at 0.5 m row spacing. The control plot, as well as the flower heads that fell on the ground or those not picked from a certain height, were collected manually. Samples with a mass of 200 g, having the same humidity, were evaluated (*Mohamed T.H. et al., 2020*).

Safflower (*Carthamus tinctorius* L.) is a medicinal plant used for hundreds of years in traditional medicine, especially in Egypt, Iran and China. The plant also has multiple uses: in the food and dye industries, as biodiesel, as viable agricultural alternative to climate change, etc. From this species, the flower petals or seeds are harvested, depending on the uses *(Delslad et al., 2018; Akgün, & Söylemez, 2022).*

Thus, in Iran, for the mechanisation of the petal harvesting operation, a prototype equipment was designed (Fig.7), consisting of: motor *(1)*, fan *(2)*, suction system *(3)*, diffuser *(4)*, storage enclosure *(5)*, mounted on a trolley for easy movement in the crop. The 2-stroke heat engine, powered by gasoline, is designed to drive the fan, with a power of 0.7kW and a maximum speed of 5500 rpm. The 12-blade radial fan is used for suction. Being characterized by a diameter of 0.3 m, a width of 0.06 m, a speed of 4400 rpm and a coefficient of 0.09, it resulted in an airflow of 0.384 $m^3\ s^{-1}$ and a specific speed of 6.157 m s^{-1}, respectively, at a static pressure of 3161 Pa. The suction system consists of a suction head and a flexible tube with an inner diameter of 0.03 m, connected to the diffuser. The airflow speed of 25.55 m s^{-1} was determined for a dynamic pressure of approx. 388.57 Pa, tube temperature of approx. 28^0C, relative humidity of 20.9% and air density of 1.19 kg m^{-3}. The diffuser is an enclosure designed to decrease the dynamic pressure and the speed of the airflow, by increasing the surface, the petals falling into the storage enclosure, by their own weight. The cylindrical diffuser has been dimensioned so that the air speed decreases inside it to approx. 2 m s^{-1}, resulting in a radius of 0.0536 m. The storage compartment, equipped at the bottom with a sealed emptying door, has a volume of 4 litres, determined according to the density of the petals and the performance of the equipment. *(Azimi et al., 2012)*.

In China, in order to improve the efficiency of the Safflower harvesting process, a petal harvesting equipment has been developed, which combines cutting with suction. Its scheme is shown in Figure 8, consisting of: fan/exhauster *(1)*, filtration system *(2)*, collecting chamber *(3)*, air tunnel *(4)*, engine *(5)*, planetary gear *(6)*, positioning mouth of safflower heads *(7)*, cutting system *(8)*, housing *(9)*, handle *(10) (Ge et al., 2016).*

During operation of the equipment, the fan/exhauster generates an airflow during the harvesting process. The petals in the corolla of the Safflower flowers reach an upright position, due to the suction pressure, being detached from the cutting head, executed by the cutting system, driven from the engine by the planetary gear. The petals are then sucked through the air tunnel to the collecting chamber, where the airflow relaxes and the petals fall to the bottom. *(Ge et al., 2016).*

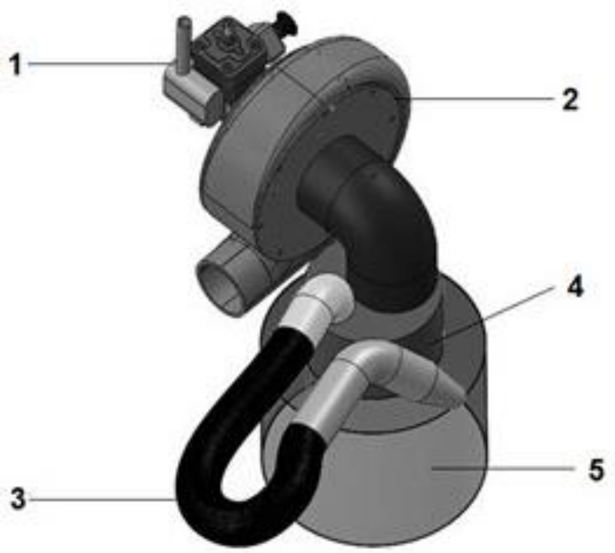


Fig. 7 – Safflower petal harvester machine (*Azimi et al., 2012*)

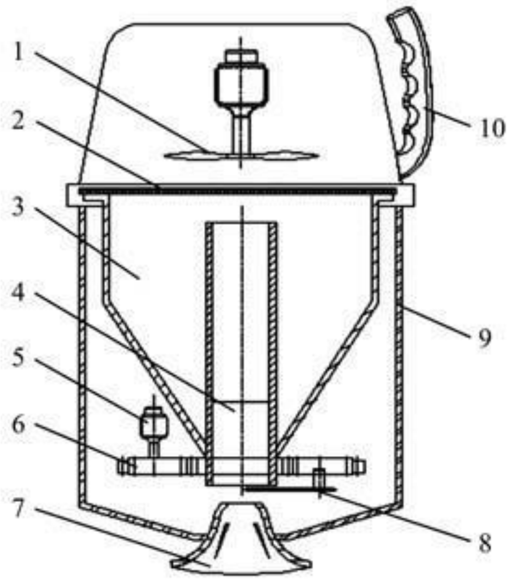


Fig. 8 – Scheme of Safflower petal harvesting device *(Ge et al., 2016)*

Also in China, for the automatic and intelligent realization of the Safflower harvesting operation, as well as for the increase of its efficiency and accuracy, a robot destined for this operation was made and tested in the laboratory (Fig. 9). It consists of: electrically operated displacement system *(1)*, frame *(2)*, positioning system *(3)*, control system *(4)*, actuation system *(5)*, suction fan *(6)*, transport hose *(7)*, collecting box *(8)*, wheels *(9)*, harvesting system *(10)*. The elements of the steering and harvesting system (Fig. 10) are: engine plate *(1)*, drive arm *(2)*, driven arm *(3)*, adapter *(4)*, stepper motor *(5)*, CCD camera *(6)*, harvesting device *(7)* *(Gua et al., 2022).*

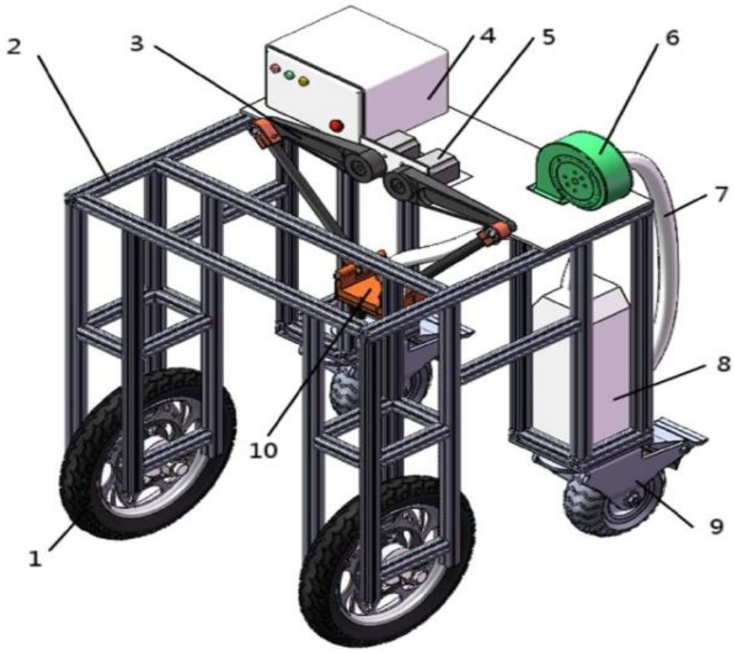


Fig. 9 – Scheme of Safflower harvesting robot
(Gua et al., 2022)

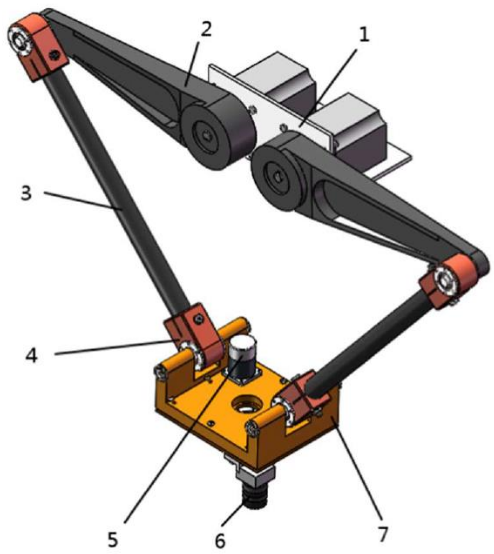


Fig. 10 – Scheme of the positioning device connected to the harvesting system
(Gua et al., 2022)

The machine moves and stops when it reaches the area where the mature Safflower is, to be harvested. A PLC controls the rotation of the motor shaft connected to the active arm of the steering device. Thus, the motor shaft rotates at a certain angle so that the harvesting system moves vertically to the target position. The Safflower enters the picking device through the flower transport hole, and the cutting device (with sliding mechanism - crank) performs the alternative shearing of the petals. Thanks to the fan/exhauster the petals are sucked into the collecting box, passing through the transport hose *(Gua et al., 2022).*

RESULTS

The experimental model of equipment for harvesting chamomile on small areas, made in Egypt, was tested to determine the optimal length of the combing system fingers (l=100,120,150, 200 mm) for different rotation speeds of the drum (50 rpm., 100 rpm, 150 rpm) obtained by varying the speed of the electric motor. After carrying out the tests, the results were compared regarding the classification of the harvested material according to the length of the fingers at different rotation speeds of the drum (Fig. 11). After the analysis, it was found that the most satisfactory results were obtained for fingers with a length of *L=150 mm (Radwan et al., 2015).*

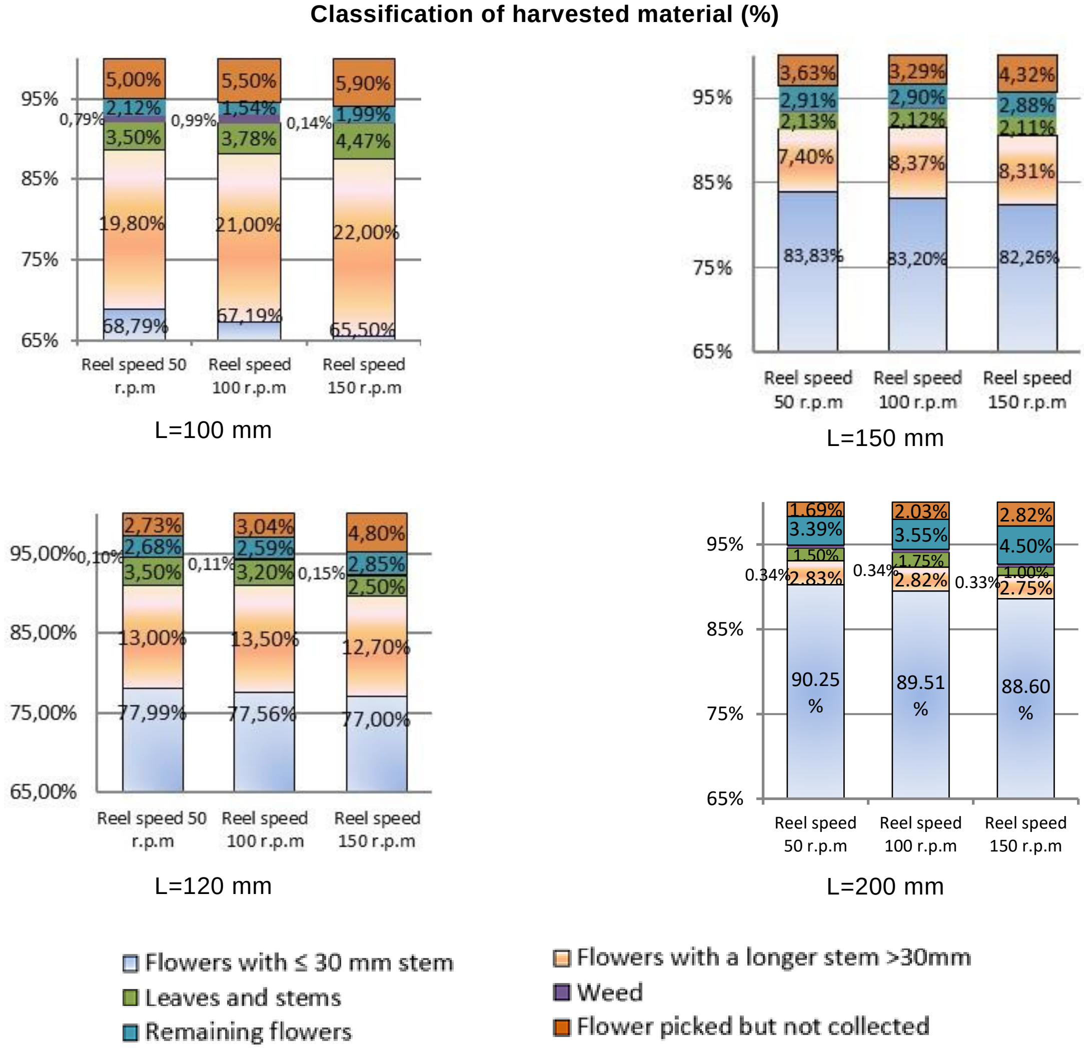


Fig. 11 - Classification of the harvested material according to the rotation speed of the drum, at different lengths of the fingers of the combing system *(Radwan et al., 2015)*

Then, for the fingers with length L=150 mm, the working performance of the equipment was analysed according to the rotation speed of the drum (50 rpm., 100 rpm, 150 rpm) and respectively their angle of inclination to the horizontal, namely: 0^0, 10^0, 20^0 (Fig. 12) *(Radwan et al., 2015).*

For a finger length of 150 mm, inclined at 10^0 and respectively a drum speed of 100 rpm, the best harvesting degree (expressed as a percentage) was obtained in the amount of 92.59%, losses of 7.41%. Of the harvested inflorescences, 85.58% were harvested correctly with a petiole ≤ 30 mm. *(Radwan et al., 2015)*

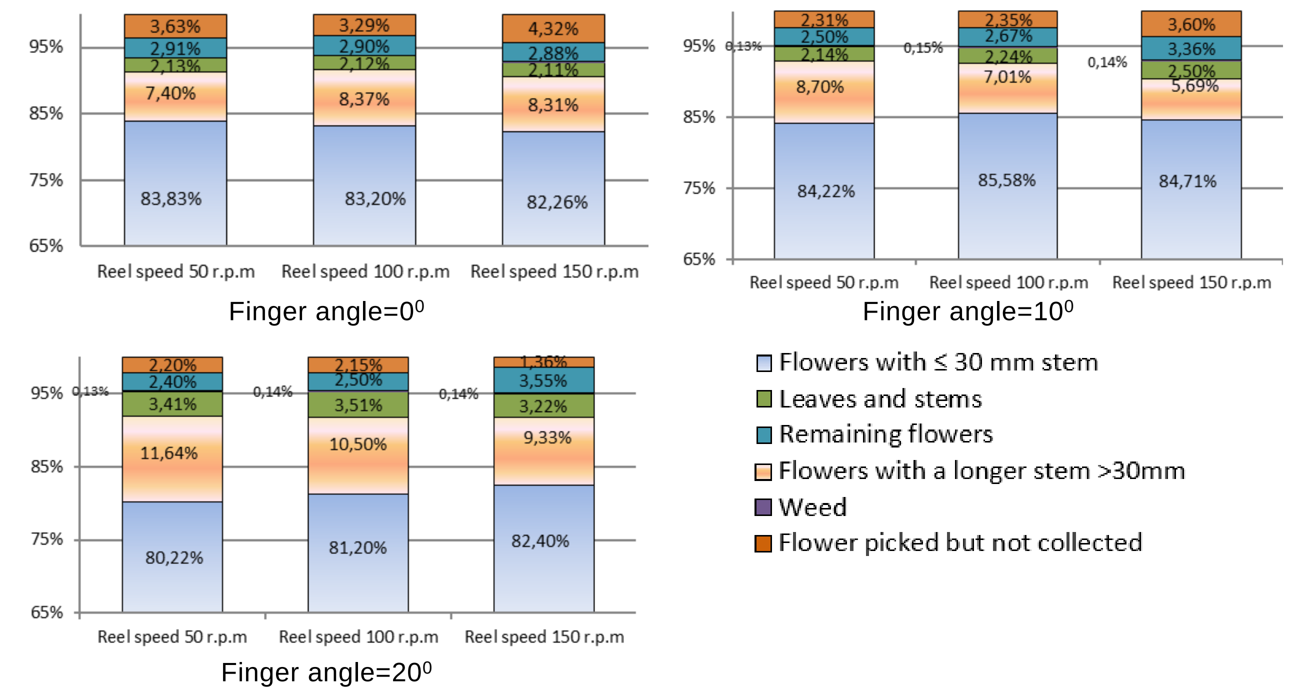


Fig. 12 – Classification of the harvested material obtained for fingers with L=150mm, depending on the rotation speed of the drum and the angle of inclination of the fingers *(Radwan et al, 2015)*

The results obtained during the experiments for the equipment for chamomile harvesting on small areas can be compared with those from the *Colorio's* study from 2011 regarding the prototype *Innovative system for harvesting chamomile*, summarized in Table 1.

Table 1

Prototype collecting efficiency when harvesting chamomile inflorescences
(Colorio 2011)

Units of measur-ement	Effective average production of inflorescences	Harvested flowers	Flowers left on the plant	Flowers picked but not collected	Flowers harvested with a petiole ≤ 30mm	Flowers harvested with a petiole > 30mm
[g/m^2]	258.5	214	32	12.5	151.8	62.2
[%]	100	82.8	12.4	4.8	70.9	29.1

The results in Table 1 demonstrated the efficiency of the *Innovative system for harvesting chamomile*, a high-capacity self-propelled machine. After harvesting with this equipment, the chamomile inflorescences were selected mechanically, approximately 70% being top quality (petiole ≤ 30mm). *(Colorio, 2011)*. Regarding the plant material collected by the KBEM type chamomile harvester, it was uniform, flowers with a petiole >30 mm having a very low weight. Therefore, the first economic evaluations showed that the reduction of harvesting losses below 10% and the elimination of the subsequent selection operation of the collected inflorescences, determine important savings per hectare *(Ehlert, 2014).*

For the experimental model of the equipment for chamomile harvesting on small areas, the harvesting losses were below 10% (7.41%), and from the harvested material approx. 86% was top quality, resulting in over 20-fold cost reduction for 1 kg of machine-harvested dried chamomile compared to hand-harvested one *(Radwan et al., 2015).*

In their paper from 2014, *Ivanovic et al.* underline the fact that the harvesting method greatly influences the profit in the case of a chamomile crop, because manual harvesting and mechanized harvesting generate different costs, but also different incomes.

The experimental model of the Marigold harvester, intended for use on small areas, was first tested to determine the optimal variant of the disc knife between the types: smooth (toothless), with 50 teeth, with 100 teeth, and its most suitable speed of the variants: 2.79 m s^{-1}, 4.17 m s^{-1}, 5.56 m s^{-1}, 6.97 m s^{-1}, 8.34 m s^{-1}, noted with S1…S5.

Thus, the following figures refer to the classification of the harvested material (Fig. 13), as well as to the total picking ratio (Fig. 14) depending on the type of disc used and its speed (*Mohamed et al., 2020*).

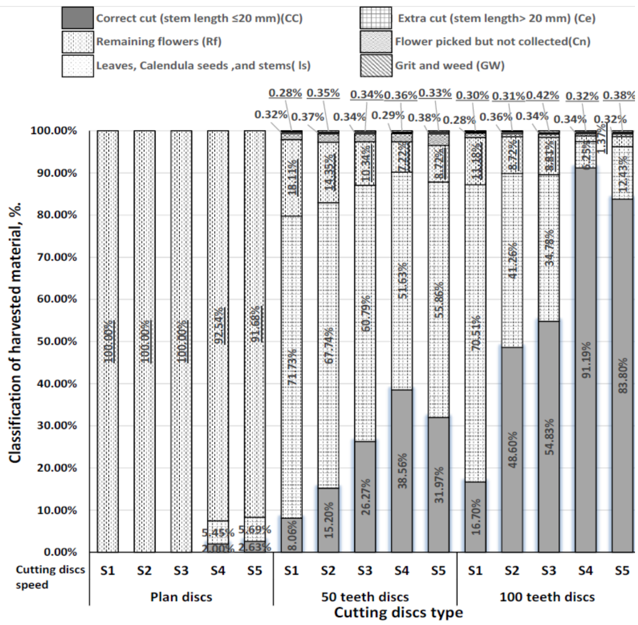


Fig. 13 - Classification of harvested material, depending on disc type and speed
(*Mohamed et al., 2020*).

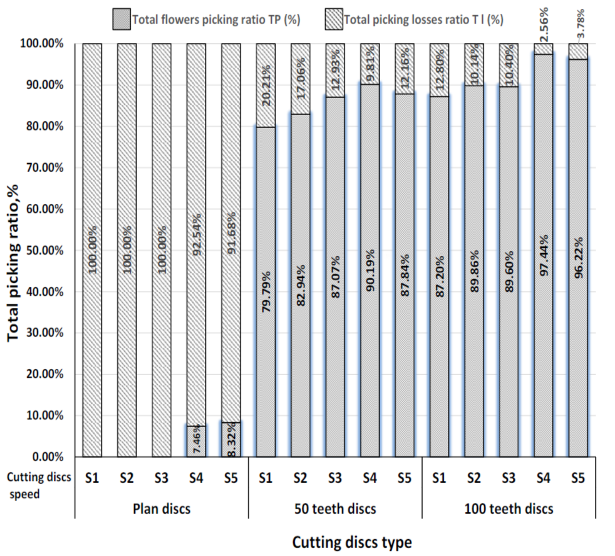


Fig.14 - The total picking ratio, depending on disc type and speed
(*Mohamed et al., 2020*).

Thus, for the disc with 100 teeth and a linear speed of 6.97 m s^{-1} (S4), the highest total harvesting rate of 97.44% and total losses of 3.78% were obtained. Then, for these conditions, the optimal length of the combs was determined between the variants of 125 mm, 150 mm, 175 mm, 200 mm, as well as their optimal angle of inclination to their horizontal, between the variants of: 0^0, 10^0 and 20^0, in order to obtain the highest harvesting degree (picking ratio) for marigold flowers. For this, the harvested material (Fig. 15) and the total picking ratio (Fig. 16) were analysed according to the length of the combs and the angle of inclination (*Mohamed et al., 2020*).

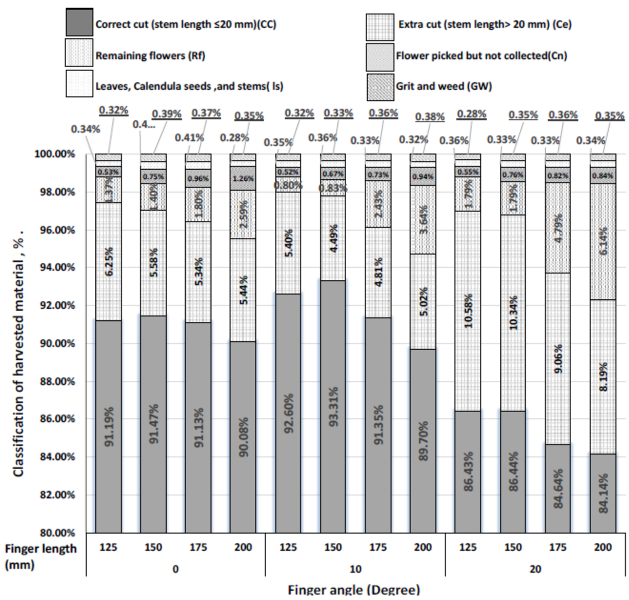


Fig. 15 - Classification of the harvested material, depending on the length of the combs and the angle of inclination
(*Mohamed et al., 2020*).

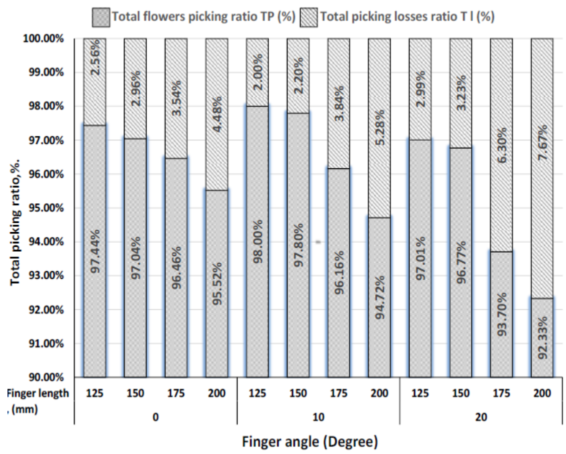


Fig. 16 - The total picking ratio, depending on the length of the combs and the angle of inclination
(*Mohamed et al., 2020*).

The best results were obtained for the discs with 100 teeth, with a linear speed of 6.97 m s^{-1}, at a finger length of 150 mm, inclined to 10^0. Thus, the average percentage of correct cutting of the stem was 93.31% (the biggest), 4.49% additional stem cutting, 0.83% flowers left, 0.67% flowers cut but not harvested, 0.36% leaves and stems, 0.33% weeds, finally obtaining a total harvesting degree of 97.80% and total losses of 2.20% *(Mohamed et al., 2020)*.

The results obtained can be compared with those obtained in the study of *Veselinov B. et al.,* from *2014,* carried out for a trailed equipment used to harvest marigolds. Thus, the flower harvesting degree was approx. 97%, and of the harvested material 65% was top quality (flowers with petiole ≤ 20 mm), the remaining 35% being made up of flowers with stems >2 cm. However, following the mechanized harvesting with trailed equipment, the number of successive harvests and, consequently, the yield, were reduced because of the destruction and elimination of buds *(Veselinov B. et al. 2014)*. For the experimental model of the marigold harvester, intended for small areas, this aspect was not analysed, but thanks to the design and the way of use, these shortcomings can be avoided to a large extent.

Safflower harvesting equipment by suction was tested for several petal moisture, respectively 70%, 60%, 50%, 40%, performing well in all cases. Assessing the economic efficiency of the equipment, it was obviously much higher compared to manual harvesting (Tab.2) *(Azimi et al., 2012)*.

Table 2

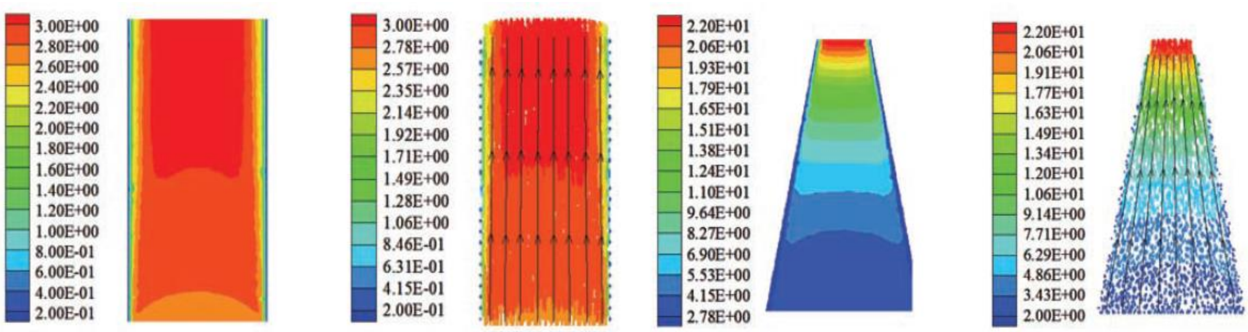
Economic analysis
(*Azimi S. et al. 2012*)

Safflower petals harvesting type	Indicators				
	Cost of machine [$]	Labour cost [$ day^{-1}]	Mass of collected petals [kg day^{-1}]	Harvested area [m^2 day^{-1}]	Fuel consumption [litres day^{-1}]
Mechanised	183	30	2.3	328	20
Manual	-	30	0.35	49	-

For environmental protection, for the safflower harvesting equipment by suction it is recommended to use as energy source a hybrid engine instead of a thermal one. Also, to increase productivity, it is possible to mount several suction systems on a frame supported by the tractor, the drive of these systems being made by the latter (*Azimi et al., 2012*).

For the equipment for harvesting Safflower by cutting combined with suction, the flow of air carrying the petals was theoretically analysed. The critical speed was determined to be between the values of 19.29 – 19.8 m s^{-1}, for the maximum frontal area of safflower petals between 11 - 40 mm^2, the amount of petals of a single safflower plant was between 0.121-0.456 g, and the density was between 120-196 kg/m^3 *(Ge et al., 2016)*.

Also, using a fluid analysis software, the relationship between the type of flow and the speed of the airflow was analysed and simulated (Fig.17), considering the natural characteristics of the air (T=30^{0}C, ρ=1.2 kg m^{-3}, λ=259 W m^{-1} K^{-1}, c=1.005 J kg^{-1} K^{-1}, η=18 10^{-5} Pa s, v=1.5 10^{-5} m^2 s^{-1}) *(Ge et al., 2016).*



a) Speed nephogram b) Velocity vector c) Speed nephogram d) Velocity vector
Cylindrical air tunnel *Contractile air tunnel*

Fig. 17 - Flow field simulation of the suction tunnel
(Ge et al., 2016).

The flow type is incompressible, and the airflow field is turbulent, according to the stability analysis, in the cylindrical tube no speed gradient being obtained (Fig.17 a,b).

The initial speed of the suction mouth reached the critical speed of the safflower petals of 19.8 m/s, and the exit speed is slightly different, being about 20 m/s.

The transverse speed gradient flow field with an output speed of approximately 160 m/s was obtained for the suction channel as a contraction pipe (Fig.17 c,d), having a contraction angle of 34^0 and the dimensions of the diameters D2=25 mm (at the outlet), D1=7 mm (at the inlet), to which is added the length of the pipe L=30 mm. The dimensions were chosen according to the parameters of the Safflower heads and petals.

The results of the flow field simulation were consistent with the conclusions of the theoretical analysis. It was found that petals with higher humidity are much more suitable for this harvesting method *(Ge et al., 2016).*

For the Safflower picking robot, a kinematic analysis of the positioning mechanism was performed, whose arms move in the mirror, the angular differences being 0.001^0~0.005^0, determining a movement accuracy of 0.2174–0.9387 mm, which was within the accuracy requirements for the testing phase (Fig.18). Based on the MATLAB simulation software and the Monte Carlo method, the working space of the mechanism was determined to be pprox.. an equilateral triangle with a side of 0.35 m (Fig.19) *(Gua et al., 2022).*

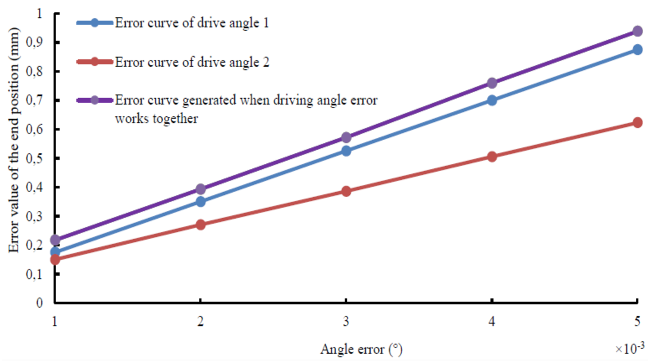


Fig. 18 - Curve of drive angle error
(Gua et al, 2022)

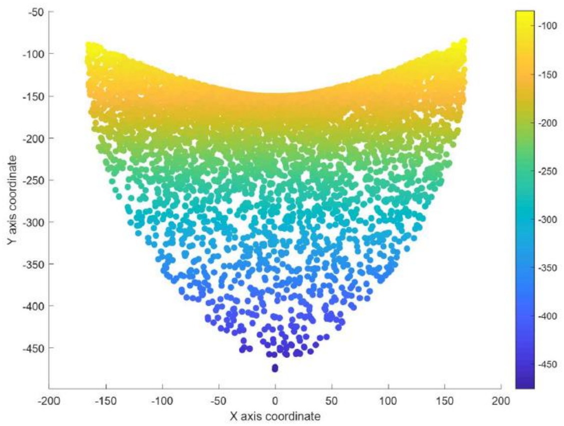


Fig. 19 - Parallel manipulator workspace diagram
(Gua et al., 2022)

The robot for Safflower harvesting has a compact structure, being able to recognize the Safflower head, to position it, to pick the petals and to collect them. Following the tests performed in the laboratory, related to the harvesting operation of Safflower petals an average harvesting degree of 87.91% was obtained, the harvesting time of the petals, being on average 16 s, for each flower head *(Gua et al., 2022).*

CONCLUSIONS

The equipment analysed was designed to meet the requirements imposed by the harvesting of each species, as well as by the fact that their use refers to small areas. Thus, the dimensions, shape and materials from which it was made were chosen so that it is easy to handle, portable, without the need for additional elements (e.g. energy sources), without being difficult to handle or transported in the field. In addition, the cost price is a very important element related to the accessibility of small farmers to these machines.

The use of the equipment did not require the modification of the cultivation technology for the respective species. Also, the harvesting of Chamomile inflorescences, Marigold flowers and Safflower petals made with the analysed equipment was more efficient from an economic point of view, compared to manual harvesting.

The testing results of inflorescence harvesting equipment are promising and an important reference for further optimization of this equipment. Also, the values of the technical and constructive parameters for which the experimental results were obtained, constitute an important starting point for other research in the field of equipment for harvesting medicinal and aromatic plants, grown on small areas.

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