REVIEW ON THE DEVELOPMENT OF LAVENDER HARVESTING TECHNIQUES
/
薰衣草收获技术发展综述

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ABSTRACT
The harvesting technology of China's lavender industry is in urgent need of improvement, and there is a pressing demand to expedite the development of mechanized collection equipment to facilitate the modernization process and optimize efficiency within the sector. This article adopts a literature review method to introduce the current research status of lavender harvesting techniques, including mechanical properties, harvesting time, and distribution of essential oils in stems and leaves, both domestically and internationally. It is found that there is relatively little research on lavender harvesting techniques in China, and the main research hotspots are focused on industrial development and essential oil extraction. By summarizing the mechanical harvesting equipment and its characteristics of lavender both domestically and internationally, it is analyzed that developed countries have fully achieved mechanical harvesting of lavender, while China's level of mechanical harvesting of lavender lags far behind developed countries. It is proposed to develop diversified lavender harvesting equipment, strengthen the research and cooperation of lavender harvesting machinery, promote the integration of agricultural machinery and agronomy, and combine basic research with equipment development. These development measures have a certain reference and promotion effect on accelerating the process of mechanical harvesting of lavender in China.

摘要
中国薰衣草产业的收获技术亟待提升，追切需要加快机械化采收装备的研发步伐，以促进产业的现代化进程和效率优化。本文采用文献综诉法，介绍了国内外薰衣草机械力学特性、收获时间、茎叶精油分布等有关收获技术的研究现状，发现中国在薰衣草收获技术方面的研究较少，主要研究热点集中在产业发展、精油萃取等方面。通过总结国内外薰衣草机械化收获装备及其特点，分析出发达国家已全面实现了薰衣草的机械化收获，而我国薰衣草的机械化收获水平远落后于发达国家，提出开发多样化的薰衣草收获装备，加强薰衣草收获机械的研发与合作，促进农机与农艺相融合，基础研究与设备研制相结合等发展措施，对加快中国薰衣草机械化收获进程具有一定的参考和促进作用。

INTRODUCTION
Lavender, a member of the *Labiaceae family*, is a small perennial shrub that is 30-60 (100) cm tall, gray in color, and has a strong odor *(Katarzyna et al., 2014)*. Lavender is a semi-heat-resistant plant with fragrant purple-blue flowers. The spines of lavender consist of rings of 6-10 flowers which are bilabiate, small, 0.8 cm-long. The majority of the oil, extracted from the flowers, is contained in the glands on the calyx *(Raev et al., 2002)*.

Lavender flowers contain 2-4.5% essential oils *(Katarzyna et al.,2014; Fakhriddinova et al., 2020; Prusinowska et al., 2014)*, the main components of which are linalool acetate, linalool and geranyl, but also contain compounds such as flavonoids, anthocyanins, phenolcarboxylic acids, zinc, calcium, magnesium, manganese, etc. *(Costea et al., 2019)*. Extensive research indicates that lavender and its essential oil possess antibacterial, anti-inflammatory, freckle-removing, skin-whitening, sedative, analgesic, and anti-anxiety effects, making them widely used in medical, beauty, aromatherapy, cosmetics, and other areas *(Sha et al., 2021; Guo et al.,2023)*, and could also be used as an insect repellent *(Sabara et al., 2019)*. In addition, lavender is a good honey plant - one hectare of lavender during its flowering period gives more than 100 kg of white, aromatic and tasteful honey *(Zatuchny et al., 1972)*.

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Lavender is native to the Mediterranean and southern Europe *(Yao et al., 2002)* and prefers bright, dry conditions *(Zhang et al., 2016)*. The main planting area of lavender is concentrated in France *(Monge et al., 2012),* Bulgaria *(Stanev et al., 2016)*, Italy *(Contino et al., 2020)*, Turkey *(Gul et al., 2016),* Spain *(Fernandez et al., 2020)*, Japan, China and other places, while the main producers of lavender are France and Bulgaria *(Giray et al., 2018)*. Thanks to its favorable geographical and climatic environments, Xinjiang's Yili region, which shares the same latitude as Provence, France, stands as the world's third-largest planting base of lavender *(Li., 2016)*.

Lavender blooms from mid-June to mid-July each year *(Muntean et al., 2016)*, depending on geographic region. Generally, when the flowers are 60% full *(Hassiotis et al., 2014)*, they can be harvested. Because of the backward development level of agricultural mechanization in Yili region, the harvesting of lavender has been mainly artificial, which seriously restricts the large-scale production and development of lavender. In this paper, the development status of lavender harvesting machinery at home and abroad and the basic research affecting lavender harvesting were summarized, the problems existing in domestic lavender harvesting technology were found, and the relevant suggestions were put forward.

Lavender harvesting techniques

Mechanical properties of lavender

Design engineers working with plant material need to know their properties and structures when subjected to cutting, bending, tensile, and compressive forces in order to understand the behavior of the material in conjunction with the machine involved. A designer should therefore be conversant with the physical and mechanical properties of the investigated plant.

Deniz Yilmaz from Suleyman Demirel University in Turkey studied the relationship between the harvesting time of lavender and the mechanical characteristics of different stem segments and the stem. The study reveals that with the extension of time, the shear stress of each stem segment of lavender decreases. The mechanical characteristic parameters such as biological yield strength, shear force, and bending stress of the bottom stem segments are much greater than those of the top stem segments. Consequently, it is advisable to harvest lavender closer to the top during harvesting *(Deniz et al., 2016)*.

Christos I. Dimitriadis and James L. Brighton from the School of Applied Sciences, College of Science and Technology at Cranfield University in the UK used an Instron 1122 tensile testing machine to measure the force required to separate lavender flowers from stems and the ultimate tensile stress (UTS). They also examined the resistance of the flowers in airflow and the terminal velocity of the flowers during free fall. The findings indicate that the force needed to separate lavender flowers from stems is lower than that required to break the stem and it is viable to harvest lavender by only removing the flowers *(Dimitriadis et al., 2014).*

Deniz Yilmaz and Mehmet Emin Gokduman at Suleyman Demirel University in Turkey uncovered through experiments that moisture notably influences the physical and mechanical characteristics of lavender, such as flower stem size, flower-stem ratio, picking force, and essential oil content *(Deniz et al., 2014)*.

Trendafilov and Delchev from Bulgaria, conducted a comparative study on lavender harvesters using arc cutting knives and straight knives. The study results showed that the use of arc cutting tools could significantly reduce the impurity content compared with the straight knife cutting; however, there was almost no difference in the percentage of lavender loss between the two. Therefore, it is recommended to apply arc cutting units in lavender harvesters to effectively improve the quality of harvested materials *(Trendafilov et al., 2006)*.

Lavender harvest time

The distribution of essential oil in the stems and leaves of lavender affects the way lavender is harvested. When harvesting, the flowers are harvested together with the stems and leaves, and the stalks should be cut to a suitable length. If the stem is too long, it will increase the transportation cost and also affect the quality of lavender essential oil extraction. If the lavender flower is stripped from the stem and harvested separately, whether it will affect the yield of essential oil is a question that needs to be discussed.

There are several views on the distribution of essential oil content in lavender. The lavender harvesting starts in the second year of the crop at flowering, which takes place in June-July and continues yearly for 12-15 years in conditions of high productivity. Beyond this time interval, the crop becomes less feasible *(Muntean et al., 2016)*. The crop enters full productive capacity in the second and third years post-establishment *(Giannoulis et al., 2020)*.

The period and duration of flowering varies with geographical region. In Eastern Europe silvosteppe areas, the flowering, with a flowering duration of 15-20 days, occurs earlier than in colder temperate regions, where flowering can occur later and lasts about 25-30 days *(Muntean et al., 2016)*.

Gonceariuc, M. and Zbanc, A. et al., in their Practical Guide to Lavender Cultivation and Commercial Management, Lavender harvesting differs depending on the plant variety - it can have an early, medium or late flowering period. As a rule, small crops can be harvested when the flowers are 75-80% open. While for the extended crops, which are harvested within 10-15 days, the picking process can be initiated when the plants are 50-60% open and ends when they reach a threshold of 95-100% flowering *(Gonceariuc et al., 2019)*. The best time to harvest lavender during the day is from 10 a.m. to noon or after noon *(Muntean et al., 2016)*.

Baydar and Erbaku of Lyman Demirel University studied lavender harvested on four different dates and dried at four different temperatures to assess the effects of harvesting time and drying temperature on its essential oil content and composition. The results showed that both harvesting time and drying temperature had an impact on the essential oil content. The highest linalool content was harvested in the middle of flowering period (mid-July), and the drying temperature was recommended between 30-40°C to maintain the high quality of dried lavender *(Baydar et al., 2009)*.

Hassiotis et al, from the Aristotle University of Thessaloniki in Greece, tapped into how the quality and quantity of lavender essential oil (EO) change during the flowering period in two regions of Greece. They unveiled that the best time to harvest lavender is when 60% of the flowers are in bloom *(Hassiotis et al., 2014)*.

Çiğdem Sönmez and Hülya Okkaoğlu from the Faculty of Agriculture at Izmir Ege University in Turkey carried out a random allocation experiment to study the effects of different harvesting times on the fresh flower yield and essential oil yield of lavender. The findings suggest that at 8:00 in the morning during the lavender harvest time, the average of fresh forage yield, dry forage yield, floating forage yield, essential oil content, and essential oil yield are highest, while the average is lowest at 14:00 in the afternoon *(Çiğdem et al., 2019)*.

Jiang Xinming and Guo Danli from the Institute of Agricultural Science, the Fourth Division of Xinjiang Production and Construction Corps utilized gas chromatography-mass spectrometry and steam distillation to measure and analyze the components of lavender essential oil harvested at different flowering periods and different times. They found that the flowering periods and varieties of lavender weigh heavily on essential oil quality, while the harvest time exerts a minor impact. This provides a theoretical basis for determining the harvest time of different lavender varieties *(Jiang et al., 2016)*.

Distribution of essential oil in stems and leaves of lavender

The distribution of essential oil in the stems and leaves of lavender affects the way lavender is harvested. When harvesting, the flowers are harvested together with the stems and leaves, and the stalks should be cut to a suitable length. If the stem is too long, it will increase the transportation cost and also affect the quality of lavender essential oil extraction. If the lavender flower is stripped from the stem and harvested separately, whether it will affect the yield of essential oil is a question that needs to be discussed when harvesting lavender.

There are several views on the distribution of essential oil content in lavender. Lavender essential oil is found in the upper part of the calyx, more precisely in the oil glands on the surface of the calyx, but also in the leaves or dried flowers of the plant. Fresh lavender flowers contain about 0.7-1.4% of volatile oils. When plant material dries, it loses some of its volatile oils. On average, one ton of fresh inflorescence produces about 10 kilograms of volatile oils *(Muntean et al., 2016)*.

Wilson T.M. et al., reconfirmed in a recent study that the calyx is the main part of lavender that accumulates volatile oil, with the calyx alone producing 1.3%, followed by the corolla (0.1%) and leaves (0.05%), and the entire flowering top producing 0.7% *(Wilson et al., 2021)*. Blinova et al showed in their experimental results that all parts of the plant contain essential oils (lavender): leaves - up to 0.4%, stems - up to 0.2%, and large amounts of essential oils accumulate in the inflorescence (3.5-4.5%) (*Blinova et al., 1990*).

Rabotyacov and Yakovlev, from the US, explored the variability of lavender volatile oil. They found that during harvest time, lavender essential oil is mainly concentrated in glands, which are primarily located on sepals and petals. The yield of extracted oil is proportional to the number and size of essential oil glands *(Rabotyacov et al., 1980)*. In 1997, Petras Rimantas Venskutonis et al, from the Department of Food Technology at Kaunas University of Technology in Lithuania, analyzed the volatile oils in lavender flowers and stems using capillary gas chromatography and gel chromatography. They discovered that the oil content in lavender stems is more than 30 times lower than that in lavender flowers, providing the correct direction for efficient mechanical harvesting of lavender *(Petras et al., 1997)*. A report from the Department of Agriculture in Western Australia in 2000 pointed out that the mass of dry matter during distillation affects that of the oil. Therefore, it is recommended to harvest lavender stems not exceeding 15 centimeters in length under minimal wind conditions with temperatures below 28°C. Otherwise, oil yield will be impacted *(Bulletin, 2000)*.

Dimitriadis from the Alexander Technological Educational Institute of Thessaloniki, Greece, found that the most economically efficient lavender harvesting operation does not occur at maximum yield. Instead, it is attained by setting machines to harvest the largest flower heads with the minimum percentage of stems *Dimitriadis et al., 2016)*.

Ana Clara Aprotosoaie and Elvira Gille, from the Carol Davila University of Medicine and Pharmacy of Romania, conducted a systematic study of the chemical composition of lavender essential oil based on research from the past 15 years. The findings show that lavender essential oil can be extracted from parts other than the inflorescence; however, the oil content is low, and the quantity of components such as linalool and camphor is also meager *(Aprotosoaie et al., 2017)*.

Détár Enikő and Éva Zámboriné Németh from St. Stephen University in Hungary evaluated the essential oil characteristics of six narrow-leaved lavender and two intermediate lavender varieties to verify the influence of varieties and growth years on lavender and lavender essential oil characteristics. According to the experiments, intermediate lavender possesses a lower ratio of acetic linalool ester to total esters than narrow-leaved lavender, and the growth year does not notably influence the characteristics of lavender essential oil *(Détár et al., 2020)*.

Shiyuge from Xinjiang University employed two extraction techniques, steam distillation and headspace solid-phase micro-extraction, to analyze the volatile chemical components of narrow-leaved lavender, toothed lavender, and different parts of narrow-leaved lavender utilizing gas chromatography and gas chromatography-mass spectrometry. The analysis shows that in narrow-leaved lavender, the flowers contain the most volatile components, followed by the leaves, with the stems harboring the least quantity. The quality of narrow-leaved lavender surpasses that of toothed lavender *(Shi et al., 2012)*.

In summary, research on lavender harvesting technology was conducted earlier and more comprehensively abroad, involving various aspects such as lavender mechanical properties, harvesting time, and essential oil distribution in stems and leaves. Research on lavender in China mainly focuses on essential oil extraction, industrial development, and other aspects. For example, Zhao Wenbin and Chen Hanying selected extraction pressure, extraction temperature, CO2 flow rate, and extraction time as influencing factors, and determined the optimal extraction process conditions for supercritical fluid extraction of lavender volatile oil using orthogonal tests *(Zhao et al., 2009)*. Huang Xiaode and Yang Jianxin et al. improved the traditional water vapor oil extraction device. The improved integrated lavender essential oil extraction device can significantly reduce the amount of distillation water used and increase the extraction rate of lavender essential oil *(Huang et al., 2022)*. Liu Ying delved into the industrial development of lavender in Huocheng County, Xinjiang, summarized the advantageous conditions and industrial foundation, and proposed countermeasures and suggestions for the issues that arose during the development of the industry in the county *(Liu et al., 2019)*. Ding Lijuan studied the historical development of the lavender industry in the Yili region and put forth that cooperation between operating entities represents the most effective developmental trajectory for the local lavender industry *(Ding et al., 2019)*.

Lavender harvesting machinery

Foreign lavender harvesting machinery

Foreign research started rather early on lavender harvesting machinery. In the late 1940s, foreign lavender producers, entrepreneurs, and engineers attempted to mechanize lavender harvesting. In 1949, the world's first lavender harvester was developed and put into use at the Bridestowe Lavender Farm in Australia. The operational principle of the lavender harvester resembles that of a forage harvester, employing blades to cut lavender stems. Then the cut lavender is conveyed to a collection box at the machine's rear through a conveying device (Fig. 1) *(Mcleod, 1994)*.

Fig. 1 - The first lavender harvester at the Australian farm

In 2005, Dimitriadis, Pavloudi and others from the Alexander Technological Educational Institute of Thessaloniki, Greece, designed and manufactured a small lavender harvester (Fig. 2), which deploys a rotating drum with a stripping component to harvest lavender. While in operation, the machine can selectively remove lavender flower heads and preserve the majority of stems. The separated lavender flower heads are conveyed to the rear collection box by the airflow generated from the rotating drum *(Dimitriadis, 2005)*. This new lavender harvester can be used to produce high-quality lavender essential oil, reducing transport and distillation costs, but is not commercially available due to harvesting efficiency.

Fig. 2 - Small lavender harvester

Since the beginning of the 21st century, developed countries such as Japan, France, the Netherlands, Italy, and Bulgaria have successively achieved the mechanical harvesting of lavender. At present, mainstream foreign lavender harvester manufacturers include Germany's CLAAS and RIBERI, France's CLIER, and Italy's BONION. There are self-propelled harvesters capable of harvesting three rows at once, without being restricted by planting patterns or row spacing. There are also small, traction single-row harvesters that offer flexibility, convenience, low maintenance costs, and ease of operation. Additionally, there are small handheld lavender harvesters that cater to the diverse needs of lavender growers.

The German CLAAS JAGUAR 950 self-propelled forage harvester can be used for lavender harvesting (Fig. 3). The machine is equipped with a powerful Mercedes OM520 engine, a 3m-wide variable header drive, and can harvest a maximum of four rows of lavender concurrently. It allows for precise adjustment of the cutting length, ensuring a high level of automation. The series of models provides users with two harvesting methods to choose from. One option involves employing a single harvester to complete lavender harvesting, collecting, bundling, and unloading. The other option necessitates a transport vehicle during the harvesting process. The harvester first cuts the lavender along the neck position, then shreds the lavender with blades, and finally transfers it to the discharge spout for conveyance to the transport vehicle traveling side by side.

Fig. 3 - German CLAAS JAGUAR 950 forage harvester

The Italian BONINO BE series traction lavender harvester, as shown in Fig. 4, can be used with tractors with a power of 70 kW or more. The two V-shaped toothed brushes at the front of the machine can lift fallen lavender, convey it to the cutting system, and cut it with a rotating cutter bar with a cutting width of up to 1m. The cut lavender is then transported to a 17m^3 hopper via a loading ladder. After being filled with lavender, the hopper can be unloaded using the hydraulic device.

Fig. 4 - Italian BONINO BE400 lavender harvester

The SALIUNCA model lavender harvester from Italy's RIBERI (Fig. 5) is affixed to the right side of a tractor for operation. During operation, the front-mounted crop lifter straightens fallen lavender and transports it to the cutting system by the undulating comb teeth. The cut lavender is subsequently conveyed to the rear hopper using the lifting device.

Fig. 5 - Italy RIBERI SALIUNCA lavender harvester

The Dutch EazyCut 1200 hand-pushed small harvester, shown in Fig. 6, was originally used mainly for tea harvesting, but in recent years has also been used for lavender harvesting. The harvesting device is mainly composed of vertical arranged comb teeth and transverse curved serrated blades, which can not only harvest lavender, but also prune it, and the height can be adjusted. In addition, the machine's supporting blower and collection bag can realize the automatic bagging of lavender after harvest.

Fig. 6 - Dutch EazyCut 1200 hand-push lavender harvester

Chinese lavender harvesting machinery

In the 1950s, lavender was introduced into China for trial planting in regions such as Xinjiang, Henan, and Shaanxi, with the Yili region proving to be the most suitable natural environment for growing lavender (*Zhang et al., 2016*). Currently, the lavender planting area in the region has reached 4900 hm^2, but the mechanical harvesting of lavender is still in the initial development stage. From 1955 to 2010, all domestic lavender was harvested manually. After 2010, some domestic experts and scholars began the design and research of lavender harvesting machinery.

In 2013, Li Lujun, a farmer at Telehala Ranch in Xinyuan County, Xinjiang, designed a lavender harvesting machine, which became the first self-developed lavender harvesting machine in China. The aircraft began testing at the Lavender Base of Yining Airport on June 18 of that year (Fig. 7). The harvester is a single-row, self-propelled type, with the cutter on the header swinging and cutting under the action of the swing axle. The cut lavender is conveyed to the rear charging box by a fan and suction pipe. Operating at an efficiency of two hectares/day, the harvesting rate is 85%, essentially meeting the technical requirements for lavender mechanical harvesting *(Li., 2013)*. However, due to the harvesting quality, efficiency and the existence of damaged seedlings in the later period, there was no commercial mass production for promotion and use.

Fig. 7 - First domestic lavender harvester

The rest of the domestic research on lavender harvesting machinery is mostly recorded in patent literature, only theoretical design, and has not been produced.

Guo Jing from Urumqi, Xinjiang invented a traction type lavender harvester, which was composed of a shifting fork, a holding cylinder, a baling machine, a straw bale flatbed truck, a compression chamber, etc., as shown in Fig. 8. During operation, the rotating lifting cylinder at the front end of the machine can erect the falling lavender stalk and cut it by the rotating cutting cutter. After cutting, the lavender is driven by the gearbox to push the crank, connecting rod and fork into the feeding port of the compression chamber. In the compression chamber, the lavender is pressed into a rectangular grass block with a certain density (the length of the grass block is 300~1200 mm and the weight is about 8~18 kg). Then the square grass blocks formed by compression are bundled with plastic rope by the baling machine, and finally transported to the straw bale flat truck. Its advantages are that it can adapt to small plots and irregular plots, can maintain a consistent cutting height, and can automatically compact and bundle lavender *(Guo, 2012)*.

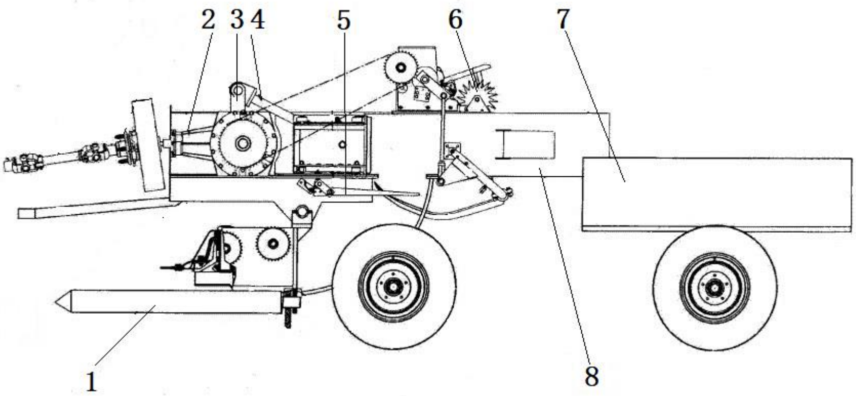

Fig. 8 - Traction lavender harvester

1. Crop lifter 2. Gearbox 3. Crank 4. Connecting rod 5. Fork 6. Bander 7. Bundle transporter 8. Compression chamber

Liu Jiaodi and Tian Dongyang from Shihezi University devised a lavender cutting device suspended on the side of a tractor, as shown in Fig. 9. Before operation, manually adjust the adjusting screw assembly to determine the opening angle of the feeding assembly. At the beginning of harvesting, the divider in front of the lavender is righted, the hydraulic motor provides power to the drive sprocket, drives the wave conveyor belt movement, the righted lavender is gathered and tightened, and then evenly and stably sent to the cutting assembly, and then the cutting assembly is driven by the crank connecting rod mechanism to cut the lavender *(Liu et al., 2016)*. The advantages of this device are fast harvesting speed and consistent cutting height, which can adapt to a variety of cultivation modes of lavender.

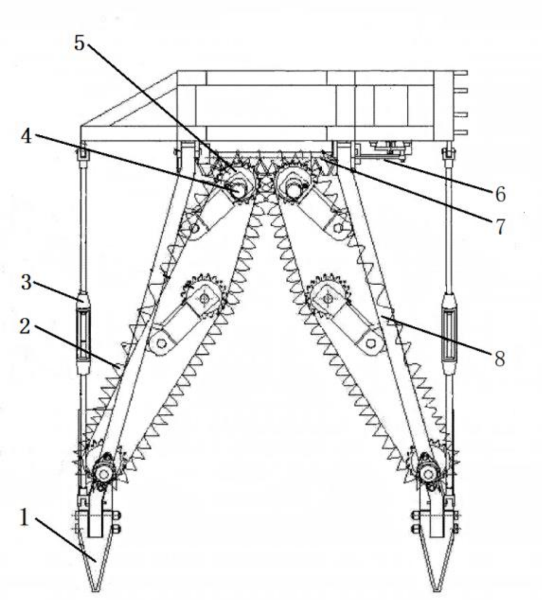

Fig. 9 - Lavender cutting device

1. Divider; 2. Undulating conveyor belt; 3. Regulating screw; 4. Hydraulic motor; 5. Drive sprocket; 6. Crank linkage mechanism; 7. Cutting assembly 8. Feeding assembly

Li Lin and others from Xinjiang Zhongzhi Agricultural and Animal Husbandry Machinery Co., Ltd. invented a new type of trailed lavender harvester, as shown in Fig. 10. When working, first connect the suction equipment outside the negative pressure mouth to make the middle of the negative pressure mouth produce negative pressure. The divider straightens the lavender, and the moving belt can send the lavender to the rotating cutter for cutting, and the cut lavender is collected into the negative pressure mouth under the action of negative pressure. The ground is not normal, the left end of the divider guide rod can be supported on the ground, driving the angle of the mounting plate to change, so that the harvesting process is smoother and the working stability is better. In addition, the machine uses only one motor as a power source, which can effectively save energy *(Li et al., 2020)*.

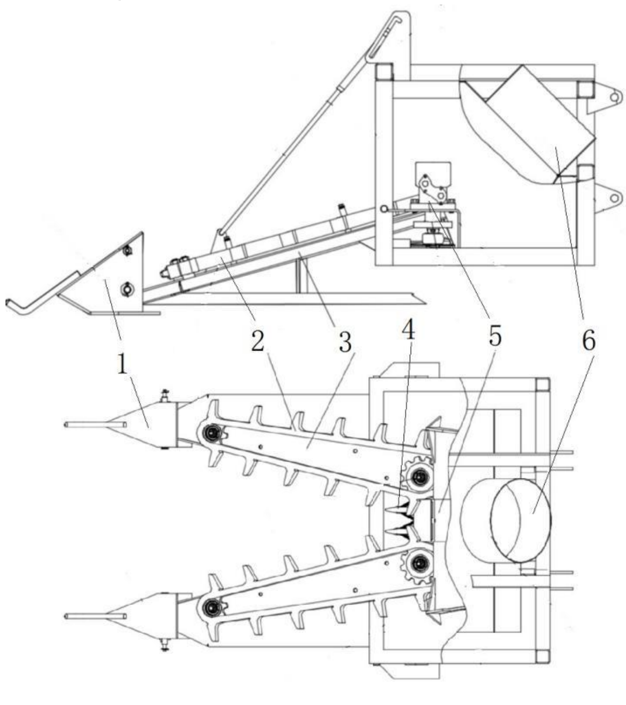

Fig. 10 - A new lavender harvester

1. Divider; 2. Conveyor belt; 3. Mounting plate; 4. Cutting tool; 5. Motor; 6. Negative pressure port

Ni Zhiming and Ni Shengdao of Yancheng Xinmingyue Machinery Manufacturing Co., Ltd. invented a small self-propelled lavender harvester, as shown in Fig. 11.

The machine includes a harvesting device, a cutting table, a conveyor belt, a storage hopper, etc. In the process of operation, the lavender is guided to the cutting table after being righted by the grass holding device in front of the machine, and the cut lavender is transported to the storage hopper by the conveyor belt, which can realize the integrated operation of cutting, conveying and storage. It has the advantages of simple structure and small volume, and can adjust the tilt of the conveyor belt and the height of the cutting device by using the lifting cylinder, and the operation is flexible *(Ni et al., 2023)*.

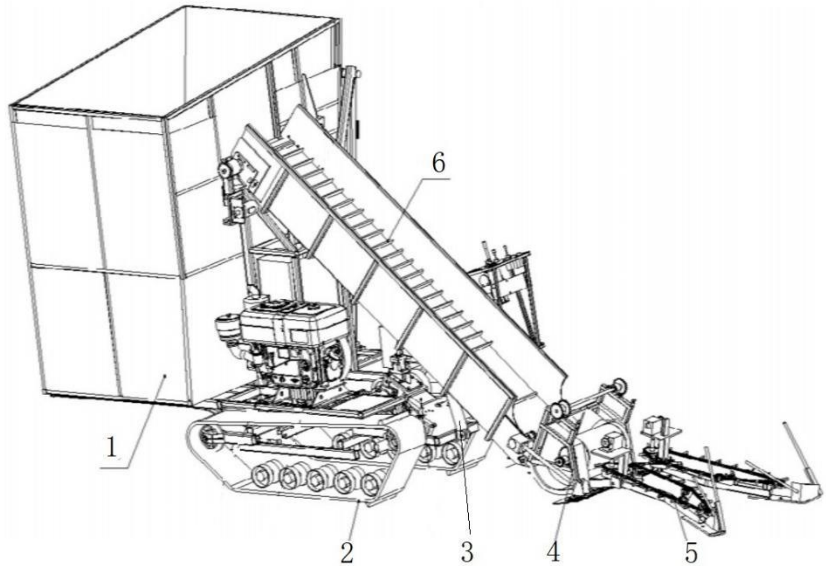

Fig. 11 - Small self-propelled lavender harvester

1. Storage hopper 2. Traveling crawler 3. Lifting cylinder 4. Header 5. Divider 6. Conveyor belt

In recent years, some areas in Chabuchaer County, Yili Kazakh Autonomous Prefecture, have started using foreign side-hanging lavender harvesters to harvest lavender. However, due to compatibility issues between foreign models and local lavender planting patterns, the usage area is limited. In Huocheng County, Yili Kazakh Autonomous Prefecture, some farmers have modified the headers of combine harvesters, originally used for wheat harvesting, for harvesting lavender. This modification has significantly increased harvesting efficiency. However, this harvesting method has not gained widespread adoption due to the substantial loss of lavender flower spikes during harvesting and the longer stems post-harvest compared to manual harvesting, which hinders essential oil extraction and greatly impacts the essential oil's quality.

Problems with lavender harvesting techniques

(1) The level of mechanical harvesting lags far behind that of developed countries. Foreign research on lavender harvesting machinery started rather early and has developed rapidly, resulting in comprehensive mechanical lavender harvesting at present. More than 98% of China's lavender planting area is concentrated in the remote Xinjiang Yili area, human resources and scientific research level is relatively backward, agricultural machinery research and development level is insufficient. So far, the domestic research on lavender harvesting machinery is only documented in patent literature, there is no independent research and development of commercial lavender harvesting machine, lavender harvest is still mainly artificial, mechanized harvest rate is less than 10%.

(2) The integration of agricultural machinery and agronomy is insufficient. During manual lavender harvesting, there is no strict requirement for plant spacing. To maximize per-acre yield while ensuring sufficient photosynthesis, farmers tend to densely plant lavender. During mechanical harvesting, factors such as tractor wheel spacing, width, and turning present substantial requirements for lavender plant spacing and field plot configuration. However, current lavender planting in China adheres to manual harvesting. Directly employing existing harvesting machinery for cutting may lead to plant damage and pressurizing, thus posing more challenges to mechanical harvesting. Moreover, lavender planting in the Yili region is dispersed. Besides major zones like Tianshan Huahai in Yining County and Jieyou Gongzhu in Huocheng County, the remaining planting areas are scattered. Some areas are even situated on slopes, making it difficult for large-scale mechanical operations. Consequently, only small single-row harvesters are utilized, resulting in low efficiency and high labor intensity.

(3) There is little research on lavender harvesting techniques. The mechanical and physical characteristics of lavender are fundamental for designing and researching mechanical equipment for lavender planting and harvesting *(Deniz et al., 2016)*. The study of lavender harvesting time and essential oil distribution in stems and leaves is also an important factor to improve the yield and essential oil quality of lavender. Foreign research on lavender harvesting began early and encompasses a wide range of aspects, including lavender essential oil, the physical and mechanical characteristics of lavender, and mechanical harvesting. In contrast, China primarily concentrates on lavender essential oil extraction and industrial development, with limited reports on the physical and mechanical characteristics of lavender.

Suggestions for the development of lavender harvesting techniques

(1) Attach importance to the research of key technologies of lavender harvesting, and develop diversified lavender harvesting equipment. China should start from the physical and mechanical characteristics of lavender, essential oil distribution and other aspects affecting mechanized harvesting, pay attention to the basic research of harvesting technology, can accelerate the development process of mechanized harvesting equipment of lavender, and promote the development of lavender industry.

If the quality of lavender essential oil is not high, or only used to make incense bags, pillows and other derivatives after harvest, you can use conventional harvesting machinery, together with the stem and flower piece cut to harvest lavender. For lavender that needs to process high-quality essential oils, it can be done by harvesting only lavender flowers, which requires more diverse lavender harvesting equipment.

Optimize lavender planting patterns and facilitate the integration of agricultural machinery and agronomy. First, following the requirements of "increasing areas of small fields, squaring angled fields, and leveling sloped fields", it is essential to reorganize scattered and fragmented farmlands, create farmlands suitable for machinery (Zheng et al.,2023), and encourage farmers to adopt lavender planting in line with mechanical harvesting patterns. Second, it is essential to develop lavender harvesting machinery with strong adaptability, thus meeting the requirements of self-propelled combined harvesting by large planting enterprises, as well as the models suitable for small planters. Meanwhile, lavender harvesters should integrate adaptive profiling technology to cater to the applications in diverse terrains and farmlands.

(3) Improve the utilization rate of lavender harvesting machinery. The flowering period of lavender is short, the annual flowering duration is 20-30 days, and the harvesting time is more concentrated. Large self-propelled lavender harvester prices up to several million yuan, only 20-30 days a year, idle the rest of the time, is obviously not conducive to the improvement of lavender economic benefits. If during the harvesting, the cutting table of the combine harvester is replaced by a lavender harvesting table, such problems can be effectively solved. In addition, the hanging lavender harvesting device used in conjunction with the tractor has low manufacturing costs, and should also be the focus of domestic lavender harvesting machinery research and development.

CONCLUSIONS

This paper describes the development status of lavender harvesting machinery at home and abroad, introduces the types and characteristics of lavender mechanized harvesting equipment. The research status of lavender harvesting technology at home and abroad was summarized from the aspects of mechanical characteristics of lavender, harvesting time, essential oil distribution in stems and leaves, etc. It was found that the mechanized harvesting level of lavender in China was far behind that in developed countries. The reason is that in addition to the concentration of planting area in remote areas with relatively backward human resources and scientific research level, it is also related to the lack of integration of agricultural machinery and agronomy, and less research on lavender harvesting technology. Finally, according to the actual situation of lavender in China, the relevant suggestions were put forward, which has important reference significance for speeding up the mechanized harvesting process of lavender in China.

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