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Semi-Auto Lemongrass Harvesting Machine

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Abstract

Lemongrass harvesting remains labor-intensive, time-consuming and of inconsistent quality when performed manually, limiting scalability to meet increasing demand. This study introduces a semi-automatic lemongrass harvesting machine designed to reduce labor dependency and increase efficiency. Developed using a structured engineering process, the prototype integrates a two-stroke engine, a chain sprocket assembly and a rake blade for continuous uprooting. Small-scale laboratory tests and limited field testing were conducted due to financial constraints. Results showed that the machine required 10 seconds per harvesting cycle compared to 12 seconds manually, achieving 360 clumps per hour (720 kg/h) compared to 300 clumps per hour (600 kg/h) using the manual method. This equates to a 20% efficiency increase and a time saving of approximately 7 hours per hectare. Although the improvement in performance is clear, large-scale field trials are recommended to confirm reliability under real-world conditions. Future improvements should focus on integrating security, remote monitoring, and adjustable blade mechanisms to optimize practicality and usability.

1. Introduction

The agricultural sector has long been challenged by the labor-intensive nature of harvesting, which is not only time-consuming but also physically demanding. Traditional methods of harvesting, such as manual plucking, are often inefficient and can lead to inconsistent results. This is particularly true for crops like lemongrass, which require exact handling to maintain quality. The development of semi-automatic harvesting machines offers a promising solution to these challenges by combining human supervision with mechanical efficiency. Traditional harvesting methods using hand picking or manual tools, are highly labor intensive and often produce inconsistent quality due to human error and fatigue [1]. Additionally, these methods are not scalable, making it difficult to meet the increasing demand for agricultural products. The introduction of semi-automatic systems aims to address these issues by automating parts of the harvesting process while still allowing for human control and oversight. For example, a semi-automatic grafting machine for vegetables has shown significant improvements in efficiency and success rate compared to manual methods. Similarly, the proposed semi-automatic lemongrass harvesting machine aims to increase productivity and consistency in lemongrass harvesting.

Recent advancements in agricultural technology have led to the development of various semi-automatic and fully automatic harvesting machines. These machines often incorporate robotic arms, image processing techniques, and advanced sensors to improve efficiency and accuracy. For example, a semi-automatic system for tea leaves harvesting uses a robotic arm and image processing to identify and pluck leaves based on their grade [1]. Similarly, a robotic system for citrus harvesting uses visual servicing and mechanical design to improve fruit detection and picking efficiency [2][3]. These innovations highlight the potential for similar technologies to be applied to lemongrass harvesting, where precision and efficiency are crucial. The semi-auto lemongrass harvesting machine is designed to address the specific challenges associated with lemongrass harvesting. The machine typically consists of several key components, including feeding slots, slicing knives, and a releasing slot [4]. The design allows for manual feeding of lemongrass into the machine, which then slices the stems with high precision. This method not only increases the speed of harvesting but also ensures consistent quality by maintaining uniform slice thickness. The machine's efficiency has been demonstrated in tests, showing high working capacity and efficiency in both perpendicular and inclination slicing conditions [4].

The development of a semi-auto lemongrass harvesting machine represents a significant advancement in agricultural technology. By combining human oversight with mechanical precision, this machine addresses the inefficiencies and inconsistencies of traditional harvesting methods. The integration of advanced technologies, such as robotic arms and image processing, further enhances the machine's capabilities, making it a valuable tool for modern agriculture. As the demand for agricultural products continues to grow, innovations like the semi-auto lemongrass harvesting machine will play a crucial role in meeting this demand while ensuring high-quality produce.

1.1 Literature Review

Lemongrass Cymbopogon spp. is a widely cultivated aromatic crop, primarily used in the aroma and pharmaceutical industries due to its essential oil content. The increasing demand for natural products has necessitated the development of efficient harvesting and post-harvest management techniques to maintain product quality and reduce economic losses [5].

1.2 Challenges in manual harvesting method

Currently, there is no significant mechanization in lemongrass cultivation, either for planting or harvesting, apart from the use of simple gardening tools during the harvesting process. Research on lemongrass harvesting machinery remains limited, with most studies emphasizing manual harvesting methods and post-harvest handling, with little attention given to the development and testing of specialized machinery for lemongrass. Manual practices continue to dominate primarily because mechanized equipment is costly and often inaccessible to small-scale growers [6]. Moreover, the use of inappropriate tools and the absence of proper sanitation procedures during harvesting present major challenges, resulting in variable intervals between harvest and processing, as well as inconsistent product quality [7]. These limitations highlight the broader set of barriers that restrict the adoption of mechanized harvesting in lemongrass production. Several challenges hinder the adoption of mechanized harvesting for lemongrass. These include:

- High Initial Costs: The cost of specialized machinery is prohibitive for small-scale farmers, who often rely on manual labor [6].
- Inconsistent Harvesting Techniques: The use of inappropriate tools and lack of standardized procedures result in variable product quality [7].
- Post-Harvest Handling: Improper post-harvest handling, such as drying and storage, can significantly affect the quality of lemongrass essential oil [5].

1.3 Existing Harvesting Machinery for Other Crops

To draw parallels, it is useful to examine the development of harvesting machinery for other crops. For instance, mechanical harvesting technology for citrus in Florida has been driven by the need to increase labor productivity and reduce costs. This technology includes various types of equipment, such as disc mowers and mower conditioners, which have been adapted to handle different crop conditions [8], [9]. Similarly, hay and forage equipment has been tested for biomass harvesting of switchgrass, demonstrating the potential for high throughput rates and efficient handling of voluminous material [9].

1.4 Potential for Mechanized Lemongrass Harvesting

The potential for mechanized lemongrass harvesting lies in adapting existing technologies from other crops. For example, the use of disc mowers and mower conditioners, which have shown high efficiency in harvesting switchgrass, could be explored for lemongrass [9]. Additionally, the development of specialized machinery, such as hedge trimmers, has shown promise in increasing harvest performance for similar crops like lemon balm [6].

1.5 Future Directions

The literature on lemongrass harvesting machinery highlights significant gaps and challenges that need to be addressed to improve efficiency and product quality. By drawing on the advancements in harvesting technology for other crops and focusing on the development of specialized, cost-effective machinery, the lemongrass industry can achieve greater productivity and meet the growing demand for high-quality natural products.
Future research should focus on:

- Development of Specialized Machinery: There is a need for the development and testing of specialized machinery tailored to the unique requirements of lemongrass harvesting.
- Cost-Effective Solutions: Research should aim to develop cost-effective mechanized solutions that are accessible to small-scale farmers.
- Standardization of Procedures: Establishing standardized harvesting and post-harvest handling procedures to ensure consistent product quality.
- Cross-Crop Technology Transfer: Exploring the adaptation of existing harvesting technologies from other crops, such as citrus and switchgrass, to lemongrass.

Table 1 *Summaries of literature review*

Aspect	Current State	Challenges	Potential Solutions
Manual Harvesting	Prevalent due to high costs of machinery [6]	Inconsistent quality, labor-intensive [7]	Development of cost-effective mechanized solutions
Mechanized Harvesting	Limited research and adoption [4],[6]	High initial costs, lack of specialized machinery [6]	Adaptation of existing technologies from other crops
Post-Harvest Handling	Variable drying and storage methods [4], [5]	Quality deterioration, economic losses [5]	Standardization of procedures, improved handling techniques
Research Focus	Primarily on manual methods and post-harvest handling [4],[5],[10]	Lack of comprehensive studies on mechanized solutions [6], [7]	Focus on development and testing of specialized machinery

Table 1 summarizes the findings from previous literature on harvesting and post-harvest practices, outlining the current state, key challenges, and potential solutions discussed by various researchers. Manual harvesting remains dominant due to the high costs of machinery but is constrained by low efficiency and inconsistent quality, while mechanized harvesting is still limited because of high investment costs and lack of specialized equipment. Post-harvest handling practices are highly variable, often leading to product deterioration and economic losses, whereas existing research has mainly emphasized manual methods with relatively few studies on mechanization. Overall, the literature suggests a pressing need for cost-effective mechanized solutions, technology adaptation, and improved handling techniques to enhance efficiency and reduce losses.

By addressing these challenges and focusing on the development of efficient harvesting machinery, the lemongrass industry can significantly improve its productivity and product quality, meeting the increasing global demand for natural products. In line with this, the project seeks to introduce innovative technology that makes lemongrass harvesting easier, faster, and less labor-intensive are required. By integrating mechanized tools and precision farming approaches, the solution is expected to boost productivity while also improving post-harvest handling and storage. This not only minimizes spoilage and waste but also provides a cost-effective and sustainable approach to support the growth of the lemongrass industry.

2. Methodology

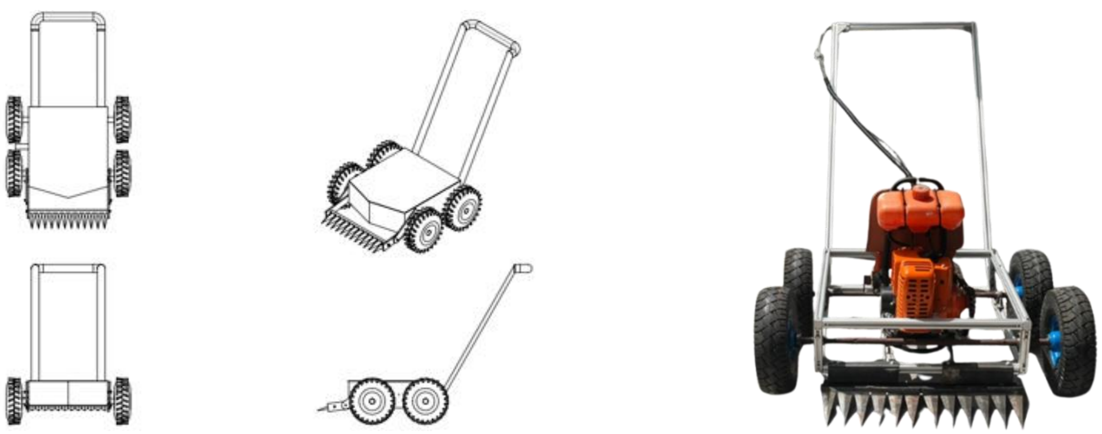
2.1 System Design

The semi-automatic lemongrass harvesting machine was developed through a structured engineering design process. Several design concepts were evaluated using a weighted criteria matrix based on functionality, ease of operation, manufacturability, and cost. Design 4 was selected as the optimal configuration due to its ergonomic layout, stable frame, and effective integration of the rake blade (see Fig. 1). A final technical drawing was produced to guide fabrication and assembly.

Fig. 1 *Concept design evaluation for Semi-Auto Lemongrass Harvesting Machine*

2.2 Prototypes Design

Design 4's sketch is chosen and expanded upon. The system integrates a two-stroke engine connected to a chain sprocket assembly, converting rotary motion into wheel movement while simultaneously actuating the plucking mechanism. This configuration ensures continuous forward motion and efficient plant extraction. Material selection was based on mechanical strength, durability, weight, and cost-effectiveness. Aluminum profiles were chosen for the frame due to their lightweight, corrosion resistance, and recyclability. Steel components were applied in load-bearing and cutting sections to ensure structural integrity. Auxiliary components, including throttle, stop switch, and sprocket system, were selected for compatibility with the two-stroke engine The program was used to model the engineering drawing using SolidWorks 2023(see Fig. 2). The semi-automatic lemongrass harvesting machine's body dimensions (L x W x H) are 300 x 300 x 100 mm.



(a) (b)

Fig. 2 *Semi-Auto Lemongrass Harvesting Machine (a) Isometric drawing (b) Final prototype*

2.3 Operating principle

Fig. 3 presents the operating principle of a semi-automatic harvesting machine. The process begins with the supply of fuel to the two-stroke engine, which generates mechanical power. Under the operator's control, this power is transmitted through a chain sprocket assembly to turn the wheels. Once the wheels are set in motion, the machine begins to move forward under the control of the machine operator. The machine is directed to the lemongrass clump to be uprooted, the mechanism at the front enables the machine to perform the harvesting task efficiently.

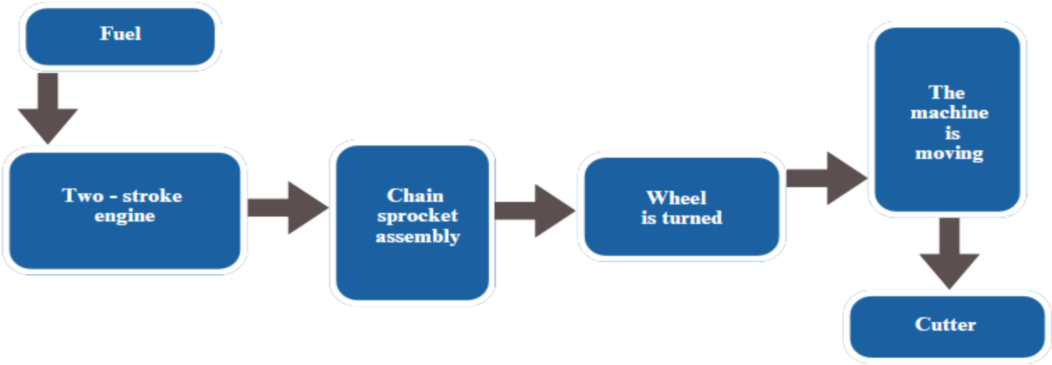


Fig. 3 *Semi-Auto Lemongrass Harvesting Machine operating principle*

3. Result and Discussion

When the movement time between clumps is considered, the overall harvesting cycle changes significantly. Based on actual testing, the machine required 5 seconds to uproot a clump of lemongrass, and an additional 5 seconds to move to the next clump, giving a total cycle time of approximately 10 seconds. In contrast, the manual method took 7 seconds for uprooting and about 5 seconds for movement, resulting in 12 seconds per cycle. At a planting density of 12,500 clumps per hectare, the machine achieved a harvesting rate of about 360 clumps per hour, equivalent to 34.7 hours per hectare, while the manual method reached 300 clumps per hour, or 41.7 hours per hectare.

Table 2 *Comparison of manual and machine*

Material & Equipment	Manual	Machine
Uprooting time(s)	7	5
Movement time(s)	5	5
Number of clumps (clump/hour)	300	360
Hours/ha (12500 clumps)	34.7	41.4

Table 2 shows the time reflection saving of roughly 7 hours per hectare, or 16.8% improvement in overall efficiency. Moreover, since manual measurement excludes operator fatigue, the real-world advantage of the mechanized system would be even greater in continuous large-scale harvesting.

Considering an average clump weight of 2 kg, the harvesting performance between machine and manual methods shows a clear difference. Based on the calculated throughput, the machine is capable of uprooting approximately 360 clumps per hour, which translates to about 720 kg of lemongrass harvested per hour. In comparison, the manual method achieves only around 300 clumps per hour, equivalent to 600 kg per hour. This indicates that the mechanized system provides an additional 120 kg of yield per hour, highlighting its efficiency and potential to significantly enhance overall harvesting productivity. In terms of efficiency, this represents a 20% improvement over the manual method, which not only increases hourly output but also reduces the time and labor required for large-scale harvesting.

4. Conclusion and Recommendations

The development and testing of the semi-automatic lemongrass harvesting machine demonstrate clear improvements over traditional manual harvesting methods. Actual testing showed that the machine requires approximately 10 seconds per cycle, compared to 12 seconds for manual harvesting, resulting in a time saving of about 7 hours per hectare. Furthermore, the machine achieved a throughput of 360 clumps per hour, equivalent to 720 kg per hour, compared to 600 kg per hour for manual harvesting. This translates into a 20%

improvement in overall efficiency, highlighting the potential of mechanization to address the limitations of labor-intensive practices. Although laboratory-based and small-scale field tests confirmed the performance and efficiency of the machine, the scope of this study was limited by financial constraints, preventing full-scale testing on commercial farms. Therefore, further evaluation should be conducted under real-scale farm conditions to confirm its reliability and adaptability to diverse field environments. Such tests will help identify practical issues such as soil variability, terrain irregularities and long-term use, which are not fully captured in controlled or small-scale trials.

In addition, improvements are recommended to optimize the uprooting mechanism for different soil types, reduce vibration and improve operator comfort during extended operations. Safety should be prioritized by integrating advanced features such as distance sensors and emergency stop mechanisms to protect both the operator and the equipment. The inclusion of a remote monitoring and control system will also allow farmers to supervise and operate the harvester via a computer or mobile device, increasing convenience and enabling proactive management of harvesting activities. Furthermore, adding a blade leveler to adjust the cutting depth according to the plant height will ensure accurate harvesting, minimize unnecessary plant damage and maximize efficiency. These improvements will not only improve operational performance but also strengthen the practicality of the machine and its long-term use by farmers.

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Conflict of Interest

There is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors have contributed to this past of the paper as follows: ***study conception and design*:** Muhammad Muhaimin Ajmal Mohd Rashidi and Nur Syahirunnisaa Afini Hafizi; ***data collection*:** Mohammad Aiman Amlzyi and Muhammad Muhaimin Ajmal Mohd Rashidi; analysis and ***interpretation of results:*** Muhammad Muhaimin Ajmal Mohd Rashidi; ***draft manuscript preparation*:** Muhammad Azri Othman, Rosdi Ab Rahman, Nur Syahirunnisaa Afini Hafizi and Mohammad Aiman Amlzyi. All authors reviewed the results and approved final version of manuscript.

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