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Design and Manufacturing of Pick and Drop system for Automatic Vegetable Transplanter

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Abstract - *It has been a challenge to design, develop, and manufacture innovative Pick-Drop mechanisms for an Automated Multi-Vegetable Transplanter. The transplanter is intended to streamline the process of planting various vegetables in agricultural fields, improving efficiency and reducing labour requirements. Developing sophisticated pick and drop systems for precise handling and placement of vegetable plants and advanced planting systems that can precisely plant different vegetable varieties at specific intervals to integrate the systems into an automated multi-vegetable transplanter that can be easily operated by agricultural workers. A transplanting experiment of the prototype was carried out, the picking success rate had reached 70%-75% and transplanting success rate was 80%-88% during experiment, which showed that the integrated operation of picking and planting seedlings can be realized by the proposed mechanism. This mechanism runs fully mechanically.*

Key Words: Automated Multi-Vegetable Transplanter, Pick and Drop Mechanism, Innovative Design, Precision Planting, Agricultural Automation, Transplanting Experiment, Mechanical Operation.

1.INTRODUCTION

In India, a significant portion, approximately 70 to 75%, of the population relies on agriculture, particularly for cultivating vegetables such as tomatoes, brinjals, chilies, and cabbage [1]. However, the traditional manual labour-intensive methods used for planting these crops are inefficient and face challenges due to labour shortages [2-3]. Contrastingly, developed nations like China, America, Italy, France, and Japan have introduced semi-automatic and automatic vegetable transplanters to address these issues effectively [4-7]. Innovative technologies such as Ferrari's gear and linkage system and Yanmar's ejector clamping mechanism have demonstrated success rates ranging from 80 to 90% in seedling picking and planting while minimizing damage [8], [9-11]. Additionally, pneumatic systems have been employed for precise seedling handling [12-14], although their effectiveness is hampered by mechanical stress and wear, particularly at increased transplanting speeds. The use of pick and drop mechanisms has been identified as a technical bottleneck hindering further advancements in this field. The transplanters utilized in developed countries, characterized by complex designs and multiple grippers [15-16], are unsuitable for India's smaller field sizes. Therefore, there is a pressing need to develop a new pick and drop system tailored specifically to the Indian agricultural context. This system aims to achieve an efficiency level of 70 to 80%, significantly surpassing manual planting while rivalling advanced international models. With a target of planting up to 2000 seedlings per hour, this innovation promises increased productivity and precision in seedling placement [17-18], thereby addressing the limitations of pneumatic systems and enhancing crop quality. By focusing on mechanical kinematic links [19-20], this new system aims to ensure affordability and suitability for smaller field sizes prevalent in India. The potential benefits of this project include reducing reliance on manual labour, enhancing planting speed and efficiency, and improving crop quality and yield. Additionally, the integration of automation and sensor technology is envisaged to further enhance precision and efficiency [21-23]. Cost-effective materials and manufacturing techniques will also be explored to facilitate wider adoption of the technology.

In summary, this project holds tremendous potential for transforming Indian agriculture by tackling critical challenges related to manual labour dependence and planting accuracy. The development of a mechanically-driven, India-specific pick-and-drop system promises sustainable and productive vegetable farming practices [24]. To enhance the technical summary, it is recommended to include images depicting existing manual planting methods in India [25], examples of international automatic vegetable transplanters, schematic diagrams of the proposed pick-and-drop mechanism using mechanical linkages, and visualizations illustrating the potential benefits in terms of planting speed, accuracy, and labour reduction. These elements will contribute to creating a more engaging and informative overview of the project's goals, challenges, and potential impact on Indian agriculture.

2.LITERATURE REVIEW

To initiate this project, we conducted a thorough review of transplanting literature from various research papers. In

India, the absence of a readily available automatic vegetable transplanter has led to labor shortages and inefficiencies during planting [26]. While existing research primarily focuses on techniques such as robotic arms [27-29], pneumatic systems, hybrid drives [30-31], Planetary Gear Train [32-33], push-out, and clamping combined mechanisms [34], these solutions are predominantly explored outside of India. To address this gap, we propose the design and development of a fully automatic vegetable transplanter tailored for Indian agricultural settings. The objective is to mitigate reliance on manual labor by automating seedling planting while ensuring high accuracy and cost-effectiveness. Our approach involves conducting an extensive literature review to identify existing automatic transplanting technologies and assess their applicability to the Indian market.

Furthermore, we have conducted field visits to vegetable nurseries, farms, and engaged with farmers to understand their specific needs. Based on our research and user feedback, we aim to design a novel planting mechanism powered by mechanical means that is robust and cost-effective for Indian agricultural conditions [35-38]. The envisioned automatic vegetable transplanter seeks to enhance planting efficiency, reduce labor costs, and improve accuracy and uniformity in seedling placement [39].

3.COMPONENTS AND ITS WORKING

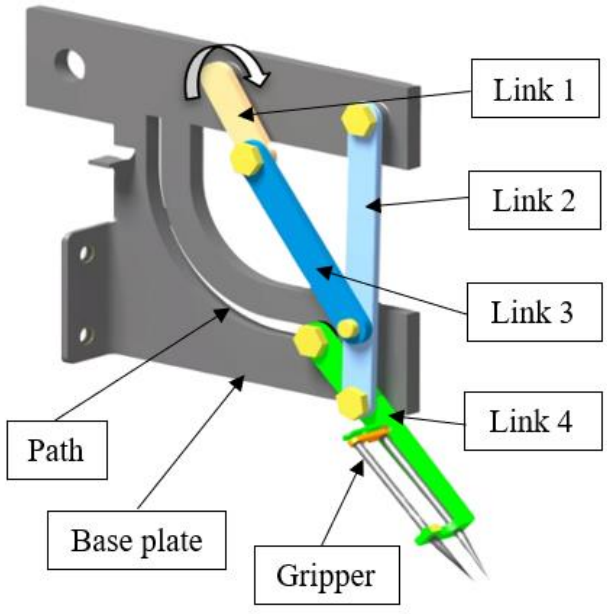

Fig.-1: Pick and Drop Mechanism

The above figure shows, four bar mechanism designed for the purpose of picking and dropping of a seedling with two degrees of freedom is delineated in a schematic representation. This illustration provides a comprehensive depiction of the mechanism, encompassing detailed specifications such as the lengths of the constituent bars, locations of joints or hinges, and their respective configurations.

Table -1: Sizes and Material of Part

No.	Part	Sizes	Material
1	Link 1	50 mm	Cold Rolled Steel (CR)
2	Link 2	100 mm	Cold Rolled Steel (CR)
3	Link 3	150 mm	Cold Rolled Steel (CR)
4	Link 4	180 mm	Cold Rolled Steel (CR)
5	Base Plate	-	Cold Rolled Steel (CR)
6	Gripper	-	Stainless Steel (SS)

Link 1 (Driving Arm): - Facilitated by a chain drive, the driving arm efficiently transfers power from the transmission. This power is then utilized to operate the pick-and-drop mechanism, ensuring a seamless and controlled motion essential for the transplanting process.
Link 2 (Hinge Arm): - This arm serves as the connector between the motion transfer arm and the gripper mechanism. Operating as a lever hinge, it plays a crucial role in transmitting motion, allowing for a coordinated and controlled movement of the gripper.
Link 3 (Motion Transfer Arm): - Functioning as a crucial intermediary, the motion transfer arm converts rotational motion into the translation of the hinge arm. This transformation enables the gripper to follow its designated slotted path with precision and accuracy.
Link 4 (Gripper Mounting Arm): - The gripper arm holds and guides the gripper mechanism along its slotted path, seamlessly following the motion transferred by the hinge arm. This ensures precise and accurate placement of the gripper during the planting process.
Gripper Mechanism: - The gripper mechanism is designed to delicately pick up the sapling using its two gripping arms. Its precise operation ensures the gentle removal of saplings from the tray, minimizing the risk of damage during the transplanting process.
Path: - It is one type of slotted part used to change the direction of gripper mechanism for Picking and Dropping the seedling from the tray. Bearings are strategically affixed to the moving link, facilitating its smooth interaction with the cam. This arrangement ensures the efficient transfer of motion from the cam to the gripper mechanism, promoting overall operational fluidity.

Base Plate: - The base plate serves as the foundational frame for the pick-and-drop system, housing and supporting all components. It plays a crucial role in securing the pick-and-drop mechanism to the main frame of the transplanter, providing stability and structural integrity.

Inner Mounting: The inner mounting component is employed to affix the inner wire, which serves as a conduit for transmitting the cam-generated power to the gripper mechanism, orchestrating the picking and dropping of seedlings from the tray.

Fix Link: The fix link contributes to the secure mounting of the inner wire and additionally provides support for holding the spring in place.

Spring: Springs play a critical role in mitigating the force exerted during the dropping action of the sapling, facilitating its transfer to the digger hopper. The controlled movement of the inner wire is achieved through the harmonized operation of the spring, ensuring a smooth and controlled process.

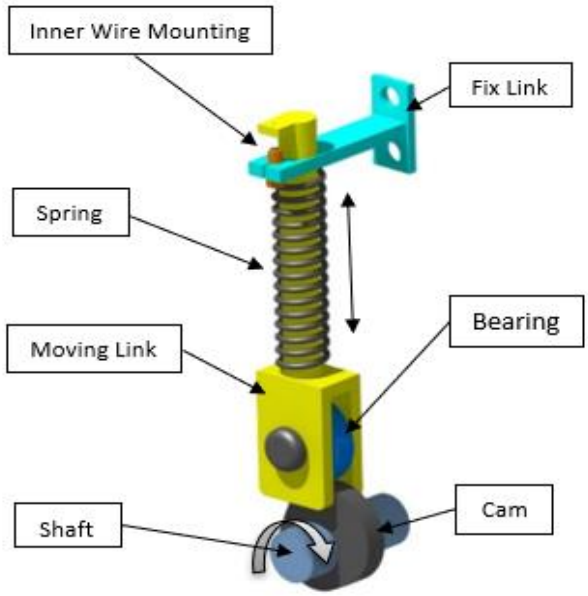

Fig.-2: Cam and Follower

Moving Link: The moving link serves as a conduit for transmitting the motion generated by the cam to the inner wire within the gripper mechanism, enabling the seamless operation of the picking and dropping actions.

Bearing: Bearings are strategically affixed to the moving link, facilitating its smooth interaction with the cam. This arrangement ensures the efficient transfer of motion from the cam to the gripper mechanism, promoting overall operational fluidity.

Cam: The cam serves a pivotal role in the gripper mechanism, facilitating the precise execution of picking and dropping actions. The temporal synchronization of these actions relies on the cam profile, ensuring accurate timing [40-43].

Shaft: The shaft is instrumental in effecting the rotation of the cam, thereby initiating the dynamic sequence of movements essential for the gripper mechanism.

4. METHODOLOGY

The following flowchart depicts the systematic process employed to gather information on the pick and drop mechanism utilized for seedling transplantation. This methodical approach involves the identification and collection of relevant data points related to the seedling transfer process, emphasizing the scientific principles underlying the mechanism's functionality.

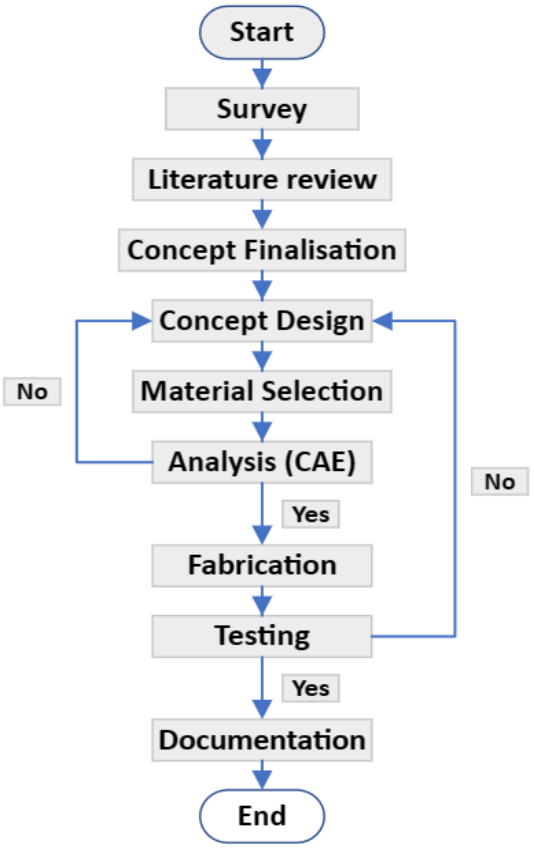

Fig.-3: Flow chart

The current Seedling picking and dropping mechanisms employed in machinery such as Yammer's and Kubota exhibit intricate structures, leading to elevated production costs. In India, reliance on foreign machinery further amplifies expenses due to importation costs, compounded by the challenge of component unavailability in the domestic market. The complexity of these machines also results in time-consuming repairs [44-45]. In response to these challenges, a novel seedling picking and dropping mechanism is proposed.

To develop an effective solution, an extensive field study was conducted, encompassing visits to various farms,

nurseries, and an in-depth analysis of field parameters [46-49]. Factors taken into consideration included field area, seedling characteristics, tray dimensions, weight and planting methodologies [50-51]. This comprehensive analysis laid the groundwork for the innovation of a streamlined and cost-effective sapling picking and dropping mechanism.

Fig.-4: Survey of Field and Seedling

Fig.-5: Prototypes

The innovation process involved multiple iterations of trial and error, utilizing readily available raw materials such as paper, cardboard, wooden plywood, metallic rods, and sheets. Prototypes (a), (b), (c) were meticulously crafted such as paper, cardboard, wooden plywood, metallic rods, and sheets. Prototypes were meticulously crafted based on the insights gained from the field study, resulting in a series of images depicting the evolution and refinement of the proposed mechanism. These prototypes aim to address the identified issues by offering a simplified and efficient alternative, thereby potentially revolutionizing sapling handling in the agricultural sector.

Specification of Seedling and Tray: -

Fig.-6: Seedling Tray

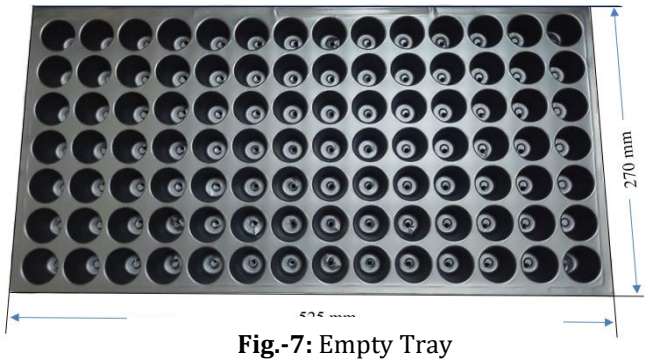

Fig.-7: Empty Tray

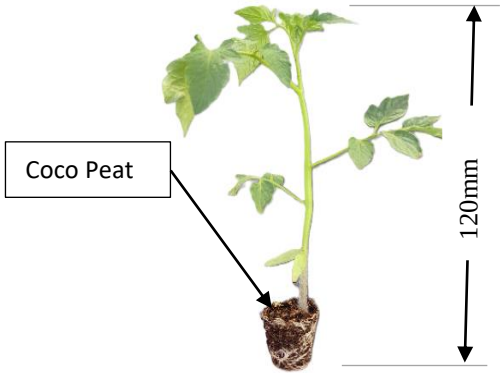

Fig.-8: Developed Seedling

In various locations, discrepancies in tray and seedling dimensions, including variations in length, breadth, diameter, height, and weight, have been observed [52-53]. After careful consideration, a standardized tray size of 270x525mm has been selected, commonly utilized by the majority of nurseries, accommodating 98 seedlings arranged in 14x7 configuration. The individual seedling

cups within the tray have dimensions of 35mm in diameter and 40mm in height. It is noted that in certain countries, a specialized tray designed for reusability is employed in seedling production, whereas in India, disposable trays are predominantly utilized. Upon reaching full development, seedling heights range from 80 to180mm.

5.RESULT and DISCUSSION

The provided description outlines a mechanism for the automated picking and dropping of seedlings from a tray to a planting mechanism. The process involves a gripper mechanism equipped with tips that close and open to securely hold and release seedlings. The initiation of the gripping action occurs when the gripper mechanism approaches the tray, and the tips delve into the seedling cup. Subsequently, the gripper, holding the seedling, moves towards a hopper. When the gripper is positioned above the hopper, the tips of the gripper open to release the seedling into the hopper.

Fig.-9: Picking and Dropping

The synchronization and timing of the gripper mechanisms tip movements, specifically the opening and closing actions, are regulated by a cam and follower system. The entire mechanism operates in a clockwise rotational direction. The speed of the picking and dropping process is modulated by the cam and follower, and an increase in speed results in a reduction in the overall time required for picking and dropping seedlings. The interplay of the cam and follower ensures a coordinated and efficient motion of the gripper mechanism, facilitating the successful execution of the seedling transfer process.

Table 2: Operation Time to Pick Single Sapling

Sr. No.	Shaft Rotation (rpm)	Picking and Dropping time (sec)
1	34	1.8 sec
2	28	2.1 sec
3	22	2.7 sec
4	16	3.6 sec
5	13	4.5 sec
6	11	5.4 sec

In a comparable fashion, the relationship between the speed of the mechanism and the timing of seedling picking and dropping is elucidated through a chart displaying RPM (revolutions per minute) and corresponding time intervals in seconds. The timing of the seedling picking and dropping process is contingent upon the planting distance. Specifically, when the distance between plants is maximized, the speed of the picking and dropping mechanism decreases. Conversely, in situations where the plant-to-plant distance is minimized, there is a heightened requirement for an increased speed in the picking and dropping mechanism. The presented data establishes a quantitative correlation between the speed of the mechanism, the timing of the seedling transfer, and the varying planting distances.

6. CONCLUSIONS

Following a comprehensive research, design, and testing process, the Pick and Drop Sowing System has emerged as a promising solution for modernizing automotive vegetable transplanting. Developed through collaboration with experts in robotics and agriculture, the system integrates advanced technology to streamline planting processes, enhancing agricultural efficiency. The systematic approach, encompassing literature review, prototyping, and testing,

has yielded a functional prototype capable of precise seedling placement, uniform crop spacing, and optimized resource utilization. During the testing and validation phase, the system demonstrated effectiveness in both simulated and real-world agricultural settings, showcasing its potential to revolutionize traditional planting methods. Comparative studies with manual planting methods underscored the Pick and Drop Sowing System's superiority in terms of labour efficiency [54], planting speed, and crop uniformity. Moving forward, continuous refinement and optimization are deemed crucial to further enhance the system's performance and ensure adaptability to diverse agricultural contexts. The Pick and Drop System represents a significant advancement in agricultural automation, poised to drive sustainable farming practices and improve future crop yields. Moving forward, continuous refinement and optimization are deemed crucial to further enhance the system's performance and ensure adaptability to diverse agricultural contexts. The Pick and Drop System represents a significant advancement in agricultural automation, poised to drive sustainable farming practices and improve future crop yields. Challenges encountered, including mechanical wear, calibration issues, and occasional malfunctions, have been identified as areas for potential improvement in future iterations. Opportunities for enhancements include integrating advanced sensors for object detection, implementing predictive maintenance algorithms, and optimizing control algorithms for improved performance. Conclusively, the Pick and Drop System, with a transplanting success rate of 80%-88% during experiments, has provided valuable insights into the design, implementation, and operation of automated systems for material handling tasks.

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