Automatic Multi vegetable Transplanter for Chilli Cultivation

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Abstract — Automatic vegetable transplanting machines help reduce hard work, save time, and improve planting accuracy compared to manual methods. Technologies like robotics and automatic seedling pick-up systems make transplanting easier and more efficient with less human effort. However, more research is still needed to make these machines cheaper, simpler, and suitable for different farming conditions.

Keywords: Automatic Vegetable Transplanting Machine; Agricultural Robotics; Seedling Transplanting System; Precision Farming; Farm Mechanization; Smart Agriculture Technology;

I. INTRODUCTION

The automatic multi-vegetable transplanter is a highly useful and advanced agricultural machine that improves the efficiency and accuracy of vegetable transplanting operations. Traditional manual transplanting requires a large amount of labour, time, and physical effort, while semi-automatic machines still depend on continuous manual feeding of seedlings. The developed transplanter overcomes these limitations by automating the planting process and ensuring uniform transplanting with minimum human intervention.

The machine is designed to transplant different types of vegetable seedlings such as chili, tomato, brinjal, cabbage, and cauliflower. It is capable of maintaining proper row-to-row and plant-to-plant spacing through an adjustable gear mechanism. Once the spacing is adjusted, it remains constant throughout the field operation, ensuring uniform crop growth and better field management. The machine also maintains proper planting depth, which helps in healthy root establishment and improved survival rate of seedlings. One of the major advantages of this transplanter is that it handles seedlings carefully without damaging the saplings. The automatic seedling pickup and dropping mechanism places the seedlings accurately into the soil, reducing missing plants and improving planting precision. The machine generally consists of components such as a seedling tray holder, pickup mechanism, furrow opener, planting unit, press wheels, transmission system, and supporting frame. Some advanced systems may also include robotic manipulators, grippers, machine vision systems, or automated indexing mechanisms for efficient seedling handling.

With the increasing demand for vegetables in local, national, and international markets, farmers are shifting towards vegetable cultivation for higher income generation. In this context, automatic multi-vegetable transplanters play an important role in promoting precision agriculture and farm mechanization. They help farmers save labour costs, increase efficiency, and achieve timely transplanting operations, which are essential for obtaining higher yields and better-quality.

However, there is still scope for further improvement in areas such as reducing machine cost, improving adaptability for different soil and field conditions, increasing operational speed, and enhancing the reliability of automatic seedling pickup mechanisms. Overall, the automatic multi-vegetable transplanter is an effective and promising solution for modern vegetable farming and sustainable agricultural development.

II. LITERATURE REVIEW

The study of Pralhad magar et.atimely transplantation of vegetable seedlings is vital for horticultural productivity but is increasingly challenged in India due to labor shortages, limited mechanization, and high costs of imported transplanters. To addressthese issues, a simple, low cost vegetable transplanting device with an automatic plug-tray seedling extractor was designed and developed [1].

Chaudhari tushar et.al This project focuses on designing and implementing an automatic transplantation system using a conveyor belt and a Programmable Logic Controller (PLC) to improve efficiency in agricultural operations. The system automates the transfer of seedlings from trays to fields or larger containers, reducing labor requirements and increasing planting precision [2].

Jin et al. Developed an automatic vegetable seedling conveying system to enhance the automation, precision, and reliability of mechanized transplanting. The system integrates a tank-wheel seedling storage unit, a seedling tray conveyor, and a hanging cup circulating mechanism for efficient seedling transfer [3].

The study of Nag et.al India ranks second after China in global vegetable production, with about 8.5 million hectares under cultivation and producing roughly 188 million tons about 15% of the world's total. Despite this large production, vegetable transplanting in India remains largely manual, making it labor-intensive, time-consuming, and inefficient. To improve productivity and meet the growing food demand, mechanization in vegetable transplantation is essential. The study by Nag et al. Reviews the design, development, and performance of various types of vegetable transplanters [4].

The study by Han et al. Focuses on the performance and development of seedling picking devices, which are key components of automatic transplanting machines. These devices directly affect efficiency, quality, and cost in transplanting operations and play a major role in advancing agricultural automation. Currently, there is a trade-off between picking speed and success rate, meaning that faster operation often reduces accuracy [5].

Sharma and khar et.al The study focused on improving the efficiency of vegetable transplanters by developing two semi-automatic mechanical seedling feeding mechanisms for a tractor- Automatic multi vegetable transplanter for chilli cultivation KIT, Shelve, Pandharpur 6 mounted transplanter: the Revolving Multi-Chamber Disc Mechanism (FMRMD) and the Horizontal Dragging

Magazine Mechanism (FMHDM). Study The research was carried out at the Sher-e-Kashmir University of Agricultural Sciences & Technology of Jammu, India.[6]

The study by Kakade et al. Highlights the challenges and advancements in vegetable transplanting. In India, vegetable transplanting is largely done manually, which is labor intensive, time-consuming, and physically demanding, often causing muscular fatigue due to prolonged bending and squatting [7].

Shao et al. Developed a multi-functional vegetable pot seedling transplanting machine integrating transplanting, fertilization, soil covering, watering, film covering, and drip irrigation tape laying in a single operation. The machine includes a duckbill-type planter, fertilization mechanism, power transmission system, soil covering device, watering device, and film/pipe laying mechanism [8].

The study of Han et.al Vegetable production is crucial for food security in Bangladesh, but manual seedling transplantation is slow, labor-intensive, and costly. To address this, Miah et al. Developed and evaluated two semi-automated vegetable seedling transplanters: [9].

The study by Kumar et al. focused on the design, development, and evaluation of a manual vegetable transplanter for two crops tomato and chilli to reduce labor and time in transplanting operations. The transplanter comprised several components, including a frame, wheels, supporting rod, seedling stand, seedling delivery tube, jaw mechanism with pedal, and a furrow covering device. During operation, the delivery tube penetrates the soil with minimal effort, and seedlings are dropped through the tube while the jaw opens via a pedal mechanism [10].

Hin et.al In Cambodia, vegetable crops are mostly planted manually, which limits production and makes it difficult to meet local market demand. To address this, researchers developed and evaluated a locally made mechanical vegetable transplanter compatible with two-wheel tractors to reduce labor and input costs [11].

Khadatkar et.al Manual vegetable transplanting is a labor-intensive and time-consuming process. While semi-automatic transplanters exist, their efficiency is often constrained by the manual feeding rate of seedlings, which depends on the operator's skill and endurance. To address these challenges, automation and robotics are being integrated into vegetable transplanting systems to save labor and time [12].

Paradkar et al. Developed an automated metering mechanism for a vegetable transplanter designed to handle tomato seedlings grown in biodegradable paper pots. The system integrates Automatic multi vegetable transplanter for chilli cultivation KIT, Shelve, Pandharpur 7 a 3-degree-of-freedom (3-DOF) serial robotic arm with an automatic feedingconveyor[13].

Mahapatra et.al Vegetable transplanting is labor-intensive, accounting for around 20% of total labor in cultivation, and is particularly challenging in small plots in eastern and northeastern India. To address this, Mahapatra et al. Developed a power-tiller operated vegetable transplanter with two attachments [14].

Ji et.al The automatic transplanter effectively coordinated all its components to complete the transplanting process. It met operational requirements for dry land cultivation and provides a theoretical basis for future fruit cultivation in solar greenhouses [15].

The study mohanty et.al evaluated a two-row semi-automatic vegetable transplanter to determine the optimum funnel side slope angle in its feeding and metering mechanism for different seedling types and ages. Using a three-factor Completely Randomized Design with four replications, the experiments showed that funnel angles below 75° reduced seedling slippage, especially for crops with larger seedlings or more foliar growth [16].

Habineza et.al Seedling transplanting is a crucial but labor- intensive step in vegetable cultivation. This study reviewed existing vegetable transplanters and analyzed the kinematics of their key mechanisms. Transplanters are generally classified as handheld, semi-automated, or fully automated, with main mechanisms including seedling picking and dibbling, using bar based or gear-based systems[17].

The study of Jorg et.al.Vegetable transplanting is vital for production, and recent interest has grown in automatic and robotic transplanters. This study designed and tested two types of grippers a needle gripper and a two-finger gripper for picking, lifting, and transplanting plug seedlings. Tests on fennel, leek, chicory, and lettuce showed average success rates of 81.75% for the needle gripper and 95% for the two-finger gripper [18].

The study of Sun et.al. focuses on improving the performance of the duckbilled planting device, a key component of automatic transplanters, which often suffers from low transplanting rate, poor upright planting angle, and instability. To address these issues, a five-pole transplanting mechanism was designed. Its parameters were analyzed and optimized using MATLAB. A virtual prototype was created in solidworks and then imported into ADAMS for kinematic simulation, yielding the trajectory, velocity, and acceleration curves of the duckbilled tip.[19]

The study of Ray and Moses et.al. addresses the challenges of labor-intensive vegetable transplanting due to variability in seedling size and spacing requirement [20].

III. Methodology

A. *Selection of mechanism*

After understanding existing solutions, suitable mechanisms such as digging, chain mechanism, sprocket, robotic arm, gripper mechanism, connecting rod are evaluated. The selection is based on factors like crop type, seedling size, soil conditions, cost, and efficiency. Detailed analysis is performed to determine how well the chosen mechanism can meet the design requirements.

B. *Design of mechanism*

In this stage, the selected mechanism is converted into a detailed engineering design. This includes creating 3D models, calculating dimensions, forces, material selection, and other technical parameters. The design ensures that the mechanism functions smoothly, safely, and efficiently in actual working conditions.

1) *Calculation of wheel Seedling spacing relationship*

$$D = \frac{N \times P}{\pi}$$

$$= \frac{1 \times 0.38}{3.14}$$
$= 0.12$ mm

2) Calculation of sprocket
determine the required transmission ration

$$i_{re} = \frac{ground\ wheel\ circumference}{no.of\ planting\ cup \times sp}$$
$$= \frac{0.38}{1 \times 0.30}$$
$= 1.266$

3) Calculation of chain

$$= \text{Chain liner speed} = f \times Lc$$
$$Vc = 1 * 0.377$$
$$= 0.377\ m/min$$

4) calculation of plant density (area basis)

Area per plant = sp × sp
= 0.45 × 0.38
= 0.171 m^2

Plant density (D_p) = $\frac{Plant\ density\ (Dp)}{AP}$
$$= \frac{10000}{0.171}$$
=58479.53 plant / ha

C. Actual model

Fig. 1: Actual model of vegetable transplanter

D. CAD model

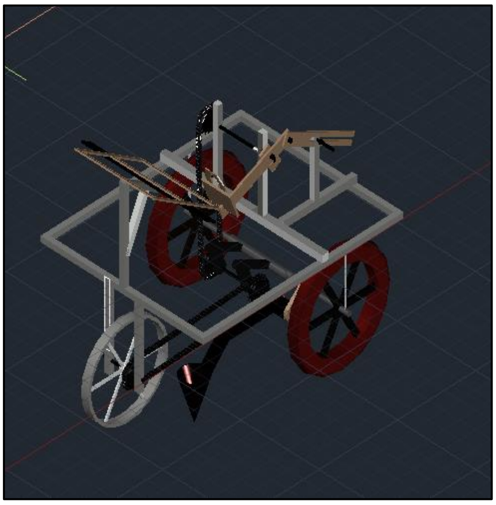

Fig. 2: 3D model of vegetable transplanter

IV. Conclusion

1) A thorough study of various transplanter mechanisms was carried out, including their structural design, working principles, and operational characteristics. This analysis helped in identifying the strengths and limitations of existing systems, such as planting accuracy, labor requirements, cost, and field suitability. The insights gained from this study provided a strong foundation for developing a more efficient and improved transplanting mechanism.
2) Based on the understanding acquired from the study of existing mechanisms, the proposed transplanting mechanism was successfully designed and fabricated. Appropriate materials, components, and fabrication techniques were selected to ensure durability, ease of operation, and functionality. The completed prototype accurately reflected the intended design and proved to be structurally sound and operationally feasible during initial trials.
3) The performance of the fabricated mechanism was evaluated under practical conditions and compared with existing transplanter systems. The analysis revealed that the proposed mechanism demonstrated better consistency in plant spacing, ease of operation, and overall efficiency. The improved design also showed potential for reducing labor requirements and operational time. These results confirm that the proposed mechanism provides advantages over traditional systems and can serve as a viable alternative for effective transplanting.

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