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Design and Development of Small-Onion Harvester for Sustainable Farming

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ABSTRACT: *In this modern era, mechanization plays a vital role in reducing the risk factors faced by farmers. In India, mechanization is one of the growing platforms, a lot of machinery is invented for agricultural purposes. Harvest plays a major role in agriculture because it is the key step for production. Harvesting can be a difficult process, because improper harvesting of crops may lead to crop damage and wastage. There are different methods for harvesting different variety of crops. Many harvesting machinery are invented based on the nature of crops and the soil. Root crops like potatoes, carrots, turmeric, and onion play a major growth for agriculture sector in India. Harvesters are manufactured for root crops but the major drawbacks faced by the farmers are high cost, tractor-drawn, and difficult to carry in roadways. A small-onion harvester is designed and fabricated for sustainable farming for the farmers with more advantages. This project mainly focuses on the efficiency of the harvester and harvesting time, minimal requirement of labor, simple and compact design, easy to transport to the farmland, and cost-effective. Small and marginal-scale farmers can utilize modern mechanization and improve their yield by reducing the damage to the onion bulbs.*
KEYWORDS: *Root crop harvester, Small -onion harvester, Sustainable farming.*

I. 1.INTRODUCTION

Agriculture is the backbone of India and it is a labor-intensive process, from seeding to harvesting which requires a large number of labourers. Modern technology can minimize farmers' efforts in the field. In certain areas, such as irrigation, people have already begun to employ contemporary methods and tools. Because of their nature, some processes like harvesting, offer substantial opportunities for technological advancement [1]. Onion harvesting is challenging and takes a significant amount of time and labor and one of the key factors of low productivity is a lack of farm mechanization. The process of harvesting bulb onions involves pulling a breaker bar through the dirt underneath the onions to uproot them and expose the bulbs. In other cases, the untopped onions are picked first and in the packing location, they are manually topped. Nevertheless, manual procedures are costly, time-consuming, and prone to worker injuries [2]. One of the environmental-friendly methods is sustainable farming which allows the production of crops or livestock without causing damage to humans or natural systems and prevents effects on soil, water, and biodiversity. Various nonconventional agricultural practices, commonly referred to as organic, alternative, regenerative, ecological, or low-waste input, are included in sustainable agriculture. However, a farm is not necessarily sustainable just because it is organic or alternative. Sustainable agriculture blends conventional conservation-minded farming practices with contemporary technologies rather than reverting to pre-industrial revolution practices. Sustainable systems make use of the newest advancements, certified seed, soil and water conservation techniques, and contemporary machinery [8].

Plenty of research on the harvesting process has shown that the various methods of harvesting the onion bulbs impact both the quality and storage life of the onions [3]. According to Younus and Jayan [4], root crop harvesters should be designed so that in comparison to traditional harvesting, it should boost productivity. The machine should lessen the amount of time that workers interact during the harvesting stage and solve the issue of labor drudgery that arises during traditional harvesting methods. Onion plants are ready for harvest when the leafy green tops start to turn yellow and eventually collapse just above the bulb. This usually occurs 70 to 90 days after transplanting, depending on the variety of the crop [5].

In India, small-onion grows in temperate zones under subtropical conditions and there are two harvest cycles for onions. The first cycle occurs from November to January, while the second cycle runs from January to May. During the early harvest, the onion bulbs sprout, and secondary roots develop during storage in the late harvest. Farmers use a khurpi to physically remove the onion bulbs and leaves from the field during the harvest.

After harvesting, the leaves are clipped to 20-25 mm above the onion bulbs at neck height, after allowing them to sun-cure for two to three days [6].

Despite the development of tractor-drawn elevator-style potato diggers, the biometric characteristics of onions and potatoes are completely different. Farmers currently harvest onions in India by leaning over to remove the bulbs by holding the onion plant's neck in place and then sitting down to remove the leaves. When excavating well-matured bulbs by hand, workers' posture is hunched forward, which is highly inefficient and makes their work tedious. When compared to other working positions, the stooping stance has a higher vitality utilization and causes a lot of biomechanical stress in the back.

II. MATERIALS AND METHODS

The harvester was designed and developed to dig an onion bulb, lift the bulb, and move the dug onion to a separation unit to remove the soil mass from the crop and they can be picked up by hand with the least amount of damage to the onion bulbs [7].

2.1 Components used:

2.1.1 BEARINGS:

Ball bearing is used in small-onion harvesters, it consists of an inner ring, outer ring, balls, and cage the inner diameter of the ball bearing is 15 mm, and the outer diameter of the bearing is 35 mm. Mostly, one ring is stationary and the other ring is attached to the rotating assembly. When force is applied to the ball bearing, it converts sliding friction into rolling friction. In this case, the friction is reduced and allows the bearing to accommodate radial and axial loads. Bearings are most commonly used in all mechanical instruments to reduce friction. There is minimal relative contact that takes place between the bearing and the moving part of an assembly. Lubrication is done often to reduce wear and friction.

Figure 1: Bearings

2.1.2 FRAME:

The frame acts as a supportive structure that holds components like conveyor belts, blades, wheels, chain conveyors, batteries, and motors. Frames are made up of high-strength materials like steel or alloys to withstand vibrations during operation. Frames can withstand heavy loads and protect the components from damage.

Figure 2: Frame

2.1.3 BELT CONVEYOR:

A belt conveyor is a continuous loop of material handling equipment used to carry bulk goods or objects from one location to another. It is widely used in many industries, including manufacturing, mining, agriculture, and logistics. As part of the conveyor system, a belt—typically made of rubber, PVC, or cloth—moves across rollers or pulleys to move cargo.

2.1.4 CHAIN CONVEYOR:

A chain conveyor is a type of mechanical conveyor system that uses a chain to move materials or commodities along a predefined path. Unlike belt conveyors, which use a continuous loop of flexible material

(like cloth or rubber), chain conveyors use a more rigid chain to move large or bulky products. Chain conveyors are therefore ideal for moving big, heavy loads or unevenly shaped items that need to be handled carefully and the dimension of a chain conveyor is 550*350 mm.

2.1.5 BATTERY:

A battery is an energy storage device that undergoes chemical reactions and provides electrical energy and it provides a portable and reliable power source. The battery supplies power to the motor to run the chain conveyor and belt conveyor. Rechargeable batteries with 12V capacity are used in small onion harvesters. Batteries are connected in series because Voltage increases and amps become constant. If they are connected in parallel the amps increase and voltage remains constant, at this condition, the power fluctuation takes place and the working of machinery stops abruptly. So, they are connected in series.

2.1.6 MOTOR:

A motor is an electromechanical device that converts electrical energy into mechanical energy. An electric power is supplied to the motor from the battery and the electrical energy is converted as mechanical energy and is supplied to the conveyor system. A Stepper motor is used in the fabrication of a small-onion harvester because it is more effective at moving loads slowly, thereby the damage to onion crops and the labor can be minimized. DC motor is used in small-onion harvester.

2.1.7 BLADE:

Blades are made up of high carbon steel which is highly durable and has excellent wear resistance. There are different types of blades used for various applications. Straight blades are used for harvesting a row crop without any damage because they are not much sharpened when compared with other types of blades. Straight blades are used for slicing the soil and it loosens the soil around the onion bulb. While harvesting the small- onion, the straight blades are used to dig the onion bulbs without causing any damage to the bulbs.

2.1.8 GEAR:

Based on the application, worm gears are used to reduce rotational speed or transmit higher torque. A total of 1440 rpm is reduced by half to withstand the torque produced. Worm gears are mainly used in chain conveyors and belt conveyors to reduce the torque.

2.2 METHODOLOGY

2.2.1 DESIGN OF HARVESTER

The initial process of developing a harvester includes design and design software. In this technological era, there are much mechanical design software have been developed to solve the risk factors faced by the manufacturing industries and many advanced levels of designing software with new features are imported day by day in the designing field.

This project design is mainly based on the software named “Solid Works” with advanced features it is a basic design software that can be accessed easily and is the best learning platform for a design engineer. By considering the following factors, such as field size, spacing between crop and bund, the height of the bed, and physical characteristics of small-onion the harvester was designed using the software. The basic requirements for manufacturing a harvester include handles, frames, Conveyors, and Wheels that are designed with appropriate measurements such as Length(L), Width (W), and Height (H). The different parts of the harvester are designed separately and later they are assembled and the outline of a product is resulted through this platform in 3-D view.

2.2.2 WORKING PROCEDURE

Using a straight blade, the developed harvester first digs the soil before sending it to its adjacent conveying unit. Here, a chain conveyor is used to move the onion bulb from the bottom to the top by rotational motion with the help of motor speed that prevents onion bulbs from damage, and the conveyor aids in removing the soil mass from the onion bulb. They are subsequently moved to the belt conveyor, which is connected at the top, following the chain conveyor. The harvested onion bulb is pushed aside in the field by a belt conveyor, making it easier to collect the onion by hand later.

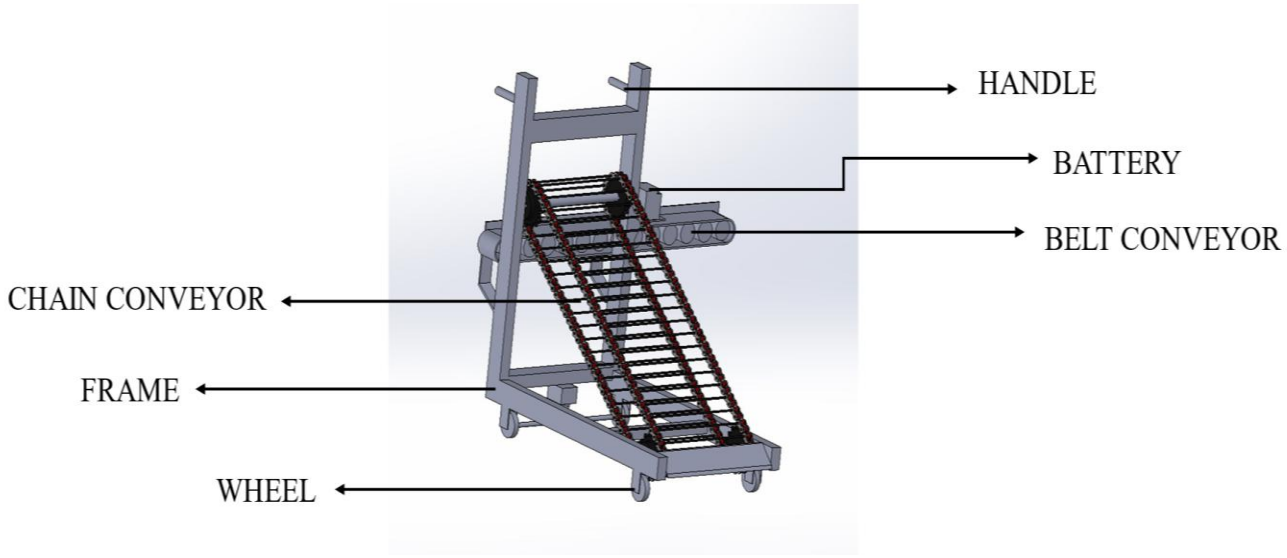

Figure 3: Design of small-onion harvester

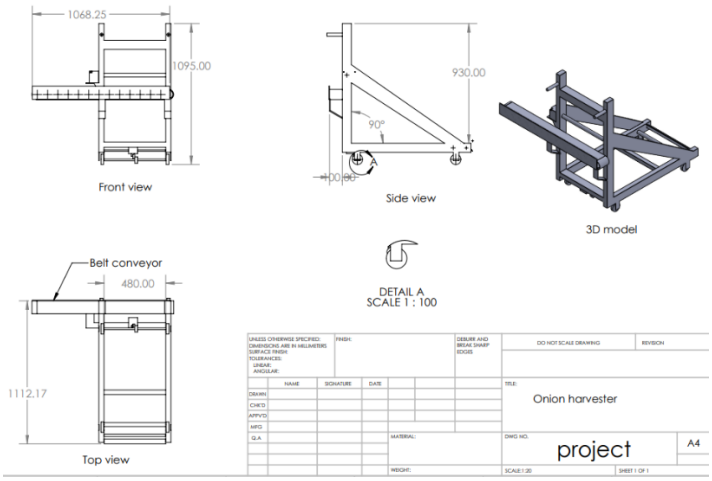

Figure 4: 2D view of harvester

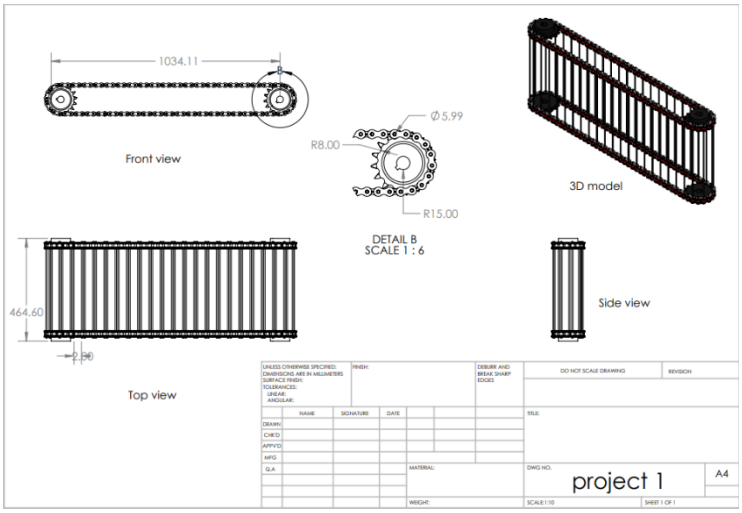

Figure 5: 2D view of Chain conveyor

The onion harvester can simultaneously dig, lift, clean, and gather onion bulbs. It is a one-row with a single forward speed and no reverse operation. Compared to harvesting by hand, the developed onion harvester involves significantly less labor. So, this can lower the cost of labor as well as harvesting time. It is compact and easy to transport to the fields through roadways. It can be utilized by small-scale and marginal farmers.

Figure 6: Developed onion harvester

III. RESULT AND DISCUSSION

3.1 Physical features of small-onion and description of harvester

The physical features of the small onion was analyzed based on its diameter, width of small onion measured across its widest part, and weight (baby onion or pearl). All these factors are tabulated in Table 1 and the specification of the harvester are listed in Table 2.

Table 1:Physical Parameters

Diameter (cm)	Weight (g)	Width (cm)	Height of stem (cm)
2.4	27	2.5	22
3.1	29	2.8	25
3.4	26	3.3	19
2.9	34	2.9	27
3.7	25	3.5	20

Table 2: Specification of Harvester

S.NO	COMPONENTS	SPECIFICATION
1	Machine overall dimension and weight	
	Length, mm	1112
	Width, mm	480
	Weight, kg	30
2	Type of power transmission	
	Battery	Rechargeable battery
3	Gear Type	Worm
4	Digger blade	
	Type	Straight
	Material	Mild Steel
	Dimension: L*W	477 *75
5	Soil-onion separating device	
	Conveyor Type	Chain
	Material	Mild Steel
	Spacing, cm	2
	Dimensions: L *W (mm)	550*350

3.2 Performance test of small onion harvester

3.2.1 Effect of yield analysis

When comparing traditional and machine-based methods, the yield of small onions over time exhibits distinct patterns.

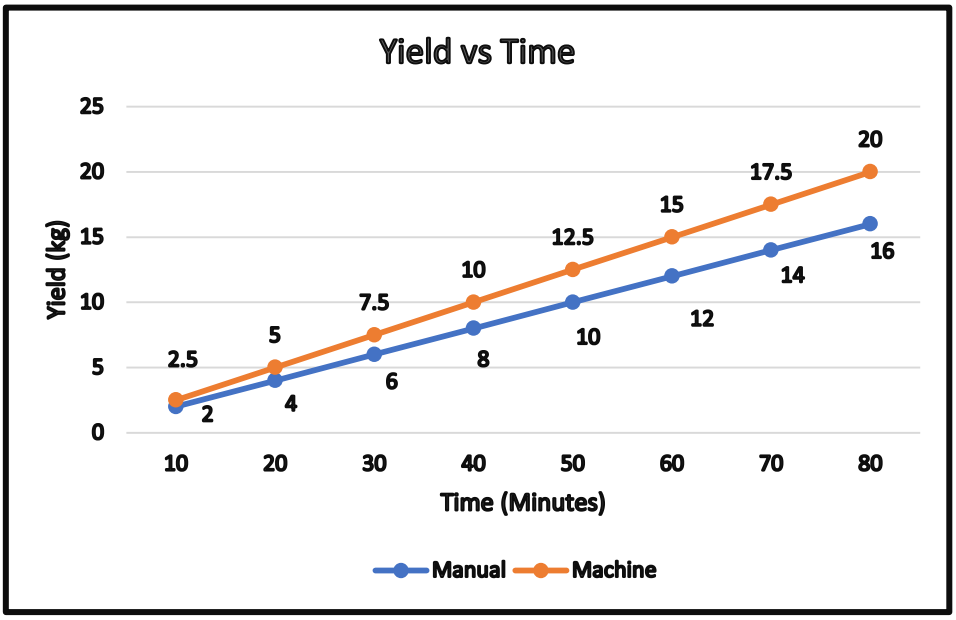

Figure 7: Correlation Plot of Yield and Time

Figure 7, results the peak yield difference between mechanization and conventional method of harvesting. The rate of yield for 10 minutes is approximately 2 kg by means of manual harvesting by persons, while using harvester the yield obtained approximately 2.5 kg. A yield of 16 kg was obtained in 80 minutes by manual harvesting whereas, using the developed harvester the same yield was obtained within 70 minutes. This demonstrates a notable decrease in small-onion production when harvested by hand and a notable increase in machine harvester.

3.2.2 Effect of wages analysis

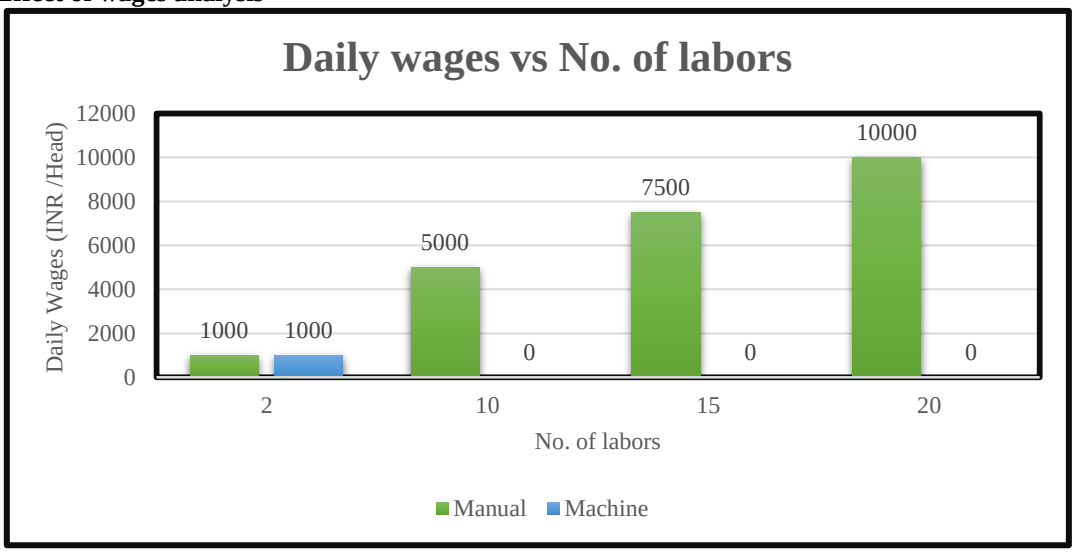

Figure 8: Distribution of Wages for Machine vs Manual Harvest

It takes 30 to 35 workers to harvest one acre of small onion fields, and each worker is paid Rs 500. According to the bar chart in Figure 8, as the number of workers rises, so do the wages paid to them. When compared to the manual harvesting approach, the harvester requires the least amount of labor. About two workers are needed to operate the equipment, which costs Rs. 1000 each day. While a mechanized harvest can be finished in two days, a manual harvest takes four to five days to accomplish. Therefore, harvesting by machine costs less than harvesting by hand.

3.2.3 Effect of depth of harvest on actual yield

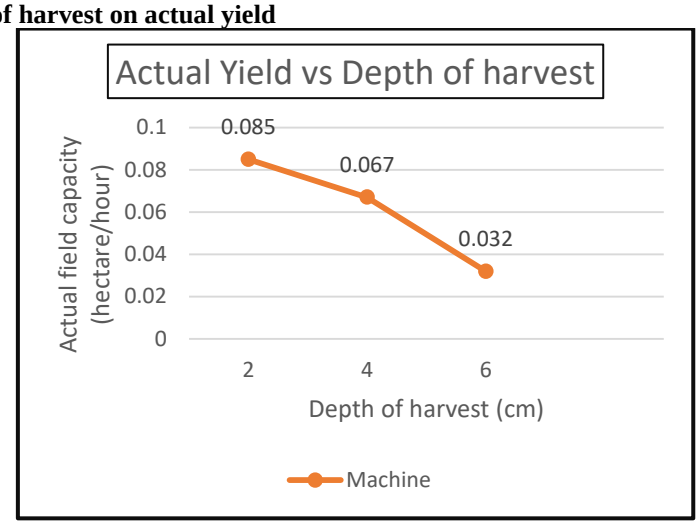

Figure 9:.Correlation of Actual Yield and Depth of Harvest

In Figure 9, the actual field capacity of 0.085 hectare/hour is the highest at a shallow depth around 2 cm, as the depth increases the field capacity decreases. By increasing the depth of harvest from 2cm to 6 cm the actual field capacity drops 0.085 hectare/hour to 0.067 hectare/hour and from 0.067 hectare/hour to 0.032 hectare/hour.

In small-scale onion fields, this 12V battery-operated harvester works typically for 8 hours, and the performance of the harvester was stable throughout the process, showing no decline in power during continuous use. As it is a rechargeable battery, it can be recharged throughout the night for better operation and it is economically benefit for farmers. The other major parameter of the battery-operated small-onion harvester was able to reduce damage to the onion bulbs when compared to the traditional method of harvesting. The harvester was found to be lightweight, weighing 30-40 kg, and was designed to minimize physical strain for the laborers.

IV. CONCLUSIONS

Onion harvesting by hand is a labor-intensive and expensive process. Onion bulb shelf life is impacted by the delay in harvesting because there are decreasing numbers of laborers available for farm operations and this may also lead to a decrease in production. The developed small-onion harvester demonstrates significant potential for improving harvesting efficiency. The harvester performs key operations such as digging, lifting, and conveying onions with minimal damage. Field test results that the machinery reduces harvesting time and minimal usage of labor. The main advantage of the use of a battery-operated harvester is eco-friendly with low maintenance cost. Overall, this harvester addresses labor challenges in onion harvesting and provides a sustainable solution for enhancing production.

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