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Shrawan Bajya
Innovator (Informal Sector), Sikar
District, Rajasthan, India

Ritul Dobariya
Research Associate-II / Scientist-E,
National Innovation Foundation-
India, An Autonomous Body of the
Department of Science &
Technology (DST), Government of
India

Rakesh Maheshwari
Research Associate-II / Scientist-E,
National Innovation Foundation-
India, An Autonomous Body of the
Department of Science &
Technology (DST), Government of
India

Akash Bhavsar
Former M.Tech Student (Machine
Design), Nirma University,
Gujarat, India (2016-2018), and
Intern, National Innovation
Foundation-India

Corresponding Author:
Shrawan Bajya
Innovator (Informal Sector), Sikar
District, Rajasthan, India

Development of integrated tractor front mounted onion harvester with inbuilt leaf de-topping unit

Shrawan Bajya, Ritul Dobariya, Rakesh Maheshwari and Akash Bhavsar

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Abstract

India is the second largest onion producer. Typically, both the harvesting and the post-harvest leaf cutting of onions is done by conventional manual method, which are a time-consuming, expensive and drudgeries activities. A project was initiated to develop an integrated tractor front-mounted onion harvester with inbuilt leaf de-topping unit. Based on discussion with stakeholders and review of literature, few concepts were ideated and prototype of most appropriate concept was developed. The machine was found performing satisfactory in field. The field capacity of the harvester was observed 0.39 ha/h with field efficiency of 82.97%. On weight basis, the percentage of damaged bulbs, buried bulbs and harvesting efficiency were found as 3.30%, 0.33% and 96.37%, respectively. The mechanised harvesting can reduce time required per hectare and cost involved (Rs/ha) by 97.9% and 84.48% respectively as compared to manual operation. Additionally, the speed of operation made the significant impact on efficiency of leaf de-topping caused a significant decreased in de-topping efficiency from 96% to 83% while increasing the tractor forward speed from 1.5 to 2.5 km/h, representing a reduction of approximately 13%.

Keywords: Onion harvester, leaf de-topping, leaf topping, root crop harvester, etc

1. Introduction

India is the second-largest producer of onions with an anticipated production of 307.71 lakh tonnes of onions after China ^[1]. India has exported 2.60 lakh tonnes of onion to the world during the year 2024-25². However, India's onion productivity is far lower than that of China and other nations i.e. 14.21 tonnes/ha ^[2]. The majority of onions in India are harvested using manual method, which is labour-intensive and time-consuming process. Manual labor costs for cultivation, harvesting, and post-harvest processing resulted in 60 - 70% of the production cost when bulb onions are grown from sets (Laryushin and Laryushin, 2009) ^[3]. According to Kawale and Ramappa (2019) ^[4], harvesting mature bulbs with a hand shovel (khurpa) costs 21.4% of the overall cost of cultivation onions.

Boyer (1964) ^[5] developed a machine for harvesting and topping onions, uproot onions and transport it rearward with the advancement of the carriage. A housing was mounted on carriage adjacent the rear with a suction fan creating a vacuum in housing to draw air upward through conveyor and into an opening in the bottom of housing. A rotating cutter blade was provided above the conveyor and beneath the fan to cut the tops of onions. Richard *et al.* (2002) ^[6] developed a mechanical harvester for root crops that can perform harvesting, topping and sacking bulb crops. A conveyor system to transport dug crop to cutting assembly was provided. In cutting assembly, elongated cutting blades were arranged in efficient manner to accept and cut the root and leaves from the bulb. It was also having inspection assembly was incorporated for inspection, sorting, grading and further distribution. Robert (2002) ^[7] developed a harvester and trimmer for root crops having tops growing from the crown of the crop. It was a movable vehicle with severing and lifting mechanism mounted at front. Trimmer was consisting of series of rotating and caged flail drum with series of transverse knives provided on its circumference.

As the tops or roots of the gathered crop was striking the slots only the tip portion of the knives were adapted to contact the tops or roots. Abenavoli (2004) ^[8] developed a mechanical harvester that combined a digger blade with the with the advancement it can crumbled soil and removes the bulbs that had separated from roots as a result of shearing stress which followed by a

conveyor belt and by sorting and unloading mechanism. This machine was developed in width 1 to 1.5 m and operated at forward speed 2.5 - 3.5 km/h. Average bulb pull capacity was reported 0.35 ha/h with 1% of damage when operated at 3 km/h. Duane *et al.* (2006) ^[9] developed an onion harvester with leaf topper machine. Plurality of rotating rollers were used that were pulling the vegetable in inverted position, with leaf in top down orientation and forward it to cutting system. These rollers were delivering the onion to the cutting system in top down position which increased the efficiency of the leaf cutting and trash removal.

Khura *et al.* (2011) ^[10] examined different digger blade shapes and discovered that the inverted V-shaped blade had the least amount of draft. Through field testing, the ideal design values of the elevator's length, transmission ratio, and slope were obtained as 1.2 m, 1.25:1, and 15° respectively, with a digger efficiency of 97.7% and 3.5% bulb damage. Akinbamowo *et al.* (2011) ^[11] reported that best suitable operating condition for the harvester was 4 km/h, 20° blade angle and 540 rpm web speed in developed a tractor PTO powered cocoyam harvester. Singh (2014) ^[12] used high carbon steel EN45 to make blade of the digger and depth adjustment wheels attached to adjust the depth of cutting operation. He reported a lift percentage as 94.9%, mean digger efficiency as 89.8% and damage percentage as 5.1% at best suitable speed of operation 4 km/h. Hong *et al.* (2014) ^[13] observed that with increase of tractor forward speed from 5.0 cm/s to 15.8 cm/s, damage rate increased from 4.55% to 11.29%, for developed tractor mounted welsh onion harvester. Mehta and Yadav (2015) ^[14] developed a tractor mounted onion harvester, to dig the onion and laid them unevenly on the surface of the bed, resulting field capacity of 0.57 ha/h and 78.95% field efficiency, at speed of 2.52 km/h, 470 kg draft, 4.39 hp power and 2.53 lit/h fuel consumption. The damaged and buried bulbs were 3.21% and 0.34% respectively. Zhensheng and Yongfeng (2017) ^[15] developed an onion harvester which was self-propelled. It was also having a mechanical stack to collect onion and scallion piled with mechanical conveyor.

Kumawat and Raheman (2022a) ^[16] & (2022b) ^[17] reviewed the available onion harvesting options and their performance, and proposed a design of onion harvester suited to Indian conditions. The study noted that the harvesters with combined topping and digging operations are present in foreign countries, however their mechanisms are complex. Hence, a simple, integrated harvester with topping, digging, and soil separation is required to reduce labour and harvesting costs for Indian farmers. Carolin and Senthil (2024) ^[18] developed and assessed various detopping tool designs using helical rollers, square shafts with two and four cutting edges, and lead screws. A detopping efficiency, a damage percentage, conveying efficiency and a capacity were reported 98.44%, 2.05%, 97.60%, and 372.60 kg/h, respectively and the helical roller type detopping tool was found to be the most effective of these mechanisms.

In traditional farming practice the bulbs are sown in a random manner. The tractor rear-mounted harvesters, if used for digging the onion, crush significant amount of onions before digging them due to its weight. To overcome this difficulty an efficient tractor front mounted harvester was required. Bajya (2017) ^[19] a farmer and one of the author of this paper observed this and developed a tractor front mounted digger. It was having a digger blade, slat conveyor, collector, etc. The machine had working width of 1.37 m and field capacity 0.2 ha/h. He further noticed

that before digging the onion bulbs, de-topping of the leaves was needed. He developed another small machine for de-topping the leaves before operating the tractor operated digger. The leaf cutter had cutting width 1.75 m and field capacity 0.11 ha/h.



Fig 1: Bike operated onion leaf cutter



Fig 2: Tractor front mounted onion harvester

A project was undertaken to further improve the tractor front mounted onion digger by combining both machines (digger and de-topping machine) which can be used for harvesting onion, garlic and potato with minor adjustments.

2. Materials and Methods

2.1 Considerations

Based on the study of existing machines, soil and crop parameters and feedback of onion growing farmers, following were considered for designing the onion harvester machine.

2.1.1 Agronomical parameters (showing pattern, spacing and bulb depth)

The cultivation of onion crops in the field is practiced using seedlings are raised in a nursery before being transplanted into the main and the spacing between two row and plant to plant were considered as 10 cm. Depth of onion bulb varies with the variety of onion, type of soil and quality of soil; it was considered in the range of 5 to 7 cm. Generally, onion harvesting process is carried out after the 50-80% of the neck fall of onion leaves, 18-20% soil moisture content maintained at the time of harvesting.

2.1.2 Functional and Engineering Requirements

The development criteria for the onion harvester with inbuilt de-topping unit include the use of a tractor (35 hp and above) for economical operation by small farmers (Mandal and Maity 2013) ^[20], covering the tractor's full track width, suiting to this overall width of the harvester should be 1.8 to 2 m. The standing onions should be dug along with leaves by the harvester unit at a

consistent depth and moved to the conveying unit where it should de-top the onion leaves which being uprooted by the harvester unit. The de-topped onions should be conveyed to storage unit through conveying unit. The harvester should maximise the onion bulb digging with minimum onion damage during de-topping, digging and conveying. Operational speed of the tractor should be in range of 2 to 3 km/h (avg. 2.5 km/h or 0.69 m/s) with maintaining depth of operation at 8 - 10 cm. Considering the soil type as Sandy loam and the specific soil resistance at a harvesting depth of 10 cm should be between 0.3 to 0.65 kg/cm² (Kepner, *et al* 2005^[21] and Ganeshan, 2004^[22]). Considering the working width and depth operation of harvester is 185 cm and 10 cm, respectively (use of full width of tractor), the raw soil cut-out is equal to 185 x 10 = 1850 cm² and the soil type as sandy loam, soil resistance would be 0.65 kg/ cm²

Draft force (N), $D = 9.8 \times \text{soil resistance (kg/cm}^2) \times \text{cross section area (cm}^2) \dots\dots\dots$ (1)
 $= 9.8 \times 0.65 \times 1850 = 11784.5 \text{ N}$

Power required, $P = \text{Draft (N)} \times \text{forward speed of the tractor (m/s)} \dots\dots\dots$ (2)
 $= 11784.5 \times 0.69 = 8131 \text{ W} = 10.9 \text{ hp}$

The transmission and drawbar power efficiency of the tractor at 60-70% of the tractor BHP and factor of safety as 2, above 35 hp

tractor was found to be the best fit for operating the developed onion harvester.

2.2 Conceptualization

Some concepts of leaf cutting and de-topping that can be combined with the onion harvester (Bajya 2017)^[19] were developed to explore the merits and demerits of combining the operations of harvesting onions and cutting/ de-topping leaves.

Concepts 1, 2, and 3 were developed with a chain conveying system made of flat twisted bars and chains which would be mounted in front of the tractor via a hydraulic system and a mounting harvester blade for uprooting the onion bulb. A horizontal rotary strip (a cage of twisted flat stripped plates with a sharp edge) type (concept 1, Fig 3), a vertically rotary type height-adjustable leaf cutter (concept 2, Fig. 4), and a rotary wire brush with an oscillating set of fixed and movable blades (concept 3, Fig. 5) can be provided before to the harvesting operation for the leaf cutting/de-topping process.

These ideas, especially for leaf cutting, made the entire system heavy and may cause damage due to the front mounted attachment. Additionally, the ability to adjust height for effective leaf cutting on uneven farm fields can complicate the transmission drive.

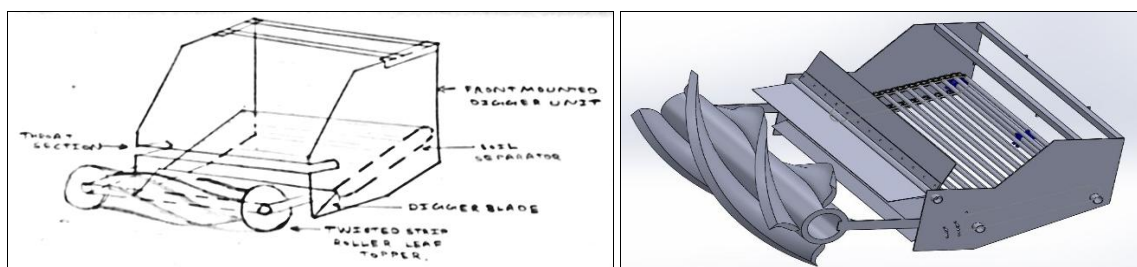


Fig 3: Conceptual 1 Design 1

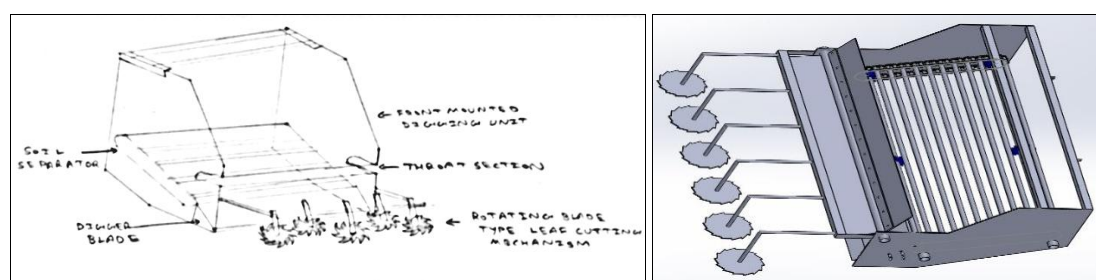


Fig 4: Conceptual 2 Design 2

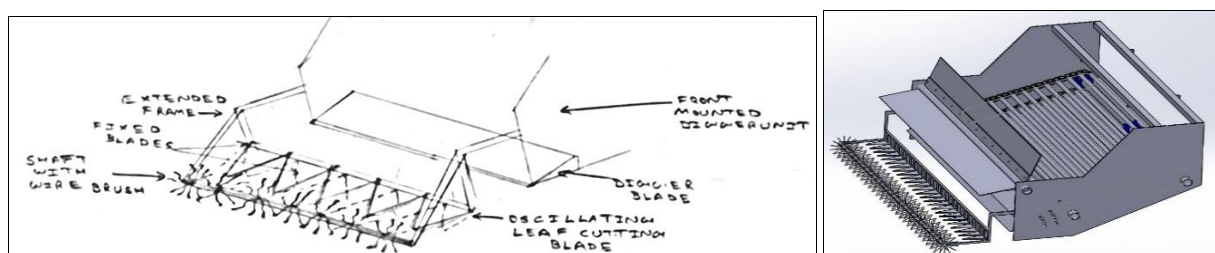


Fig 5: Conceptual 3 Design 3

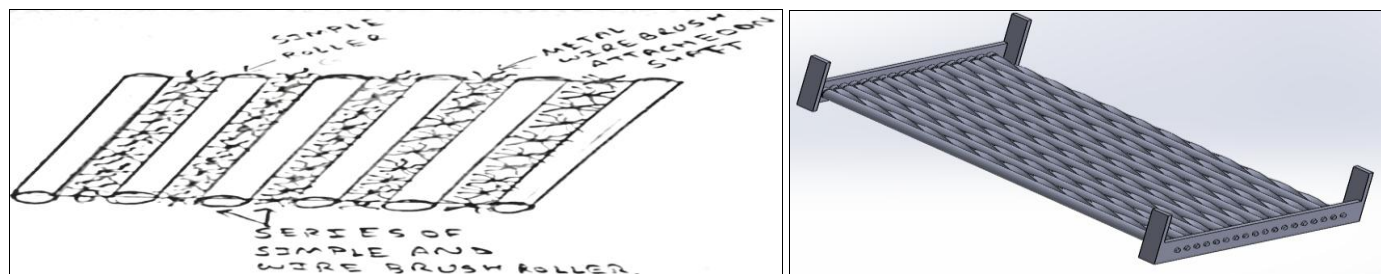


Fig 6: Conceptual 4 Design 4

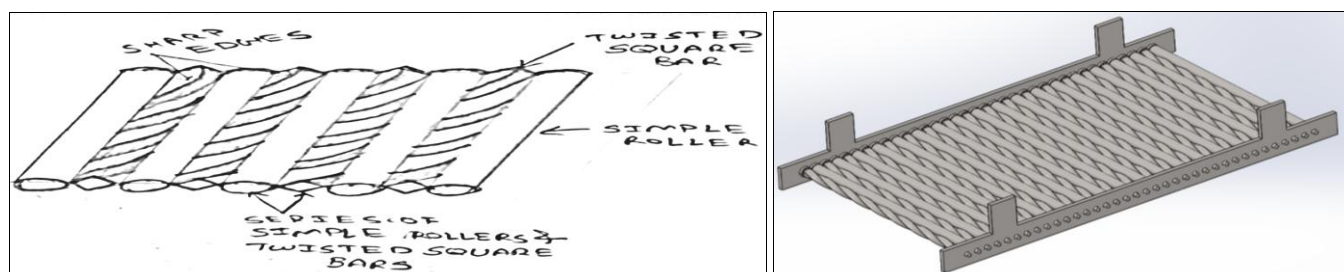


Fig 7: Conceptual 5 Design 5

Concepts 4 and 5 were developed using the tractor-mounted harvesting attachments from concepts 1, 2, and 3. In Concept 4 (Fig. 6) and 5 (Fig. 7), a sequence of plain, twisted, and combination plain and twisted rollers were used, which rotate in opposite directions to form a conveyor for de-topping onion bulbs from their leaves. Concept 4 consisted of using wire brush rollers to pull off onion leaves that got stuck in between with the rotation of the rollers. However, there was the possibility of stacking onion leaves, which reduced leaf cutting efficiency.

Concept 5 incorporated a combination of plain and twisted bars as a roller to form a crack at the onion's neck and minimize the force required to extract leaves from onion bulbs

Tractor front mounted harvesting and soil separation from concepts 1, 2, and 3 and onion leaf de-topping from concept 5 were found to be the best possible designs in the final CAD model that was created after taking into account all of the engineering inputs and concepts. The basic design of attachment to tractor based on the selected concept was like Fig 8.

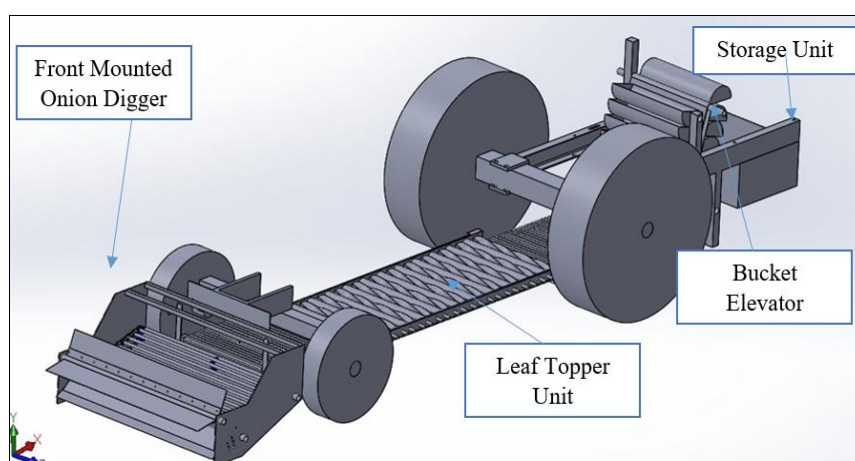


Fig 8: Conceptual design of integrated tractor front mounted onion harvester with inbuilt leaf de-topping unit

2.3 Design and development

The entire machine was designed in four sections 1) Tractor front mounted attachment (which includes onion digging unit and soil separator cum conveyor, 2) Onion leaf cutting/de-topping cum conveying unit, 3) Bucket elevator and storage assembly and 4) Power transmission unit

2.3.1 Development of different parts of the tractor front mounted attachment

Different parts of the Tractor front mounted attachment are shown in the Fig. 9.

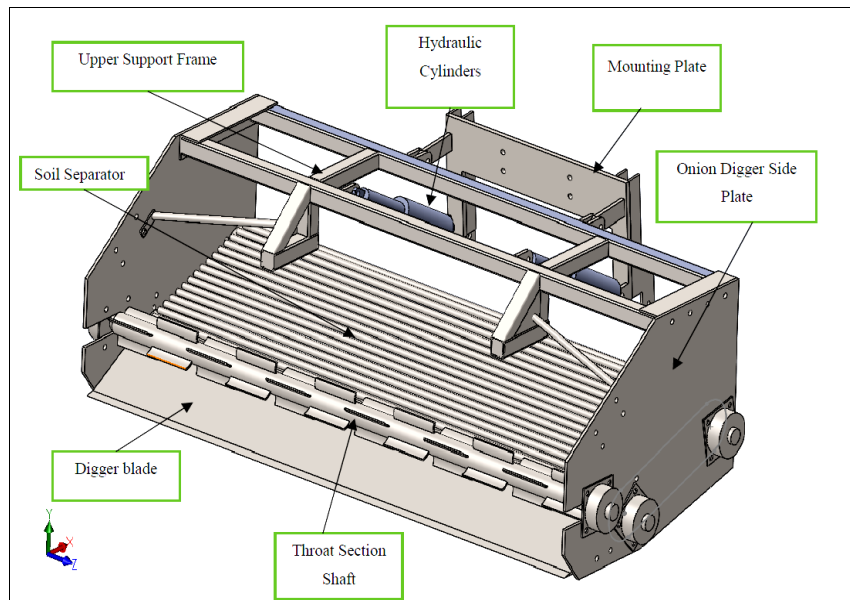


Fig 9: Tractor front mounted attachments and their parts

2.3.1.1 Harvester Blade

The function of harvester blade was to break up the soil layer and dig onion bulbs without causing damage. For ease of fabrication and maintenance by farmer simple flat blade made of 45C8 carbon steel with yield strength 310 MPa [Source: IS: 1570(Part 2/Sec 1) -1979] [23] was selected. The harvester blade was attached with guide mounted at angle of 25 degrees from the harvester blade for easy and smooth flow of soil on soil separator. As the length of blade should be distance greater than or equal to the track width of the tractor. Overall length of the blade was taken as 1.85 m. Assuming forward speed of the tractor for the harvesting operation 2.5 km/h (0.69 m/s), row to row spacing of onions as 10 x 10 cm, average weight of each onion 70 g, the height of the layer formed by soil up to 20 cm and density of soil as 1800 kg/ m³. Thickness of blade was calculated, which can bear load of both soil and the onion dug with following relations.

The draft forces on the harvester driven by calculating the soil passive resistance at soil metal friction angle based on two-dimensional soil failure model, as suggested (Hettiarachi *et al.* (1966)) [24]

$$P = (\gamma Z_1 N_\gamma + C Z_1 N_c + C_a Z_1 N_{ca} + q Z_1 N_q) \dots \dots \dots (3)$$

Where,

P = Soil passive resistance at soil metal friction angle with the normal to the interface, N, γ = Soil bulk density (1800 Kg/m³), Z_1 = Depth of operation (0.1 m), C = Soil cohesion (770 Kg/m²), C_a = Soil-interaction adhesion (assuming 0 kg/m²), q = Soil surcharge pressure from the surface above the failure plan (negligible i.e. q = 0), N_γ , N_c , N_q , and N_{ca} are the dimensionless N factors.

These N factors defines the soil failure surface shape and are the function of shearing resistance of soil angle, soil metal friction angle (δ) and rake angle (geometry interface (α)). N_γ is 1.49 and N_c is 1.66 (N- factors for soil metal friction angle ($\delta = 20^\circ$) and internal friction ($\alpha = 25^\circ$))

Considering the width of blade as 1.85, the passive resistance is calculated as = 286.084 kg $\approx$ 286 kg

The parallel force acting on blade face (P1 as 97.84 kg) and the perpendicular force acting on blade face (P2 as 268.83) are quantified with following relations

$$P1 = P \cos(90 - \delta) \dots \dots \dots (4)$$

$$P2 = P \cos(\delta) \dots \dots \dots (5)$$

According to (Bernacki *et al.* 1972) [25], the mean soil resistance acting on the blade is applied at a distance of 0.2 Z_1 from the cutting edge. And the thickness of the blade is calculated by reference to the load applied to the blade, so the direct stress or load is calculated by the following equations:

$$\text{Direct stress } (\sigma) = (\sigma_b + \sigma_d) \times FS \dots \dots \dots (5)$$

$$\text{Bending stress } \sigma_b = \frac{BM \times 6}{b t^2} \dots \dots \dots (6)$$

$$\text{Direct stress } \sigma_d = \frac{P1}{bt} \dots \dots \dots (7)$$

Where, FS is factor of safety (consider as 2.5), b is breadth of blade (0.15 m), BM is bending moment = $P2 \times b = 40.32$ kg.m, t is thickness of blade. The total stress with safe stress of blade material considered as 3.16×10^7 kg/m² (310 MPa) as blade made of 45C8 carbon steel with yield strength 310 MPa.

Solving the equation, thickness of cutting blade will get $t \approx 0.010$ m (equals to 10 mm). The rear end of the blade was firmly fabricated to a base frame using nuts and bolts and fixed welding structure maintaining rake angle between 25° . The side plates were firmly fabricated on which harvester blade was mounted.

To carry forward uprooted onion along with soil on the conveyor, a shaft with a solid rubber pad was installed on the throat section. The throat height should be sufficiently maintained had to pass the onions along with leaves and foreign material passes which was kept between 0.185 and 0.2 meters. Throat section shaft was made from structural steel pipe YST 310 Grade IS: 1161 and the throat section shaft bearing was a standard bearing with pedestal.

2.3.1.2 Soil separator cum conveyor

To separate soil from onion bulbs, a slat/rod conveyor with roller chain drive and rods attached maintaining spacing between two rods as 30 mm, considering the minimum diameter of the onion (30 mm). Soil separator shaft and rod were made from structural steel pipe YST 310 Grade IS: 1161. Standard chain and sprocket available in market were used as soil

separator chain and sprocket. Standard bearing with pedestal were used to hold the shaft.

2.3.1.3 Hydraulic cylinders

During the operation on field the front mounted onion digger unit was kept in contact with soil and after the completion of each row, it was required to be lifted up for easy turning of the tractor on the farm field. It was also required to lift the entire front unit when tractor was travelling on normal road. For this, hydraulic cylinders (220 psi working pressure and 600 mm of stroke length) operated by hydraulic power of tractor were provided during the harvesting operation they also helped to resist the forces acting on front mounted unit.

2.3.1.4 Frame of the tractor front mount attachment

The frame of the front mounted onion digger unit was made using MS Plate 45C8; it was having three parts. Upper mounting frame for supporting gearbox and shaft was connected to mounting frame with hinge joint and hydraulics. It should be capable to lift load of entire front unit. Second was the side plates, on which harvester blade, throat section shaft and soil separator unit were mounted. Third was mounting frame, bolted on tractor front for supporting the entire front onion digger unit to the tractor.

2.3.2 Onion leaf cutting/de-topping unit cum conveying unit

This unit was made in three parts. The actual leaf cutting operation was carried out only in middle part and remaining two parts were belt - rod conveyor and simple belt conveyor. The belt rod conveyor was acting as both conveyor and soil separator. The second part was actual leaf de-topping unit also act as conveyor which was combination of simple and twisted roller bars rotating in opposite direction and arranged in parallel to the direction of the onion flow in machine. In order to cut leaves minimum distance of 0.8 to 1.0 mm was kept between the rollers. Extra toothed blades of 1 mm were provided just below the leaf de-topping conveyor in crossword direction to make leaf cutting operation smoother. The third part was belt conveyor for conveying onion to the bucket elevator. In addition to that each these conveyors can be set to angle for smooth flow of onion through the entire leaf de-topping unit. All of these were mounted on frame specially designed according to the mounting points available on tractor John Deere 5042. A 3 Ply PVC green belt bare bottom 3 mm thick with 12 N/mm strength was used as conveyor belt. Leaf de-topping set up, twisted roller were made from square bright bar while plain roller was made from structural steel pipe YST 310 Grade IS: 1161.

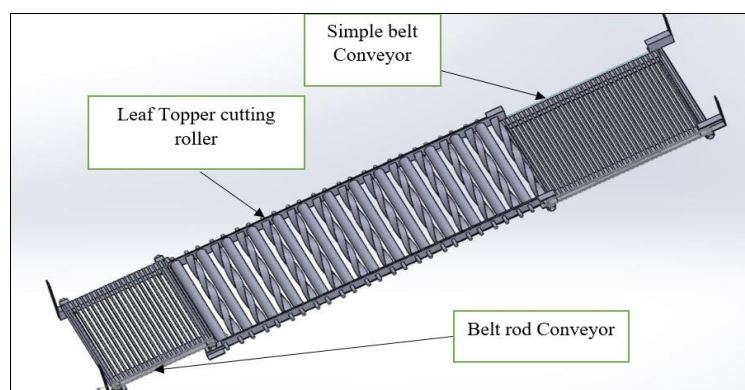


Fig 10: Leaf de-topping Unit

2.3.3 Bucket Elevator and Storage Assembly

The onions from conveyor belt to the storage were conveyed with the help of bucket elevator. The entire back assembly was mounted on frame made of rectangular standard section and mounted at the rear of the tractor. Buckets elevator (made from Mild Steel sheet of 20 gauge) of the bucket were fabricated in

semi-cylindrical shape and riveted to the PVC belt (3 Ply PVC green belt bare bottom 6mm thick with 15 N/mm strength)

2.3.4 Power Transmission System

All the parts were provided drive from the power take off (PTO) of the tractor using the layout given in Fig. 11

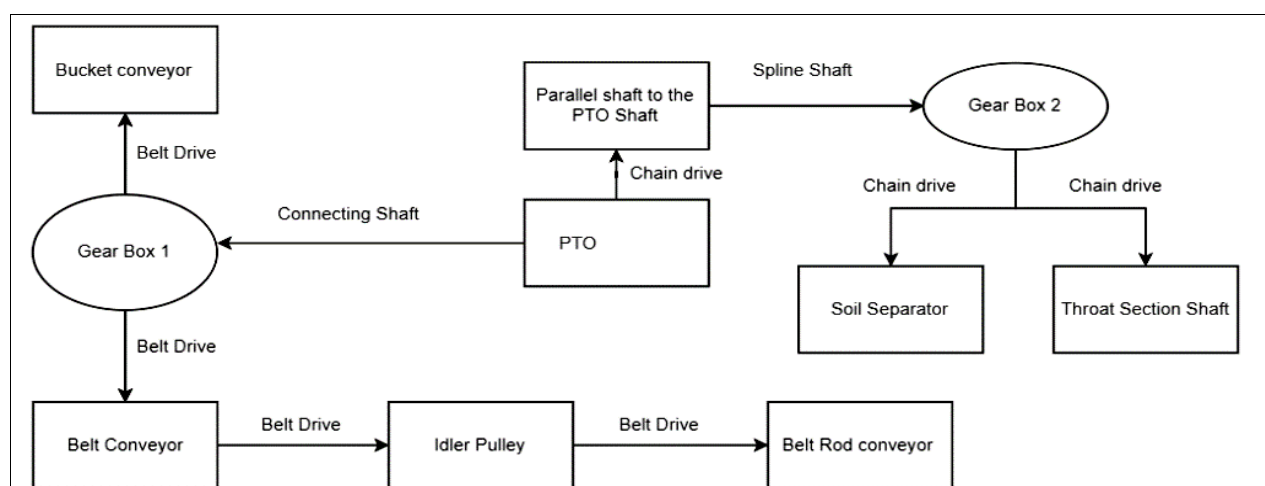


Fig 11: Power Transmission System

SH-type Gear Box (bevel gearbox, 1:1 transmission ration) provided to maintain the rpm of the tractor PTO. Power was transferred to the belt conveyor with belt drive from the same shaft of Gearbox 1.

2.3.4.1 Theoretical Power requirements of different sections

The theoretical power requirements at different parts of machine is given in table 1.

Table 1: Power requirement at different sections of machine

Component / unit Name	Rated Power	Rated RPM
Throat section (Harvester unit)	1.33 kW	200 rpm
Soil separator cum conveyor unit	3.32 kW	360 rpm
Belt Rod Conveyor (De-topping unit)	0.68 kW	540 rpm
Belt Conveyor (De-topping unit)	0.58 kW	360 rpm
Bucket Elevator	1.0 W	216 rpm

2.4 Performance evaluation of the onion harvester in field operation

The integrated tractor front mounted onion harvester with inbuilt leaf de-topping unit was evaluated for harvesting of onions at the farmer's field (Sikar, Rajasthan). The developed onion

harvester's performance was evaluated in order to determine field capacity, harvesting efficiency, damage percentages, and onion leaf cutting efficiency. The machine was fabricated at National Innovation Foundation- India, Gandhinagar and field trials were conducted at Sikar, Rajasthan.



Fig 12: Integrated tractor front mounted onion harvester with inbuilt leaf de-topping unit

2.5 Cost Analysis

IS: 9164 was used to compute the operating costs of the developed integrated tractor front mounted onion harvester with an integrated leaf de-topping unit. There were fixed and variable costs associated with the developed onion harvester. Fuel, lubricants, repair maintenance costs, and labor wages are examples of variable costs, while depreciation, interest on the capital cost, shelter, insurance, and taxes were considered fixed costs, according to Kamboj P, *et al.*, 2012 ^[26]. and Diwan P, *et al* 2022 ^[27]. The development cost of the onion harvester was estimated as Rs. 200,000/-. The digger was estimated to have an

8-year lifespan with 300 hours of annual use. 10% of the original cost, 10% annually, and 2% were the salvage value, interest rate, and labor required, respectively. The cost of diesel at 90 Rs./l, fuel consumption at 2.5 l/h, lubrication at 20% of fuel cost, repair and maintenance 5% of initial cost, as well as shelter tax 2% of initial cost, were then calculated.

3. Results and Discussion

The machine was tested in the field at Sikar, Rajasthan. During the field testing field data collected are summarised in table 2 and 3.

Table 2: Observations before Harvesting Operation

S. No.	Parameters	Observations
1	Name of the crop	Onion
2	Soil type	Sandy Loam soil
3	Average Area of trial plots	0.03 ha
4	Method of Transplanting	Manual Transplanting
5	Plant geometry	Unevenly distributed
6	Avg. depth of root	5.18 cm with standard variation of 1.15 cm
7	Avg. weight of onion bulb	57.9 g with standard variation of 13.46 g

Table 3: Performance parameters during the field test

S. No.	Parameters	Value
1	Forward speed of tractor (km/h)	2.47 with standard deviation of 0.029
2	Depth of the harvesting operation (cm)	7.5 with standard deviation of 0.5
3	Width of harvesting (cm)	185
4	Theoretical field capacity (ha/h)	0.45
5	Actual field capacity (ha/h)	0.39
6	Field efficiency (%)	82.97

During the harvesting, 2.5 m x 2.5 m areas were selected from where onion bulbs were collected separately and inspected for the damaged onions. The calculations of losses and efficiency were followed by:

$$\text{Percentage of undamaged onions} = (B / A) \times 100 \dots\dots\dots(8)$$

$$\text{Percentage of damaged onion bulbs} = (C / A) \times 100 \dots\dots\dots(9)$$

$$\text{Percentage of buried onion bulbs with plant} = (D / A) \times 100 \dots\dots\dots(10)$$

$$\text{Harvesting efficiency} = 100 - E \dots\dots\dots(11)$$

Where, A is total quantity of onions (kg); B is total quantity of undamaged onions (kg), C is total quantity of damaged onions (kg), D is buried onion bulbs with plant from sample area (kg), and E is percentage of total onion bulb losses)

Table 4: Efficiency calculations of onion harvester

S. No.	Parameter	Efficiency	
		Number basis	wt. basis
1	Damaged onions	3.30%	1.96%
2	Buried onion bulbs with plant	0.33%	0.21%
3	Total onion bulb losses (damage onions + buried onion bulbs with plant)	3.63%	3.17%
4	Harvesting efficiency considering bulb losses	96.37%	97.83%

Onion Leaf cutting efficiency: To determine the efficiency of the leaf cut by leaf de-topping unit readings were taken at tractor forward speed of 1.5, 2.0 and 2.5 km/h. During all the observations amount of onion bulbs cut off leaf from neck portion and bulbs with leaf were segregated from collected onions. Efficiency of the leaf de-topping unit was recorded 96%, 92.4% and 83%, respectively.

Field evaluation of the tractor front mounted onion harvester with an inbuilt de-topping unit resulted a significant improvement in operational efficiency over conventional harvesting methods. Mechanised harvesting resulted in a 97.9% reduction in harvesting time and an 84.48% reduction in harvesting cost for combined harvesting and leaf de-topping

operations. The machine achieved an actual field capacity of 0.39 ha/h with a field efficiency of 82.97%, indicating effective utilization of operating time under field conditions.

Statistical study noted that tractor forward speed had a significant impact on de-topping efficiency. An increase in operating speed from 1.5 km/ h to 2.5 km/h caused a significant decrease in de-topping efficiency from 96% to 83%, representing a reduction of approximately 13%. In contrast, harvester efficiency remained consistently high across operating conditions, with mean efficiencies of 96.37% (number basis) and 97.83% (weight basis), indicating minimal losses during uprooting and collection of onion bulbs.

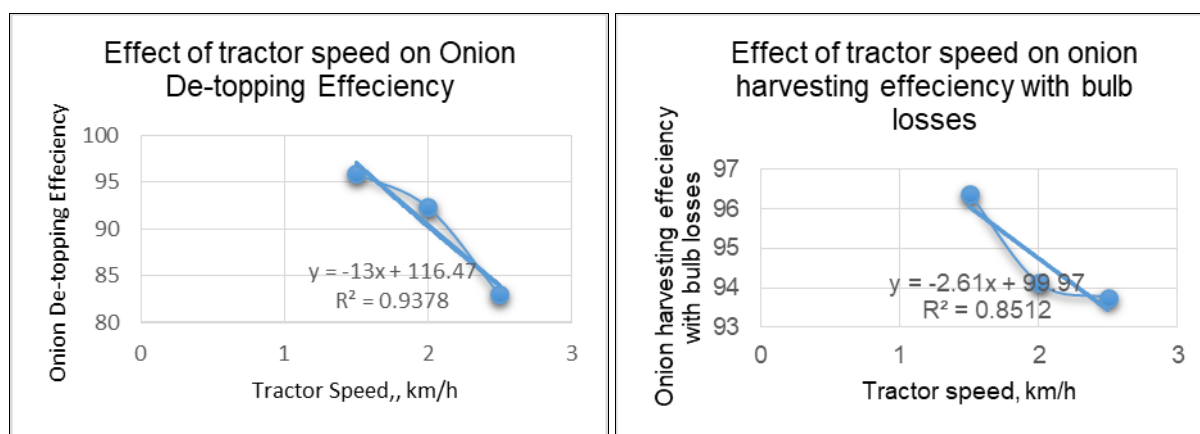


Fig 13: Effect of tractor speed on onion de-topping and harvesting efficiency

Cost economics in Manual and Mechanised Methods of Onion Harvesting

In terms of time and operating costs, a comparison was made between the manual and mechanical harvesting techniques. The machine's capital cost was assessed by taking fabrication costs and component prices into account. A single prototype tractor front mounted onion harvester with an integrated leaf de-topping unit was estimated to cost ₹200,000. The operational cost using the harvester was calculated as Rs.1419.74/ha, with an average

actual field capacity of 0.39 ha/h maintaining tractor forward speed of 2.47 km/h, which is substantially less than the estimated Rs. 9310/ ha for manual harvesting (Table 5 and 6). The developed tractor front mounted onion harvester with integrated leaf-de-topping unit, takes 2.56 h/ha. This indicates a cost savings of Rs. 7865 / ha, which translates to an 84.48% cost reduction when utilizing the developed tractor front-mounted onion harvester with an integrated leaf de-topping unit in comparison to the conventional manual method.

Table 5: Cost of operation of developed onion harvester with inbuilt de-topping unit

S. No.	Particular	Calculated Amount, Rs.	
		Tractor (john deere 5042D)	Onion Harvester
1	Purchase cost / development cost, Rs.	700,000	200,000
2	Life, year	10	8
3	Life, h/year	1000	300
4	Fixed cost		
4.1	Depreciation @ 10% salvage value, Rs./h	63	18
4.2	Interest 10% per annum, Rs./h	3.85	1.1
4.4	Insurance & Taxes	1.05	0.3
4.3	Shelter 1% of initial cost, Rs./h	0.7	0.2
4.4	Total fixed cost, Rs./h	68.6	24.1
5	Variable cost		
5.1	Fuel rate, Rs./l	90	-
5.2	Fuel consumption, l/h	2.5	-
5.3	Fuel cost, Rs./h	225	-
5.4	Lubrication, Rs./h	45	-
5.5	Repair cost 5% of initial cost, Rs./h	8.8	4.5
5.5	Labour required	1	2
5.6	Working hour, h/ha	8	8
5.7	Labour cost, Rs./day	500	1000
5.8	Labour cost, Rs./h	62.5	125
5.9	Total variable, Rs./h	341.3	129.5
6	Cost of operation, Rs./h	409.9	153.6
7	Cost of operation, Rs./ha	1051.03	393.8
8	Total cost including tractor cost, Rs./h	563.5	
9	Total cost including tractor cost, Rs./ha	1444.82	

Table 6: Economical comparison of mechanical and manual harvesting

Sr. No.	Particular	Mechanised Harvesting	Manual Harvesting	Increase (+) or Decrease (-)
1	Total time required (man -h/ha)	7.69	366.38	(-) 97.90%
2	Total Harvesting cost Rs/ ha	1444.82	9310.00	(-) 84.48%

4. Conclusion

The integrated tractor front mounted onion harvester with inbuilt leaf de-topping unit was performed efficiently. Compared to conventional machines damage of onion was quite low, as the loss (crushing) was reported due to movement of tractor over onion bulbs which can be has been eliminated.

From the results of field trials, it was observed that mechanised harvesting with front mounted onion harvester with inbuilt de-topping unit can reduce time and cost required for harvesting with leaf de-topping up to 97.9% and 84.48%, respectively, with an average actual field capacity of 0.39 ha/h and field efficiency of 82.97%.

The tractor speed found to be affects the de-topping efficiency, which significantly decreases from 96% to 83% with increasing tractor forward speed from 1.5 km/h to 2.5 km/h. While, the harvester efficiency found consistently 96.37% and 97.83% on the basis of number and weight respectively.

5. Scope of Future Improvements

The machine was able to integrate both of the operations i.e. onion de-topping and digging onions in one unit. Even though it was successful in carrying out its intended functions, the machine's performance still needs to be enhanced in a few areas. For the onion leaf de-topping conveyor, which was optioned out alternative materials instead of plain rollers and metal twisted bars. The machine's weight might be decreased. It is necessary to assess harvester performance at various speed ratios.

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