[F] PhD Extended Abstract Form

DEVELOPMENT OF A HAND TRACTOR POWERED TOPPER CUM DIGGER FOR ONION CROP

By

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Extended Abstract

1. Chapter 1 :

Title: Introduction

Onion harvesting is a complex operation involving digging of onion bulbs and cutting of matured leaves from the onion bulbs which are repetitious, tiring and involves a lot of bending postures. This complex harvesting process often leads to delays which ultimately results in a financial loss to the farmer. Traditional harvesting practices rely heavily on human labors which are time-consuming and leads to the wastage of a huge amount of produce. Among the various cultivation practices followed for raising onion crops, harvesting of onion which involves topping or cutting of matured onion leaves and digging of bulbs at right time is one of the most important operations. In India, mechanization in onion harvesting is very low as compared to other tuber crops such as potatoes. Many attempts have been made to mechanize onion harvesting using potato diggers and other root crop harvesters. As the biometric properties of onion bulbs are entirely different from the crops for which these harvesters are intended, leading to unsatisfactory performance, i.e., the cleaning efficiency is low and the damage percentage is high. Moreover, these harvesters only uproot the onion bulbs, but the matured leaves from the onion bulbs are required to be cut, which requires human intervention and time.

A partially mechanized harvesting operation (when topping of leaves is done by hand and digging of onion bulbs is done by machine) requires on an average 155 man-h ha^{-1} as compared to nearly 563 man-h ha^{-1} with manual harvesting. Further, the shortage of labor and unexpected weather change are barriers to timely harvesting and cause loss to the farmers. Timely harvesting is a prerequisite for better storage of onions and it is also necessary for reducing harvest losses and for higher storage life.

Hand tractors or power tiller being small in size as compared to tractors, enough scope exists for their utilization in small size lands. Instead of larger tractors, hand tractors are frequently used in small land holdings to power various agricultural operations.

In India, limited research work has been made to develop an onion harvester that can dig and trim the leaves simultaneously in small land holdings. Considering the non-availability of farm workers at the peak time of harvesting onions, the limitations of using large harvesting machines by the marginal farmers and easiness in handling hand tractor operated machines in small land holdings as well as for increasing the working hours of the hand tractor, an attempt has therefore been made to develop and evaluate a hand tractor operated topper cum digger (TCD) for onion crop with the following specific objectives:

(i) To develop a laboratory setup (simulating field crop) for measuring the power requirement of a wire-type rotary cutting unit to cut the matured leaves of onion crop with a provision to vary cutting speed, cutting width, and forward speed of operation.
(ii) To study the effect of operational parameters on the cutting of onion leaves under controlled laboratory conditions.
(iii) To design and develop an onion harvester (TCD) to be fitted to a 9.70 kW hand tractor for small land holding.
(iv) To evaluate performance of the developed hand tractor-powered TCD in the actual field.

2. Chapter 2 :

Title: Review of Literature

From the review of available literature on various aspects of traditional as well as mechanical harvesting of onion, it was found that a few attempts were made outside India to develop an onion harvester with a leaf topper but no such attempt was made in India till date. In India, manual harvesting of onion is mostly adopted because of the unavailability of suitable harvesters specifically designed for onion crops.

As an alternative to manual harvesting, a few other root crop harvesters are tried to dig only the onion bulbs along with onion tops. The posture of labor at the time of manual harvesting i.e., pulling onion bulbs from the soil and also at the time of topping onion leaves from the bulbs is bending and squatting, respectively, which causes drudgery of laborers and reduces their efficiency.

Among the different cutting mechanisms used for topping the onion bulbs, rotary cutters are found to be the best ones in terms of de-topping efficiency and power requirement. Though a few onion harvesters with simultaneous topping and digging of onion bulbs are available outside India, but the mechanisms employed in those harvesters are very complicated and they are large size machines, hence not suitable for small land holdings.

3. Chapter 3:

Title: Materials and Methods

In the first stage, a laboratory setup was developed which simulated the onion crop standing in the actual field. Row-to-row and plant-to-plant spacing were kept as standard provided by the ICAR-Directorate of Onion and Garlic Research, Pune. The experimental setup consisted of a processing trolley, a rail for supporting the processing trolley, and a bulb holding unit above the ground surface. The processing trolley could move over the rail to cut leaves at different rotational speeds of the cutting unit and at different forward speeds using a motor controller. A HBM QuantamX data acquisition system (DAS) with a laptop was used to acquire and record data on torque from the HBM torque transducer using Catman easy software package in XLS format.

In the second stage, a study was conducted to measure the torque required for cutting the leaves by varying the operational parameters. A total of 27 runs were made with three replications for each operational parameter. The frictional losses in the cutting unit and the absolute maximum cutting torque (AMCT) required for cutting onion matured leaves were obtained from the data acquired by the DAS. Cutting torque and topping efficiency were measured and the effects of various operational parameters on cutting torque and topping efficiency were studied. The operational parameters (rotational speed, forward speed, and cutting width) at which lowest cutting torque and highest topping efficiency were obtained were finalised using optimization technique.

In the third stage, a TCD for onion crop was designed and developed to be powered by a 9.70 kW hand tractor. A 3D conceptual design of the hand tractor powered TCD was made in SolidWorks 2020 software before the development of the field prototype. It comprised a topping unit at the front and a digger cum vibratory conveying unit at the rear of the hand tractor. The digger cum conveying unit was fixed after removing the complete assembly of the tiller unit of the hand tractor. The topping unit and the digging unit covered the complete track width of 600 mm of the hand tractor.

In the fourth stage, performance of the developed prototype hand tractor operated TCD was evaluated for harvesting onion crops when more than 50% of the leaves had turned yellow, which indicated the starting of harvesting season for onion. The average height of onion leaves at the harvesting stage was found to be 236.5±35.2 mm with a CV of 14.91% with 6-9 leaves per plant.

Initially, the developed TCD was tested in a separate onion field to finalize the rake angle and depth of digging with the least draft requirement.

The performance parameters were measured when the hand tractor was operated at an average forward speed of 0.83 km h^{-1}. The actual field capacity was computed along with field efficiency. Performance parameters such as topping efficiency, digging efficiency, and onion bulb damage percent were measured. The cost of harvesting onions with the developed TCD was computed and compared with traditional method of harvesting.

4. Chapter 4:

Title: Results and Discussion

The data obtained under actual field conditions for cutting torque and topping efficiency at the operational parameters of rotational speed of cutting unit, forward speed of machine, and cutting width were compared with the laboratory tested results. The mean values of cutting torque and topping efficiency were found to be 1.60 N-m and 95.67%, respectively at 1800 rpm of rotational speed of cutting unit, 600 mm of cutting width, and 0.27 m s-1 of forward speed of machine. The corresponding figures from the field tests were obtained as 2.12 N-m and 82.15%. Hundred random samples of dug out onion bulb were taken after harvesting. The topping height above the crown of the bulb was measured to be 43.3±7.12 mm. A little higher topping height was noted compared to standard height. The cutting unit was kept slightly above the ground to protect the attached torque sensor in dynamic field conditions. Therefore, the topping height was observed higher than the ideal height performed under laboratory setup. Actual field capacity was computed by measuring actual time required to cover the given area and turning time at head land. Turning time was measured using stopwatch and average turning time was found to be 11.32 s for each of the field trials conducted for a length of 10 m. When the conveying unit was operated in first gear of the rotor shaft, the actual field capacity of the hand tractor-powered TCD was computed to be 0.042±0.001 ha h-1 at an average forward speed of 0.828 km h^{-1}. Similarly, while the conveying unit was operated in second gear, the relevant value was observed to be 0.040±0.001 ha h^{-1}. The value of topping efficiency of the developed wire type cutting unit was obtained as 82±3.63% at a rotational speed of 1790.95±3.07 rpm. The performance parameters such as digging efficiency, topping efficiency, bulb damage per cent were found to be 92±3.08, 82±3.63, and 10±1.45, respectively. The total cost of harvesting onion using the developed hand tractor operated TCD was calculated. The cost of operation for 200 h annual use by using the developed TCD was found to be 208.64 Rs h^{-1} (4 \$ h^{-1}). The total cost of harvesting onion using the developed hand tractor powered TCD was found to be 7722 Rs ha^{-1} (\$ 83). Total saving in cost for carrying out onion harvesting with the developed TCD was found to be 72.56% with respect to fully manual harvesting of onion crops. Total time required for harvesting 1 ha was found to be 25 man-h. Total saving in time with respect to complete manual harvesting was obtained as 95.55%.

5. Chapter 5:

Title: Conclusions

In conclusion, the development and evaluation of the hand tractor-operated TCD for onion harvesting represent a commendable endeavor that embodies the spirit of innovation, technical excellence, and social impact in agriculture. Its successful implementation demonstrates a transformative approach to addressing pressing challenges in crop harvesting, offering tangible benefits to farmers and advancing the sustainability and resilience of agricultural systems.

Final remarks concerning benchmarks and strength points of the the Pellizzi Prize 2024

The project innovates specialized onion harvesting machinery for small farms, departing from manual methods, integrating wire-type cutting and conveying units for efficient automation. It significantly impacts agriculture by reducing labor dependency, enhancing timely harvesting, and cutting costs, benefiting smallholder livelihoods and overall productivity. Rigorous testing ensures technical reliability and performance understanding, crucial for scalability and adoption. Economic analysis showcases substantial cost savings and increased hand tractor use, enhancing sustainability. Design features indicate scalability and adaptability across diverse agricultural contexts, fostering widespread adoption. Contribution to research fills crucial gaps, offering insights into onion harvesting challenges and advancing agricultural engineering. The project's social impact is notable, empowering farmers, reducing labor burdens, and aligning with broader goals of rural development.