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DEVELOPMENT OF A SELF-PROPELLED WALK-BEHIND TYPE SINGLE ROW ELECTRIC CABBAGE HARVESTER

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1 Introduction



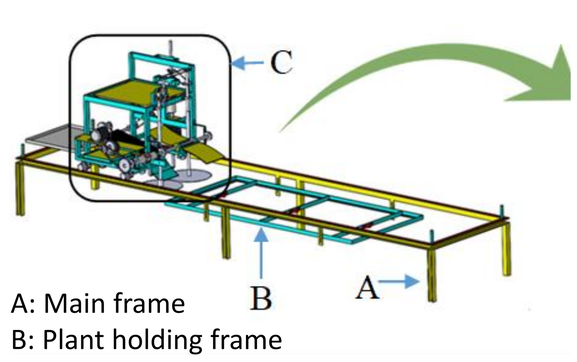
1. Traditional cabbage harvesting techniques with sickle/knife
2. Muscle-strain and back pain during manual cabbage harvesting
3. Bigger commercial cabbage harvesters unsuitable for small lands
4. Environmental impacts by commercial cabbage harvesters

Fig. 1 Problems associated with small scale cabbage harvesting

Research objectives

- To develop a laboratory setup to measure the power requirement of the counter-rotating disk cutting unit.
- To optimize cutting mechanism parameters under controlled laboratory conditions to minimize power requirement.
- To develop a deep learning-based cabbage detection system to minimize damage during conveying.
- To design and develop a vision-guided, self-propelled electric walk-behind cabbage harvester prototype.
- To evaluate field performance and economic feasibility of the developed cabbage harvester.

2 Development of Laboratory setup and Optimization

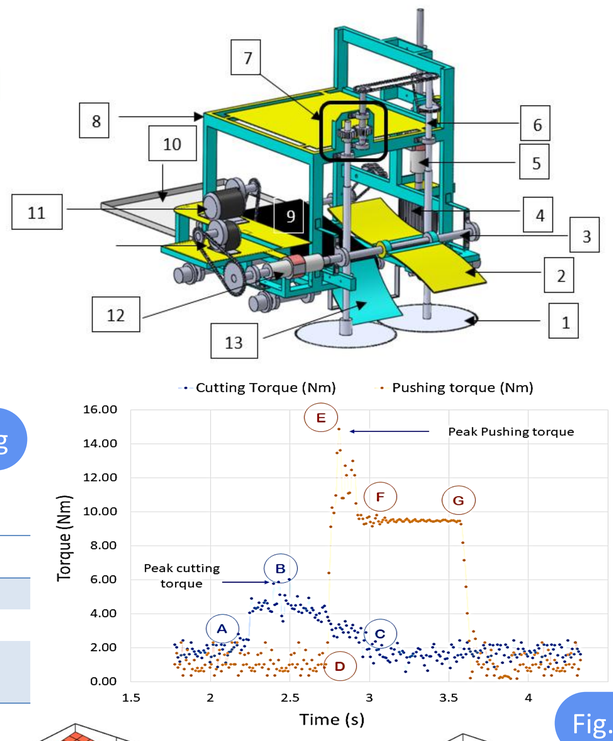


A: Main frame
B: Plant holding frame
C: Processing trolley

Fig. 2 Laboratory setup of cabbage harvesting

Table 1. Experimental plan

Independent parameters	Low level	High level
Cutting speed (rpm)	400	600
Forward speed (m/s)	0.22	0.32
Cutting height from bottom of the head (cm)	0	2



1. Cutting disc
2. Curved plate for pushing
3. Pusher shaft
4. DC motor for cutting
5. Torque transducer for cutting torque
6. Cutting shaft
7. Counter-rotating arrangement
8. Frame
9. Conveying belt
10. Tray
11. DC motor for propelling and conveying
12. Torque transducer for cutting torque
13. Inclined plate

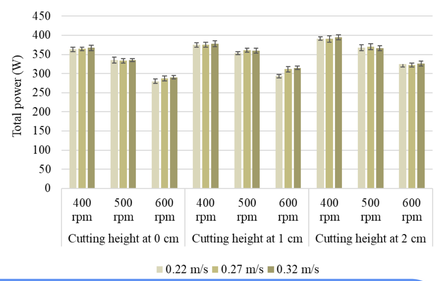


Fig. 4 Variation of power requirement

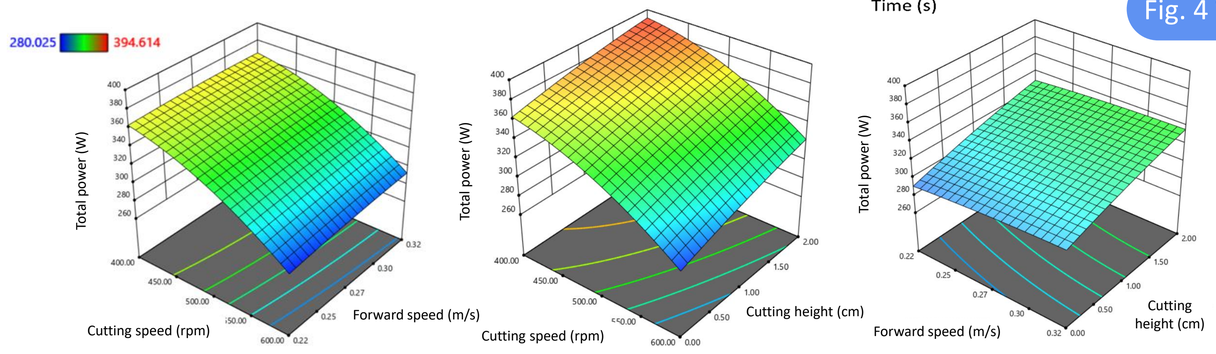
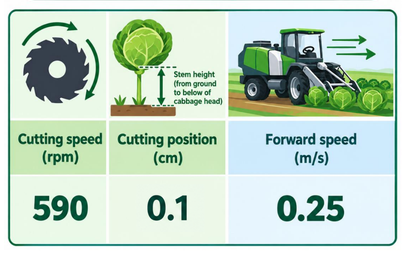


Fig. 3 Optimization for minimum power requirement

Optimized parameters



3 Cabbage Detection System

In the developed YOLOv8 model for detecting cut cabbages, an F1 score of 0.90 was achieved at a confidence of 0.149 and with a mAP@0.5 of 0.938. This model could detect the cabbages under all lighting conditions with a precision and recall values of 90.32% and 84.85%, respectively.

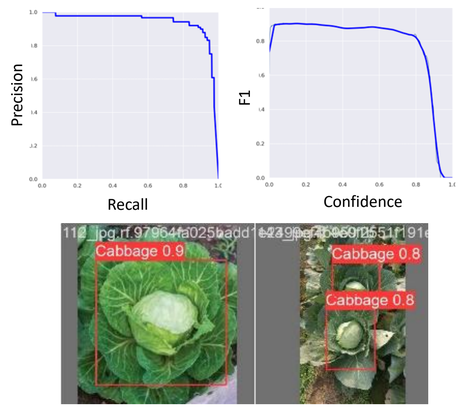


Fig.5 Developed YOLOv8 detection model

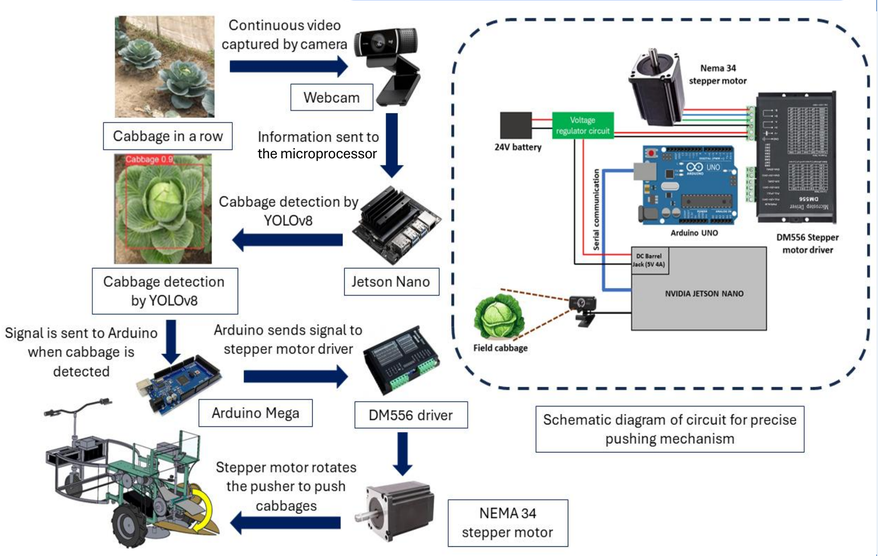


Fig. 6 Precise cabbage pushing mechanism

4 Design and Development of Cabbage Harvester

- The dimensions of the critical components of the designed harvester such as cutter shaft (A), pusher shaft (B) and propelling shaft (C) were set after calculation and were checked for safety using finite element analysis (FEA).
- The prototype was fabricated at the workshop of Agricultural and Food Engineering Department, IIT Kharagpur. The developed harvester had an overall dimension of 2571×880×742 mm with a total weight of 176 kg.

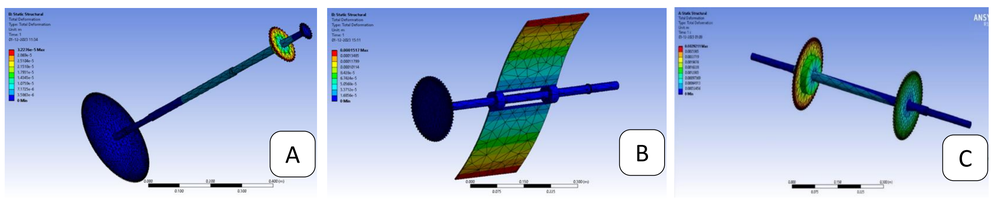


Fig. 7 FEA of critical components

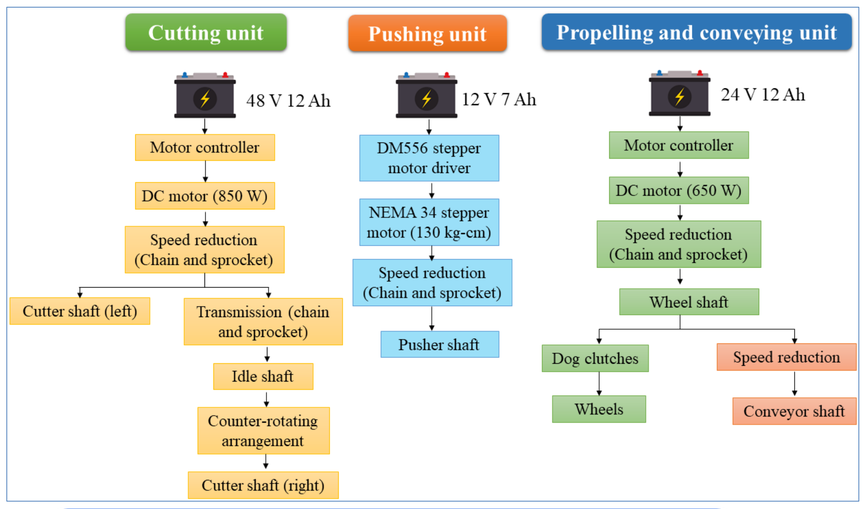


Fig. 8 Electric power allocation in cabbage harvester

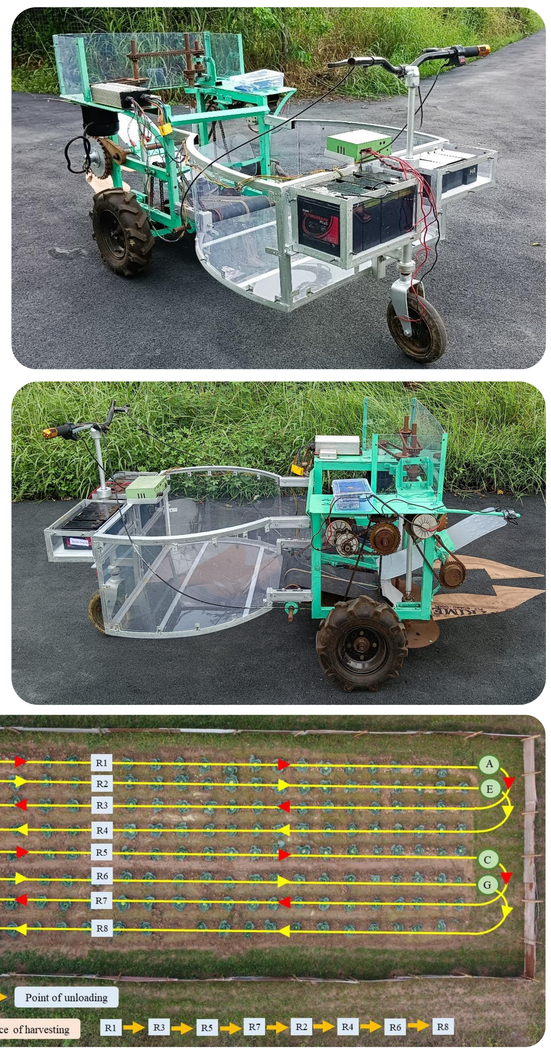


Fig. 9 Developed prototype and experimental field

5 Field Performance Evaluation



Fig. 10 Field operation

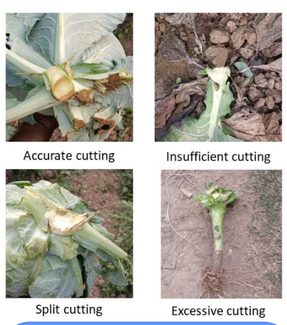


Fig. 11 Types of cuts

Table 2. Field Performance Evaluation Parameters

1	Field capacity	0.029 ha/h
2	Field efficiency	54.86%
3	Cutting efficiency	80%
4	Harvesting loss	10.21%
5	Instantaneous power consumption	978.64 W
6	Noise	78 dB(A)
7	Vibration	2.26 m/s^2

6 Final Remarks

Economic analysis of the harvester

- Harvesting cost: ₹9,143.51 ($77.42)/ha
- Operational cost: 26.85% lower than traditional manual harvesting
- Break-even point: 6.43 ha/year
- Labour requirement: 58.5% reduction compared with manual harvesting

This PhD Thesis has achieved:

- Seven journal publications, one conference proceeding and one granted Indian patent.
- Indian Society of Agricultural Engineers –TAFE Sivasailam Gold Medal for best PhD Thesis.