Performance Evaluation of an End-Effector Designed Based on Harvesting Multiple Cotton Bolls at a Time

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Introduction

- ❑ Cotton bolls at the bottom third to half of the plant have the highest value and yield.
- ❑ Harvesting cotton bolls as soon as they open can maintain the fiber quality and reduce yield loss.
- ❑ Currently, cotton is harvested by a widely used, heavy, and expensive mechanical harvester.

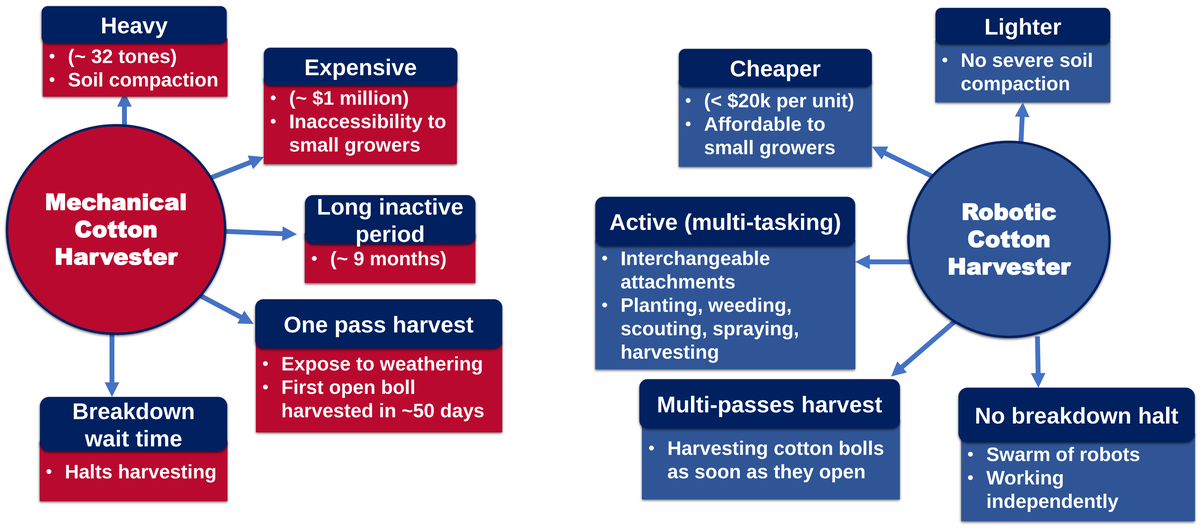


Fig. 1: Cotton production sustainability perspective of mechanical and robotic cotton harvesters

Components of a Robotic Cotton Harvesting System

Sensing	Planning	Navigating	Manipulating
• Cotton boll detection • Obstacle detection	▪ Optimized path planning	▪ Moving toward the target	▪ End-Effector manipulation

- ❑ A handful of studies have been performed on robotic cotton harvesting, which all have end-effectors that are designed based on the approach of detecting individual cotton bolls and harvesting single boll at a time, resulting in slow harvesting time per boll.
- ❑ Harvesting speed can be improved from a new approach: harvesting multiple cotton bolls at a time.

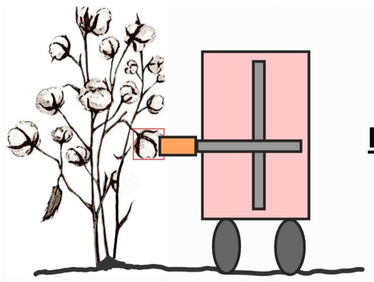


Fig. 2: Harvesting single cotton boll at a time approach, slow

Harvesting Approaches

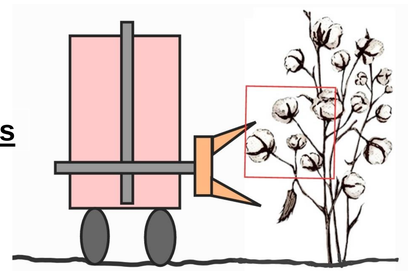


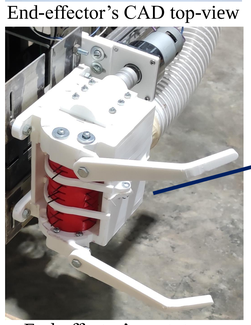
Fig. 3: Harvesting multiple cotton bolls at a time approach, faster

Objective

- ❑ To evaluate the harvesting performance of an end-effector design based on harvesting multiple cotton bolls at a time and compare with other robotic cotton harvesting systems

Materials and Methods

End-effector's CAD top-view



End-effector's prototype

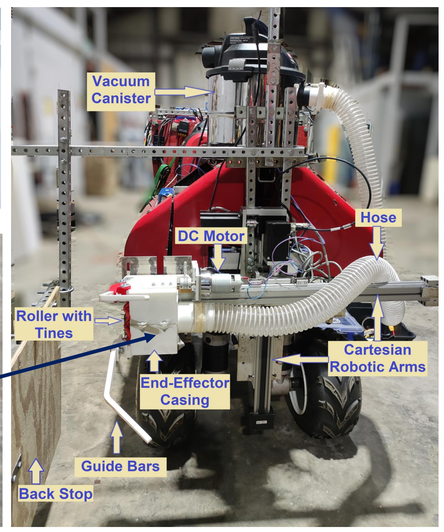


Fig. 4: Parts of the robotic cotton harvesting system

End-effector

- ❑ CAD modeled in Autodesk Inventor 2022
- ❑ 3D printed using Ultimaker S5
- ❑ Roller (height =125mm, 60 mm dia., 28 tines)

Robotic platform

- ❑ Small Red Rover
- ❑ Cartesian type of robotic arm

Vacuum system

- ❑ CRAFTSMAN, 120V AC, 850watt, 85 CFM
- ❑ Hose 2-1/2" diameter & 6 ft long

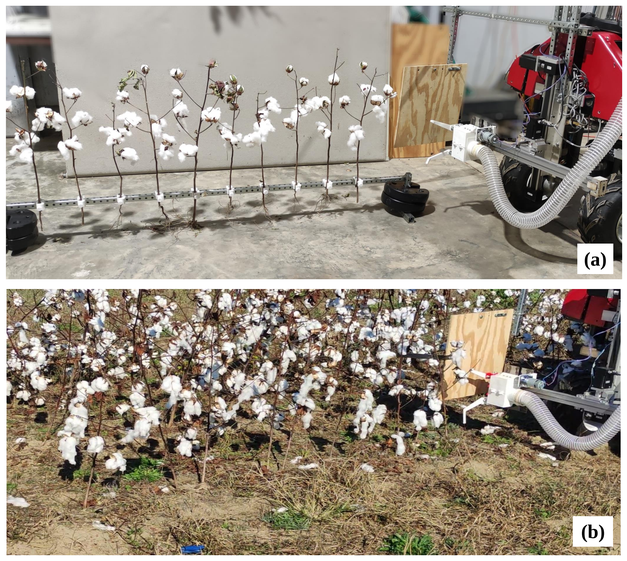


Fig. 5: (a) Lab test setup, (b) Field test setup

Test setups

- ❑ 2 seed/foot
- ❑ Lab tests: 3 rows (5 ft long)
- ❑ Field tests: 3 rows (5 ft long), 2 rows (10 ft long)

Other Settings

- ❑ No vision system & manually controlled rover
- ❑ Roller:165 RPM and 3.02 Nm stall motor torque

Measured indices

$$Picking\ Ratio = \frac{picked\ seed\ cotton\ weight}{picked + unpicked\ weights}$$

$$Picking\ Time/boll = \frac{total\ time\ to\ harvest}{no.\ of\ cotton\ picked}$$

Results

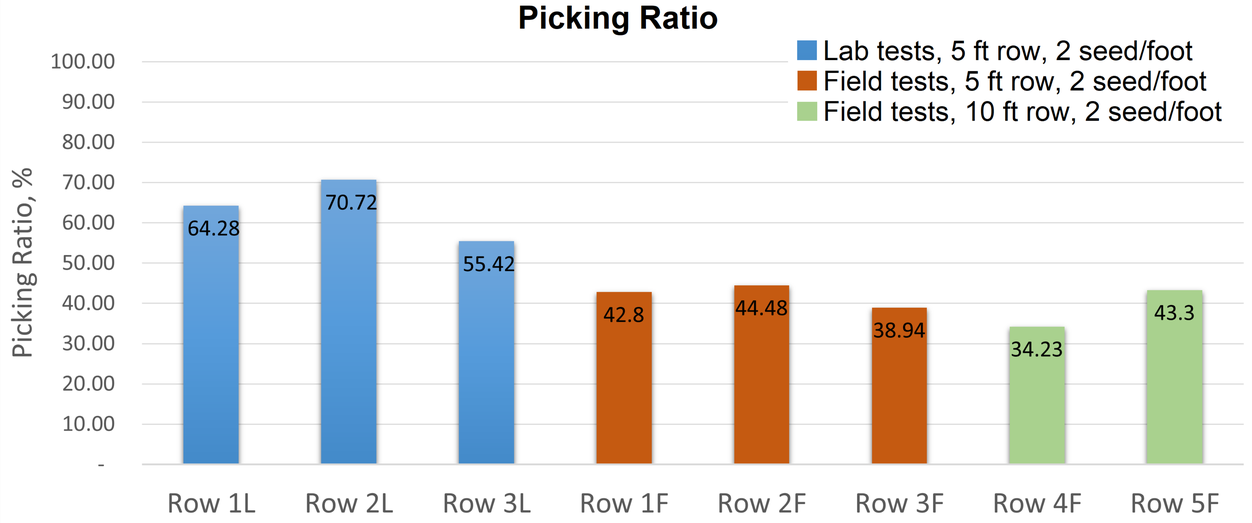


Fig. 6: Picking ratios for every row in the lab and field tests

Table. 1: Average picking ratio, average picking time per boll and average rover speed for the lab and field tests

Test	Avg. Picking Ratio, %	Avg. Picking Time/Boll, sec/boll	Avg. Rover Speed, MPH
Lab	63.47 (SD 7.68)	1.93 (SD 0.45)	0.23 (SD 0.03)
Field	40.75 (SD 4.20)	5.52 (SD 1.97)	0.12 (SD 0.02)

Conclusions

- ❑ The end-effector showed statistically higher performance in lab tests than in field tests, primarily due to the presence of rigid plants in the simulated environment, resulting in a greater success rate of encounters with cotton bolls.
- ❑ The end-effector has a significantly faster harvesting time per boll than the other robotic cotton harvesting systems.
- ❑ The end-effector has significant room for improvement in the picking ratio.

Future Research

- ❑ Improve picking ratio; upcoming studies will investigate the potential benefits of using larger and wider end-effectors.
- ❑ Investigate the quality of cotton fiber harvested from a mechanical harvester and the robotic cotton harvester.
- ❑ Implement a vision system with a cotton detection model to optimize picking ratio.

Acknowledgement