

Research Highlights

Mechanization Efforts in Fruit Harvesting

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Overview

Labor represents one of the largest and most uncertain cost components in U.S. fruit production. Harvesting, pruning, thinning, and other orchard operations remain highly labor intensive, and fruit growers face chronic labor shortages during peak production periods. Even short harvest delays can reduce fruit quality and value, while prolonged delays may result in complete crop loss. In this context, mechanization and automation have become central strategies for sustaining the economic viability of specialty crop production.

Orchard Design and Biological Constraints

This study reviews current efforts to mechanize fruit harvesting and emphasizes the critical role of orchard design in enabling automation. Traditional tree architectures with dense, irregular canopies limit fruit visibility and accessibility for machines. In contrast, fruiting-wall systems—such as vertical or V-shaped canopies—create narrow, uniform structures that improve fruit exposure, worker productivity, and compatibility with robotic technologies. Evidence from commercial orchards suggests that angled and planar canopies can increase yields while simultaneously improving access for mechanized operations, although they may introduce trade-offs for robotic reach and navigation.

Robotic Harvesting Technologies

Robotic fruit harvesting has advanced substantially over the past four decades, moving from laboratory prototypes to commercially oriented systems developed by start-up firms. Modern robotic harvesters rely on computer vision, machine learning, and robotic arms to identify, reach, detach, and transport fruit. Two key performance metrics determine economic feasibility: fruit picking efficiency and pick cycle time. Both metrics are strongly influenced by canopy structure, fruit occlusion, hardware design, and software performance. Current prototypes achieve moderate success rates but remain limited by speed, reliability, and cost.

Economic and Industry Implications

The analysis highlights that mechanized harvesting is not solely an engineering challenge but a systems problem requiring coordination across biology, horticulture, engineering, and economics. High capital costs, biological variability, and uncertainty about adoption remain barriers to commercial deployment. However, continued increases in labor costs and improvements in artificial intelligence, sensing, and robotic design are narrowing the gap

between manual and automated harvest systems. The study concludes that mechanization, coupled with orchard systems designed for machine compatibility, represents a promising pathway for addressing labor shortages and enhancing the long-term competitiveness of the U.S. fruit industry.