

Revolutionizing Seed Spice Harvesting: Robotic Solutions for a Sustainable Future

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India, renowned as the land of spices, holds a prominent position in global spice production, consumption, and export. The country is the world's largest producer and exporter of spices, generating 10.49 million tonnes (MT) of spices over an area of 4.52 million hectares (Mha) during 2020–21 (Anonymous, 2021). The International Organisation for Standardisation (ISO) lists approximately 109 crops as spices worldwide, with around 63 of these farmed in India; among these, 20 are seed spices (Singh and Solanki. 2015). These seed spices, including coriander, fenugreek, cumin, fennel, anise, celery, caraway, ajwain, dill, and nigella, are vital for their culinary, medicinal, and industrial applications. Seed spices cover about 1.74 million hectares and produce approximately 1.45 million metric tonnes, significantly contributing to the

Indian spice economy. Despite its significant production capacity, India exports only 15% of its spice production annually, meeting 50-60% of the world's demand (Anonymous, 2021). Declining productivity of seed spice crops is a mounting concern due to inefficient harvesting methods and the delicate nature of the crops, leading to production shortfalls. Conventional harvesting involves manual labor, which is tedious, time-consuming, and reduces farmer profitability (Yadav et al., 2007). Mechanization in horticulture remains low, at less than 1% (Tiwari et al., 2017). Mechanical harvesters designed for cereal crops are unsuitable for seed spices, causing significant losses due to their shorter stature and susceptibility to shattering (Dar et al., 2019). Additionally, these methods lead to high dust and particulate matter concentrations (Ekka and Kumar, 2019), causing health issues for operators.

To address these limitations and meet the growing demand, a specialized robotic harvester for seed spices is essential. This robotic solution offers enhanced efficiency, reduced crop losses, and decreased reliance on manual labour, improving operator safety and well-being. Integrating sophisticated control systems will enable autonomous navigation and real-time decision making, optimizing performance across various field conditions.

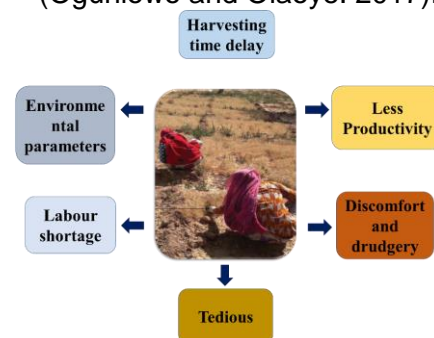
Despite the benefits, challenges like high initial costs, technical expertise requirements, and diverse field conditions hinder widespread adoption. This article aims to revolutionize seed spices harvesting in India with innovative solutions, enhancing productivity and reinforcing India's global position as a leading supplier of high-quality seed spices.

Challenges in Conventional Harvesting Methods

Manual Harvesting

Manual harvesting of seed spices in India uses tools like knives, sickles, and scythes, facing several challenges

- **Labor Shortage:** Agricultural labor is declining 59.1% in 1991 to 54.6% in 2017 due to new employment opportunities and policies like MGNREGA.
- **Discomfort and Drudgery:** Manual harvesting is labour-intensive and physically demanding, leading to fatigue and health issues (Pandey and Devnani. 1981).
- **Harvesting Time Delays:** Manual harvesting is slow, causing delays and crop losses due to shattering, hampering market demands (Ogunlowo and Olaoye. 2017).



Mechanical Harvesting

Mechanical harvesters designed for cereal crops are unsuitable for seed spices due to:

- **Crop and Machine Parameters:** Seed spices are shorter (20-50 cm) and prone to shattering. Existing harvesters are too heavy and not manoeuvrable enough for these delicate crops.
- **Operator and Environmental Challenges:** Mechanical harvesters generate high dust and particulate matter, causing health risks from vibrations and pushing force. Prolonged use leads to musculoskeletal issues and poor work performance in high temperatures and low humidity (Ekka and Kumar, 2019; Gururaj and Mehta. 2020).

Scope of Robotic Harvesters

• Increased Productivity:

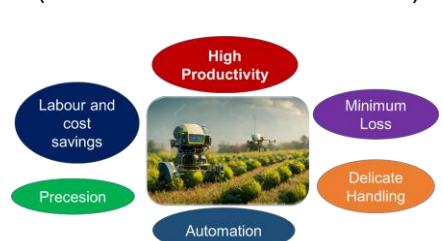
These machines operate continuously and efficiently, boosting harvesting speed and productivity to meet growing market demands (Xiong et al., 2020).

• Precision and Delicate Handling:

Robotics ensure gentle handling, minimizing crop damage and preserving quality through advanced sensors and tailored algorithms (Silwal et al., 2017).

• Labor Savings:

By reducing reliance on manual labour, robotic harvesters make spice cultivation more economically viable, alleviating labour shortages and cutting costs associated with manual methods (Eberhardt and Vollrath. 2016).



Research Needs

To optimize robotic harvesters for seed spices, research should focus on:

• Crop-Specific Harvesting

Components: Developing components tailored to specific crop properties to minimize

damage and enhance efficiency.

• Improved Efficiency and Automation:

Enhance performance through advanced automation, reducing reliance on manual labor and ensuring consistent harvesting quality (Ling et al., 2019).

• Navigation and Control Systems:

Implement advanced control systems for autonomous navigation and real-time decision-making, enabling robots to adjust to varying field conditions.

• Sustainability and Economic Viability:

Ensure eco-friendly practices and affordability for small and marginal farmers. Innovations should aim for minimal environmental impact and cost-effectiveness to ensure wide adoption.

Conclusion

Robotic harvesters have the potential to revolutionize seed spices harvesting in India, enhancing productivity and reinforcing the country's global supply position. By addressing the limitations of manual and mechanical methods and customizing the technology to crop properties, it enhances productivity and reinforces India's position as a global seed spices supplier. However, addressing challenges like cost, technical expertise, and field conditions is crucial. Collaboration between industry and government is essential to ensure successful adoption and sustainability in the spice sector.

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