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Mechanization of Litchi (*Litchi chinensis S.*) Cultivation: Current Scenario and Future Needs of India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

India stands as the world's second-largest producer of litchi (*Litchi chinensis S.*), with a majority of its cultivation concentrated in the eastern regions. Litchi cultivation involves diverse unit operations such as land preparation, pit digging, circular fertilizer pit creation, pruning, pest control, girdling, plant safeguarding, and harvesting. These operations predominantly rely on conventional, manual tools, resulting in time-consuming and labour-intensive tasks that reduce net profits for farmers. Despite the potential of mechanization to enhance production efficiency, its application in litchi cultivation remains limited to specific tasks such as land preparation and intercultural operations. Challenges like small land holdings, fragmented agricultural spaces, inadequate road access, and a

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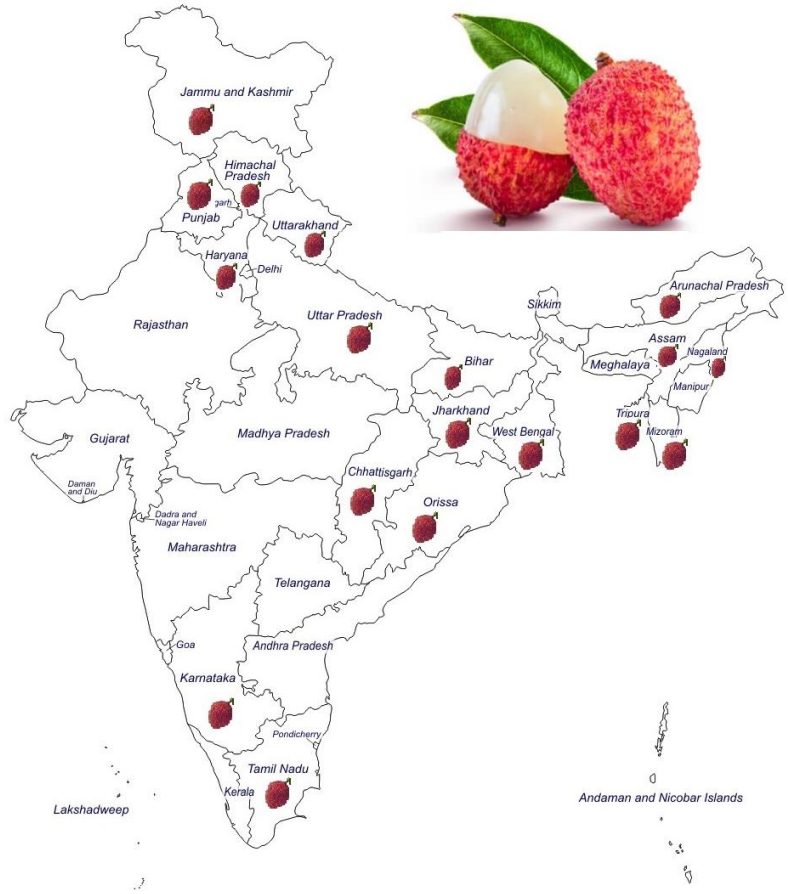
lack of awareness among farmers hinder widespread mechanization. Urgent intervention is needed to introduce advanced technologies that reduce operational costs and labour intensity to increase litchi production and productivity. This paper examines the current status of mechanization in litchi cultivation in India, highlighting the potential for mechanization in various aspects. The adoption of improved mechanization technology is crucial for enhancing orchard productivity, increasing farmer income, and promoting environmental sustainability. This study outlines present requirements and proposes future research directions for litchi mechanization. Recommendations are made to encourage mechanized production, emphasizing the need for matching and efficient power equipment to ease labour-intensive tasks such as pit digging, circular fertilizer pitting, pruning, girdling, caterpillar killing, and harvesting operations. Developing advanced equipment to streamline these critical tasks is essential for the sustainable growth of litchi cultivation in India.

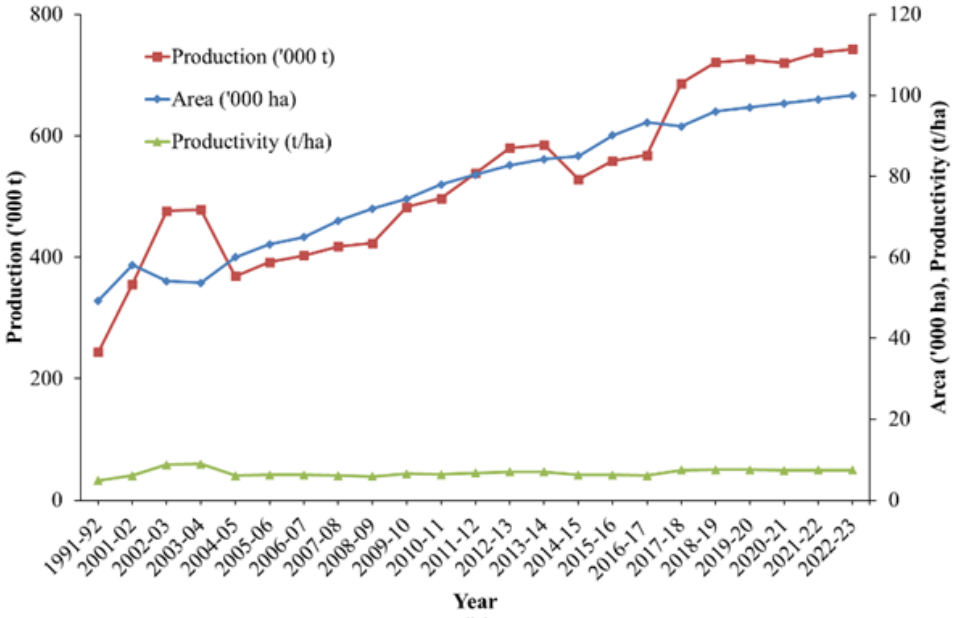
Keywords: Labour-intensive; litchi cultivation; litchi mechanization; mechanized production; girdling; spraying.

1. INTRODUCTION

Litchi (*Litchi chinensis S.)* is one of the major fruit crops in India, also known as the queen of fruits. Litchi cultivation requires highly specific climatic conditions, which restrict its commercial production in a few tropical and subtropical countries in the world (Menzel et al., 1995). India is the second-largest producer of litchi in the world after China, with a total annual production of 743,000 tons (t) from 1,00,000 hectares (ha) in 2022-23 (Anonymous 2022). In India, due to its climatic requirements, the production of litchi is limited to only a few states. Bihar, West Bengal and Jharkhand are the major litchi producing states, which produce about 66% of the country's production. Other states producing litchi are Punjab, Himachal Pradesh, Arunachal Pradesh, Jammu and Kashmir, Tripura, Karnataka and Tamil Nadu (Sahni et al., 2020) (Fig. 1a).



(a)



(b)

Fig. 1. Litchi cultivation in India (a) major producing states and (b) trends in area, production and productivity during 1991-2023

Litchi cultivation serves as a crucial source of livelihood for millions of people as it supports on- and off-farm employment to small and marginal farmers in these states. Driven by the attractive profitability of litchi cultivation, the cultivation area has been steadily increasing year by year. This expansion has seen the litchi cultivation area grow from 49,300 ha in 1991-92 to a substantial 1,00,000 ha in 2022-23 at a compound annual growth rate (CAGR) of 3.27% (Fig. 1b). The production of litchi also boosted from 243,800 to 743,000 t at CAGR of 5.20% in the same period. Despite these advancements, the productivity of litchi cultivation remains stagnant at around 7.4 t/ha, notably lower than the achievable productivity under well-managed conditions.

Apart from being consumed as fresh fruit, litchi is also used in making processed products and in traditional medicine. Major challenges in litchi production include uneven fruit production, a short harvesting period, and short shelf life (Cronje et al., 2023).

Agricultural mechanization is crucial for enhancing crop productivity and profitability while reducing labour, time, and drudgery (Rasouli et al., 2009; Sahni et al., 2018; Tiwari et al., 2017). Studies have consistently shown a strong correlation between mechanization levels and farm productivity, with states having higher mechanization levels achieving greater yields (Tiwari et al., 2019; Singh et al., 2019; Singh et al., 2012). However, mainly litchi cultivation in India remains unmechanized, relying on labour-intensive manual operations like pit digging, pruning, and harvesting. The lack of suitable mechanization and rising labour costs threaten the sustainability of litchi production. This paper explores the current status of mechanization in litchi cultivation and identifies the need for advanced, cost-effective machinery to enhance productivity and profitability in this sector.

2. MECHANIZATION STATUS OF LITCHI CULTIVATION

Mechanization in litchi production remains at a nascent stage, with predominant reliance on manual labour for major operations such as pit digging for planting and fertilizing, pruning, girdling, timely pest or disease control and harvesting. The major unit operations performed in litchi cultivation and implements or tools used to perform these operations in litchi orchards are shown in Table 1. The prevalence of manual methods in these crucial operations underscores the current low level of mechanization in the litchi production process, warranting attention and strategic interventions to enhance efficiency and productivity in this important sector.

Table 1. Major unit operation in litchi cultivation and implement used

Operation	Implement used	Power Source
Field preparation	MB Plough, Disc plough, Cultivator, Harrow	Tractor/ power tiller
Pit digging for plantation	Manually with spade	Manually
Intercultural operation	Cultivator, Harrow	Tractor/ power tiller
Pruning/training	Air assisted pruner	Manually
Plant protection	Sprayers	Manually
Bark eating caterpillar killing	Cycle spokes	Manually
Pit for fertilizer application	Manually done with Spade, Fawda	Manually
Girdling of litchi	Girdling knifes	Manually
Harvesting	Manually plucked by hand	Manually

2.1. Field Preparation

Field preparation is carried out before nursery raising and planting the young trees in litchi orchards. It is mainly done with the help of widely available tillage implements (Fig. 2) such as MB plough, disc plough, cultivator, rotavator, disc harrow, power harrow, etc. These implements collectively contribute to the effective and efficient preparation of the field.

Fig. 2. Implements used for field preparation in litchi cultivation

2.2. Pit Digging for Plantation

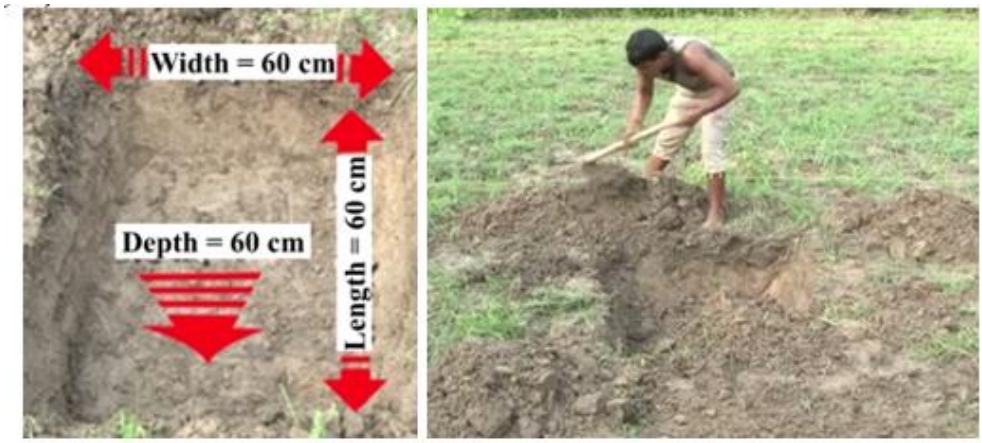


Fig. 3. Traditional pit digging operation for litchi plantation

(a) (b)

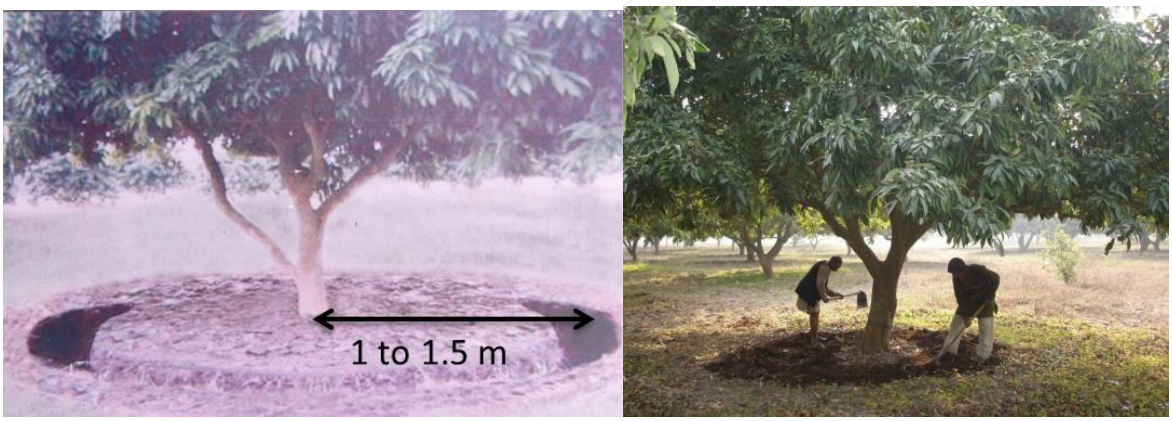
Fig. 4. Pit hole diggers (a) motorized and (b) tractor-operated for digging pits for litchi planting

The process of planting litchi layering involves the placement of the young plants in pits, with the size of these pits contingent upon the soil type. The recommended pit sizes for light, heavy, murrum (gritty) and loamy soils are 60 × 60 × 60 cm, 90 × 90 × 90 cm, 150 × 150 × 100 and 50 × 50 × 50 cm, respectively. Pits are generally made manually with the help of a spade, which is a labour-intensive, time-consuming and drudgery full operation (Khatri et al., 2022) (Fig. 3).

There is an urgent need of pit digger for planting operations in litchi cultivation. While crafting a cuboidal pit with machinery may present challenges; the possibility of employing tractor-operated or motorised pit diggers for circular pits exists in the market (Fig. 4). Furthermore, a comprehensive study needs to be conducted to meet the litchi-specific planting requirement in terms of the diameter and depth of the planting pit.

2.3. Fertilizer Pit Preparation for Fertilizer Application

In litchi cultivation, fertilizer application involves labour-intensive manual digging of circular pits around trees, a process that is inefficient and drudgery-prone (Singh et al., 2015). In litchi cultivation, fertilizer is applied after making a circular dig of around 25-30 cm deep and 20-25 cm wide, referred to as fertilizer pit. The outer diameter of the pit is the same as the outer canopy diameter of the plant, usually 1 to 1.5 m away from the trunk (Fig. 5a). Generally, digging of the pit is done manually with the help of spade and fawda (Fig. 5b). Post-hole diggers, though portable and compact, are inefficient and require high labour intensity. In India, fertilizer pitting remains largely manual, with no specialized equipment available. Developing a tractor-operated or self-propelled implement for fertilizer pitting would significantly reduce labour demands, enhance efficiency, and boost productivity in litchi cultivation.



(a) (b)

Fig. 5. Fertilization in litchi (a) required circular pit, and (b) manual digging of a circular pit

2.4. Intercultural Operation

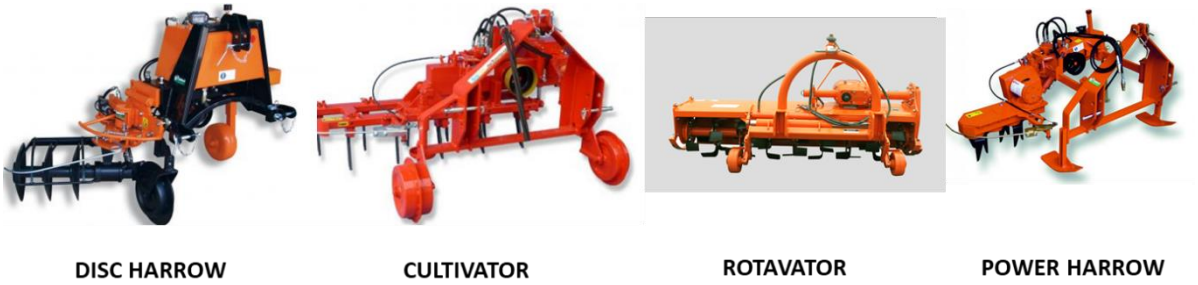


Fig. 6. Implements used for intercultural operation in litchi cultivation

Efficient weed removal is a crucial operation in litchi orchards, typically carried out twice a year. The first round occurs after the rainy season in October, and the second round occurs after the harvest in June or July. Moreover, during the initial years of growth, litchi orchards are meticulously maintained free from any weed infestations. For this operation, offset secondary tillage implements (Fig. 6), such as disc harrow, cultivator, power harrow, etc., are used for this essential operation. Using these implements ensures efficient weed management in litchi orchards, contributing to the overall health and productivity of the orchard. This practice underscores the significance of mechanized approaches in maintaining a weed-free environment and optimizing litchi cultivation practices.

2.5. Pruning and Training

One of the necessary requirements for litchi trees is training and pruning, as regular pruning is essential for induction of the reproductive phase. In addition, it provides the desired shape, removes diseased wood after harvesting, removes additional growth flushes, allows light penetration into the leaf canopy and controls tree height to facilitate cultural management practices. Currently, manual pruning operation is carried out using hand-operated tools such as handheld pruner or telescopic pruner (Fig. 7a). Lower branches are pruned using scissors or saw and higher branches are operated using long-reach telescopic pruners. On average, a person can prune 1-2 trees per hour.

Handheld power-aided pruning equipment can significantly reduce the labour intensity of farmers. Various power source types, including combustion engines, hydraulic systems, batteries and air compressors, can be utilized for pruning equipment. The electric pruning scissor powered by a battery is lightweight and easy to carry. A handheld, high-stick scissor is suitable for pruning practices of adult tree branches less than 20 mm in diameter. Pruning of tree branches that are more than 20 mm in diameter is mainly done with a power pruning saw by climbing up the fruit tree directly or with the aid of a ladder (Li et al., 2011). Figure 7(b) shows the portable hydraulic pruners for efficient pruning operation in the litchi orchards. A CIAE-developed tractor-operated pruner may be used for pruning operations in a big litchi orchard. This transition to mechanized pruning technologies holds immense potential for enhancing the productivity and sustainability of litchi cultivation while simultaneously reducing the physical burden on farmers.

(a)

(b)

Fig. 7. Pruning operation in litchi (a) traditional telescopic pruner and (b) portable hydraulic pruners

2.6. Spraying Operation

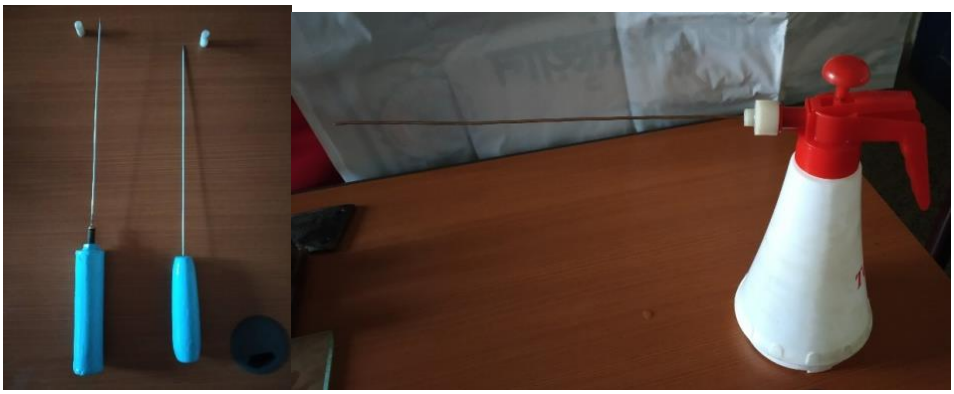
Regular spraying is imperative to control insects, pests, and weeds in litchi cultivation. The required number of sprays in a litchi orchard to control insects, pests, and weeds can vary depending on several factors, including the specific pests and diseases present, the local climate, and the orchard's management practices. This can range from 3 to 10 or more sprays per season. Spraying practices, predominantly reliant on manpower using traditional manual tools, involve the use of backpack sprayers and pedal sprayers, both of which are conventional types (Li et al., 2011) (Fig. 8a). The capacity of these sprayers ranges between 0.8-1.5 ha/day. To enhance efficiency and coverage, several tractor/engine-operated air-assisted sprayers are available for spraying operation in litchi gardens (Fig. 8b). The air blast sprayer offers advantages such as improved spray penetration, more uniform coverage throughout the canopy, reduced spray drift, lower carrier volume, and high plant protection efficiency (Rathnayake et al., 2022). Adopting these mechanized spraying technologies accelerates the spraying process and ensures more effective pest and disease control, contributing to the overall health and productivity of litchi orchards. This transition to advanced spraying equipment represents a significant step toward sustainable and efficient litchi cultivation practices.

(a)

(b)

Fig. 8. Spraying operation in litchi (a) traditional hand- and leg-operated sprayers and (b) air-assisted sprayers

2.7. Bark Eating Caterpillar Killing Tools



(a) (b)

Fig. 9. Caterpillar killing (a) hand tool to pinch larva and (b) hand injector to apply chemical in the bore

Litchi orchards occasionally face heavy infestations of bark-eating caterpillars and trunk borer, which bores inside the trunk/main stem. These pests emerge during the night, feeding on the bark of the stem and creating large silken webs for protection. When the affected branch ceases, the stem becomes weak and may ultimately fall to the ground. Traditionally, the infested plant parts are cleaned and the cotton wool soaked in kerosene oil or nuvacron or formalin needs to be inserted in the hole with the help of a bicycle spoke, followed by sealing with moist mud of fresh cow dung. These caterpillars are killed with the help of a bicycle spoke. To streamline and alleviate the drudgery associated with this operation, a hand tool with a flexible wire has been developed (Fig. 9a). Additionally, a hand-operated suction pump equipped with an extended nozzle for introducing chemicals into the bore has proven to be beneficial in killing the caterpillar inside the bore (Fig. 9b). These innovative tools not only reduce manual effort but also enhance the efficacy of the caterpillar elimination process, contributing to the overall health and sustainability of litchi cultivation.

2.8. Girdling

Girdling is a selective wounding process that removes strips of bark (Kumar et al., 2017) (Fig. 10c). Since the woody xylem part remains intact, water and nutrients reach the leaves. After the preparation of photosynthate, it is not transported to other parts below the girdle and accumulation of photosynthate just above the girdle region takes place, which in turn enhances the carbon-to-nitrogen ratio and ultimately improves flowering (Kumar et al., 2015; Li et al., 2001). Generally, girdling is performed on 75% of primary branches of litchi crops, i.e. three out of four primary branches being girdled in a tree. The advantages of girdling include increased fruit size and yield, promoted earliness of harvest, fruits coming in bunches, increased percentage of crop harvested in first picking and increased

(a) (b) (c)

Fig. 10. Traditional girdling process (a) serrated knife, (b) girdling knife and (c) girdling operation

red skin colour, thereby enhancing marketability (Kumar et al., 2017; Kumar et al., 2015; Li et al., 2001).

Currently, girdling is done with the help of a simple serrated knife (Fig. 10a) or falcon's girdling knife (Fig. 10b). However, this manual approach is time-consuming, taking 10-15 minutes per branch and also the girding depth is non-uniform. The use of a motorized girdling tool with depth and width control arrangement can significantly reduce the time and drudgery associated with this operation, offering a more precise and efficient method for enhancing the benefits of girdling in litchi cultivation. This technological advancement aligns with the broader goal of improving the overall productivity and quality of litchi orchards.

2.9. Harvesting

Harvesting in litchi orchards remains a labour-intensive and inefficient process, predominantly carried out manually and accounting for approximately 30-50% of total labour cost (Li et al., 2022). Litchi needs to be harvested within a narrow timeframe of about one week during their maturity phase; otherwise, there is a risk of the fruits becoming over-mature or even rotten while still on the tree. This implies that large manpower is required during the harvesting season (Tran et al., 2016, Wang et al., 2017). It is common for farmers to remove fruits using secateurs or long-handled picking tools to cut panicles from the lower height part of the tree. To obtain fruits that are beyond reach and at the uppermost sections of the tree, farmers harvest fruits using ladders or climbing up the tree, which is at high-risk potentiality (Fig. 11a). Addressing these challenges, there is a shift towards the adoption of a tractor-mounted hydraulic operated ladder (Fig. 11b). However, the current tractor-mounted solutions have limitations, particularly in terms of adaptability to varied orchard terrains and the associated high manufacturing and operational costs.

(a) (b)

(c) (d)

Fig. 11. Harvesting aid for litchi (a) harvesting ladders, (b) tractor-operated hydraulic platform, (c) hydraulic operated ladder, and (d) self-propelled hydraulic platform

Further advancements have been explored with the introduction of elevating the harvesting platform in terms of picking efficiency and worker safety with ladder harvesting aid. The utilization limit of the elevating harvesting platform (Fig. 11d) is that the current products are restricted to the plain orchard, which has a high manufacturing and operation cost. Efforts were made to refine and expand the applicability of such platforms, addressing current limitations and fostering a more widespread and cost-effective adoption in litchi orchards. A tractor-operated hydraulic platform developed by CIAE may be used for harvesting litchi, which is an effective solution.

3. SCOPE AND FUTURE NEEDS IN LITCHI MECHANIZATION

Overhauling traditional production management practices poses a considerable challenge in the quest for mechanized litchi orchard production. A more viable approach involves the widespread introduction, modification, and popularization of low-cost, manoeuvrable, and user-friendly machinery based on existing general-purpose orchard machinery. The major unit operations performed in litchi cultivation and the implements or tools used to perform these operations are shown in Table 2.

Field preparation and intercultural operations in litchi cultivation are fully mechanized. The switch from rectangular to circular pits, using tractor-operated pit diggers or improved tools, could lead to better results. The use of organic fertilizers is crucial for high-quality litchi production, highlighting the need to develop suitable fertilizer-pitting ditchers. Additionally, post-hole diggers could be adapted for this purpose. Pruning equipment should focus on creating simplified, lightweight, battery-powered tools to reduce labour intensity and increase productivity. The promotion of small-sized air-blast sprayers and the integration of mechatronics in spraying machinery would further improve efficiency. Addressing drudgery in girdling, ICAR-CIAE, Bhopal, has developed a motorized girdling tool, and small hand tools for caterpillar control offer targeted solutions. Promoting hydraulic platforms for harvesting operations will advance litchi cultivation, contributing to its mechanization, sustainability, and productivity.

Table 2. Scope and future needs in litchi mechanization

Operation	Proposed implement	Remarks/ Researchable issues
Field preparation	MB plough, disc plough, cultivator, harrow	Available
Pit making for plantation	Pit hole digger	Available, may be modified according to litchi crop requirement
Intercultural operation	Cultivator, harrow, power harrow	Available
Pit for fertilizer application	Fertilizer pit digger/ pit hole digger	Need to develop a tractor operated fertilizer pit opener / ditcher
Pruning/training	Hydraulic/electric pruner	Hydraulic pruner with long hose is required
Plant protection	Air assisted blast sprayer	Available or small air blast sprayer can be developed
Girdling	Girdling knifes	A hand operated motorized tool needs to be developed
Bark eating caterpillar killing	Larva pincher/ bore chemical applicator	Larva pincher and hand injector needs to be developed
Harvesting	Manually	Available, platform is developed to pluck the litchi /need further modification and adaptation

4. CONCLUSION

This study highlights the growth of litchi cultivation in India. Despite the increase in cultivation and production, productivity has stagnated, requiring attention. The paper examines the challenges faced by litchi farmers and offers insights for improving cultivation practices. Promoting agricultural machinery and orchard equipment is crucial to increasing mechanization, reducing labour, and boosting productivity in litchi orchards. Further research on mechanizing litchi cultivation is essential to provide farmers with modern tools and enhance their success, ensuring the sustainable growth of litchi farming in India.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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