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Development and evaluation of hand-injector for bark-eating caterpillar (*Indarbela quadrinotata; Indarbela tetraonis*) control in litchi crop

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Abstract

Litchi (*Litchi chinensis S.*), a major fruit crop in India, faces severe threats from the bark-eating caterpillar (*Indarbela quadrinotata* and *Indarbela tetraonis*), which can cause significant damage to trees and reduce fruit yield. Traditional control methods, such as manual removal or chemical injection using a syringe, are often labour-intensive and inefficient. This study aimed to develop and evaluate a manual hand-injector tool for effective caterpillar control in litchi orchards. The hand-injector, designed at ICAR-CIAE, Bhopal, features a flexible wire and extended nozzle that enables precise application of insecticides directly into caterpillar boreholes, minimizing operator exposure and improving safety. Field testing in litchi orchards at ICAR- National Research Centre on Litchi, Muzaffarpur, Bihar, demonstrated the tool's effectiveness in significantly reducing caterpillar infestation across multiple litchi varieties within seven days of application. The tool proved to be highly efficient, safe, and time-saving, offering substantial drudgery reduction for farmers. This innovation represents an important advancement in mechanized pest management for litchi cultivation, providing a practical and sustainable solution to improve orchard productivity and protect crops.

Key words: Litchi, hand injector tool, bark-eating caterpillar, pest control, chemical application, orchard management

Introduction

Litchi (*Litchi chinensis* S.), often called the "queen of fruits," is a high-value commercial crop in India, with cultivation concentrated in regions like Bihar, West Bengal, Uttarakhand, Uttar Pradesh, and Jharkhand due to its specific climatic needs (Menzel *et al.*, 1995; Sahni *et al.*, 2020). However, litchi production faces significant challenges from insect pests, notably the bark-eating caterpillar, which severely damages trees and reduces fruit yield. Two primary species, *Indarbela tetraonis* and *Indarbela quadrinotata*, are known to infest litchi across several Indian states (Verma and Khurana, 1974; Khurana and Gupta, 1972), with *Indarbela tetraonis* being particularly damaging in Bihar, affecting litchi, guava, mango, and ber crops (Arya and Dubey, 2017; Ali *et al.*, 2007; Sharma and Kumar, 1986).

The bark-eating caterpillar bores into tree trunks and branches, creating tunnels up to 25 cm long. These infestations disrupt sap flow, stifle new growth, and reduce fruit production (Singh *et al.*, 2021; Verma and Khurana, 1976). Traditional pest control methods involve labour-intensive techniques, such as cleaning infested areas and applying kerosene-soaked cotton into boreholes, but these methods require constant monitoring and are challenging to implement across large orchards.

Given these limitations, there is a critical need for an efficient, safe, and mechanized solution to manage bark-eating caterpillar infestations in litchi cultivation. This study aimed to address this gap by developing and evaluating a hand-injector tool that can directly deliver pesticides into caterpillar tunnels, thereby reducing manual labour and improving the effectiveness of pest control practices in litchi orchards. This research presents a modernized approach to pest management, enhancing both productivity and safety for farmers.

Materials and methods

Development of hand injector: A hand-injector tool was designed and developed at ICAR-Central Institute of Agricultural Engineering (CIAE), Bhopal, to control bark-eating caterpillars by injecting insecticide directly into their boreholes. CAD models (Fig. 1) were created, and prototypes were fabricated (Fig. 2). The tool consists of a 1-litre tank, a hand-operated suction pump, and an extended nozzle made from flexible wire, enabling precise chemical application into caterpillar tunnels. This design minimizes manual labour and enhances the effectiveness of pest control by directly targeting caterpillars within the tree. The specifications of the hand injector are summarized in Table 1.

Table 1. Specification of hand injector

Specification	Dimension
Over all dimension, mm[3]	500 x 333 x 136
Top diameter of tank, mm	37
Bottom diameter of tank, mm	113
Height of tank, mm	190
Cap height, mm	90
Total height of sprayer (cap+tank), mm	280
Nozzle pipe length, mm	337
Nozzle length, mm	360
Nozzle height, mm	243
Capacity of tank, mm	1000 mL

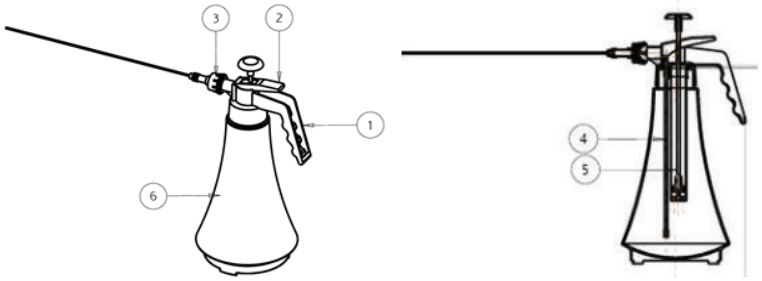

Fig. 1. CAD model of hand injector (1-handle, 2-spraying unit lever, 3-nozzle, 4-suction pipe, 5- piston, 6- chemical storage)

Fig. 2. Prototype of hand injector

Magnitude of infestation of bark-eating caterpillar: The study focused on five litchi varieties: China, Shahi, Rose Scented, Bombai, and Purvi. Five trees of each variety (totalling 25) were selected for infestation observation. Trees with a score of 2 or higher, as per Mathew's (1997) scoring system, were included, ensuring significant infestation levels. The scoring criteria used in the study is presented in Table 2.

Table 2. Infestation level scoring criteria

Score	Number of borers in the tree	Magnitude of infestation
0	No borer attack	Healthy tree
1	Only one borer	Low infestation
2	2 to 4 borers	Medium infestation
3	More than 4 borers	Heavy infestation

The infestation was identified by the presence of silk-and-bark sleeves extending from tunnels and the presence of active borers.

Field testing and observation: Field trials were conducted in litchi orchards at the ICAR-National Research Centre (NRC) on Litchi, Muzaffarpur, Bihar. Observations included recording any frass ribbons on infested trees, indicative of recent caterpillar feeding. The infestation intensity was quantified by counting active boreholes on each infested tree, and a caterpillar incidence index was calculated as follows (Verma and Khurana, 1976) and used by many researchers (Atwal and Singh, 1990; Kumar *et al.*, 2021). This index helped assess the hand-injector's efficacy in reducing caterpillar populations within the orchards.

$$\text{Caterpillar incidence index} = \frac{\text{Trees infested \% x Mean no. of active holes/infested tree}}{100}$$

Results

Field testing of the hand-injector tool was conducted in litchi orchards at the ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar (Fig. 3). The test included 25 trees of five litchi varieties: China, Shahi, Rose Scented, Bombai, and Purvi. Visible signs of bark-eating caterpillar infestation—such as ribbons of wood chips, frass, and silken threads—indicated active caterpillar burrows. The insecticide was applied to these burrows using the hand injector, and infestation severity was documented for each variety. Table 2 provides a summary of infestation metrics, including incidence, intensity, and the caterpillar incidence index.

The Bombai variety recorded the highest caterpillar incidence index (5.90), making it the most heavily infested, followed by the China variety (5.67). Rose Scented had the lowest incidence index (3.61), indicating comparatively lower infestation severity. These findings reflect the susceptibility of different varieties to infestation, possibly due to genetic or structural factors of each type.

Table 2. Infestation level scoring criteria

Litchi varieties	Incidence (%)	Intensity (No. of active holes per tree)	Magnitude of infestation	Index of caterpillar incidence
China	75.63	7.5	Heavy infestation	5.67
Shahi	70.23	7.0	Heavy infestation	4.92
Rose Scented	60.12	6.0	Heavy infestation	3.61
Bombai	76.68	7.7	Heavy infestation	5.90
Purvi	64.00	6.4	Heavy infestation	4.10

Tool performance and efficiency: Observations conducted seven days after application showed no live caterpillars in the treated burrows across all litchi varieties, demonstrating the high efficacy of the hand-injector tool. The insecticide Chlorantraniliprole was used effectively (Satyanarayana and Arunakumara, 2016), killing the caterpillars within a short period, highlighting the tool's precision in pest elimination. The manual hand injector reduced application time significantly, with each caterpillar hole treated in under a minute. This represents a remarkable improvement over traditional pest control methods.

Discussion

The high infestation index in Bombai and China varieties may be linked to specific structural characteristics of these trees, making them more susceptible to bark-eating caterpillars. Compared to previous studies, such as Thakur and Thakur (1998) on plum trees and Verma and Khurana (1976) on other fruit crops, the observed infestation levels align with reported findings, emphasizing the widespread and persistent impact of this pest across multiple tree varieties and crops.

The manual hand injector demonstrated notable time efficiency and precision, which is particularly advantageous for large-scale orchards. Traditional syringe-based methods are labour-intensive and expose operators to chemical risks. The hand injector's design, with its extended nozzle and 1-litre capacity tank, minimizes chemical exposure while reducing drudgery, making it a practical, farmer-friendly solution.

Practical implications and economic impact: Adoption of the hand injector can improve caterpillar control efficacy, reducing labour costs and enhancing operator safety. Given its affordability and ease of use, this tool is suitable for different litchi-growing regions and has potential applications for other crops affected by similar pests.

Fig. 3. Testing of the hand injector at NRC on litchi, Muzaffarpur, Bihar

The hand-injector tool demonstrates significant potential as an innovative solution for caterpillar control in litchi orchards, offering a practical, efficient, and safe alternative to traditional pest management methods.

Key findings show that the tool effectively eliminates bark-eating caterpillars with high precision, reducing infestation levels and minimizing chemical exposure risks for operators. The tool's ease of use and time efficiency also contribute to reduced labour demands, making it a valuable asset for farmers and orchard managers aiming to increase productivity while maintaining sustainable practices. One limitation of this study is that the hand injector's efficacy was only tested on bark-eating caterpillars in litchi trees. Future studies should evaluate its performance on other pests and tree types to determine its broader applicability. Future research should explore the tool's adaptability to other crops and pest types, examining its efficacy in diverse agricultural contexts. Additionally, modifications to the tool's design such as adjustable nozzle configurations and increased tank capacity could enhance its versatility, broadening its applicability across various orchard and farm settings. This study marks a promising step forward in pest control technology, encouraging further advancements that support sustainable and effective pest management for improved orchard health and yield.

Declaration: The authors assert that they possess no conflict of interest.

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