वार्षिक प्रतिवेदन
ANNUAL REPORT
2025

भा.कृ.अनु.प.–राष्ट्रीय लीची अनुसंधान केन्द्र
ICAR-National Research Centre on Litchi
मुशहरी प्रक्षेत्र, मुशहरी, मुजफ्फरपुर–842 002, बिहार, भारत
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Published

March, 2026

Correct Citation

ICAR-NRCL Annual Report 2025, ICAR-National Research Centre on Litchi Muzaffarpur 842 002, Bihar, India, 92 p.

Back Cover Illustration

Aerial view of ICAR-NRCL Main Campus at Muzaffarpur

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मुशहरी प्रक्षेत्र, मुशहरी, मुजफ्फरपुर - 842 002 (बिहार)

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प्रस्तावना

लीची की खेती भारतीय बागवानी में अपनी उच्च आर्थिक महत्ता, निर्यात क्षमता तथा पूर्वी भारत के उत्पादकों की आजीविका को समर्थन देने में महत्वपूर्ण भूमिका के कारण एक विशिष्ट स्थान रखती है। भारत विश्व के प्रमुख लीची उत्पादक देशों में शामिल है, इसलिए उत्पादकता, फल गुणवत्ता, भंडारण क्षमता तथा जलवायु अनुकूलता में सुधार के लिए वैज्ञानिक हस्तक्षेपों की आवश्यकता निरंतर बढ़ रही है। भा.कृ.अनु.प.-राष्ट्रीय लीची अनुसंधान केन्द्र, मुजफ्फरपुर इन चुनौतियों का समाधान करने हेतु केन्द्रित अनुसंधान, प्रौद्योगिकी विकास तथा प्रसार गतिविधियों के माध्यम से किसानों और लीची क्षेत्र से जुड़े अन्य हितधारकों के हित में निरंतर कार्यरत है।

वर्ष 2025 के दौरान केन्द्र ने लीची में फसल सुधार, उत्पादन, संरक्षण, कटाई उपरांत प्रबंधन तथा मूल्य संवर्धन से संबंधित अनुसंधान में उल्लेखनीय प्रगति की। बेहतर फल भार, गूदा पुनर्प्राप्ति, मिठास तथा बाजार आकर्षण वाले उत्कृष्ट जीनोटाइपों की पहचान की गई, जबकि उत्परिवर्तन प्रजनन, GWAS आधारित फेनोटाइपिंग तथा आणविक लक्षणन में हुई प्रगति ने फसल सुधार प्रयासों को और मजबूत किया। इन-सीटू माइकोराइज़ेशन तथा एकीकृत पोषण प्रबंधन ने मृदा उर्वरता और पोषक तत्व उपलब्धता में सुधार किया तथा रासायनिक उर्वरकों पर निर्भरता कम की। DRIS आधारित पोषण मानकों ने छिपे हुए पोषक असंतुलनों की पहचान में सहायता की, जबकि अध्ययनों से राइजोस्पीयर स्वास्थ्य पर गर्डलिंग के प्रतिकूल प्रभाव तथा फरवरी को पोषक तनाव की दृष्टि से महत्वपूर्ण अवधि के रूप में चिह्नित किया गया। कैनोपी के नीचे मिनी-स्प्रिंकलर सिंचाई तथा पूर्व-तुड़ाई बैगिंग द्वारा फल फटने और झुलसन का प्रभावी प्रबंधन किया गया। फसल संरक्षण अनुसंधान में पैनिकल ब्लाइट को एक प्रमुख उपज-सीमित कारक के रूप में पहचाना गया तथा प्रभावी फफूंदनाशी और जैव-उत्तेजक आधारित प्रबंधन रणनीतियों का सत्यापन किया गया। कीट प्रकोप, कीटनाशी अवशेष, परागण पारिस्थितिकी तथा सेमियोकेमिकल आधारित उपायों पर किए गए अध्ययनों से टिकाऊ कीट प्रबंधन के लिए उपयोगी जानकारी प्राप्त हुई। केन्द्र ने बागानों की पारिस्थितिकी को बनाए रखने में परागणकों और परजीवी कीटों की भूमिका को भी रेखांकित किया। कटाई उपरांत प्रबंधन में बैसिलस सब्टिलिस आधारित फॉर्मुलेशन, हाइड्रोकॉलॉयड कोटिंग, लाख कोटिंग, मेलाटोनिन उपचार तथा संशोधित वायुमंडलीय पैकेजिंग जैसी तकनीकों ने फल गुणवत्ता और भंडारण अवधि में प्रभावी सुधार किया। लीची फाइबर युक्त कुकीज़, लीची लेदर, स्टार्च निष्कर्षण तथा कार्बोनेटेड RTS पेयों पर किए गए मूल्य संवर्धन अध्ययनों ने लीची उपोत्पादों के बेहतर उपयोग की संभावनाओं को प्रदर्शित किया।

देश के विभिन्न भागों में लीची उत्पादकों की अपेक्षाओं पर खरा उतरते हुए, केन्द्र ने लीची उत्पादक क्षेत्रों में किसानों और अन्य हितधारकों तक पहुंचने के लिए समन्वित प्रयास किए। वर्ष के दौरान कई क्षमता निर्माण और प्रशिक्षण कार्यक्रम आयोजित किए गए तथा 5000 से अधिक हितधारक प्रशिक्षण और प्रसार गतिविधियों से लाभान्वित हुए। लीची आधारित पेयों के लिए उद्यमियों के साथ समझौता ज्ञापन और लाइसेंस हस्तांतरण भी किए गए। केन्द्र ने विभिन्न किसान मेलों में भाग लेकर हितधारकों के बीच लीची प्रौद्योगिकियों का प्रदर्शन और प्रसार किया। मूल दक्षता विकास तथा मानव संसाधन विकास के उद्देश्य से केन्द्र ने कृषि अनुसंधान एवं शिक्षा में स्नातक और स्नातकोत्तर विद्यार्थियों को आकर्षित और प्रशिक्षित करना जारी रखा।

मुझे ICAR-NRCL की वार्षिक प्रतिवेदन 2025 प्रस्तुत करते हुए गर्व हो रहा है। मैं केन्द्र की प्रगति के लिए ICAR-NRCL के वैज्ञानिकों एवं कर्मचारियों के समर्पित कार्य और निष्ठा को अभिलेखित करता हूँ। मैं डॉ. एम.एल. जाट, सचिव, DARE एवं महानिदेशक, ICAR तथा डॉ. एस. के. सिंह, उप महानिदेशक (उद्यान विज्ञान), ICAR के निरंतर सहयोग और मार्गदर्शन के लिए आभार व्यक्त करता हूँ।

(बिकाश दास)
निदेशक

मार्च, 2026
मुज़फ्फरपुर

PREFACE

Litchi cultivation continues to hold a unique place in Indian horticulture because of its high economic value, export potential and importance in supporting the livelihoods of growers in eastern India. With India ranking among the leading litchi-producing countries, there is a growing need for scientific interventions to improve productivity, fruit quality, post-harvest life and climate resilience. The ICAR-National Research Centre on Litchi, Muzaffarpur, remains committed to addressing these challenges through focused research, technology development and outreach for the benefit of farmers and other stakeholders across the litchi sector.

During 2025, the Centre made significant progress in research on crop improvement, production, protection, post-harvest management and value addition in litchi. Elite genotypes with superior fruit weight, pulp recovery, sweetness and market appeal were identified, while advances in mutation breeding, GWAS-based phenotyping and molecular characterization strengthened crop improvement efforts. In-situ mycorrhization and integrated nutrient management improved soil fertility, nutrient availability and reduced dependence on chemical fertilizers. DRIS-based nutrient norms helped identify hidden nutrient imbalances, while studies revealed the adverse impact of girdling on rhizosphere health and identified February as a critical nutrient stress period. Fruit cracking and scorching were effectively managed through under-canopy mini-sprinkler irrigation and pre-harvest bagging. Crop protection research identified panicle blight as a major yield-limiting factor, and effective fungicidal and bio-stimulant-based management strategies were validated. Studies on pest dynamics, pesticide residues, pollination ecology and semiochemical-based approaches generated useful insights for sustainable pest management. The Centre also highlighted the role of pollinators and parasitoids in maintaining orchard ecology. In post-harvest management, technologies such as Bacillus subtilis-based formulations, hydrocolloid coatings, lac coatings, melatonin treatment and modified atmosphere packaging effectively improved fruit quality and shelf life. Value addition studies on litchi fibre-enriched cookies, litchi leather, starch extraction and carbonated RTS beverages demonstrated the potential for better utilization of litchi by-products.

Living up to the expectations of litchi growers in different parts of the country, the centre made concerted efforts to reach out to farmers and stakeholders in litchi-growing areas all over the country. Several capacity building and training programmes were organized during the year and more than 5000 stakeholders were benefitted through our training and extension activities. MoU and licence transfer for litchi-based beverages have been inked with entrepreneurs. The centre also participated in various Farmers' Fair to showcase and disseminate litchi technologies among stakeholders. With the aim of developing core competence and human resource development, the centre has continued to attract and train UG and PG students in agricultural research and education.

I am proud to present the Annual Report 2025 of ICAR-NRCL. I place on record the sincere work and dedication of scientists and staff of ICAR-NRCL for the progress of this Centre. I am thankful to Dr. M.L. Jat, Secretary DARE & DG, ICAR, and Dr. S. K. Singh, DDG (HS), ICAR for their constant support and guidance.

March, 2026 | **(Bikash Das)**
Muzaffarpur | Director

About the Centre

The ICAR-NRCL is the premier national institute for conducting research and development in litchi and provides leadership at national level. It also acts as a national repository for information on litchi production, processing, value addition, and provides consultancy services to end users.

Genesis and Growth

The ICAR-National Research Centre on Litchi (ICAR-NRCL) was established on 6th June, 2001 under the aegis of the Indian Council of Agricultural Research. With the lease deedhaving signed on 25thJune, 2002 between theICAR and Government of Bihar to transfer 100acres of land to the Centre at Mushahari, Muzaffarpur, ICAR-NRCL began its journey. The Centre grew in strength and number in subsequent years as more scientists and staff were allotted from the Council. The Centre is constrained today by its scientific strength, but have all modern laboratories with core equipment, a sprawling farm and experimental area, and a buzzing campus. The Centre is located at Mushahari, on Muzaffarpur-Pusa Road at 26°5'87'' N latitude, 85°26'64'' E longitude at an elevation of 210 m. It is located at about eight km distance from Muzaffarpur railway station. The research farm of the Centre is spread over an area of 35 hectares.

Mission, Mandate and Functions

Mission

Harnessing science and technology by interfacing research and extension activities for enhanced quality production, productivity, processing and use diversification for sustained litchi production, industry and trade.

Mandate

- Applied and strategic research on genetic resources and production technologies for enhanced, sustained, and safe production of litchi
- Transfer of technology and capacity building for stakeholders for enhancing and sustaining productivity of litchi

Infrastructure Facilities

The research farm of the Centre has modern propagation structures, screen houses, glasshouses, irrigation networking and water sources. Modern analytical and diagnostic equipments like RT-PCR, GCMS, AAS, UV-VIS spectrophotometer, HPLC, CHNS analyzer, leaf area meter, portable photosynthesis system, horizontal electrophoresis unit, nitrogen analyzer, flame photometer, trinocular phase-contrast upright microscope, trinocular compound microscope, inverted phase contrast microscope, stereo binocular microscope, lyophilizer, bioformentor, ultracentrifuge, modified atmospheric packaging unit, hydro-cooling system, forced-air cooling system, litchi grading machine, plastic strip sealing and packaging machine, litchi peeling machine, cool storage chamber, bottle washing machine, litchi harvester cum pruner, power sprayer and mist chamber have been installed for different research and supportive activities.

Library

NRC on Litchi is endeavoring to create an excellent library at the center. The center has obtained 1906 books (300 in Hindi and 1606 in English), including the Encyclopaedia, Britannica and Wealth of India. Additionally, the center has subscribed to 15 Indian and 15 foreign magazines to support research activities. The Centre Institute has published technical folders in Hindi and English, extension folders, pamphlets, reports, information bulletins, technical bulletins, and extension bulletins. The Centre has subscribed to the Hindi journals Pratiyogita Darpan, Outlook, India Today, and Yojana. The library also preserves records of all other publications from the institute, as well as those from externally financed projects. All the books are accessible to scientists, farmers, workers, and students. The library is essential and beneficial for students participating in training programs at the institute.

Agricultural Knowledge Management Unit (AKMU)

The centre has an Agricultural Knowledge Management Unit to manage the knowledge database with software of international repute such as SAS, CAB abstracts, horticultural abstract, and other computing softwares. The centre has now installed server and LAN system for shared resources. Access to high speed internet is made available through the National Knowledge Network (NKN). The centre`s website (https://nrclitchi.org.in/) is regularly updated with the latest information and is visited by thousands of visitors from all over the world.

Research and Development Activities

ICAR-NRC on Litchi carries out its research and development programmes under six main thematic areas

1. Conservation, characterization, and utilization of genetic diversity for improvement of litchi
2. Development and refinement of integrated production technologies for improved productivity of litchi
3. Development and refinement of integrated crop protection technologies for improved productivity of litchi
4. Integrated postharvest management to reduce losses, improve marketing and product diversification
5. Litchi based farming system under changing climate scenario
6. Improving knowledge and skill of stakeholders for increasing production of litchi

The Centre regularly conducts training programmes and activities for transfer of technology to farmers and various stakeholders. Under the TSP and NEH component, the centre has laid out structured programmes for area expansion and technology dissemination in tribal belts and North Eastern hill regions of the country.

कार्यकारी सारांश

भा.कृ.अनु.प.–राष्ट्रीय लीची अनुसंधान केंद्र ने बहुविषयक कार्यक्रमों के अंतर्गत बुनियादी और अनुप्रयुक्त अनुसंधान में उल्लेखनीय प्रगति की है, जिसमें लीची के विभिन्न पहलुओं जैसे—जैविक संसाधन प्रबंधन और फसल सुधार, फसल उत्पादन, फसल संरक्षण तथा कटाई उपरांत प्रबंधन शामिल हैं। केंद्र ने विभिन्न हितधारकों के ज्ञान को बढ़ाने और उनके कौशल विकास के लिए प्रशिक्षण, जनसंपर्क कार्यक्रमों और प्रौद्योगिकी हस्तांतरण गतिविधियों का भी आयोजन किया। वर्ष 2024 के दौरान प्राप्त प्रमुख उपलब्धियों का संक्षिप्त सार यहां प्रस्तुत किया गया है।

अनुसंधान उपलब्धियाँ

फसल सुधार

- NRCL-24 और NRCL-41-1 को उपज संबंधी गुणों के लिए उत्कृष्ट जीनोटाइप के रूप में पहचाना गया, जिनमें फल भार, गूदा भार तथा गूदा पुनर्प्राप्ति लगातार अधिक पाई गई।
- NRCL-16-2 को उच्च फल एवं गूदा भार तथा अच्छी पुनर्प्राप्ति के कारण टेबल प्रयोजन हेतु एक आशाजनक क्लोन के रूप में मान्यता दी गई।
- NRCL-22 में सर्वाधिक TSS दर्ज किया गया, जो बेहतर मिठास तथा उपभोक्ता पसंद की उच्च संभावना को दर्शाता है।
- L1P6 अपनी आकर्षक, एकसमान चमकीली गुलाबी से गहरे गुलाबी-लाल रंग तथा चमकदार स्वरूप के कारण प्रीमियम बाजार वर्ग के लिए उपयुक्त पाया गया।
- सभी उत्परिवर्तनकारी विधियों से महत्वपूर्ण आकृति-शारीरिक विविधता प्राप्त हुई, जिसमें पौधे की संरचना तथा पत्ती गुणों में परिवर्तन शामिल थे। गामा विकिरण (Co^{60}) में LD_{50} 46 Gy पर निर्धारित किया गया; अधिक मात्रा (55–100 Gy) पर उत्परिवर्तन की आवृत्ति बढ़ी, लेकिन पौधों की जीवित रहने की क्षमता और वृद्धि कम हुई, जबकि नई विविधताएँ उत्पन्न हुईं। EMS उत्परिवर्तन में मात्रा-निर्भर मृत्यु दर देखी गई; लगभग 0.05% सांद्रता को स्वीकार्य पौध जीवितता के साथ विविधता उत्पन्न करने हेतु सर्वोत्तम पाया गया।
- फल रंग, भौतिक, उपज तथा जैव-रासायनिक गुणों के मूल्यांकन हेतु 42 लीची जर्मप्लाज्म की विविध पैनल का अध्ययन किया गया, जिससे GWAS के लिए मजबूत फेनोटाइपिक डेटा प्राप्त हुआ। सभी गुणों में पर्याप्त फेनोटाइपिक विविधता देखी गई, जो जर्मप्लाज्म पैनल की विविधता तथा सहसंबंध अध्ययन के लिए उसकी उपयुक्तता को दर्शाती है।1 मि.ग्रा./ली. 6-BAP, 1.5 मि.ग्रा./ली. 2,4-D तथा एंटीऑक्सीडेंट युक्त MS माध्यम पर पत्ती एक्सप्लांट का उपयोग करते हुए लीची के लिए एक मानकीकृत टिश्यू कल्चर प्रोटोकॉल विकसित किया गया। 1.5% सोडियम हाइपोक्लोराइट के बाद 0.1% $HgCl_2$ वाले सबसे प्रभावी स्टेरिलाइजेशन विधि से 50–60% तक स्थिर कैलस प्रेरण प्राप्त हुआ, जबकि अधिकतम सफलता 69.79% रही, जिससे शूट पुनर्जनन के लिए मजबूत आधार प्राप्त हुआ।
- SSR तथा ISSR आधारित माइक्रोसैटेलाइट मार्करों का उपयोग करते हुए भारतीय लीची आनुवंशिक संसाधनों का आणविक लक्षणन किया गया, जिससे माइक्रोसैटेलाइट बारकोड के आधार पर देशी जर्मप्लाज्म विविधता का दस्तावेजीकरण संभव हुआ। संचयी मार्कर विश्लेषण द्वारा किस्मों को चार समूहों में सटीक रूप से वर्गीकृत किया गया। परिणामों से उच्च बहुरूपता, लेकिन कम समग्र जीन विविधता प्राप्त हुई, जो दर्शाता है कि भारतीय लीची किस्मों का आनुवंशिक आधार अत्यंत संकीर्ण है।

फसल उत्पादन

- यह प्रदर्शित किया गया कि वृक्षों में गर्डलिंग (छाल हटाना) राइजोस्पियर के स्वास्थ्य पर प्रतिकूल प्रभाव डालती है, जिससे AMF उपनिवेशन में उल्लेखनीय कमी (लगभग 20% तक) तथा लाभकारी सूक्ष्मजीवों की जनसंख्या में तीव्र गिरावट होती है, जो मृदा के जैविक संतुलन पर नकारात्मक प्रभाव को दर्शाता है।
- इन-सीटू माइकोराइजेशन को सतत लीची उत्पादन हेतु एक प्रभावी रणनीति के रूप में स्थापित किया गया, जिससे मृदा पोषक तत्व उपलब्धता (फॉस्फोरस 66.6% तक, पोटाश 41.3% तक) में वृद्धि, पौधों द्वारा पोषक तत्व अवशोषण में सुधार तथा राइजोस्पियर में सूक्ष्मजीवी गतिविधि में वृद्धि देखी गई।
- सर्वेक्षण की गई परिस्थितियों में लिची के लिए प्रमुख एवं सूक्ष्म पोषक तत्वों के DRIS मानक विकसित किए गए। समग्र पोषक असंतुलन को मापने के लिए पोषण असंतुलन सूचकांक की गणना की गई। उपज को सीमित करने वाले प्रमुख पोषक तत्वों का क्रम इस प्रकार पाया गया: नाइट्रोजन > जिंक > सल्फर > कॉपर।
- DRIS पद्धति पारंपरिक मृदा परीक्षण आधारित सिफारिशों से आगे बढ़कर छिपे हुए पोषक असंतुलनों की पहचान करने में प्रभावी सिद्ध हुई।
- एकीकृत पोषक तत्व प्रबंधन ने नियंत्रण की तुलना में उपज और मृदा उर्वरता में महत्वपूर्ण वृद्धि की। 50% RDF + 70 किग्रा गोबर की खाद + एज़ोटोबैक्टर + ट्राइकोडर्मा + फॉस्फोरस घुलनशील जीवाणु वाले उपचार से पूर्ण NPK मात्रा के समान उपज प्राप्त हुई।
- एकीकृत पोषक तत्व प्रबंधन के अंतर्गत रासायनिक उर्वरकों में 50% तक की कमी बिना उपज हानि के संभव हुई। एकीकृत उपचारों से मृदा कार्बनिक कार्बन और जैविक सक्रियता में सुधार हुआ, जो बेहतर मृदा स्वास्थ्य को दर्शाता है। इसके विपरीत, केवल रासायनिक उर्वरकों के प्रयोग से उचित उपज मिलने के बावजूद मृदा श्वसन और कार्बनिक कार्बन में कमी देखी गई।
- लिची में पत्ती पोषक तत्वों की सांद्रता अत्यधिक मौसमी पाई गई और यह फसल की फेनोलॉजी से निकटता से जुड़ी हुई थी। फरवरी को पोषक तत्व तनाव की एक महत्वपूर्ण अवधि के रूप में पहचाना गया, विशेषकर फॉस्फोरस, पोटाश और कॉपर के लिए। आयरन, मैंगनीज और जिंक जैसे सूक्ष्म पोषक तत्वों की सांद्रता पुष्पन के दौरान सबसे अधिक पाई गई। दूसरी पत्ती जोड़ी में पोषक तत्वों की स्थिरता सबसे अधिक थी और इसे सबसे उपयुक्त नमूना इकाई पाया गया।
- फल फटने के प्रति जीनोटाइपिक संवेदनशीलता का मूल्यांकन तथा प्रभावी प्रबंधन रणनीतियों के विकास हेतु 2024–2025 के दौरान दो वर्षीय क्षेत्रीय अध्ययन किया गया। इसमें महत्वपूर्ण जीनोटाइपिक भिन्नता देखी गई, जहाँ फल फटने की घटना 2.16% (NRCL-4) से 16.14% (शाही) तक रही।

- कैनोपी के नीचे मिनी-स्प्रिंकलर सिंचाई तथा पूर्व-तुड़ाई बैगिंग सबसे प्रभावी हस्तक्षेप के रूप में उभरे। मिनी-स्प्रिंकलर सिंचाई से कैनोपी तापमान लगभग 4.3°C कम हुआ और सूक्ष्म जलवायु स्थिर हुई, जिसके परिणामस्वरूप फल फटने में 90.22% तथा फल झुलसन में 78.80% की कमी दर्ज की गई।

फसल सुरक्षा

- मंजर झुलसा रोग को सर्वाधिक महत्वपूर्ण उपज-सीमित करने वाला पाया गया, जिसकी प्रकोप किसानों के बागों में लगभग 92% तक दर्ज की गई, जबकि रोग की तीव्रता (एक वृक्ष में संक्रमित मंजरों का प्रतिशत) अधिकांश वृक्षों में <20% रही, जो स्थानीय संक्रमण पैटर्न को दर्शाती है।
- प्रणालीगत कवकनाशकों (थायोफ़ेनेट मिथाइल, फ्लूपाइरम आधारित उपचार) की उच्च प्रभावशीलता प्रमाणित की गई, जिससे मंजर झुलसा रोग ~4.87% तक घटा तथा उपज में उल्लेखनीय वृद्धि (45.27 किग्रा/वृक्ष तक) हुई।
- जैव-उत्तेजकों (BS-01, T-01 एवं उनके फिल्ट्रेट) की क्षमता प्रदर्शित की गई, जिससे रोग की तीव्रता में कमी, फल गिरावट एवं फल छेदक कीट प्रकोप में कमी तथा फल भार एवं गुणवत्ता में सुधार हुआ।
- यह स्थापित किया गया कि जैव-उत्तेजक उपचार पश्च-फसल गुणवत्ता में सुधार करते हैं, जैसे एंजाइम गतिविधि का नियमन, उच्च फिनॉलिक सामग्री का संरक्षण, ब्राउनिंग में विलंब तथा सामान्य भंडारण स्थितियों में शेल्फ लाइफ में वृद्धि।
- *बैसिलस सबटिलिस* (BS-01) का एक स्थिर एवं क्षेत्र-उपयुक्त फॉर्मुलेशन विकसित किया गया, जिसकी जीवितता एक वर्ष तक बनी रही, जिससे पश्च-फसल प्रबंधन में इसकी व्यावहारिक उपयोगिता सुनिश्चित हुई।
- फल सतह पर BS-01 के प्रभावी उपनिवेशन एवं सुरक्षा की पुष्टि की गई, जिससे सूक्ष्मजीव संख्या में लगभग 14,000 गुना वृद्धि हुई, जबकि फल की गुणवत्ता एवं सुरक्षा पर कोई प्रतिकूल प्रभाव नहीं पड़ा।
- यह प्रदर्शित किया गया कि BS-01 आधारित उपचार फल सड़न एवं ब्राउनिंग को उल्लेखनीय रूप से कम करते हैं, जैव-रासायनिक गुणवत्ता (फिनॉलिक्स, एंथोसायनिन) बनाए रखते हैं तथा सामान्य एवं शीत भंडारण दोनों स्थितियों में शेल्फ लाइफ बढ़ाते हैं।
- स्पष्ट मौसमी कीट गतिकी देखी गई, जिसमें प्रारंभिक अवस्था में कम गतिविधि, मानसून के दौरान बदलाव, तथा मौसम के अंतिम चरण में गंभीर प्रकोप शामिल थे। विशेष रूप से ज्योमेट्रिड लूपर कॉम्प्लेक्स का प्रकोप SMW 43 के आसपास चरम पर था, जो शाही किस्म में चाइना किस्म की तुलना में अधिक तीव्र पाया गया। लेपिडोप्टेरन, विशेषकर *पेरिक्सरा इलेपिडारिया*, लिची स्टिंक बग, कोलियोप्टेरन वीविल्स तथा आम की मिलीबग में किस्म एवं फसल अवस्था के अनुसार अलग-अलग चरम प्रकोप देखे गए, जबकि मिलीबग की घटनाएं वर्षा और फसल की फेनोलॉजी से गहराई से जुड़ी हुई थीं।
- घ्राण संवेदनशीलता में स्पष्ट लिंग-विशिष्ट अंतर देखे गए। नर कीटों ने एथाइल एसीटेट, जेरानियोल, डेकानोल, अंडेकेन और β-कैरियोफाइलीन के प्रति अधिक प्रतिक्रिया दिखाई, जबकि मादा कीटों ने एथाइल एसीटेट, नोनानाल, लिनालूल और α-टर्पिनियोल के प्रति अधिक प्रतिक्रिया व्यक्त की। ये जैव-सक्रिय वाष्पशील यौगिक व्यवहारिक तथा क्षेत्रीय सत्यापन के बाद आकर्षक या प्रतिकारक प्रणालियों के माध्यम से अर्ध-रासायनिक आधारित कीट प्रबंधन में उपयोगी हो सकते हैं।
- लिची में लूपर कॉम्प्लेक्स पर Perixera illepidaria का प्रभुत्व था, जिसने गंभीर पर्णभक्षण किया और 80% तक पत्तियों की क्षति पहुंचाई। इसके मौसमी प्रकोप पर पवन वेग, बादलपन, तापमान और आर्द्रता जैसे मौसमीय कारकों का महत्वपूर्ण प्रभाव देखा गया।
- अवशेष विश्लेषण से संकेत मिला कि स्पिनोसाड और इमामेक्टिन बेंजोएट अधिक सुरक्षित विकल्प हैं, क्योंकि कटाई के समय इनके अवशेष बहुत कम या नगण्य पाए गए। इसके विपरीत, थियाक्लोप्रिड, लैम्ब्डा-साइहैलोथ्रिन और नोवालुरोन में अधिक अवशेष संचय देखा गया, जो सुरक्षित लिची उत्पादन के लिए उचित छिड़काव समय के महत्व को दर्शाता है।
- लिची के पूर्ण पुष्पन काल के दौरान मधुमक्खियों के भोजन संग्रह में लिची पराग का प्रभुत्व रहा, लेकिन मधुमक्खियों ने समय और स्थान के अनुसार विभिन्न पुष्प स्रोतों का भी उपयोग किया। पूरक पुष्पीय संसाधनों का समावेश और चरम पुष्पन से 5–7 दिन पहले छत्तों की स्थापना, परागण सेवाओं, कॉलोनी पोषण और समग्र लिची उत्पादकता को बढ़ा सकती है।
- लिची कृषि-परितंत्र में प्रमुख कीटों में फल एवं प्ररोह छेदक, पत्ती मोड़क, स्टिंक बग तथा लिची माइट शामिल थे, जिनमें छेदकों ने फल संक्रमण, प्ररोह क्षति और समयपूर्व फल गिरावट के माध्यम से सबसे अधिक नुकसान पहुंचाया। साथ ही, ब्रेकोनिडी परजीवी ततैयों की प्रचुरता तथा *एपिस मेलिफेरा* द्वारा प्रभुत्व वाली विविध परागणकर्ता समुदाय ने सतत लिची उत्पादन के लिए जैविक नियंत्रण और परागणकर्ता संरक्षण के एकीकरण के महत्व को रेखांकित किया।

फसल कटाई उपरांत प्रबंधन और मूल्य संवर्धन

- शाही लिची के विपणन मौसम के दौरान उसके भौतिक-रासायनिक गुणों में परिवर्तन पर किए गए अध्ययनों से यह स्थापित हुआ कि 25–28 मई का समय 'शाही' लिची की कटाई के लिए सबसे उपयुक्त अवधि है, जिससे सर्वोत्तम गुणवत्ता, पोषण तथा उपभोक्ता स्वीकार्यता प्राप्त होती है।
- यूफ्लेक्स आधारित MAP (संशोधित वातावरण पैकेजिंग) कटाई के बाद होने वाले नुकसान को कम करने तथा परिवहन के दौरान शेल्फ लाइफ और बाजारयोग्यता बढ़ाने के लिए सबसे प्रभावी पैकेजिंग रणनीति सिद्ध हुई।
- RSM द्वारा लिची फाइबर युक्त कुकीज़ के संवेदी गुणों के अनुकूलन पर किए गए अध्ययनों से यह स्थापित हुआ कि 5% लिची पोमेस फाइबर तथा लगभग 190°C तापमान और 15 मिनट के अनुकूलित प्रसंस्करण से उच्च संवेदी स्वीकार्यता वाली कुकीज़ प्राप्त होती हैं (वांछनीयता = 0.935)। इससे यह सिद्ध होता है कि लिची पोमेस फाइबर गुणवत्ता से समझौता किए बिना एक मूल्यवर्धित क्रियात्मक अवयव के रूप में उपयोगी हो सकता है।
- अनुकूलित हाइड्रोकोलॉइड संरचना, विशेषकर S4 (1% CMC + 3% ग्लिसरॉल), सूक्ष्मजीवों की दृष्टि से सुरक्षित (कम जल सक्रियता वाली) तथा अत्यधिक स्वीकार्य लिची लेदर तैयार करती है, जिसमें बेहतर रंग और बनावट पाई जाती है।

- शुष्क-पाउडर निष्कर्षण विधि से अधिक स्टार्च प्राप्ति, बेहतर क्रियात्मक गुण तथा कम नमी वाला स्थिर स्टार्च मिलता है, जिससे यह लिची बीजों से उच्च गुणवत्ता वाले खाद्य-ग्रेड स्टार्च उत्पादन की श्रेष्ठ विधि बन जाती है।
- हाइड्रोकोलॉइड कोटिंग अर्ध-पारगम्य अवरोधक के रूप में प्रभावी ढंग से कार्य करती है, जिससे PLW, भूरापन तथा सड़न कम होती है, जबकि कठोरता और विटामिन C सुरक्षित रहते हैं। इससे ताजा लिची की अल्पकालिक शेल्फ लाइफ और गुणवत्ता में सुधार होता है।
- मेलाटोनिन उपचार (1.5–2.0 mM) कटाई के बाद की गुणवत्ता को बेहतर बनाने में प्रभावी पाया गया, क्योंकि यह भूरापन और वजन हानि को कम करता है तथा रंग और विटामिन सी को सुरक्षित रखता है। इससे लिची की शेल्फ लाइफ बढ़ाने की अच्छी संभावना बनती है।
- लाख आधारित कोटिंग T5 (NISA-03, 3:1 घोल) सबसे प्रभावी संरचना सिद्ध हुई, जिसने रंग संरक्षण में उल्लेखनीय सुधार किया, PLW और सड़न को कम किया तथा सामान्य और शीत भंडारण दोनों परिस्थितियों में शेल्फ लाइफ बढ़ाई।
- अल्ट्रासाउंड प्राप्त निष्कर्षण की अनुकूलित परिस्थितियां (80% शक्ति और 50% जलीय अल्कोहल) जैव-सक्रिय यौगिकों की प्राप्ति (TPC, TFC, एंटीऑक्सीडेंट गतिविधि) को काफी बढ़ाती हैं, जिससे लिची बीज अपशिष्ट को मूल्यवर्धित क्रियात्मक अवयवों में बदलने की एक प्रभावी और सतत विधि प्राप्त होती है।
- बिना स्पष्ट किए गए कार्बोनेटेड लिची RTS, पोषक तत्वों के संरक्षण, भंडारण स्थिरता और दीर्घकालिक संवेदी गुणवत्ता को प्रभावी ढंग से बढ़ाता है, जिससे यह एक संभावनाशील मूल्यवर्धित पेय बनता है।

जलवायु अनुकूल खेती

- बिहार में लिची आधारित एकीकृत कृषि प्रणालियों के अध्ययन से किसानों की छह अलग-अलग श्रेणियां सामने आईं, जिनमें भूमि धारण, आय और उत्पादन प्रणालियों में महत्वपूर्ण अंतर पाए गए। इससे लिची खेती में संरचनात्मक विविधता स्पष्ट रूप से सामने आई।
- बड़े और विविधीकृत कृषि तंत्रों में ऊर्जा उपयोग दक्षता अधिक तथा कार्बन उत्सर्जन कम (1.2–1.3 टन CO_2-eq प्रति हेक्टेयर प्रति वर्ष) पाया गया। इससे यह संकेत मिलता है कि विविधीकृत और एकीकृत कृषि प्रणालियां उत्पादकता, आर्थिक लाभ और पर्यावरणीय स्थिरता के बीच सर्वोत्तम संतुलन प्रदान करती हैं।

सहयोग एवं भागीदारी

- केंद्र विभिन्न संगठनों जैसे ICAR-IARI (झारखंड), ICAR-IIAB (रांची), ICAR-NISA (रांची), ICAR-CICR, (नागपुर), ICAR-CISH (लखनऊ) के साथ सहयोग में कार्य कर रहा है।

तकनीकी हस्तांतरण

- साल 2025 के दौरान 32 औपचारिक प्रशिक्षण कार्यक्रम आयोजित किए गए और विभिन्न प्रशिक्षण एवं विस्तार गतिविधियों के माध्यम से 2000 से अधिक हितधारकों को लाभान्वित किया गया।

गुणवत्तापूर्ण पौध वितरण

- राजस्थान, मध्य प्रदेश, त्रिपुरा, सिक्किम, पश्चिम बंगाल, ओडिशा, छत्तीसगढ़, अरुणाचल प्रदेश, उत्तराखंड, उत्तर प्रदेश, कर्नाटक और बिहार में किसानों तथा विभिन्न हितधारकों को कुल 15,114 लीची के पौधे वितरित/सप्लाई किए गए।
- 2,000 उच्च गुणवत्ता वाले 'शाही' लीची पौधों के वितरण एवं 42 किसानों के क्षमता निर्माण के माध्यम से जनजातीय क्षेत्रों में लीची आधारित आजीविका विविधीकरण को सफलतापूर्वक प्रोत्साहित किया गया, जिससे वैज्ञानिक खेती के अपनाने को बढ़ावा मिला तथा उच्च मूल्य वाली बागवानी फसलों के अंतर्गत क्षेत्र विस्तार हुआ।

Executive Summary

ICAR-National Research Centre on Litchi has made commendable progress in basic and applied research under multi-disciplinary programme covering different aspects of litchi *viz.,* genetic resource management and crop improvement, crop production, crop protection and postharvest management. The Centre also conducted training, organized outreach programmes and transfer of technology activities to improve knowledge and to develop skills of different stakeholders. A concise summary of salient achievements during 2025 is presented here.

Research Accomplishments

Crop Improvement

- Clones NRCL-24 and NRCL-41-1 identified as elite genotypes for yield traits, exhibiting consistently high fruit weight, pulp weight, and pulp recovery.
- NRCL-16-2 recognized as a promising table-purpose clone due to its high fruit and pulp weight with good recovery.
- NRCL-22 recorded the highest TSS, indicating superior sweetness and strong consumer preference potential.
- L1P6 distinguished by attractive, uniform bright pink to deep rose-red fruit colour with glossy appearance, suitable for premium market segments.
- All mutagenic approaches resulted in significant morpho-physiological variability, including altered plant architecture and leaf traits. Gamma irradiation (Co^{60}) identified LD_{50} at 46 Gy; higher doses (55–100 Gy) enhanced mutation frequency but reduced survival and growth, while generating novel. EMS mutagenesis showed strong dose-dependent lethality; ~0.05% identified as optimal concentration for inducing variability with acceptable seedling survival.
- A diverse panel of 42 Litchi germplasm evaluated for fruit colour, physical, yield, and biochemical traits to generate robust phenotypic data for GWAS. Substantial phenotypic variability observed across all traits, confirming the diversity and suitability of the germplasm panel for association studies.
- A standardized litchi tissue culture protocol was developed using leaf explants on MS medium containing 1 mg/L 6-BAP, 1.5 mg/L 2,4-D, and antioxidants. The most effective sterilization method, involving 1.5% sodium hypochlorite followed by 0.1% $HgCl_2$, achieved consistent callus induction of 50–60%, with the highest success of 69.79%, providing a strong basis for shoot regeneration.
- Molecular characterization of Indian litchi genetic resources using SSR and ISSR based microsatellite markers accomplished the documentation of the native germplasm diversity based on microsatellite barcodes. Cumulative marker analysis precisely arranged the cultivars into Four groups. The results revealed high levels of polymorphism but low overall gene diversity, indicating that Indian litchi cultivars share a very narrow genetic base.

Crop Production

- Tree girdling adversely affects rhizosphere health, significantly reducing AMF colonization (down to ~20%) and causing a sharp decline in beneficial microbial populations, highlighting its negative impact on soil biological balance.
- *In-situ* mycorrhization as an effective strategy for sustainable litchi production was established, improving soil nutrient availability (P up to 66.6%, K up to 41.3%), enhancing plant nutrient uptake, and increasing microbial activity in the rhizosphere.
- DRIS norms for major and micronutrients were developed for litchi under the surveyed conditions. Nutritional Imbalance Index (NII) was calculated to quantify overall nutrient imbalance. The order of major yield-limiting nutrients was identified as: Nitrogen > Zinc > Sulphur > Copper.
- The DRIS approach proved effective in diagnosing hidden nutrient imbalances beyond conventional soil test-based recommendations.
- Integrated nutrient management significantly increased yield and soil fertility compared to control. Treatment comprising 50% RDF + FYM 70 kg + Azotobacter + Trichoderma + Phosphorus Solubilizing Bacteria produced yield at par with the full NPK dose.
- A 50% reduction in chemical fertilizers was achieved without yield loss under integrated nutrient management. Integrated treatments improved soil organic carbon and biological activity, indicating better soil health. Sole application of chemical fertilizers reduced soil respiration and organic carbon despite reasonable yield.
- Leaf nutrient concentrations in litchi were found to be highly seasonal and closely linked to crop phenology. February was identified as a critical nutrient stress period, particularly for phosphorus, potassium, and copper. Micronutrients such as iron, manganese, and zinc showed

peak concentrations during flowering. The second leaf pair exhibited the highest nutrient stability and was found to be the most representative sampling unit.

- Two-year field study (2024–2025) conducted to evaluate genotypic susceptibility and develop effective management strategies for fruit cracking. Significant genotypic variation observed, with cracking incidence ranging from 2.16% (NRCL-4) to 16.14% (Shahi).
- Under-canopy mini-sprinkler irrigation and preharvest bagging emerged as most effective interventions. Mini-sprinkler irrigation reduced fruit cracking (90.22%) and scorching (78.80%) by lowering canopy temperature (~4.3°C) and stabilizing microclimate.

Crop Protection

- Identified panicle blight as the most critical yield-limiting stage, with high incidence (up to ~92% in farmers' orchards), while confirming that disease severity (percent panicles infected in a tree) remained largely low (<20% in most trees), indicating localized infection patterns.
- Validated high efficacy of systemic fungicides (Thiophanate methyl, Fluopyram-based treatments), reducing panicle blight to ~4.87% and significantly enhancing yield (up to 45.27 kg/tree).
- Demonstrated the potential of bio-stimulants (BS-01, T-01, and their filtrates) in reducing disease severity, minimizing fruit drop and borer incidence, and improving fruit weight and quality.
- Established that bio-stimulant treatments improve post-harvest quality, by regulating enzymatic activity, maintaining higher phenolic content, delaying browning, and extending shelf life under ambient conditions.
- Distinct seasonal pest dynamics were observed, with low early activity, monsoon-driven shifts, and severe late-season outbreaks, especially the geometrid looper complex peaking around SMW 43, more intensely in Shahi than China variety. Lepidopterans, particularly Perixera illepidaria, litchi stink bug, coleopteran weevils, and mango mealy bug showed cultivar- and stage-specific peaks, with mealy bug incidence strongly linked to rainfall and crop phenology.
- Clear sex-specific differences in olfactory sensitivity were observed: males responded more strongly to ethyl acetate, geraniol, decanol, undecane, and β-caryophyllene, while females showed greater responses to ethyl acetate, nonanal, linalool, and α-terpineol. These bioactive volatiles may support semiochemical-based pest management through attractant or repellent systems after behavioral and field validation.
- Looper complex in litchi was dominated by *Perixera illepidaria*, causing severe defoliation (up to 80%) with strong seasonal outbreaks influenced by weather factors such as wind speed, cloud cover, temperature, and humidity.
- Residue analysis indicated that spinosad and emamectin benzoate are safer options due to minimal or no detectable residues near harvest, whereas compounds like thiacloprid, lambda-cyhalothrin, and novaluron showed higher residue accumulation, emphasizing the importance of spray timing for safe litchi production.
- Litchi pollen dominated bee foraging during peak bloom, but bees utilized diverse floral resources across space and time; integration of supplemental flora and timely hive placement (5–7 days before peak bloom) can enhance pollination services, colony nutrition, and overall litchi productivity.
- Major pests in litchi agro-ecosystems included fruit and shoot borer, leaf roller, stink bug, and litchi mite, with borers causing the greatest damage through fruit infestation, shoot injury, and premature fruit drop. At the same time, abundant Braconidae parasitoids and a diverse pollinator community dominated by *Apis mellifera* highlighted the importance of integrating biological control and pollinator conservation for sustainable litchi production.

Postharvest Management and Value Addition

- A stable and field-applicable formulation of *Bacillus subtilis* (BS-01) with sustained viability up to one year was developed, ensuring practical applicability for post-harvest interventions.
- Confirmed effective colonization and safety of BS-01 on fruit surface, significantly increasing microbial load (~14,000-fold) without any adverse effects on fruit quality or safety.
- Demonstrated that BS-01-based treatments significantly reduce fruit decay and browning, maintain biochemical quality (phenolics, anthocyanin), and enhance shelf life under both ambient and cold storage conditions.
- Studies on variation in physio-chemical properties of Shahi litchi during its marketing season establishes late May (25–28 May) as the optimal harvest window for 'Shahi' litchi to achieve peak quality, nutrition, and consumer acceptability.

- Uflex-based MAP is the most effective packaging strategy for reducing postharvest losses and enhancing shelf life and marketability during transportation.
- Studies on optimization of sensory parameters of litchi fibre riched cookies using RSM established that 5% litchi pomace fibre, optimized using RSM (~190°C and ~15 min), produces cookies with high sensory acceptability (Desirability = 0.935), confirming its potential as a value-added functional ingredient without compromising quality.
- An optimized hydrocolloid formulation, particularly S4 (1% CMC + 3% glycerol), produces microbiologically safe (low water activity) and highly acceptable litchi leather with superior colour and texture.
- The dry-powder extraction method yields higher starch recovery, better functional properties, and stable low-moisture starch, making it a superior approach for producing high-quality food-grade starch from litchi seeds.
- Hydrocolloid coatings effectively act as semi-permeable barriers, reducing PLW, browning, and decay while maintaining firmness and Vitamin C, thereby enhancing the short-term shelf life and quality of fresh litchi.
- Melatonin treatment (1.5–2.0 mM) effectively enhances post-harvest quality by reducing browning and weight loss while preserving color and Vitamin C, making it a promising approach for extending litchi shelf life.
- Lac-based coating T5 (NISA-03, 3:1 dilution) is the most effective formulation, significantly improving color retention, reducing PLW and decay, and extending shelf life under both ambient and refrigerated conditions.
- Optimized Ultrasound-assisted extraction conditions (80% power with 50% aqueous alcohol) significantly enhance bioactive recovery (TPC, TFC, antioxidant activity), offering an efficient and sustainable method for valorizing litchi seed waste into functional ingredients.
- Carbonation of unclarified litchi RTS effectively enhances nutritional retention, storage stability, and long-term sensory quality, making it a promising value-added beverage.

Climate Resilient Litchi Farming

- The study of litchi-based integrated farming systems in Bihar revealed six distinct farmer typologies with significant differences in landholding, income, and production systems, highlighting structural heterogeneity in litchi farming
- Larger and diversified farming systems demonstrated higher energy-use efficiency and lower carbon emissions (1.2–1.3 t CO_2-eq ha^{-1} yr^{-1}), which indicated that diversified and integrated farming systems achieve the best balance between productivity, economic returns, and environmental sustainability

Linkages and Collaborations

- The Centre is working on different aspects in close collaboration with other organizations (ICAR-IARI, Jharkhand, ICAR-IIAB, Ranchi, ICAR-NISA, Ranchi, ICAR-NIPB, New Delhi, ICAR-CICR, Nagpur, ICAR-CISH, Lucknow.

Transfer of Technology

- During the year 2025, 32 formal training programs were organized and more than 2000 stakeholders were benefitted through various training and extension activities.

Production and supply of quality planting materials

- A total of 15,114 litchi saplings were distributed to farmers /supplied to various stakeholders in Rajasthan, Madhya Pradesh, Tripura, Sikkim, West Bengal, Odisha, Chhattisgarh, Arunachal Pradesh, Uttarakhand, Uttar Pradesh, Karnataka and Bihar.
- Successfully promoted litchi-based livelihood diversification in tribal areas through distribution of 2,000 elite 'Shahi' planting materials and capacity building of 42 farmers, strengthening adoption of scientific cultivation practices and expanding area under high-value horticulture.

Contents

Research Accomplishments

1. Conservation, Characterization and Utilization of Genetic Diversity for Improvement of Litchi

1.1. Collection of indigenous and exotic germplasm, their characterization, evaluation, documentation and utilization

The evaluation of collected indigenous germplasm led to the identification of several superior litchi clones exhibiting desirable fruit quality traits. These superior clones were selected based on consistent performance with respect to fruit size, pulp recovery, sweetness (TSS), firmness, and overall market acceptability. Their distinct phenotypic and biochemical attributes indicate significant genetic variability within the germplasm pool and provide valuable material for varietal improvement, elite clone development, and future breeding programmes. The performance of these selected superior clones during early and late harvest stages is presented in Tables 1.1 and 1.2. Clones NRCL-24 and NRCL-41-1 consistently exhibited superior performance for fruit weight, pulp weight, and pulp recovery percentage, and thus emerged as elite genotypes for yield and edible portion. NRCL-16-2 also showed high fruit and pulp weight with good pulp recovery, suggesting its suitability as a promising table-purpose clone. NRCL-22 recorded the highest total soluble solids (TSS), indicating superior sweetness and consumer preference potential. Clone L1P6 was distinguished by its highly attractive and uniform fruit colour, making it a promising selection for premium market segments. The fruits exhibited a bright pink to deep rose-red pericarp with an appealing glossy appearance at maturity (Fig. 1.1). The colour development was uniform across the fruit surface, enhancing visual appeal and consumer acceptability.

Table 1.1. Fruit quality attributes of superior litchi clones (Early harvested 17th May)

Clone	Firmness	Fruit weight (g)	Pulp weight (g)	Seed weight (g)	Peel weight (g)	Pulp recovery (%)	TSS (°Brix)	Acidity (%)
NRCL-13	740.00 ± 45.09	18.20 ± 0.31	9.40 ± 0.23	3.40 ± 0.12	3.80 ± 0.20	51.64 ± 0.83	19.57 ± 0.72	0.80 ± 0.07
NRCL-20	910.00 ± 70.95	13.33 ± 1.63	4.33 ± 0.18	2.33 ± 0.18	2.40 ± 0.00	33.35 ± 3.81	19.72 ± 0.16	2.74 ± 0.15
NRCL-20(1)	660.00 ± 28.87	9.93 ± 0.37	5.33 ± 0.18	2.53 ± 0.07	2.93 ± 0.07	53.94 ± 3.57	15.40 ± 0.06	1.62 ± 0.23
NRCL-24	746.67 ± 54.87	17.87 ± 0.64	9.60 ± 0.64	3.40 ± 0.20	3.27 ± 0.07	53.62 ± 1.82	18.05 ± 0.18	0.86 ± 0.06
NRCL-4	903.33 ± 38.44	17.73 ± 0.64	9.87 ± 0.41	2.87 ± 0.18	3.40 ± 0.12	55.62 ± 0.40	17.57 ± 0.55	0.95 ± 0.08
NRCL-41-2	870.00 ± 55.08	18.53 ± 0.37	9.07 ± 0.24	4.33 ± 0.24	3.47 ± 0.07	48.91 ± 0.54	15.82 ± 0.29	0.78 ± 0.10
NRCL-41-1	773.33 ± 82.53	18.20 ± 0.40	9.80 ± 0.12	3.60 ± 0.12	3.53 ± 0.18	53.90 ± 1.36	17.92 ± 0.37	0.92 ± 0.03
NRCL-63	756.67 ± 46.67	11.27 ± 0.27	5.53 ± 0.18	2.73 ± 0.18	1.87 ± 0.07	49.11 ± 1.05	18.65 ± 0.75	1.28 ± 0.03
SEm±	55.24	0.71	0.32	0.17	0.11	2.08	0.46	0.11
SE(d)	78.12	1.01	0.45	0.24	0.16	2.94	0.65	0.16
CD (5%)	165.61	2.14	0.95	0.5	0.34	6.24	1.37	0.33
CV (%)	12.03	7.91	6.94	9.16	6.35	7.2	4.43	15.42

Table 1.2. Fruit quality attributes of superior litchi clones (Late harvested 30th May)

Clone	Fruit weight (g)	Pulp weight (g)	Seed weight (g)	Peel weight (g)	Pulp recovery (%)	TSS (°Brix)
NRCL-41-1	21.65 ± 0.80 a	13.99 ± 0.77 a	2.11 ± 0.07d	3.73 ± 0.10c	64.59 ± 2.33a	24.30 ± 0.31b
NRCL-24	21.31 ± 0.22 a	14.22 ± 0.20 a	2.41 ± 0.06c	3.79 ± 0.11c	66.73 ± 0.68a	22.73 ± 0.28c
NRCL-16-2	20.24 ± 1.96 b	13.42 ± 0.85 a	2.99 ± 0.16b	3.83 ± 0.19c	63.01 ± 1.09a	18.87 ± 0.07e

Clone	Fruit weight (g)	Pulp weight (g)	Seed weight (g)	Peel weight (g)	Pulp recovery (%)	TSS (°Brix)
L1P6 (P)	18.34 ± 0.37 b	10.24 ± 0.18 b	2.29 ± 0.05d	3.77 ± 0.12c	55.83 ± 0.86c	22.23 ± 0.50c
L1P6-1 (P)	17.78 ± 0.06c	9.22 ± 0.22c	2.36 ± 0.15c	3.69 ± 0.14c	51.86 ± 1.48d	19.77 ± 1.48d
NRCL-4-1	17.14 ± 0.42c	10.45 ± 0.35b	2.18 ± 0.09d	3.65 ± 0.11c	60.99 ± 1.27b	17.53 ± 1.50f
NRCL-16-1	16.98 ± 0.57c	9.25 ± 0.73c	2.54 ± 0.14c	4.19 ± 0.09b	54.32 ± 2.44c	25.23 ± 0.09b
L7P1 (B-III)	16.11 ± 0.94c	7.44 ± 0.57d	2.44 ± 0.06c	4.57 ± 0.18a	46.22 ± 2.01e	19.90 ± 0.17d
NRCL-70	15.89 ± 0.54c	7.86 ± 0.40d	2.31 ± 0.07d	3.72 ± 0.10c	49.41 ± 1.62d	18.37 ± 0.35e
NRCL-63	15.27 ± 0.02c	7.98 ± 0.31d	2.34 ± 0.08d	3.95 ± 0.12b	52.27 ± 1.11d	20.20 ± 0.35d
NRCL-4-2	15.09 ± 0.54c	8.88 ± 0.40c	3.21 ± 0.17a	4.41 ± 0.12a	46.10 ± 1.89e	21.50 ± 0.06d
NRCL-29	14.69 ± 2.70c	5.58 ± 0.19e	3.43 ± 0.30a	4.46 ± 0.17a	38.00 ± 0.78f	19.97 ± 0.38d
NRCL-22	13.68 ± 0.53d	6.16 ± 0.49e	2.25 ± 0.08d	4.68 ± 0.28a	45.01 ± 1.43e	29.47 ± 0.84a
B-II	13.07 ± 0.49d	8.81 ± 0.35c	3.09 ± 0.18a	4.44 ± 0.12a	50.87 ± 1.77d	18.50 ± 1.82e
L7P1 (R)	11.81 ± 0.15d	6.87 ± 0.07d	2.46 ± 0.08c	3.48 ± 0.08d	45.89 ± 0.61e	23.23 ± 1.09c
SEm ±	0.98	0.49	0.18	0.18	3.33	0.84
CD (5%)	2.83	1.41	0.51	0.53	9.62	2.42
CV (%)	10.23	9	11.3	9.37	10.29	6.76

Fig. 1.1. Attractive coloured clone L1P6

1.2. Development of improved cultivars in litchi through hybridization

A total of 6,202 flowers were pollinated across different cross combinations during March, 2025. Initial fruit set recorded on 29th March, 2025 was 1,654 fruits, resulting in an overall fruit set of 26.67%, indicating successful pollination and fertilization. Considerable variation in fruit set percentage was observed among individual crosses and panicles, reflecting differences in cross compatibility and environmental influences. By 24th April, 2025, only 205 fruits remained, indicating substantial fruit drop during early developmental stages, a common phenomenon in litchi. At final harvest (26th May, 2025), 143 fruits were successfully harvested, representing effective retention of a subset of the initially set fruits. Certain cross combinations (e.g., *Shahi* × *Kwai May Pink* and *China* × *Kwai May Pink*) showed comparatively better fruit set and retention, indicating their potential suitability for hybrid development. A total of 74 hybrid seedlings were found to be surviving in the nursery. The highest number of surviving hybrids was recorded in Shahi × Kwai May Pink (18) and Shahi × China (18). No surviving hybrids were observed in Rose Scented × Early Bedana, indicating poor establishment under nursery conditions. All surviving hybrid plants are being maintained in the nursery and will be transplanted to the field at the appropriate stage for further morphological, physiological, and horticultural evaluation.

Table 1.3. Summary of Hybridization in Litchi (2025)

Parameter	Observation
Total number of crosses (panicles)	179
Total flowers pollinated	6,202
Initial fruit set (29.03.2025)	1,654 fruits
Initial fruit set (%)	26.67 %
Fruits retained till 24.04.2025	205 fruits
Final fruits harvested (26.05.2025)	143 fruits
Major cross combinations	Shahi × Kwai May Pink, China × Kwai May Pink
Hybrid seed availability	Adequate for raising hybrid seedlings

1.3. Mutation breeding for litchi improvement

Mutation breeding has emerged as a powerful tool for expanding genetic variability and accelerating crop improvement, particularly in perennial fruit crops where conventional breeding is constrained by long juvenility and narrow genetic bases.

Gamma irradiation induced mutagenesis

Fresh seeds were irradiated in two phases using a $Co^{60}\gamma$-source: in 2022, with doses ranging from 5 to 50 Gy, which resulted in higher survival percentages and limited phenotypic variation; and in 2023, with higher doses ranging from 55 to 100 Gy to increase the mutation frequency. Morphological and physiological evaluations were subsequently conducted on mutant populations generated from irradiation doses above the estimated LD_{50} (46 Gy) to maximize mutation recovery and phenotypic variation. Analyses revealed that increasing irradiation doses reduced plant survival, height, canopy volume, and chlorophyll content, while inducing significant morpho-physiological alterations (Table 1.4 and 1.5). Several novel phenotypes were identified, including a climbing-type growth habit, dwarfism, compact canopies, and altered leaf morphology (Fig. 1.2 and Fig. 1.3).

Table 1.4. Effect of different doses of gamma irradiation on morphological characteristics in litchi

Gamma irradiation dose	Plant height (cm)	Canopy volume (cm^3)	Stem diameter (mm)	TCSA (mm^2)	Internodal length (cm)
WT	61.20^{ab}	127.79^{ab}	12.09^{a}	116.93^{a}	5.60^{abc}
55 Gy	63.60^{a}	132.80^{a}	6.47^{a}	36.52^{b}	6.90^{a}
60 Gy	36.26^{cde}	75.71^{cde}	5.62^{bc}	28.96^{bcd}	5.72^{ab}
65 Gy	45.00^{abc}	93.96^{abc}	5.79^{bc}	33.69^{bc}	2.78^{cde}
70 Gy	28.16^{cdef}	58.80^{cdef}	3.48^{cd}	10.06^{bcd}	2.58^{de}
75 Gy	42.84^{abcd}	89.45^{abcd}	5.80^{bc}	27.73^{bcd}	4.14^{abcde}
80 Gy	44.40^{abcd}	92.71^{abcd}	5.71^{bc}	26.60^{bcd}	4.70^{abcd}
85 Gy	39.60^{bcde}	82.68^{bcde}	5.12^{bc}	22.28^{bcd}	6.32^{ab}
90 Gy	13.20^{f}	27.56^{f}	2.01^{d}	5.46^{d}	1.56^{e}
95 Gy	22.60^{def}	47.19^{def}	3.84^{bcd}	13.26^{bcd}	3.57^{bcde}
100 Gy	18.20^{ef}	38.00^{ef}	2.00^{d}	7.86^{cd}	1.68^{e}
LSD	21.98	45.90	2.77	26.75	2.90

Table 1.5. Effect of gamma irradiation on physio-biochemical parameters of the mutant population

Gamma irradiation dose	RWC (%)	MII (%)	Soluble protein (mg/g FW)	Phenol (mg/g FW)	Proline (mg/g FW)
WT	73.35^{ab}	91.93^{a}	2.26^{a}	64.08^{a}	0.45^{cd}
55 Gy	67.35^{ab}	75.06^{b}	1.68^{ab}	27.02^{bcd}	0.72^{a}
60 Gy	46.01^{b}	87.85^{ab}	1.33^{bc}	14.14^{cd}	0.51^{bcd}
65 Gy	82.11^{ab}	93.33^{a}	0.85^{cd}	34.67^{b}	0.41^{d}
70 Gy	92.80^{a}	93.33^{a}	1.62^{ab}	30.91^{bc}	0.55^{bcd}
75 Gy	47.93^{b}	93.35^{a}	1.70^{ab}	34.65^{b}	0.49^{cd}
80 Gy	59.01^{ab}	88.96^{ab}	1.75^{ab}	55.36^{a}	0.53^{bcd}
85 Gy	52.28^{b}	85.23^{a}	1.18^{bcd}	29.86^{bc}	0.57^{abc}

Gamma irradiation dose	RWC (%)	MII (%)	Soluble protein (mg/g FW)	Phenol (mg/g FW)	Proline (mg/g FW)
90 Gy	24.70^{c}	91.21^{ab}	0.61^{d}	32.40^{b}	0.65^{ab}
95 Gy	60.57 ^{ab}	92.95^{bc}	1.17^{bcd}	11.00^{d}	0.56^{bc}
100 Gy	62.77^{ab}	89.85^{ab}	1.17^{d}	11.91^{d}	0.52^{bcd}
LSD	26.61	24.54	0.68	16.86	0.14

Fig. 1.2. Representative mutant population of Litchi cv. Shahi showing variation in leaf morphology and canopy compactness.

Fig. 1.3. Climbing-type novel mutant phenotype observed in mutant population (80 Gy) of litchi cv. Shahi, exhibiting a distinct climbing-type growth habit characterized by elongated internodes and flexible shoots.

1.4 EMS induced mutagenesis

Ethyl Methane Sulphonate (EMS) is a potent chemical mutagen extensively used for the induction of genetic variability in fruit crops through point mutations. By alkylating DNA bases, EMS primarily induces G/C to A/T transitions, resulting in subtle but heritable genetic changes. The effect of different EMS concentrations and treatment durations on seedling survival is presented in Table 1.6. A clear dose-dependent decline in survival percentage was observed with increasing EMS concentration. While the control recorded high survival (84% at 24 h and 86% at 48 h), even the lowest EMS concentration (0.05%) caused substantial reduction (71.43–69.77% over control). Further increase to 0.10% and 0.15% drastically reduced survival (2–10%), indicating high mutagenic intensity. Complete lethality (100% reduction over control) was observed at concentrations of 0.20% and above, irrespective of treatment duration. These findings indicate that EMS exerts strong mutagenic effects in litchi seedlings, and lower concentrations (around 0.05%) may serve as a suitable range for inducing genetic variability while retaining adequate survival for mutant population development.

Table 1.6. Seedling survival and percent reduction over control as affected by EMS concentration and treatment duration

EMS conc. (%)	Duration	Survival (%)	Reduction over control (%)
0.05	24 h	24	71.43
	48 h	26	69.77
0.10	24 h	2	97.62
	48 h	10	88.37
0.15	24 h	2	97.62
	48 h	10	88.37

EMS conc. (%)	Duration	Survival (%)	Reduction over control (%)
0.20	24 h	0	100.00
	48 h	0	100.00
0.25	24 h	0	100.00
	48 h	0	100.00
0.30	24 h	0	100.00
	48 h	0	100.00
0.50	24 h	0	100.00
	48 h	0	100.00
Control	24 h	84	-
	48 h	86	-

1.5 Colchicine induced mutagenesis

Colchicine is a well-known antimitotic agent used in mutation breeding primarily for inducing polyploidy through spindle fiber inhibition during cell division. By preventing chromosome segregation at metaphase, colchicine leads to chromosome doubling and the formation of polyploid or mixoploid tissues. The effect of colchicine concentration and duration of exposure on seedling survival is presented in Table 1.7. Colchicine treatments significantly reduced seedling survival, with higher concentrations and shorter exposure durations generally exerting greater lethality. However, moderate survival at 1.0–1.5% concentration with 48 h exposure suggests a potential treatment window for inducing polyploidy while retaining sufficient plant population for mutant selection. Morphological abnormalities observed in treated seedlings (Fig. 1.4 and Fig. 1.5) further confirmed colchicine-induced effects. These findings demonstrate the effectiveness of colchicine in inducing cytogenetic and morphological variability in litchi, thereby offering scope for the development of novel genotypes through polyploid breeding approaches.

Table 1.7. Effect of colchicine concentration and duration of exposure on seedling survival and percent reduction over control

Colchicine conc. (%)	Duration	Survival (%)	Reduction over control (%)
0.5	24 h	7	91.67
	48 h	16	81.40
1.0	24 h	4	95.24
	48 h	32	62.79
1.5	24 h	2	97.62
	48 h	32	62.79
2.0	24 h	4	95.24
	48 h	4	95.35
Control	24 h	84	0.00
	48 h	86	0.00

Fig. 1.4. Colchicine-induced mutant seedling of litchi cv. Shahi showing abnormal morphology. The seedling exhibits twin shoot emergence from the basal region, thickened and dark green leaves, and a single, poorly branched and malformed root system. These features are indicative of colchicine-induced meristematic disruption and probable mixoploidy/polyploidization.

Fig. 1.5. Phenotypic variation in litchi seedlings following colchicine-induced mutagenesis. Colchicine-treated plants exhibited altered canopy architecture, reduced apical dominance, increased lateral branching, thicker and darker green leaves, and irregular leaf morphology compared to normal seedlings. Such morphological deviations are indicative of colchicine-induced meristematic disruption and possible mixoploidy or polyploidization.

1.6. Creating variability in litchi (ICAR-AICRP on Fruits)

Three-year-old half-sib seedlings populations (68) of Litchi cv. Shahi were screened for plant growth and leaf morphological parameters. Marked variability was observed among the half-sib seedlings of *litchi* cv. Shahi (Table 1.8, Fig. 1.6).

Fig. 1.6. Morphological variability among the half-sib seedlings of *litchi* cv. Shahi

Table 1.8. Variation in plant growth parameters of the half-sib seedlings populations of Litchi cv. Shahi

	Plant height (m)	E-W (m)	N-S (m)	Stem girth (cm)	Canopy Volume (m^3)
mean	1.32	0.85	0.91	33.47	4.05
std	0.60	0.52	0.56	19.50	5.55
min	0.35	0.15	0.19	5.08	0.02
max	2.50	2.20	2.50	73.66	28.25

1.7. Evaluation of small seeded litchi variety (MLT-1 under ICAR-AICRP on Fruits)

The comparative morphological evaluation of two small-seeded litchi varieties, Early Bedana and Swarna Madhu, revealed distinct differences in vegetative growth parameters (Table 1.9, Fig. 1.7).

Table 1.9. Plant growth parameters of litchi varieties Early Bedana and Swarna Madhu

Variety	Plant height (m)	Plant spread		Stem girth (cm)	Canopy volume (m^3)
		E-W (m)	N-S (m)		
Early Bedana	1.054	0.497	0.538	15.268	1.079
Swarna Madhu	0.998	0.981	0.942	13.885	3.024
F-value	0.097	5.231	3.449	0.201	1.990
p-value	0.760	0.036	0.082	0.660	0.177
	NS	Significant	NS	NS	NS

Fig. 1.7. Morphological variability among the small seeded litchi varieties Early Bedana and Swarna Madhu

1.8. Mapping of gene(s)/QTLs for economically important traits in litchi through genome-wide association studies (GWAS)

Phenotyping of litchi germplasm for fruit quality traits

A diverse panel of 42 litchi (*Litchi chinensis* Sonn.) germplasm was phenotyped for fruit colour, physical, and biochemical quality traits to generate high-quality phenotypic data for genome-wide association studies (GWAS). Phenotypic data were analyzed using analysis of variance (ANOVA) to assess the significance of genotypic effects. Descriptive statistics including mean, standard error of mean (SEm), least significant difference (LSD at P = 0.05), and coefficient of variation (CV) were computed to quantify phenotypic variability and data reliability. Considerable phenotypic variation was observed among the litchi germplasm for all fruit colour, physical, yield and biochemical quality traits, indicating a diverse panel suitable for GWAS (Table 1.10). The observed wide range and moderate-to-high variability of traits confirm the robustness of the phenotypic dataset and its suitability for genome-wide association analysis in litchi. Several top-performing germplasm and elite trait-specific donors were identified for key traits such as fruit weight, pulp recovery, TSS, and fruit morphology, providing valuable resources for litchi improvement (Table 1.11).

Table 1.10. Descriptive statistics of fruit quality traits in litchi germplasm

Trait	Mean	SD	SEm	Minimum	Maximum	CV (%)
L*	25.03	5.52	0.49	12.32	43.44	22.07
a*	15.33	4.45	0.40	4.07	25.78	29.00
b*	17.46	3.76	0.34	11.86	28.02	21.54
Firmness (g)	855.05	121.28	10.80	588.00	1460.00	14.18
Fruit length (mm)	45.09	3.00	0.27	33.49	53.52	6.65
Fruit width (mm)	41.66	2.10	0.19	36.49	46.51	5.05
Fruit weight (g)	18.41	2.61	0.23	12.82	24.85	14.18
Pulp weight (g)	9.20	2.40	0.21	4.13	15.11	26.10
Seed weight (g)	2.97	0.88	0.08	1.01	4.38	29.54
Peel weight (g)	1.83	0.46	0.04	0.94	3.63	25.03
Pulp recovery (%)	49.37	8.03	0.72	27.49	66.72	16.27
TSS (°Brix)	22.67	2.51	0.22	12.60	26.00	11.05
Acidity (%)	0.95	0.51	0.05	0.13	3.25	53.81

Table 1.11. Top-performing litchi germplasm based on pulp recovery, fruit weight and TSS

Germplasm	Key superiority traits
Bedana Selection (Sabour)	Highest pulp weight and high TSS
Kwai May Pink	Maximum pulp recovery (%)
Gandaki Sampada	High TSS and stable pulp recovery
Ajhauli	High fruit weight and pulp recovery
Gandaki Lalima	Balanced fruit size and sweetness
Bedana	Consistently high TSS
CHL-3	Good pulp recovery with moderate fruit size
Green	Moderate yield with low acidity
Shahi	Stable performance across traits
Bedana (NAGS)	Acceptable pulp recovery and quality

1.9. Standardization of tissue culture techniques for propagation and multiplication of litchi

The journey toward standardizing litchi tissue culture began with the foundational realization that conventional propagation is too slow and genotype-dependent for commercial needs. To counter this, we have initiated a series of experiments using mature leaf explants as well as young leaf explant, placed on a precisely formulated MS medium containing 1mg/L of 6-BAP and 1.5 mg/ of 2,4-D, along with 250mg/L of citric and ascorbic acids to prevent lethal browning. The early phases, TCE-1 and TCE-2, faced immediate hurdles as sterilization with 1.5% sodium hypochlorite for up to 20 minutes failed to prevent massive fungal contamination. Even when the sterilant was switched to 0.1% $HgCl_2$ for 15 minutes in TCE-3, the results remained discouraging, with only 8 out of 126 test tubes showing any callus formation while the rest succumbed to fungi. A dramatic shift occurred in TCE-4 when the antibacterial Cefixim and antifungal Fluconazole were introduced; while they successfully created a sterile environment in all 276 test tubes, they unfortunately proved toxic to the plant tissues, resulting in zero callus growth.

This setback led to the critical breakthrough in TCE-6, where a dual-sterilization protocol was adopted—treating explants with 1.5% sodium hypochlorite for 5 minutes followed by 0.1% $HgCl_2$ for 15 minutes. This specific sequence balanced the harshness of the chemicals with the need for sterility, finally yielding significant results such as 76 successful callus formations out of 120 tubes. As the research progressed into the optimization phase across 41 distinct phases of TCE-6, success rates consistently hovered between 50% and 60%. This set the stage for the most recent comparative trials between TCE-8, TCE-9, and TCE-10. While TCE-8 (Kwai Mi Pink cultivar) achieved a 51.85% success rate, it was TCE-9 using the Shahi variety that emerged as the gold standard. By utilizing a balanced 10-minute exposure for both sodium hypochlorite and mercuric chloride, TCE-9 achieved the highest callus induction efficiency recorded at 69.79%.

The resulting callus, typically observed after 3 to 4 weeks of incubation at 25° ± 2°C, is characterized by a compact, healthy texture and a creamy white to light yellow hue. To ensure biological stability before regeneration, this callus was meticulously subcultured four times at one-month intervals. Currently, these stabilized cultures have been transitioned into the shoot initiation phase, where they are being tested across eight different media variations, primarily utilizing 6-BAP concentrations ranging from 2 mg/ to 16mg/L paired with 0.2 mg/L of NAA to trigger the first signs of green shoot development. This ongoing progress provides a robust foundation for the future goals of root induction and the eventual acclimatization of these lab-grown plantlets for large-scale agricultural use.

Table 1.12. Details on the callus formation in different experiments.

Experiment	No. of Test Tubes	No. of Callus Formed	No. of Fungal Contamination	No Growth/ No Contamination	Callus Formation %
TCE6 (29th phase)	60	34	8	18	56.66
TCE6 (30th phase)	48	27	7	14	56.25
TCE6 (31st phase)	72	39	9	24	54.16
TCE6 (32nd phase)	72	37	10	25	51.38
TCE6 (33rd phase)	84	45	10	29	53.57
TCE6 (34th phase)	72	36	9	27	50.00
TCE6 (35th phase)	84	44	9	31	52.38
TCE6 (36th phase)	72	39	8	25	54.16
TCE6 (37th phase)	48	27	6	15	56.25
TCE6 (38th phase)	120	73	11	36	60.83
TCE6 (39th phase)	108	58	9	41	53.70
TCE6 (40th phase)	108	55	11	42	50..92
TCE6 (41st phase)	96	56	10	30	58.33
TCE8	108	56	25	27	51.85
TCE9	96	67	19	10	69.79
TCE10	96	62	22	12	64.58

Note: TCE-1: sterilant - 1.5% Sodium Hypochlorite (15 min), explants were immersed in liquid MS medium containing 250 mg/L each of citric acid and ascorbic acid for one hour to prevent browning, Solid MS media having 1 mg/L of 6-benzylaminopurine (6-BAP), 1.5 mg/L of 2,4-dichlorophenoxyacetic acid (2,4-D), and incubation in MS media containing 250 mg/L each of citric acid and ascorbic acid, TCE-2: sterilant - 1.5% Sodium Hypochlorite (20 min) + TCE-1, TCE-3: sterilant - 0.1% $HgCl_2$ (15 min) + TCE-1, TCE-4: sterilant - 0.1% $HgCl_2$ (15 min), antifungal (fluconazole) & antibacterial (cefixim) explants + TCE-1, TCE-5: sterilant - 0.1% $HgCl_2$ (15 min), TCE-1 and TCE-6: sterilant - 1.5% sodium hypochlorite for 5 minutes followed by triple rinsing with double-distilled water, then sterilized with 0.1% $HgCl_2$ for 15 minutes and again washed thrice with double-distilled water; + TCE-1, TCE-8: TCE-6 + 0.1% $HgCl_2$ (15 mins) + mature leaf explant, TCE-9: TCE-6 + 0.1% $HgCl_2$ (10 mins) + mature leaf explant, TCE-10: TCE-6 + 0.1% $HgCl_2$ (5 mins) + mature leaf explant

1.10. Molecular characterization of litchi cultivars using microsatellite markers

Sixty novel EST based SSR primers were designed based on bioinformatic analyses for screening of the litchi genotypes using in-house developed perl script programme. Fresh genomic DNA was isolated from 39 varieties of litchi. The thermal profiling of the PCR protocol was calibrated with reference to the new set of primers.

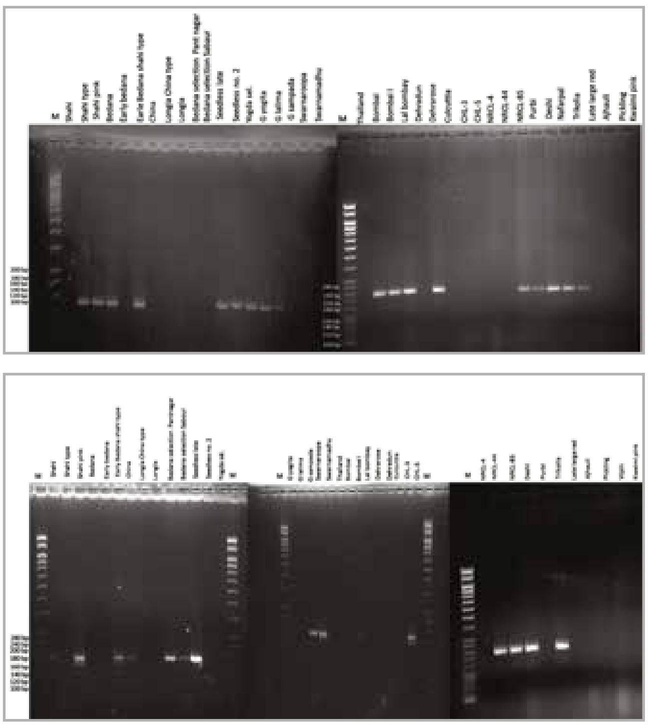


Fig. 1.8. Gel photograph of PCR amplified product showing polymorphism

The polymorphism study revealed, out of 60 SSR based primers, twelve of these were showing differential amplification pattern among the 39 genotypes. Forty-two IISR primers were also deployed for screening of these genotypes, out of which 37 ISSRs showed polymorphism pattern (scorable) during initial screening. Clear, reproducible bands were scored as present (1) or absent (0) for SSR & ISSR markers.

For SSR markers, allele sizes were recorded based on band position. To obtain genetic similarity analysis, a binary data matrix was generated from marker scores. Pairwise genetic similarity coefficients were calculated. Dendrograms were constructed using the UPGMA (Unweighted Pair Group Method with Arithmetic Mean) using NTSYS 2.0 software. Cultivars were grouped based on genetic similarity. Cluster groupings were generated based on the molecular banding pattern.

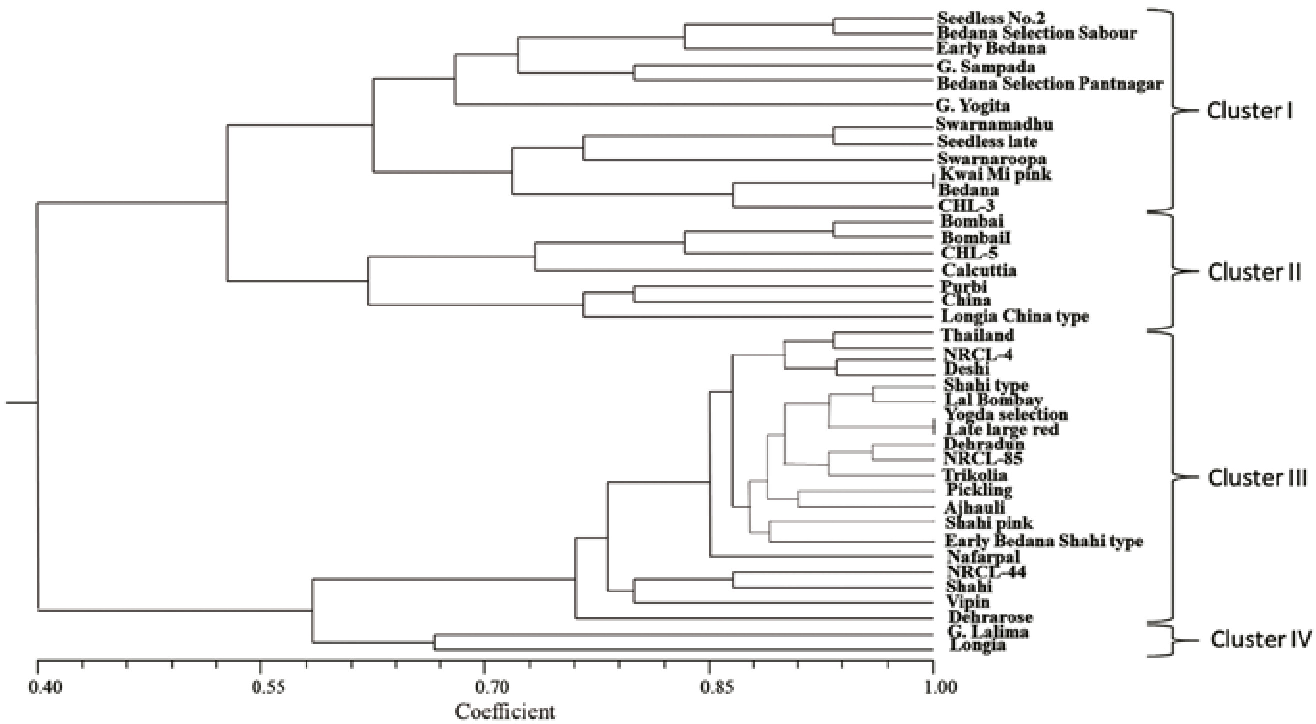


Fig 1.9. Dendrogram depicting genetic relationship among Indian litchi cultivars using molecular markers

The results revealed high levels of polymorphism but low overall gene diversity, indicating that Indian litchi cultivars share a very narrow genetic base. Among the marker systems, IISR markers showed the higher polymorphism compared to SSR; ISSR markers effectively complemented SSRs, making their combined use suitable for cultivar identification and genetic analysis. The cumulative microsatellite data showed strong potential for generating DNA barcodes for reliable cultivar discrimination.

Phylogenetic analysis grouped the cultivars into four major clusters corresponding broadly to known horticultural groups: Shahi, China, Bedana and Longia types. Importantly, molecular clustering largely aligned with morphological traits such as fruit shape, leaf characteristics, and panicle structure. Overall, the study demonstrates that despite apparent phenotypic variation, Indian litchi cultivars are genetically very similar, likely due to limited introductions and clonal propagation.

2. Development and Refinement of Integrated Production Technologies for Improved Productivity of Litchi

2.1. Investigation on mycorrhizal association and role of bio-fertilizers for sustainable production of litchi

The present investigation was undertaken to study the role of arbuscular mycorrhizal fungi (AMF) and associated biofertilizers in improving rhizosphere health, nutrient dynamics and sustainability of litchi production systems. During 2025, the project experiments was focused on (i) understanding the effect of tree girdling on mycorrhizal colonization and rhizosphere microbial population, and (ii) evaluating the impact of *in-situ* mycorrhization on soil nutrient availability, plant nutrient status and microbial activity in litchi orchard ecosystem.

Effect of tree girdling on mycorrhizal colonization and rhizosphere microbial population

The experiment was conducted to assess the impact of tree girdling on AMF colonization and dynamics of rhizosphere microbial population in litchi. The results indicated that AMF colonization was consistently higher in non-girdled trees as compared to girdled trees throughout the observation period. At the initial stage, AMF colonization was 58.7% in non-girdled trees as against 44.9% in girdled trees; however, a sharp decline was observed in girdled trees to 19.03% after three months, whereas non-girdled trees maintained stable colonization (57.9%). After six months, total colonization further increased to 71.18% in non-girdled trees, while it remained significantly lower (20.95%) in girdled trees (Table 2.1).

Table 2.1. AMF colonization (%) of fine roots of litchi

Treatment	0 D				3 M				6 M			
	A	V	A+V	Total	A	V	A+V	Total	A	V	A+V	Total
Girdled	31.7 (27.7-33.6)	9.3 (5.7-12.9)	3.9 (3.1-3.6)	44.90	14.73 (9.7-18.3)	2.77 (2.3-9.9)	1.53 (1.3-2.01)	19.03	14.62 (11.9-22.8)	6.03 (5.92-9.70)	0.30 (0.0-0.5)	20.95
Non-girdled	36.4 (33.3-36.9)	15.9 (10.4-16.0)	6.4 (3.9-6.3)	58.70	38.10 (30.9-39.3)	12.19 (9.0-12.3)	7.58 (3.6-6.9)	57.87	42.99 (34.3-44.25)	16.91 (12.70-19.05)	11.28 (9.10-12.30)	71.18

*Value in parenthesis is range

0 D = Before Girdling 3 M = 3 Months after girdling 6 M= 6 months after girdling

A=Arbuscular colonization V= Vesicular colonization

A similar trend was observed in the population dynamics of key rhizosphere microorganisms. In girdled trees, a drastic decline in microbial population was recorded over time, wherein *Trichoderma* spp. decreased from 60.13 to 1.54 cfu ×10²/10 g soil, phosphate-solubilizing bacteria from 54.29 to 1.3 cfu ×10³/10 g soil, and *Azotobacter* spp. from 17.45 to 1.62 cfu ×10³/10 g soil. In contrast, non-girdled trees maintained relatively higher and stable microbial populations throughout the study period (Table 2.2). These results clearly indicate that girdling adversely affects mycorrhizal association and significantly disrupts the microbial balance in the rhizosphere.

Table 2.2. Dynamics of microbial population in rhizosphere of girdled and non-girdled trees

Treatment (T)	Time duration interval (D)									
	Before girdling	15 DAG	1 Month	2 Month	3 Month	4 Month	5 Month	6 Month	7 Month	8 Month
***Trichoderma* spp. (cfu×10^2/10 g of soil)**										
Girdled	60.13	47.36	37.98	34.49	25.00	19.30	15.20	11.00	5.80	1.54
Non-girdled	67.80	74.69	72.28	66.90	63.90	9.78	53.48	53.99	50.92	47.72
	T				D			T×D		
LSD (p≤0.05)	1.63				3.06			4.02		
SEm (±)	0.53				1.05			2.08		
Phosphate Solubilising Bacteria (cfu ×10^3/10 g of soil)										
Girdled	54.29	42.96	35.67	30.23	25.12	19.52	15.48		6.6	6.0
Non-girdled	62.10	55.34	56.95	55.98	49.19	45.36	51.41		43.20	50.36
	T				D			T×D		
LSD (p≤0.05)	1.34				3.13			4.19		
SEm (±)	0.46				1.11			1.63		
***Azotobacter* spp. (cfu ×10^3/10 g of soil)**										
Girdled	17.45	14.61	11.21	9.76	6.90	5.20	2.96	2.0	1.92	1.62
Non-girdled	23.00	21.59	19.54	16.30	18.20	15.89	18.54	17.30	16.47	18.05
	T				D			T×D		
LSD (p≤0.05)	1.23				2.71			3.10		
SEm (±)	0.35				1.01			1.30		

Fig. 2.1. A litchi tree of cv. 'China'at fruiting stage having girdling in two primary branches at NRCL farm

Effect of *in-situ* mycorrhization on nutrient availability and microbial activity

The effect of *in-situ* mycorrhization using AMF culture along with finger millet (*Eleusine coracana*) as a host crop was evaluated under field conditions. The results demonstrated a positive influence of mycorrhization on soil nutrient status, plant nutrient uptake and microbial activity in the rhizosphere.

(i) Soil nutrient content (N, P, K): The available macronutrients in rhizospheric soil showed a consistent improvement under in-situ mycorrhization across the observation period. Nitrogen content increased by up to 8.9%, indicating gradual enrichment of soil fertility, while phosphorus exhibited a substantial increase (up to 66.6%), reflecting enhanced solubilization and mobilization under AMF association. Potassium availability also improved considerably (up to 41.3%), suggesting better nutrient cycling and retention in the rhizosphere. In contrast, the untreated control showed either marginal improvement or a declining trend in these nutrients over time.

(ii) Micronutrient content (S, Zn, Cu, Fe): Among micronutrients, sulphur content showed a notable increase (up to 30%), indicating improved sulphur dynamics under mycorrhizal influence. Copper content also exhibited moderate enhancement (up to 14.52%). However, zinc and iron showed marginal variation with slight fluctuations, suggesting relatively limited response under the existing soil conditions. The control plots, in general, showed a declining or non-significant trend for these micronutrients.

(iii) Leaf nutrient content (N, P, K): Leaf nutrient analysis indicated improvement in nitrogen and phosphorus content in mycorrhiza-treated trees, reflecting enhanced nutrient uptake efficiency. Phosphorus content increased markedly (up to 30%), which is consistent with the role of AMF in improving P acquisition. Nitrogen showed moderate improvement, while potassium exhibited only slight variation, with a relatively smaller decline in treated trees compared to control. These observations indicate improved translocation of nutrients from soil to plant system under mycorrhizal association.

(iv) Microbial activity (soil respiration): Soil microbial activity, measured in terms of soil respiration, showed a consistent increase ranging from 2.52 to 11.76% in mycorrhiza-treated trees, indicating enhanced biological activity and carbon turnover in the rhizosphere. In contrast, a significant decline (–13.89%) was observed in the control.

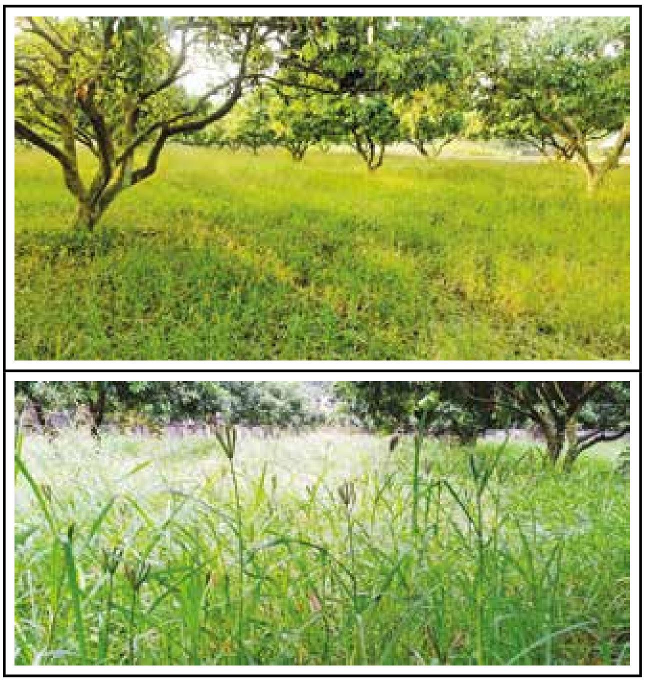


Fig. 2.2. *In-situ* mycorrhization in litchi orchard showing establishment at 3 weeks after sowing (left) and flowering stage at 3 months after sowing (right)

These results clearly indicate that *in-situ* mycorrhization enhances nutrient availability, particularly phosphorus and potassium, improves plant nutrient uptake, and stimulates microbial activity in the rhizosphere. The findings were consistent with earlier observations, with comparatively improved response observed in the current year.

Overall, the study during 2025, highlights the critical role of intact plant physiological processes and beneficial microbial associations in sustaining rhizosphere functionality. While girdling is known to influence reproductive behaviour, it adversely affects AMF colonization and microbial dynamics. In contrast, *in-situ* mycorrhization emerges as a promising approach for enhancing nutrient use efficiency and soil biological health, thereby supporting sustainable litchi production systems.

2.2 Management of fruit cracking in Litchi

Fruit cracking and scorching are critical physiological disorders limiting the productivity and marketability of litchi (*Litchi chinensis* Sonn.), particularly in the commercially important cultivar 'Shahi' (Fig. 2.3). A two-year (production season of 2024 and 2025) field investigation was conducted at the ICAR–National Research Centre on Litchi, Muzaffarpur, India, comprising two parallel experiments: (i) evaluation of litchi genotypes for susceptibility to fruit cracking and scorching, and (ii) assessment of management strategies in cv. 'Shahi'. Significant genotypic variation was observed, with cracking incidence ranging from 2.16% ('NRCL-4') to 16.14% ('Shahi') (Fig. 2.4). Among the tested interventions, under-canopy mini-sprinkler irrigation and preharvest bagging were the most effective, reducing the incidence of cracking by 90.22% and 78.24% and scorching by 78.80% and 87.76%, respectively (Table 2.3). Mini-sprinkler irrigation lowered canopy temperature by 4.3°C and maintained a stable microclimate (Fig. 2.5). Integrating genotype selection and microclimate regulation-based management provides an effective and sustainable strategy to mitigate cracking and scorching in sensitive cultivar such as 'Shahi', supporting climate-resilient litchi production systems.

Fig. 2.3. Comparative expression of physiological disorders in litchi: (a, c) fruit cracking and scorching in 'Shahi' (b) fruit cracking in 'Bedana'.

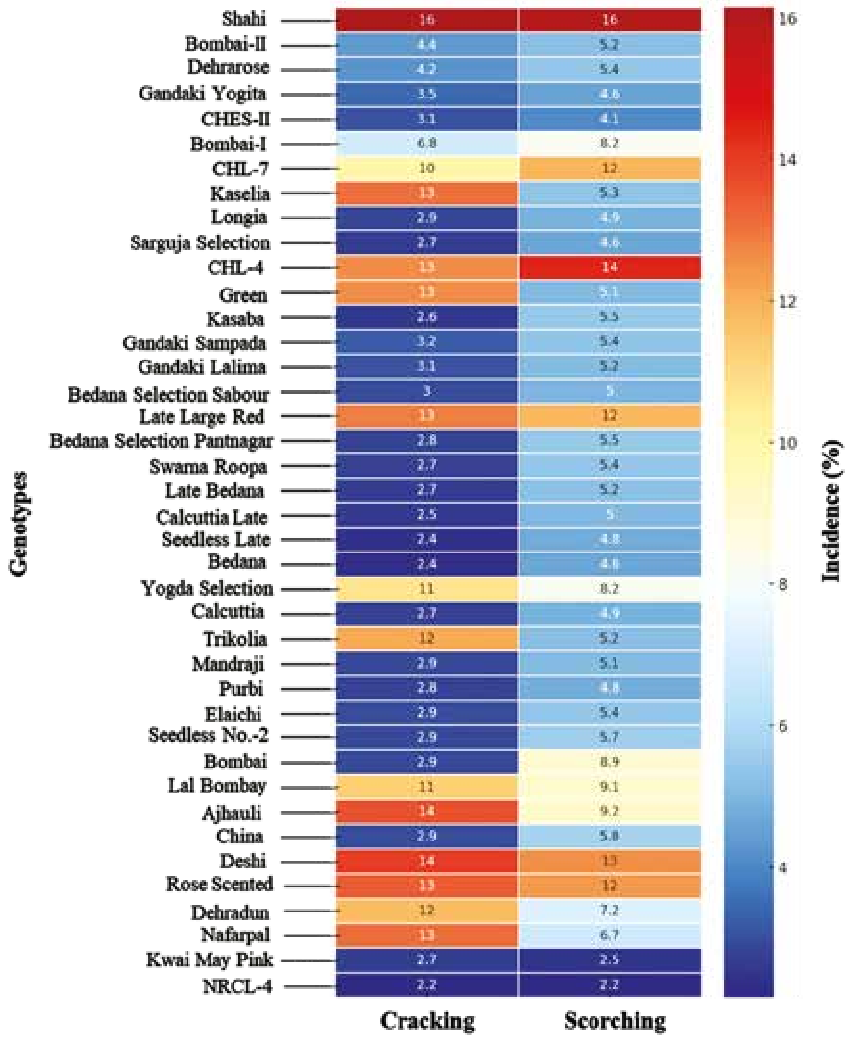


Fig. 2.4. Heatmap illustrating genotypic variation in fruit cracking and scorching incidence among 40 litchi genotypes. The color gradient represents increasing disorder severity from low (blue) to high (red) incidence (%).

Table 2.3. Effectiveness of different management strategies on fruit cracking and scorching incidence in litchi cv. 'Shahi'.

Treatment	Management intervention	Fruit cracking incidence (%)			Fruit scorching incidence (%)		
T_1	Seaweed extract (*Kappaphycus alvarezii*)	5.38 ± 0.91^{bcd} (60.44)			7.93 ± 4.39^{bcde} (48.10)		
T_2	Seaweed extract (*Ascophyllum nodosum*)	6.39 ± 1.41^{bcd} (53.01)			6.99 ± 1.14^{bcde} (54.25)		
T_3	Seaweed fortified granules	6.70 ± 1.59^{bcd} (50.74)			7.93 ± 0.82^{bcde} (48.10)		
T_4	Boron	7.60 ± 2.77^{bc} (44.12)			9.48 ± 3.71^{abc} (37.96)		
T_5	Salicylic acid @ 50 ppm	5.44 ± 1.71^{bcd} (60.00)			8.47 ± 2.14^{bcd} (44.57)		
T_6	Salicylic acid @ 100 ppm	9.03 ± 2.75^{ab} (33.60)			11.75 ± 2.36^{ab} (23.10)		
T_7	Melatonin @ 250 µM	9.12 ± 1.74^{ab} (32.94)			8.82 ± 1.20^{abc} (42.28)		
T_8	Melatonin @ 500 µM	6.45 ± 2.50^{bcd} (52.57)			7.06 ± 2.05^{bcde} (53.80)		
T_9	Jasmonic acid @ 250 µM	8.74 ± 1.86^{ab} (35.74)			7.73 ± 1.34^{bcde} (49.41)		
T_{10}	Jasmonic acid @ 500 µM	6.80 ± 2.35^{bcd} (50.00)			7.85 ± 3.04^{bcde} (48.63)		
T_{11}	Bagging with pink polypropylene bags	3.89 ± 1.99^{bcd} (71.40)			2.16 ± 0.44^{de} (85.86)		
T_{12}	Bagging with white polypropylene bags	2.96 ± 1.72^{cd} (78.24)			1.87 ± 0.50^{e} (87.76)		
T_{13}	Under canopy mini-sprinkler	1.33 ± 0.65^{d} (90.22)			3.24 ± 0.41^{cde} (78.80)		
T_{14}	Mid-canopy mini sprinkler	3.72 ± 1.44^{bcd} (72.65)			3.32 ± 1.50^{cde} (78.27)		
T_{15}	Control	13.60 ± 1.07^{a} (0.00)			15.28 ± 1.5^{a} (0.00)		
		F-value	F-Probability	LSD	F-value	F-Probability	LSD
Treatment		2.32	<0.05	5.72	2.45	<0.05	6.51
Year		0.65	<0.05	2.09	0.01	<0.05	2.38
Treatment*Year		0.26	<0.05	3.79	0.23	<0.05	3.89

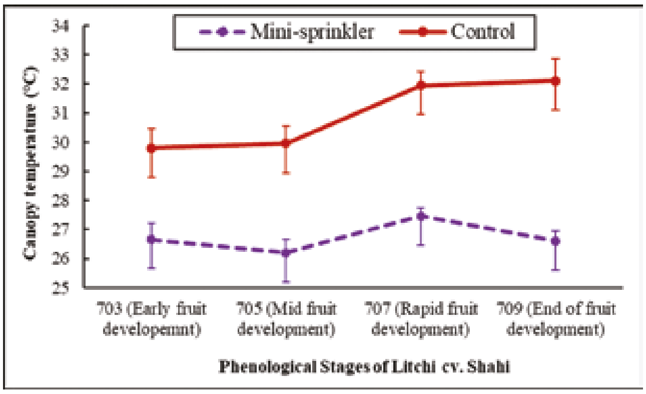


Fig. 2.5. Comparison of canopy temperatures between mini-sprinkler and control treatments during fruit development stages (BBCH 703–709) in cv. 'Shahi'. Mini-sprinkler irrigation consistently lowered canopy temperature by 3.0–5.5°C, reducing thermal stress associated with cracking onset. Error bars indicate standard error.

2.3. Integrated soil health management for quality litchi production

Declining soil fertility and excessive dependence on chemical fertilizers are major constraints to sustainable litchi production. Integrated nutrient management combining organic, inorganic, and biological inputs offers a promising strategy for improving soil health, yield stability, and environmental sustainability. This project was undertaken to identify optimum nutrient combinations that improve yield while enhancing soil biological health and reducing chemical fertilizer dependence.

A long-term field experiment was conducted with eight treatments involving different combinations of chemical fertilizers, farmyard manure (FYM), and bio-inoculants. Treatments ranged from full recommended NPK doses to reduced fertilizer levels integrated with organic and biological inputs, along with control plots. Soil nutrient status, soil respiration, organic carbon, and fruit yield were recorded to evaluate productivity, soil health, and environmental impact of different nutrient combinations.

The study demonstrated that integrated nutrient management significantly enhanced both yield and soil fertility in litchi compared to control conditions. Among the treatments, the combination of 50% recommended dose of fertilizers (RDF) with FYM at 70 kg per plant along with bio-inoculants such as Azotobacter, Trichoderma, and phosphorus solubilizing bacteria proved highly effective, producing yields comparable to the full NPK dose. This clearly indicates that chemical fertilizer inputs can be reduced by up to 50% without compromising productivity when supplemented with organic and biological sources. The integrated treatments also improved key soil health indicators, including soil organic carbon and microbial activity, reflecting better biological functioning of the soil. In contrast, the sole application of chemical fertilizers, although maintained reasonable yield, led to a decline in soil respiration and organic carbon levels, indicating long-term soil degradation risks. Control plots exhibited the poorest performance with severe nutrient depletion and the lowest yield levels. Overall, the results highlight the superiority of integrated approaches over conventional fertilizer use. The findings emphasize the importance of combining organic, inorganic, and biological inputs for sustainable litchi production. These outcomes provide strong scientific evidence for reducing chemical dependency while maintaining productivity.

Table 2.4. Integrated treatment effect on yield, soil nutrients, and biological parameters

Treatment	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Yield (kg/ plant)	CO_2 efflux*	SOC (%)
(1000:550:1000) + FYM 35 kg + ATP**	303.57 a	34.81 a	166.04 a	56.58 a	1.23 b	0.31 ab
(500:275:500) + FYM 70 kg + ATP	298.07 a	20.60 b	127.43 b	49.83 a	1.56 a	0.37 a
(1000:550:1000)	295.01 a	23.91 b	142.64 b	51.67 a	0.50 d	0.19 c
(500:550:1000) + FYM 70 kg + ATP	296.67 a	36.27 a	177.43 a	45.42 ab	1.51 a	0.36 a
(500:550:1000) + FYM 35 kg + ATP	286.32 ab	27.77 a	142.08 b	45.42 ab	1.28 b	0.29 b
FYM 70 kg + ATP	259.76 bc	19.79 b	107.81 c	41.25 bc	1.61 a	0.36 a
FYM 35 kg + ATP	251.06 bc	15.15 c	96.58 c	40.83 bc	1.29 b	0.28 b
Control	236.36 c	11.08 c	80.14 c	30.12 c	0.77 c	0.18 c
SE(m) ±	4.27	2.72	5.69	2.59	0.015	0.005
CD (P=0.05)	12.01	8.25	17.25	7.28	0.046	0.02

*CO_2 efflux in (g CO_2 m^{-2} h^{-1}); **ATP – (Azotobacter + Trichoderma + Phosphorus Solubilizing Bacteria)

Based on the findings of the study, the integrated nutrient management strategy involving 50% RDF combined with FYM at 70 kg per plant along with bio-inoculants such as Azotobacter, Trichoderma, and phosphorus solubilizing bacteria is strongly recommended for litchi orchards. This approach not only sustains yield levels comparable to full chemical fertilization but also enhances soil health and environmental sustainability. Farmers are advised to reduce chemical fertilizer application by up to 50% when it is integrated with organic manures and beneficial microbial inputs.

2.4 Understanding of seasonal variation on leaf nutrient dynamics of litchi and standardization of leaf sampling technique for alluvial plains of Bihar

Leaf nutrient analysis is a reliable tool for diagnosing nutrient status in perennial fruit crops, but its accuracy depends on proper sampling time and leaf position. In litchi, nutrient concentrations vary with season and plant phenology, leading to inconsistencies in diagnosis and fertilizer recommendations. This project was undertaken to study seasonal nutrient dynamics and standardize a representative leaf sampling method for the alluvial plains of Bihar.

Monthly leaf samples of litchi cv. Shahi were collected and analyzed for major and micronutrients to assess seasonal nutrient fluctuations. The study covered a full annual cycle to capture phenology-driven nutrient changes. In a parallel experiment, different leaf pair positions were evaluated to identify the most representative leaf for nutrient diagnosis. Nutrient concentrations were statistically analyzed to determine seasonal trends and sampling standards.

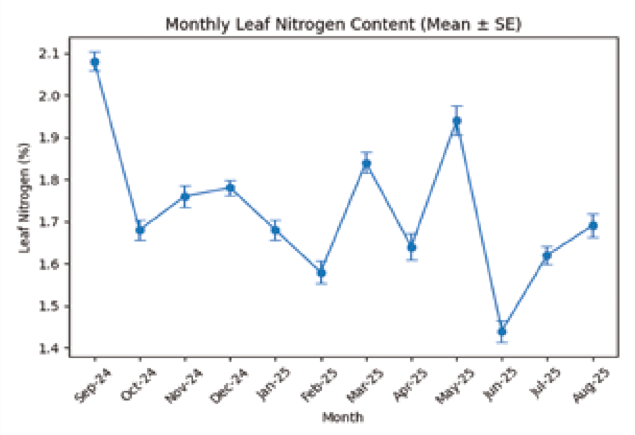


Fig. 2.6. Monthly leaf nitrogen content 2024-2025

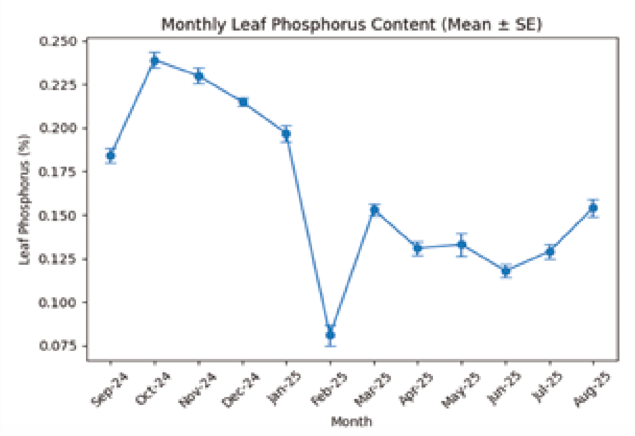


Fig. 2.7: Monthly leaf Phosphorus content 2024-2025

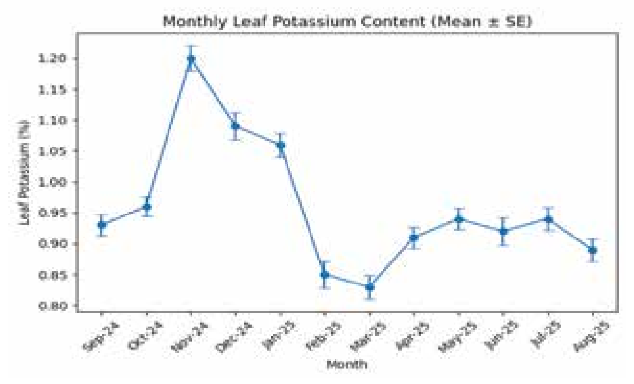


Fig. 2.8: Monthly leaf Potassium content 2024-2025

The study revealed that leaf nutrient concentrations in litchi exhibit significant seasonal variation and are strongly influenced by crop phenology. A distinct pattern of nutrient fluctuation was observed throughout the year, indicating the importance of timing in nutrient diagnosis. Among the different periods, February emerged as a critical stage of nutrient stress, particularly for essential elements such as phosphorus, potassium, and copper. This suggests that nutrient management interventions are especially crucial during this phase. Furthermore, micronutrients including iron, manganese, and zinc showed maximum accumulation during the flowering stage, highlighting increased physiological demand during reproductive growth. The findings also emphasized that nutrient dynamics are not uniform across seasons and must be interpreted carefully for accurate recommendations. In the evaluation of leaf sampling positions, it was observed that nutrient concentrations varied among different leaf pairs. The second leaf pair consistently exhibited the least variation and highest stability in nutrient content. This stability makes it a reliable indicator for assessing plant nutrient status. Therefore, the second leaf pair was identified as the most representative sampling unit for litchi. Standardizing this sampling approach can improve the accuracy of nutrient diagnosis and fertilizer recommendations. Overall, the study provides a scientific basis for optimizing both the timing and method of leaf sampling in litchi cultivation

Table 2.5. Litchi leaf nutrient content at monthly interval

Month	N (%)	P (%)	K (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)
Sep-24	2.08	0.18	0.93	16.77	11.50	10.30	96.80
Oct-24	1.68	0.24	0.96	14.77	8.90	11.30	87.00
Nov-24	1.76	0.23	1.20	15.60	7.80	9.00	62.60
Dec-24	1.78	0.22	1.09	19.80	11.60	10.80	75.80
Jan-25	1.68	0.20	1.06	22.40	6.90	7.00	95.70
Feb-25	1.58	0.08	0.85	19.90	6.50	15.60	149.50
Mar-25	1.84	0.15	0.83	19.40	5.80	12.50	74.60
Apr-25	1.64	0.13	0.91	17.90	6.30	12.10	81.20
May-25	1.94	0.13	0.94	16.30	6.70	13.10	120.10
Jun-25	1.44	0.12	0.92	16.01	7.50	13.00	114.20
Jul-25	1.62	0.13	0.94	15.60	5.90	13.80	90.00
Aug-25	1.69	0.15	0.89	14.80	6.50	10.70	65.70
SE(m)	0.03	0.01	0.02	0.17	0.28	0.28	3.90
CD (5%)	0.08	0.02	0.06	0.50	0.82	0.82	11.50

2.5. Nutrient management in Litchi (*Litchi chinensis* Sonn.) orchard using Diagnosis and Recommendation Integrated System (DRIS)

Balanced nutrition is a key factor influencing productivity and fruit quality in litchi orchards, yet most orchards are managed without scientific nutrient diagnosis. Conventional fertilizer recommendations are often generalized and do not reflect nutrient imbalances at orchard level. Therefore, a DRIS-based approach was undertaken to develop nutrient norms and identify yield-limiting nutrients in litchi under field conditions.

A systematic survey of litchi orchards was conducted across the target region. Leaf and soil samples were collected during March along with GPS coordinates, and fruit yield data were recorded at harvest. Nutrient concentrations of major and micronutrients were analyzed and yield data also recorded. Orchards were grouped into high- and low-yielding categories, and DRIS norms were developed using nutrient ratios, variance ratios, and coefficient of variation. Nutrient indices and Nutritional Imbalance Index (NII) were computed to identify limiting nutrients and overall nutritional status of orchards.

The study successfully developed DRIS norms for both major and micronutrients in litchi under the surveyed orchard conditions, providing a scientific framework for nutrient diagnosis. The Nutritional Imbalance Index (NII) was computed to quantify the overall degree of nutrient imbalance in orchards, enabling a more precise assessment of plant nutritional status. Based on the analysis, the major yield-limiting nutrients were identified in a specific order, Nitrogen > Zinc > Sulphur > Copper with nitrogen being the most limiting, followed by zinc, sulphur, and copper. This ranking highlights the critical nutrients that require priority attention for improving productivity. The findings clearly demonstrated that nutrient imbalances exist even in orchards where conventional fertilizer practices are followed. The DRIS approach proved highly effective in detecting hidden deficiencies that are not easily captured through traditional soil test-based recommendations. It also allowed for a more integrated interpretation of nutrient interactions rather than focusing on individual elements. The study emphasized the importance of nutrient balance rather than absolute nutrient levels. Overall, the results validate the usefulness of DRIS as a diagnostic tool for site-specific nutrient management in litchi orchards.

Table 2.6. DRIS Indices of low yield Litchi orchard population

N%	K%	P%	Zn ppm	Cu ppm	Fe ppm	B ppm	S%	Tot= NII	Sample No.
-916.47	-281.248	143.4241	1725.317	-288.895	244.2762	-211.808	-414.598	4226.035	12
-833.864	-230.341	569.2413	-652.588	1391.826	-40.9904	294.686	-497.97	4511.507	31
-278.918	-335.038	481.1468	-465.04	611.9496	118.5405	150.9119	-283.553	2725.098	26
92.1196	35.4919	503.9315	83.9996	-286.909	232.935	-233.184	-428.386	1896.955	10
-229.323	189.7083	1266.734	-738.948	386.3593	409.767	-1242.62	-41.6747	4505.138	30
55.2549	-157.343	-206.237	-497.485	-185.691	98.2295	928.4218	-35.1502	2163.813	1
585.7647	1055.959	590.8395	-144.159	-4786.88	892.369	1889.756	-83.6521	10029.38	5
-79.6687	361.0398	79.3107	-566.517	-431.569	43.7113	550.3667	43.3267	2155.511	29
-828.568	-229.519	96.65	-961.125	926.0921	-14.8252	2470.348	-1459.05	6986.181	9
311.431	147.6279	-341.274	-1158.78	-595.669	402.7378	965.1261	268.8035	4191.453	2
-135.01	140.4676	46.1874	-562.874	673.4162	239.2164	-728.692	327.2874	2853.15	14
176.7651	151.9626	37.4302	-223.388	86.5445	34.1119	134.022	-397.448	1241.673	6
-456.213	-36.7141	29.2308	-668.539	297.2224	89.6579	342.7057	402.6486	2322.931	17
-259.29	-102.701	334.3283	-249.292	468.9074	296.3525	132.0926	-620.398	2463.362	27
-50.0483	105.9861	-132.962	-417.224	396.9756	173.3336	279.3379	-355.399	1911.267	28
226.6755	319.3651	-82.3827	-998.861	-74.9565	351.1542	1036.143	-777.138	3866.675	8
1381.494	1959.507	1471.294	-513.067	1396.098	809.7142	-7044.75	539.707	15115.63	15
-430.167	370.4759	591.1853	-804.895	-716.269	221.072	118.1162	650.4826	3902.664	23
-135.702	94.7227	888.205	2920.196	-4430.79	-51.4575	803.2527	-88.4258	9412.753	22
-27.1307	241.1361	1693.41	-1210.55	-804.497	632.2046	-677.409	152.8393	5439.18	3
-191.614	6.1062	249.6479	-107.262	-24.9883	29.9989	113.2523	-75.1411	798.0106	34

Based on the outcomes of the study, it is recommended that nutrient management in litchi growers should prioritize the correction of nitrogen deficiency, as it was identified as the most limiting nutrient affecting yield. Simultaneously, attention should be given to micronutrients, particularly zinc and copper, which also play a crucial role in improving orchard productivity. Farmers and practitioners are advised to adopt a balanced fertilization approach rather than relying solely on conventional blanket fertilizer recommendations. Incorporating DRIS norms into advisory services can improve nutrient use efficiency and reduce unnecessary fertilizer application.

2.6. Development of plant canopy architecture in litchi (ICAR-AICRP on Fruits)

This trial consists of 10 (9+1) treatment combinations including control and laid out in RBD. The treatment includes retention of 2, 3 and 4 primary branches (P_2, P_3, P_4) each retaining 2, 3 and 4 secondary branches (S_2, S_3, S_4) along with control and replicated thrice under a square system of planting. Accordingly, the total ten treatment combinations were T_1 (P_2S_2), T_2 (P_2S_3), T_3 (P_2S_4), T_4 (P_3S_2), T_5 (P_3S_3), T_6 (P_3S_4), T_7 (P_4S_2), T8 (P_4S_3), T_9 (P_4S_4) and T_{10} (control).

Table 2.7. Effect of canopy architecture on plant growth and yield of litchi cv. Shahi

Treatment		Plant height (m)	Stem girth (cm)	Canopy volume (m^3)	TCSA (cm^2)	No. of fruit / tree	Yield (kg/tree)
T_1	P_2S_2	3.61	68.49	301.61	373.69	1162.50	21.98
T_2	P_2S_3	3.68	72.24	335.52	423.86	900.00	17.80
T_3	P_2S_4	3.31	70.52	248.31	396.30	1087.50	22.48
T_4	P_3S_2	3.18	71.03	268.30	402.56	737.50	14.22
T_5	P_3S_3	3.75	70.00	387.17	392.06	975.00	17.02
T_6	P_3S_4	3.38	60.95	300.81	295.88	912.50	16.82
T_7	P_4S_2	3.50	62.68	419.41	313.46	1025.00	19.40
T_8	P_4S_3	3.75	67.81	388.29	367.03	1150.00	20.72
T_9	P_4S_4	3.82	72.35	427.12	416.74	1542.50	26.86
T_{10}	Control	3.76	64.41	419.54	331.50	1137.50	19.05
SEm ±		0.140	2.401	27.984	27.407		2.207
CD (5%)		0.41	6.97	81.21	79.53	329.92	6.40
C.V.		7.84	7.06	16.01	14.76	21.39	22.48

Treatment 9 (P_4S_4) exhibited the most favorable balance of canopy architecture, and yield performance (Table 2.7). Treatment 8 (P_4S_3) and Treatment 3 (P_2S_4) exhibited superior fruit quality attributes with higher TSS, better pulp recovery, and moderate acidity (Table 2.8).

Table 2.8. Effect of canopy architecture on fruit quality of litchi cv. Shahi

Treatment		Fruit weight (g)	Pulp recovery (%)	TSS (°B)	Acidity (%)
T_1	P_2S_2	19.06	56.87	19.67	0.61
T_2	P_2S_3	19.72	55.84	20.56	0.62
T_3	P_2S_4	20.64	58.84	19.73	0.60
T_4	P_3S_2	19.24	55.52	19.65	0.76
T_5	P_3S_3	17.57	53.78	18.67	1.02
T_6	P_3S_4	18.42	54.44	18.35	0.86
T_7	P_4S_2	18.93	58.97	20.55	0.89
T_8	P_4S_3	17.99	59.47	21.28	0.78
T_9	P_4S_4	17.35	53.35	20.20	0.86
T_{10}	Control	16.82	52.28	18.18	0.96
SEm ±		0.575	1.413	0.519	0.073
CD (5%)		1.67	4.1	1.51	0.21
C.V.		6.19	5.05	5.27	18.26


Fig. 2.9. Fruiting in litchi cv. Shahi under different branch retention treatments.

2.7. Irrigation scheduling in litchi (ICAR-AICRP on Fruits)

The experiment consists of 7 treatments with 3 levels of irrigation and two levels of mulching and control comprising with four replications. The results clearly demonstrate that mulching combined with one irrigation at 100% ER significantly improved fruit yield in litchi cv. Shahi without adversely affecting fruit quality parameters (Table 2.9).

Table 2.9. Effect of irrigation treatments on growth, yield and fruit quality of litchi cv. Shahi

Treatment	Treatment combinations	Plant height (m)	Canopy volume (m^3)	Yield (kg/tree)	Fruit drop (%)	Fruit weight (g)	TSS (˚B)
T_1 (50% ER + M)	M_1I_1	4.46	435.96	18.70	67.82	15.57	20.02
T_2 (75% ER + M)	M_1I_2	4.40	444.55	21.88	67.50	15.39	20.24
T_3 (100% ER + M)	M_1I_3	4.48	436.52	25.50	63.38	15.97	20.14
T_4 (50% ER - M)	M_2I_1	4.44	401.89	18.69	71.78	15.93	20.40
T_5 (75% ER - M)	M_2I_2	4.36	423.98	21.58	76.42	15.52	21.50
T_6 (100% ER - M)	M_2I_3	4.40	428.36	23.61	74.36	15.80	20.54
T_7 (Control)	Control	4.12	351.23	19.37	74.08	16.07	19.84
SEm ±		0.09	23.33	1.47	5.75	0.42	0.46
CD at 5%		NS	NS	4.29	NS	NS	NS
C.V.		4.76	12.49	15.43	18.16	6.01	4.99

Fig. 2.10. Fruiting in litchi cv. Shahi under mulching combined with full irrigation (100% ER)

2.9 Using paclobutrazol and micronutrient application as a tool for productivity and fruit quality improvement of Litchi under subtropical conditions (ICAR-AICRP on Fruits)

The study was conducted during 2024–2025 to evaluate the effect of paclobutrazol and micronutrient application on flowering regulation in litchi. Foliar application of Paclobutrazol @ 50 ppm exhibited a distinct influence on yield and quality parameters of litchi as compared to the control. The treatment recorded a higher mean yield (8.28 kg/plant) as against 7.37 kg/plant in control, indicating a yield enhancement of nearly 12%, though the difference was statistically non-significant ($p > 0.05$) (Table 2.10).

Table 2.10. Effect of foliar application of paclobutrazol on yield and quality parameters of litchi cv. China

Treatment	Yield (kg/plant)	Fruiting Density (kg/m^3)	Fruit weight (g)	Pulp recover (%)	TSS (^oB)	Acidity (%)	Ascorbic acid (mg/100 ml of juice)
T_1	8.28	0.03	19.04	50.01	23.12	0.43	49.39
T_2 (Control)	7.37	0.02	19.45	47.96	23.19	0.32	48.34
t-statistics	1.48	2.32	-0.49	0.67	-0.08	2.73	1.66
p-value	0.19	0.07	0.64	0.53	0.94	0.04	0.16

3. Development and refinement of integrated crop protection technologies for improved productivity of litchi

3.1. Investigation and management of pre-harvest diseases of litchi

The present investigation was undertaken to study the incidence, severity and management of major pre-harvest diseases of litchi. The experiments comprised systematic assessment of disease dynamics of leaf, panicle and fruit blight, evaluation of fungicides for effective management of Alternaria blight, and analysis of pesticide residues in fruits to ensure safe and sustainable production. In addition, the effect of bio-stimulants on pre-harvest disease modulation and post-harvest shelf life of litchi fruits was also investigated as an integrated approach linking pre- and post-harvest phases. The studies were aimed at understanding disease progression, improving management strategies and ensuring both productivity and fruit quality.

Disease incidence and severity of leaf, panicle and fruit blight during 2025

Disease severity assessment revealed that blight diseases were prevalent under both experimental and farmers' field conditions, with varying levels of incidence and severity at different crop stages. Leaf blight was observed during the early vegetative phase and served as a primary source of inoculum for subsequent infection of panicles and fruits. The disease development was more pronounced during the monsoon period, with July to September identified as the peak period, whereas November to January recorded comparatively low disease incidence and severity. During 2025, the mean disease incidence (DI) of leaf blight during July to October ranged from 14.03 to 22.14%, while the percent infected leaves (IL) varied between 12.00 and 36.30%. The disease severity index (PDI) ranged from 24.33 to 64.18, indicating moderate to high disease pressure during favourable conditions.

Panicle blight was recorded as the most critical stage affecting crop productivity. The mean disease incidence of panicle blight in cv. 'Shahi' during 2025 ranged from 55.1–76.4% at NRCL farm and was comparatively higher in farmers' orchards (66.9–92.3%), showing an increasing trend with crop phenology. The overall mean disease incidence was 67.8% at NRCL farm and 79.4% in farmers' orchards, indicating relatively higher disease pressure under farmers' field conditions. However, the distribution of trees across severity classes revealed that the majority of trees (>86% at NRCL farm and >90% in farmers' orchards) had ≤20% blighted panicles, followed by a smaller proportion in the 21–40% category, with no trees observed in higher severity classes. This indicates that although disease incidence at orchard level was high, the severity within individual trees remained relatively low and localized (Table 3.1).

Fruit blight incidence was observed at later stages of crop development. The mean disease incidence of fruit blight in farmers' orchards during 2025 remained low to moderate (6.3–11.7%), with an overall range of 2.3–17.6%, and was comparable to previous year's observations. The progression of disease from leaf to panicle and subsequently to fruit stage highlights the role of initial inoculum build-up and favourable environmental conditions in disease development.

The overall trend indicated that despite high disease incidence at the orchard level, the severity remained predominantly low, as most trees exhibited ≤20% blighted panicles, suggesting relatively stable disease behaviour across seasons. The findings emphasize that panicle blight plays a decisive role in determining yield losses, while leaf infection serves as a critical source of inoculum for epidemic development. The results were consistent with earlier observations, with comparatively higher disease pressure observed during the current year.

Table 3.1. Disease incidence and severity of panicle blight during 2025 season

Orchard no.	NRCL farm					Mean	Farmer's Orchard					Mean
	I	II	III	IV	V		I	II	III	IV	V	
Disease incidence (%)												
9-04-2025	35.0	46.2	61.3	77.8	48.9	55.1	58.5	65.5	55.7	74.7	80.2	66.9
18-04-2025	60.2	78.1	69.5	80.1	64.3	72.0	74.8	72.2	74.8	84.9	88.2	79.0
28-04-2025	71.9	79.4	71.6	82.5	67.5	76.4	90.5	86.6	93.2	94.5	96.6	92.3
Mean	55.7	67.9	67.5	80.1	60.2	67.8	74.6	74.8	74.6	84.7	88.3	79.4
Percent distribution of trees in different level of blighted panicles												
<20%												
9-04-2025	91.6	89.2	92.4	91.5	97.6	91.2	94.2	91.5	90.7	95.3	99.5	94.2
18-04-2025	86.3	83.8	87.2	91.5	91.5	87.2	92.1	90.2	88.1	89.4	91.4	90.2
28-04-2025	73.6	80.0	83.6	90.4	93.0	81.9	89.8	85.4	86.8	85.5	90.0	87.5
Mean	83.8	84.3	87.7	91.1	94.0	86.8	92.0	89.0	88.5	90.1	93.6	90.7

Orchard no.	NRCL farm					Mean	Farmer's Orchard					Mean
	I	II	III	IV	V		I	II	III	IV	V	
21-40%												
9-04-2025	8.2	10.8	5.5	1.3	3.0	6.5	6.8	8.9	9.2	3.7	2.5	6.2
18-04-2025	13.9	18.2	13.9	9.6	9.0	13.9	8.4	9.2	11.2	12.6	9.0	10.1
28-04-2025	28.4	22.0	17.4	11.6	13.0	19.9	11.2	14.9	13.6	14.8	10.7	13.0
Mean	16.8	17.0	12.3	7.5	8.3	13.4	8.8	11.0	11.3	10.4	7.4	9.8
41-60%												
9-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
18-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
28-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	0	0	0	0
61-80%												
9-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
18-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
28-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	0	0	0	0
>80%												
9-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
18-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
28-04-2025	0	0	0	0	0	0	0	0	0	0	0	0
Mean	0	0	0	0	0	0	0	0	0	0	0	0

3.2 Effect of fungicides on litchi diseases, sunburn and yield

A field experiment was conducted to evaluate the efficacy of different fungicides against Alternaria blight of litchi under field conditions. The treatments were applied at critical growth stages, and observations on disease incidence and severity, along with yield and related parameters, were recorded to assess their effectiveness in disease management.

The results revealed that all fungicidal treatments significantly reduced panicle blight, fruit blight and sunburn incidence as compared to the untreated control. Among the treatments, Fluopyram + Tebuconazole, Fluopyram, Thiophanate methyl and Azoxystrobin + Mancozeb were found most effective in minimizing panicle blight, each recording only 4.87% incidence as against 33.20% in the control. Fruit blight incidence was also markedly reduced under fungicidal treatments, with the lowest incidence recorded in Thiophanate methyl (0.52%), followed closely by Fluopyram (0.54%) and Fluopyram + Tebuconazole (0.55%), whereas the untreated control recorded 6.9% fruit blight.

Similarly, sunburn incidence was minimized under fungicide application, with the lowest values observed in Fluopyram + Tebuconazole and Thiophanate methyl (8.13%), followed by Fluopyram (9.13%), as compared to 15.13% in the control. The reduction in disease incidence was reflected in improved yield performance. The highest fruit yield was obtained with Thiophanate methyl (45.27 kg/tree), followed by Fluopyram (45.08 kg/tree), both of which were significantly superior to the control (36.30 kg/tree). The improved yield under these treatments may be attributed to better disease control, leading to healthier panicles and improved fruit retention.

The comparative performance of fungicides clearly demonstrated the effectiveness of systemic molecules, particularly Thiophanate methyl and Fluopyram-based treatments, in managing Alternaria blight and associated disorders. The results also emphasize the importance of timely application at critical phenophases for effective disease suppression. The findings were consistent with earlier observations, with comparatively improved disease control and yield response observed during the current year.

3.3 Effect of bio-stimulants on pre-harvest diseases of litchi and post-harvest shelf life of fruits

The experiment was conducted to evaluate the effect of selected bio-stimulants on pre-harvest disease incidence and post-harvest shelf life of litchi fruits under field conditions. The treatments comprised foliar application of selected ethnomedicinal plant extracts, namely *Guma* (*Leucas aspera*) and *Hathisud* (*Heliotropium indicum*), along with microbial formulations including *Bacillus subtilis* strain BS-01 and *Trichoderma viride* strain NRCL T-01, applied either as live cells or as culture filtrates. In addition, combinations with recommended plant protection measures were also evaluated, along with an untreated control.

The microbial components included culture filtrate of *Bacillus subtilis* (CF BS-01) and culture filtrate of *Trichoderma viride* (CF T-01), as well as their respective live formulations (BS-01 and T-01). The use of culture filtrates was conceptualized as a strategy to overcome biosafety and regulatory constraints associated with live microbial inoculants, thereby facilitating easier scalability and potential field-level adoption. The selection of ethnomedicinal plants was based on their promising performance in earlier *in vitro* and *in vivo* screening studies.

The underlying hypothesis was that these bio-stimulants, through their bioactive compounds and metabolites, may enhance plant physiological efficiency, induce systemic resistance, and improve antioxidant status, thereby reducing disease susceptibility and improving fruit quality and shelf life.

Results of the studies are as under:

(i) Disease incidence and severity

Application of bio-stimulants, including ethnomedicinal plant extracts and microbial formulations, resulted in a reduction in panicle and fruit blight incidence over the untreated control. Among the treatments, the lowest panicle blight disease severity was recorded in trees treated with CF BS-01 + T-01, followed by humic acid and BS-01, indicating better suppression under microbial metabolite-based treatments. A similar trend was observed in fruit blight, wherein the lowest disease severity was recorded in BS-01, followed by humic acid and CF BS-01 + T-01, as compared to higher severity in control. Other treatments, including ethnomedicinal plant extracts (*Guma* and *Hathisud*), also showed moderate reduction in disease severity. Overall, although the magnitude of disease reduction was lower than fungicidal treatments, the consistent decline across bio-stimulant treatments indicates their potential as supportive components in integrated disease management.

Table 3.2. Effect of biostimulants application on disease severity

Treatment	Dose (ml/L)	Panicle blight (%)*			Fruit blight %
		1st (9/04/2025)	2nd (18/04/2025)	3rd (28/04/2025)	
Guma	30	24.22	29.47	32.56	12.99
Hathisud	30	24.22	29.47	34.56	9.00
CF BS-01	15	16.42	35.37	36.56	7.20
CF T-01	15	24.22	27.50	28.56	4.50
BS-01	05	6.02	17.67	18.56	4.50
T-01	05	16.42	37.33	38.56	9.00
Humic acid	15	6.02	7.83	18.77	4.50
Seaweed extract	2	13.82	19.63	22.56	9.00
Ambition	2.5	11.22	27.50	30.56	9.00
CF BS-01 + T-01	15	3.42	9.80	14.56	8.94
Control (Water spray)	-	29.42	41.27	42.56	18.09
LSD (p=0.05)		0.66	0.18	0.18	0.13
SEm (±)		0.23	0.54	1.42	0.38

*Observation based on 30 tagged panicles; ** ambition is a commercial biostimulant product taken for comparison; CF BS-01 = culture filtrate of *Bacillus subtilis* stain BS 01, CF T-01= Culture filtrate of *Trichoderma viride* strain NRCLT-01. BS-01= *Bacillus subtilis* strain BS 01 (live cells), T-01= *Trichoderma viride* strain NRCLT-01 (live cells)

(ii) Fruit drop, fruit cracking, sunburn, fruit borer incidence and fruit weight

The application of bio-stimulants had a significant influence on fruit retention, pest incidence and fruit quality parameters. Fruit drop was markedly reduced under bio-stimulant treatments, with the lowest fruit drop recorded in BS-01, as compared to very high fruit drop under the untreated control. Fruit borer infestation, assessed at harvest based on infestation in a sample of 60 fruits, was also reduced under bio-stimulant treatments. The lowest infestation was recorded in CF BS-01 (11.67%), followed by BS-01 (17.03%), indicating the effectiveness of microbial formulations in reducing pest incidence, whereas higher infestation was observed in control.

In contrast, bio-stimulants were less effective in managing physiological disorders such as fruit cracking and sunburn, where only marginal differences were observed among treatments, although all treatments recorded comparatively lower values than control. Fruit weight was significantly influenced by bio-stimulant application, with the highest fruit weight recorded in Guma (1.10 kg), followed by BS-01 and CF BS-01, all of which were superior to control. The improvement in fruit weight may be attributed to enhanced nutrient uptake and better physiological efficiency under bio-stimulant application. Overall, the results indicate that bio-stimulants, particularly microbial formulations, were effective in reducing fruit drop and fruit borer infestation and improving fruit weight, although their effect on sunburn and fruit cracking was limited.

Table 3.3. Effect on fruit drop, fruit cracking, sunburn, fruit borer incidence and fruit weight

Treatment	Dose (ml/L)	Fruit drop/tree		Fruit borer (%)*	Fruit cracking (%)	Sunburn (%)	Fruit weight (60 fruits)
		1st (22/04/2025)	2nd (28/04/2025)				
Guma	30	14.33	71.33	26.68	5.10	30.10	1.10
Hathisud	30	17.33	69.33	41.69	3.06	15.05	0.74
CF BS-01	15	22.33	45.33	11.67	5.10	15.05	0.94
CF T-01	15	11.33	48.33	30.02	3.06	15.05	0.89
BS-01	05	13.33	30.33	17.03	3.06	10.03	0.91
T-01	05	29.33	38.33	46.70	3.06	10.03	0.88
Humic acid	15	17.33	38.33	28.35	5.10	15.05	0.87
Seaweed extract	2	9.33	32.33	33.36	2.04	15.05	0.72
Ambition**	2.5	19.33	37.33	20.01	3.06	15.05	0.78
CF BS-01 + T-01	15	18.33	38.33	20.01	3.06	20.07	0.88
Control (Water spray)	-	41.33	142.33	60.04	3.06	15.05	0.79
LSD (p=0.05)		0.096	0.061	1.997	0.035	0.324	0.039
SEm (±)		0.032	0.020	0.627	0.012	0.109	0.013

*Observation taken on 60 fruits

(iii) Effect of biostimulant treatments on enzymatic activity and phenolic content in fruits after harvest

Bio-stimulant treatments had a significant influence on enzymatic activity and phenolic content of litchi fruits during ambient storage, indicating their role in regulating post-harvest physiological and biochemical changes (Fig. 3.1).

a) Polyphenol oxidase (PPO) activity: PPO activity increased with storage period across all treatments; however, comparatively lower activity was observed in T-01, BS-01 and humic acid-treated fruits, indicating better retention of fruit quality. In contrast, control and Guma treatments recorded higher PPO activity, suggesting faster enzymatic browning and quality deterioration. Treatments such as BS-01, T-01, humic acid and CF BS-01 showed relatively slower increase in PPO activity, indicating better control over enzymatic browning.

b) Peroxidase (POD) activity: A similar trend was observed for POD activity, wherein BS-01 and CF BS-01 treatments consistently recorded lower POD activity, reflecting reduced oxidative stress and slower quality degradation. In contrast, control and seaweed extract treatments showed higher POD activity, indicating faster deterioration, while humic acid and Ambition exhibited moderate levels.

c) Phenylalanine ammonia-lyase (PAL) activity: PAL activity showed a declining trend with increase in storage period at 25°C across all treatments. However, the decline was relatively slower in BS-01-treated fruits, indicating better retention of enzyme activity. In contrast, a sharp decline was observed in control, which may be associated with faster degradation of anthocyanin pigments. The relatively sustained PAL activity under BS-01 treatment suggests slower loss of anthocyanin and better maintenance of fruit colour.

d) Total phenolic content: The total phenolic content decreased progressively during storage in all treatments. However, higher initial phenolic content was recorded in BS-01 (270 mg GAE/100 g) and T-01 (190 mg GAE/100 g), which also retained comparatively higher levels by day 6 (57.90 mg and 30.35 mg GAE/100 g, respectively). In contrast, treatments such as Ambition showed the lowest phenolic retention (7.06 mg GAE/100 g by day 6), indicating rapid depletion. CF BS-01 and CF T-01 combination treatments maintained moderate phenolic levels during storage.

Overall, the results indicate that bio-stimulant treatments, particularly BS-01, T-01 and CF BS-01, were effective in regulating enzymatic activity and maintaining higher phenolic content, thereby contributing to delayed senescence and improved post-harvest quality of litchi fruits.

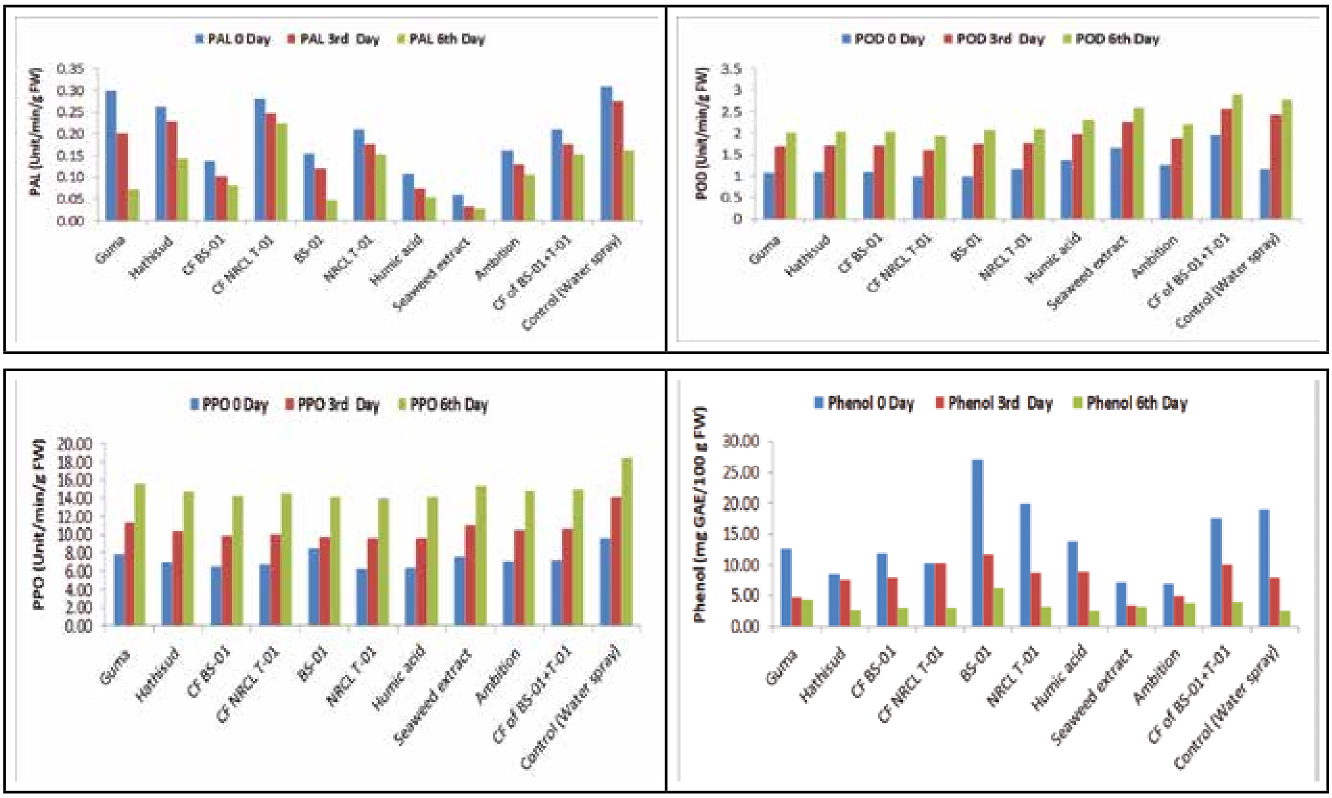


Fig. 3.1. Effect of biostimulant treatments on enzymatic activity and phenolic content in fruits after harvest

(iv) Browning index and fruit decay

Browning index and fruit decay were assessed during ambient storage (25°C) to evaluate the effect of bio-stimulant treatments on post-harvest quality. The browning index of litchi pericarp was measured following the method described by Wu et al. (2017) using a standard visual scale.

Browning index increased progressively with storage duration across all treatments; however, fruits treated with BS-01 (1.89**)**, T-01 and their culture filtrates (CF BS-01 and CF T-01 + BS-01; ~2.01**)** recorded comparatively lower browning values than the untreated control (2.80) and seaweed extract, indicating better retention of pericarp colour (Fig. 3.2). A similar trend was observed in fruit decay, wherein BS-01 and CF BS-01 + T-01 treatments recorded markedly lower decay incidence by 6 days after harvest, whereas control, CF BS-01 alone and seaweed extract showed comparatively higher decay(Fig. 2). Overall, the results indicate that BS-01-based treatments, particularly in combination with culture filtrates, were most effective in delaying browning and suppressing fruit decay, thereby improving post-harvest shelf life of litchi under ambient conditions.

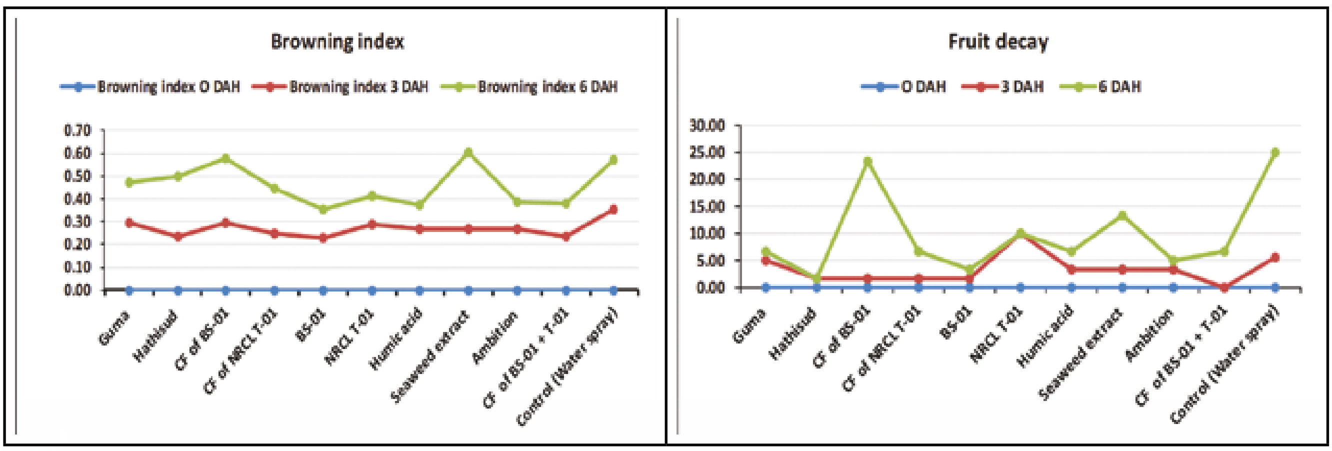


Fig. 3.2. Effect of biostimulant treatments on browning and fruit decay after harvest

(v) Anthocyanin, titratable acidity (TA) and total soluble solids (TSS)

Bio-stimulant treatments significantly influenced key quality parameters of litchi fruits during storage, particularly total soluble solids (TSS), anthocyanin content and titratable acidity. TSS values showed a declining trend with storage; however, comparatively higher values were maintained in BS-01 (19.92°Brix) and Guma, indicating better retention of fruit sweetness under these treatments. Anthocyanin content also decreased during storage across all treatments, but higher initial content and better retention were observed in Guma (38.19 mg/100 g) and BS-01 (37.99 mg/100 g), which remained at 20.32 and 21.84 mg/100 g, respectively, after 6 days of storage. This indicates improved colour stability and slower pigment degradation under these treatments. Titratable acidity (TA) followed a gradual declining trend during storage, with relatively better retention observed in BS-01 and Guma treatments compared to control, indicating delayed senescence and better maintenance of fruit quality (Fig. 3.3).

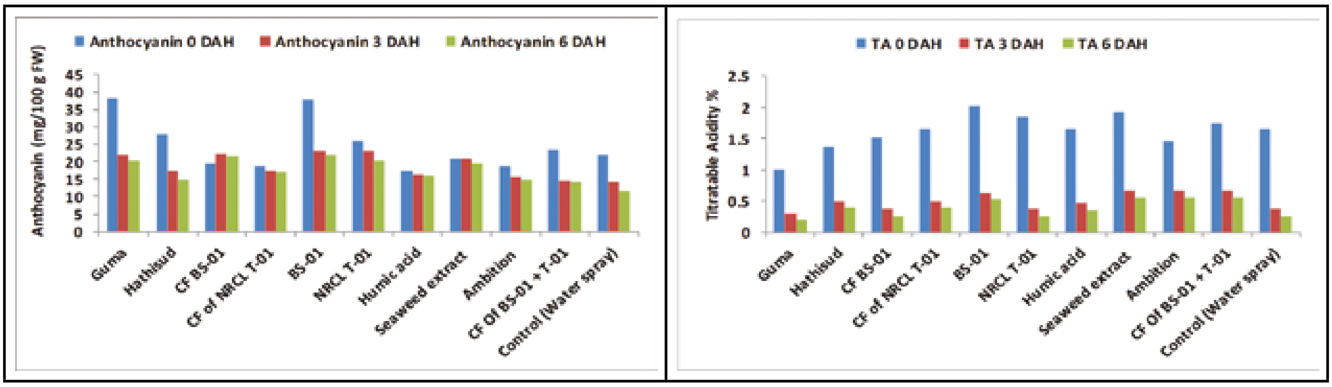


Fig. 3.3. Effect of biostimulant treatments on anthocyanin, titratable acidity and total soluble solids after harvest of fruits

3.2. Investigation and management of insect-pest complex of litchi

Impact of different insecticides on stink bug (*Tessarotoma javanica*), flower webber (*Statherotis leucaspis*) and fruit borer (*Conopomorpha sinensis*) infestation

The efficacy of different insecticides against litchi stink bug, *Tessarotoma javanica*, was evaluated 24 h after spraying at 20 and 10 days before harvest (DBH). Significant differences among treatments were observed at both spray timings ($P < 0.05$). At 20 DBH, beta-cyfluthrin 8.49% + imidacloprid 19.8% recorded the highest reduction in stink bug population (98.78 ± 1.76%), followed by thiacloprid 21.7% SC (90.90 ± 2.56%), lambda-cyhalothrin 5% EC (85.71 ± 3.21%), tetraniliprole 18.18 SC (80.00 ± 3.21%), and thiamethoxam 12.6% + beta-cyhalothrin 9.5% (80.00 ± 1.14%). The lowest reductions were observed with novaluron 10% EC (12.50 ± 2.21%) and spinosad 45% SC (13.33 ± 3.21%).

At 10 DBH, beta-cyfluthrin + imidacloprid again proved to be the most effective treatment with 93.33 ± 1.32% reduction, followed by lambda-cyhalothrin 5% EC (91.66 ± 1.45%) and thiamethoxam 12.6% + beta-cyhalothrin 9.5% (84.61 ± 1.34%). Comparatively lower efficacy was recorded with broflanilide 20% SC and spinosad 45% SC (18.18 ± 1.67% and 18.18 ± 1.45%, respectively). The significant F-values and low LSD values confirmed clear variation among insecticidal treatments, indicating that beta-cyfluthrin + imidacloprid was the most consistent and effective treatment against stink bug infestation (Fig. 3.4).

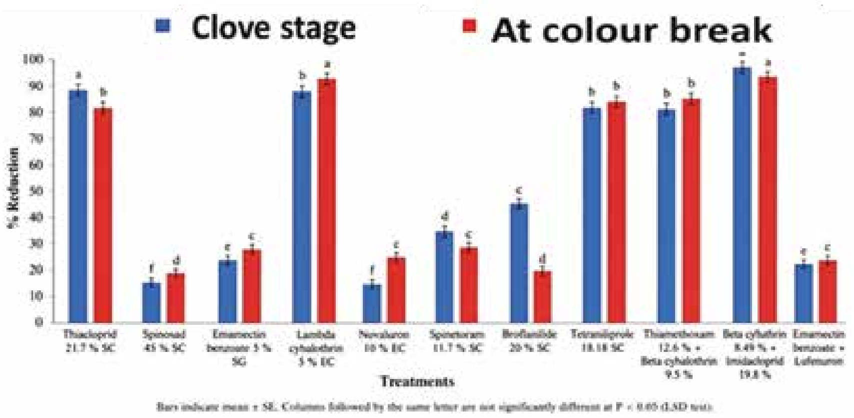


Fig. 3.4. Efficacy of different insecticides against litchi stink bug, *Tessarotoma javanica*

The efficacy of different insecticides against litchi flower webber, Statherotis leucaspis, was assessed during the "before flower opening" and "clove stage" conditions. Significant differences among treatments were observed ($P < 0.05$). During the before flower opening stage, beta-cyfluthrin 8.49% + imidacloprid 19.8% recorded the highest reduction (71.42 ± 4.15%), followed by spinosad 45% SC and emamectin benzoate 5% SG (66.67 ± 1.98% and 66.67 ± 2.15%, respectively). Thiacloprid 21.7% SC, lambda-cyhalothrin 5% EC, and emamectin benzoate + lufenuron were comparatively less effective. At the clove stage, novaluron 10% EC and beta-cyfluthrin + imidacloprid were found to be the most effective treatments, each recording 83.33% reduction in flower webber population. Lambda-cyhalothrin 5% EC and emamectin benzoate + lufenuron also showed high efficacy with 75.00% reduction, whereas thiacloprid 21.7% SC recorded the lowest reduction (16.67 ± 1.67%). The results clearly indicated that beta-cyfluthrin + imidacloprid maintained consistent performance across both stages and was among the best treatments for managing flower webber infestation (Fig. 3.5).

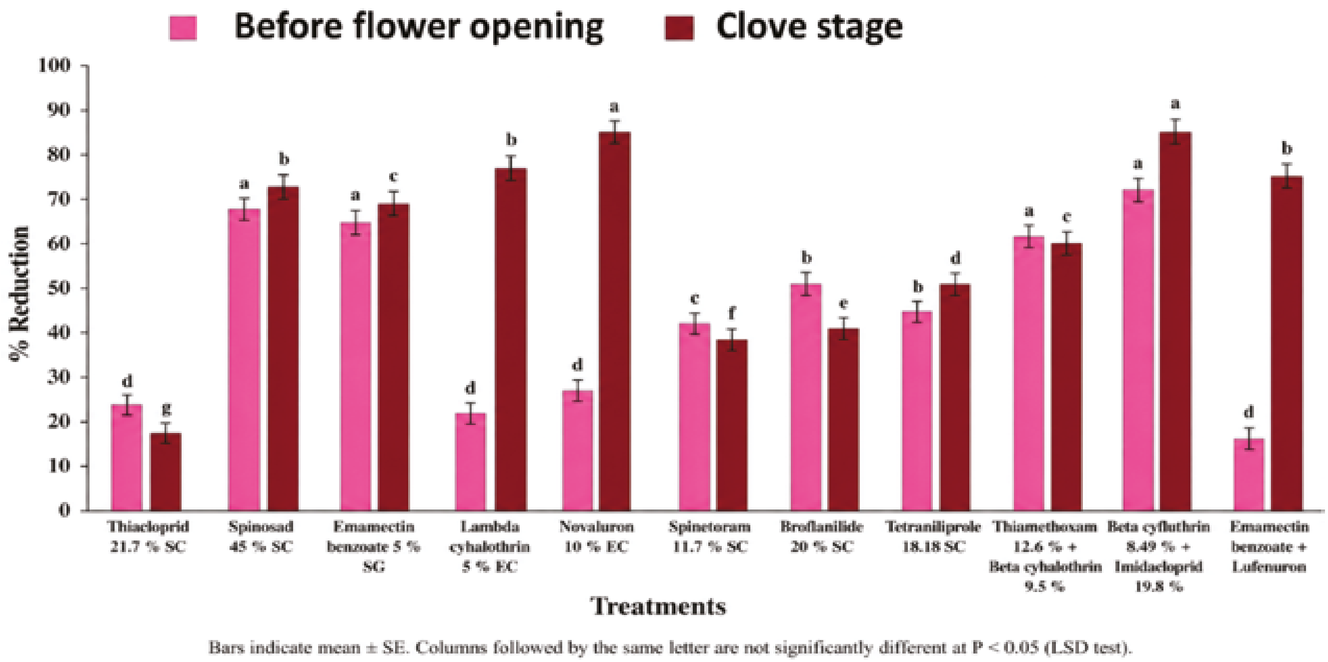


Fig. 3.5. Efficacy of different insecticides against litchi flower webber, *Sthaerotis leucaspis*

The study assessed insecticide efficacy against fruit borer by measuring fruit drop and fruit infestation at 20 and 10 days before harvest (DBH). At 20 DBH, emamectin benzoate 5% SG and spinetoram 11.7% SC were most effective, showing 0.00 ± 0.00 fruit drop after the first spray and 0.00 ± 0.00 infested fruits at harvest, whereas thiacloprid 21.7% SC was less effective (5.71 ± 0.67 drop; 10.00 ± 0.67 infestation). At 10 DBH, emamectin and spinetoram again provided near-complete control (~0 drop and ~0 infestation), while thiacloprid showed higher losses (6.25 ± 0.78 drop; 6.67 ± 1.07 infestation). Treatment effects were significant at both timings ($P < 0.05$; LSD 2.87 at 20 DBH and 3.89 at 10 DBH), confirming emamectin benzoate and spinetoram as the most effective options (Table 3.4).

Table 3.4. Efficacy of different insecticides against litchi fruit and shoot borer, *Conopomorpha sinensis*

Treatments	Fruit borer infestation (20 days before harvesting)		Fruit borer infestation (10 days before harvesting)	
	Number of fruits dropped after 1st spray	Number of fruits infested at harvest /100 fruit	Number of fruits dropped after 2nd spray	Number of fruits infested at harvest /100 fruit
Thiachloprid 21.7 %SC	5.71 ± 0.67 b	10.00 ± 0.67 d	6.25 ± 0.78 b	6.67 ± 1.07 c
Spinosad 45 %SC	5.56 ± 0.98 b	16.67 ± 1.23 c	0.00 ± 0.89 d	5.00 ± 0.08 c
Emamectin benzoate 5 % SG	3.70 ± 0.29 c	15.38 ± 0.98 c	5.00 ± 0.76 b	0.00 ± 0.78 d
Lambda cyhalothrin 5 % EC	2.85 ± 1.00 c	28.57 ± 1.56 b	5.00 ± 0.74 b	0.00 ± 0.64 d
Novaluron 10 % EC	6.66 ± 0.34 b	0.00 ± 1.67 e	5.55 ± 0.56 b	0.00 ± 0.63 d

Treatments	Fruit borer infestation (20 days before harvesting)		Fruit borer infestation (10 days before harvesting)	
	Number of fruits dropped after 1st spray	Number of fruits infested at harvest /100 fruit	Number of fruits dropped after 2nd spray	Number of fruits infested at harvest /100 fruit
Spinetoram 11.7 % SC	5.26 ± 0.56 b	0.00 ± 0.00 e	0.00 ± 0.04 e	3.57 ± 0.67 c
Broflanilide 20 % SC	6.66 ± 0.58 b	28.07 ± 1.67 b	4.35 ± 0.78 c	8.33 ± 0.60 b
Tetraniliprole 18.18 SC	3.12 ± 0.54 c	12.19 ± 1.78 d	5.71 ± 0.56 b	10.53 ± 0.89 b
Thiamethoxam 12.6 % + Beta cyhalothrin 9.5 %	5.88 ± 0.53 b	13.33 ± 1.74 c	8.57 ± 0.53 b	0.00 ± 0.74 d
Beta cyfluthrin 8.49 % + Imidachloprid 19.8 %	2.86 ± 0.98 c	15.90 ± 1.83 c	6.66 ± 0.64b	0.00 ± 0.67 d
Emamectin benzoate + Lufenuron	0.00 ± 0.00 d	14.28 ± 1.78 c	2.85 ± 0.07c	5.26 ± 0.63 c
Control	33.33 ± 0.78 a	60.00 ± 1.84 a	26.47 ± 0.63 a	60.00 ± 0.67 a
F-value	125.98	231.05	129.93	229.142
P-value	< 0.05	< 0.05	< 0.05	< 0.05
LSD	2.87	3.89	2.16	3.81

Incidence of looper complex in litchi

This study investigates the species composition, phenology, and weather-driven dynamics of looper pests associated with the Shahi variety of litchi (Fig. 3.6). Molecular identification using COI barcoding revealed five looper species: *Perixera illepidaria, Hyposidra talaca, Thalassodes immisaria, Sympis rufibasis*, and *Autoba abrupta*. Among these, *P. illepidaria* was identified as the dominant pest, exhibiting the fastest life cycle (approximately 15–19 days from larva to adult) and causing up to 80% defoliation in certain outbreaks. We observed significant differences in the developmental stages of these species, with *H. talaca* having the longest larval phase (10.93 ± 0.34 days) and *A. abrupta* showing the longest pupal (13.27 ± 0.60 days) and adult longevity (11.13 ± 0.16 days).

The seasonal abundance of loopers varied significantly between 2024 and 2025, with *P. illepidaria* showing peak infestations in late autumn of 2025, reaching densities as high as 49 larvae per unit. Weather parameters, such as wind speed and cloud cover, were identified as significant predictors of looper abundance, with *H. talaca* and *P. illepidaria* exhibiting strong negative correlations with temperature and humidity. Regression models explained 36.20% of the variation in *H. talaca* populations, with wind speed and cloud cover being key predictors. These findings highlight the critical role of weather conditions and seasonal plant phenology in shaping looper dynamics. Our study provides insights that can enhance pest forecasting and integrated pest management strategies, contributing to sustainable litchi cultivation by optimizing control interventions based on species-specific biology and climatic patterns.

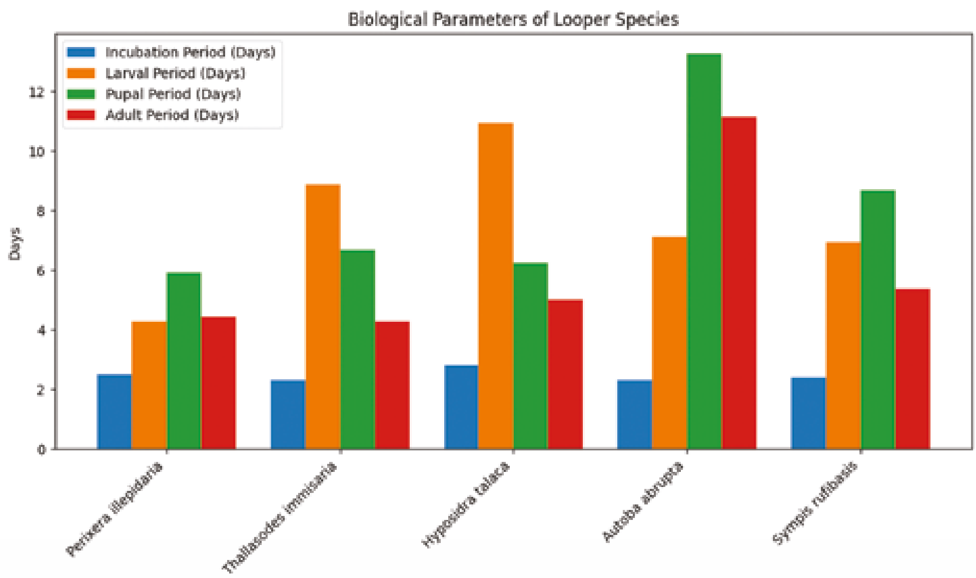


Fig. 3.6. Biology of different looper species in litchi

3.3. Understanding spatio-temporal changes in host-pests interactions and population dynamics of litchi under changing climate scenarios

Population dynamic and Seasonal incidence of insect pest of litchi in 2025 (SMW 1–52)

Pest monitoring on Shahi and China litchi revealed strong seasonal peaks and clear cultivar differences across lepidopteran complexes, litchi stink bug (*Tessarotoma javanica*), and coleopteran pests (ash and red weevils). Overall, pest pressure was low in early weeks, shifted during the monsoon, and peaked most severely in the late season, especially for the geometrid complex.

Lepidopteran pests: On Shahi, early-season activity (SMW 1–9) was moderate, followed by a major pre-monsoon build-up of *Sthaerotis leucaspis* from SMW 13 with a peak in SMW 19 (20.25), then disappearance by SMW 25. During the humid/rainy period, *Dudua aprobola* dominated from SMW 21–31 and peaked in SMW 25 (17.30). The most serious outbreak occurred in SMW 41–46, driven by the geometrid complex; the annual maximum was in SMW 43, when *Perixera illepidaria* reached 49.23, along with high *Hyposidra talaca* (9.60) and *Thallasodes immisaria* (11.78). Overall dominance on Shahi was *P. illepidaria* > *D. aprobola* > *S. leucaspis*. On China, lepidopteran activity started later (after SMW 7), remained low–moderate mid-season, and S. leucaspis dominated during humid weeks (SMW 25–34) peaking in SMW 31 (5.50). The major geometrid outbreak also occurred in SMW 35–46, peaking in SMW 43 with *P. illepidaria* 19.00, accompanied by *H. talaca* (4.00) and *T. immisaria* (3.20); minor noctuids peaked in the same week. Infestation ended after SMW 46–48.

Litchi stink bug (*T. javanica*): On Shahi, eggs peaked early in SMW 14 (4.125), and nymphs showed the highest seasonal peak in SMW 16 (48.41). Adult populations persisted and showed a strong late-season rise, reaching the maximum in SMW 50 (24.73). On China, eggs were lower and peaked in SMW 24 (1.25), while both nymphs and adults reached their highest levels in SMW 35 (nymphs 4.57; adults 7.525). Adults persisted longer into late weeks with a minor increase around SMW 48.

Coleopteran pests (ash and red weevils): On Shahi, coleopterans were mainly late-season pests (SMW 33–45). Ash weevil dominated, peaking in SMW 36 (2.45) with a second rise in SMW 40 (2.15); red weevil remained low, peaking in SMW 35 (1.10). On China, coleopterans appeared earlier (from SMW 26) and peaked in SMW 35 (ash weevil 2.00; red weevil 1.55), then declined sharply after SMW 46.

Key annual risk windows: (i) SMW 19 (pre-monsoon *S. leucaspis* peak on Shahi), (ii) SMW 25 (monsoon peak of *D. aprobola* on Shahi), (iii) SMW 35–36 (stink bug peak on China; coleopteran peaks on both cultivars), and (iv) SMW 41–46, especially SMW 43, the highest geometrid outbreak period, particularly severe on Shahi.

Incidence and identification of mango mealy bug, *Drosicha mangiferae* in litchi

Litchi (*Litchi chinensis Sonn.*), a major subtropical fruit belonging to the Sapindaceae family, is extensively grown in India. However, it faces significant threats from various insect pests, notably the mango mealy bug, *Drosicha mangiferae* (Stebbing). This research was conducted at the Litchi farm of ICAR-NRC on Litchi, Muzaffarpur, Bihar, India, from the 2nd week of April 2023 to the last week of June 2025. The study focused on examining the population dynamics and seasonal incidence of mango scales on litchi. The adult insects were identified based on their morphological characteristics, along with molecular identification using partial mitochondrial cytochrome oxidase 1 (*CO1*) gene sequences (Fig. 3.7). Both nymphs and adults of the mango scale suck sap from young shoots, inflorescences, and fruit peduncles, causing distorted leaves, yellowing, and premature fruit and flower drop. These pests significantly affect fruit retention and ultimately, the yield of litchi crops. The results revealed that the incidence of mango scales first appeared in the 2nd week of April and persisted until the fruit harvest. The peak population was observed during the 1st week of May (18th SMW) in 2023–2024 and the 2nd week of May (19th SMW) in 2024–2025. Additionally, the mango scales population exhibited a significant positive correlation with rainfall ($r = 0.78^*$), emphasizing the critical role of rainfall in the emergence and life cycle of these pests. These findings provide detailed insights into the incidence, damage symptoms, identification, and seasonality of mango scales in litchi cultivation in Bihar, India. The data gathered can be utilized to predict seasonal pest outbreaks and aid in the planning of integrated pest management strategies, particularly targeting key phenological stages of the litchi crop.

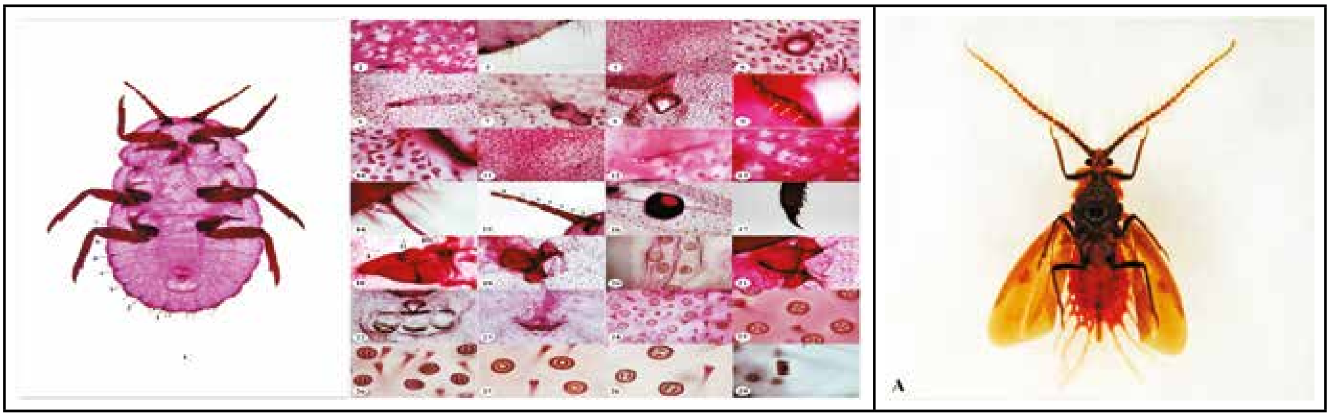


Fig. 3.7. Detailed morphological features of female and male of mango mealy bug, *Drosicha mangiferae*

3.4. Characterisation of behaviour modifying chemicals for the management of insect pests of litchi

The electrophysiological response of litchi stink bug, *Tessarotoma javanica*

Over the last two years, mean electrophysiological (EAG) responses of *Tessarotoma javanica* were recorded against a broad panel of litchi-associated volatiles, including terpenoids, aldehydes, alcohols, alkanes, and sulfur compounds (e.g., β-caryophyllene, ethyl acetate, linalool, geraniol, nonanal, decanal, undecane, tridecane, dimethyl disulfide, dimethyl trisulfide).

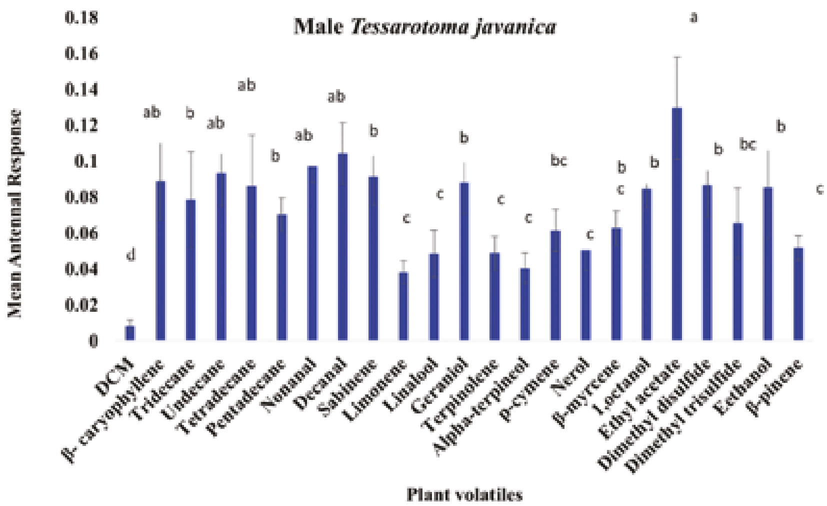


Fig. 3.8. Mean antennal response of male stink bug, *Tessarotoma javanica* to different plant volatiles

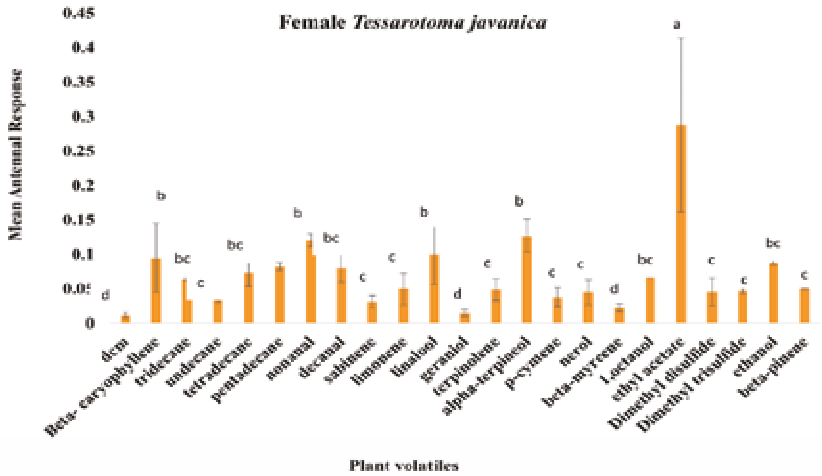


Fig. 3.9. Mean antennal response of female stink bug, *Tessarotoma javanica* to different plant volatiles

Pooled two-year mean data showed that males consistently exhibited the strongest antennal sensitivity to ethyl acetate, geraniol, decanol, undecane, and β-caryophyllene, indicating high responsiveness to selected host-related cues. In contrast, females displayed higher mean responses to ethyl acetate, nonanal, linalool, α-terpineol, and β-caryophyllene, suggesting stronger perception of aldehydes and monoterpene alcohols commonly linked with host plant odors (Figure 3.8 and 3.9). The two-year mean response profiles confirm sex-specific differences in volatile perception, implying that males and females may rely on partially different olfactory cues for host location and/or reproductive behavior.

Further work is recommended to validate behavioral relevance through laboratory bioassays and field trials, testing these candidate volatiles as attractants/repellents and integrating them with plant-based repellents and pheromone-based tools for stink bug management.

Biology of litchi stink bug, *Tessarotoma javanica* and litchi leaf folder, *Sthaerotis leucaspis* reared on litchi cultivar China

The biology and life cycle of stink bug, *Tessaratoma javanica* was studied in caged net and laboratory conditions. In field conditions, under caged net, the egg period, 1st nymphal period, 2nd nymphal period, 3rd nymphal period, 4th nymphal period, 5th nymphal period and adult period were observed to be 6-10 days, 5-7 days, 10-12 days, 7-8 days, 7-10 days, 10-14 days and 40-45 days respectively. The age stage survival rate of *T. javanica* on Shahi and China cultivars is depicted in figure 3.10 & 3.11.

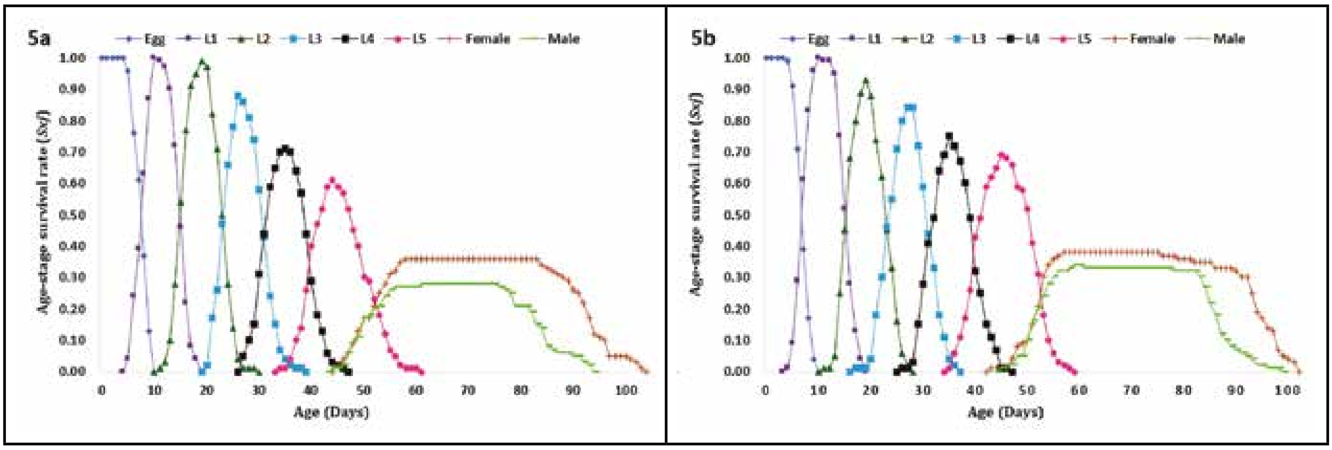


Fig. 3.10. Life table studies of *Tessarotoma javanica* in Shahi and China cultivars of litchi

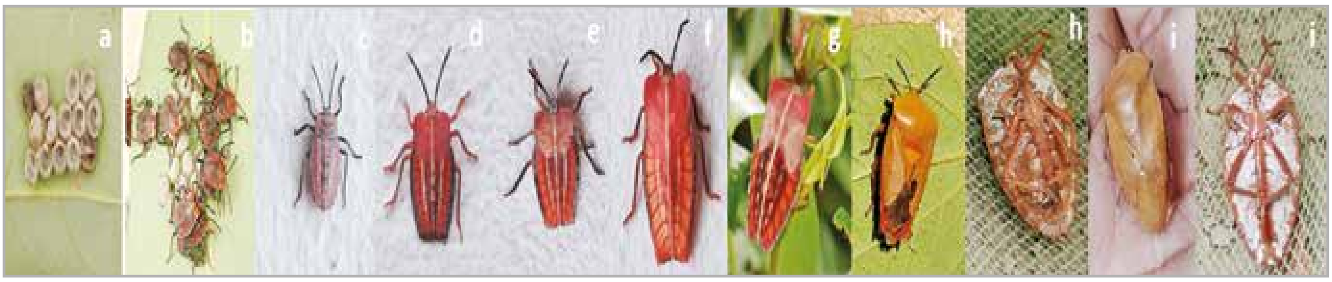


Fig. 3.11. Detailed biological parameters of *Tessarotoma javanica* on Shahi and China variety of litchi

3.5. Residue analysis of pesticides in litchi fruits

Studies were conducted to assess the residue levels of fungicides and insecticides in litchi fruits under different conditions to evaluate their safety and compliance with permissible limits. Fruit samples were analyzed for residue load in both peel and pulp. The study included three categories of samples, viz., (i) fruits from planned experimental plots with known spray schedules, (ii) samples collected from farmers' orchards, and (iii) market samples collected from retailers at different locations.

(i) Residue levels in experimental samples (known spray schedule)

In the planned experiment, fungicides were applied at 15, 10 and 5 days before harvest, and residue levels were estimated at harvest. Fungicide residues were detected in all the samples of peel from fruits sprayed at 15 days, 10 days, or 5-days before harvesting except thiophanate methyl at 15 and 10 days, compared to residue level below limit of quantification in fruits from untreated trees. Residues in pulp samples were below detectable limit (BLQ) except copper oxychloride and carbendazim but that were also below MRL (Table 3.5).

Table 3.5. Fungicide residues in litchi fruit peel and pulp

Compound name	Sampling before harvest (days)	Litchi peel Mean Residue concentration (mg/kg)	Litchi pulp Mean Residue concentration (mg/kg)
T1 (Thiophanate Methyl)	15	BLQ	BLQ
	10	BLQ	BLQ
	5	0.18 ± 0.01	BLQ
T2 (Difenoconazole)	15	0.43 ± 0.03	BLQ
	10	0.72 ± 0.03	BLQ
	5	1.04 ± 0.05	BLQ
T3 (Azoxystrobin)	15	0.15 ± 0.05	BLQ
	10	0.43 ± 0.01	BLQ
	5	0.53 ± 0.03	BLQ
T4 (Copper oxychloride)	15	1.74 ± 0.02	1.10 ± 0.07
	10	2.36 ± 0.11	1.48 ± 0.05
	5	3.58 ± 0.24	2.54 ±
T5 (Carbendazim)	15	0.28 ± 0.29	BLQ
	10	0.52 ± 0.01	0.02 ± 0.01
	5	0.94 ± 0.06	0.03 ± 0.01
T6 (Control)	15	BLQ	BLQ
	10	BLQ	BLQ
	5	BLQ	BLQ

SD-Standard deviation, BLQ- Below limit of Quantification i.e. < 0.010 mg/kg

(ii) Residue levels in farmers' field samples

Residue analysis of 20 samples collected from farmers' orchards showed that most of the samples were either below detectable limit (BLQ) or below MRL. Only a few samples showed detectable residues. Residues, wherever detected, were confined to the peel, while pulp samples were mostly BLQ.

(iii) Residue levels in market samples

Analysis of 30 market samples revealed that majority of the samples was below detectable limit (BLQ) or below MRL, with only a few samples showing detectable residues. Similar to field samples, residues were detected mainly in the peel, while pulp samples were mostly BLQ.

Thus, the results of the studies indicated that pesticide residues in litchi fruits were largely confined to the peel, while pulp remained mostly free from residues (BLQ). Thiophanate methyl was found to be safe when applied up to 10 days before harvest, and most of the farmers' and market samples were within safe limits.

Pesticide residue analysis in litchi samples collected from NRCL experimental plots, farmer fields and markets

The results of pesticide residue analysis on litchi fruits, based on various compounds and spray intervals before harvest, show that Spinosad (T2) and Emamectin Benzoate (T3) had no detectable residues when sprayed 15 days before harvest (Table 3.6). For these compounds, no residues were found in the pulp, and the peel showed minimal traces, making them ideal choices for use closer to harvest. Thiacloprid (T1), Lambda Cyhalothrin (T4), Spinetoram (T6), and Flubendiamide (T7) exhibited some residue levels, with Thiacloprid and Lambda Cyhalothrin showing increased residue concentrations as the harvest time approached (1 day before harvest). These compounds were found to have higher residue levels, especially in the peel, closer to harvest, indicating that longer pre-harvest intervals might be necessary to ensure lower residue concentrations.

Novaluron (T5), in particular, showed the highest residue concentrations at the 1-day pre-harvest interval, making it less suitable for use near harvest time. Despite this, Spinosad and Emamectin Benzoate remained the most favorable options due to their lower residue levels even at shorter pre-harvest intervals. On the other hand, Flubendiamide and Spinetoram, which showed no residues at 15 and 10 days before harvest, had only small traces at shorter intervals, further emphasizing the importance of timing in pesticide application.

In conclusion, Spinosad and Emamectin Benzoate are recommended as the best options for pesticide use when spraying 15 days before harvest, as they result in minimal residues. Thiacloprid, Lambda Cyhalothrin, and Novaluron should be avoided or used with caution as their residue levels tend to increase closer to harvest. Proper timing of pesticide applications is crucial to ensuring both effective pest control and minimal residue levels in harvested litchi fruits.

Table 3.6. Level of insecticide residue in litchi fruits, when sprayed at different days before harvest

S. No.	Name of the compound	Spray before harvest (days)	Average residues (mg/kg)	
			Peel	Pulp
1	T1 (Thiacloprid)	15	0.154	BLQ
		10	0.274	BLQ
		5	0.741	BLQ
		1	1.345	BLQ
2	T2 (Spinosad)	15	BLQ	BLQ
		10	BLQ	BLQ
		5	0.034	BLQ
		1	0.412	BLQ
3	T3 (Emamectin benzoate)	15	BLQ	BLQ
		10	BLQ	BLQ
		5	BLQ	BLQ
		1	0.347	BLQ
4	T4 (Lambda cyhalothrin)	15	0.066	BLQ
		10	0.165	BLQ
		5	0.352	BLQ
		1	0.84	BLQ
5	T5 (Novaluron)	15	0.348	BLQ
		10	0.716	BLQ
		5	1.056	BLQ
		1	1.587	BLQ
6	T6 (Spinetoram)	15	BLQ	BLQ
		10	0.1	BLQ
		5	0.221	BLQ
		1	0.346	BLQ
7	T7 (Flubendiamide)	15	BLQ	BLQ
		10	BLQ	BLQ
		5	0.057	BLQ
		1	0.476	BLQ
8	T8 (Control)	15	BLQ	BLQ
		10	BLQ	BLQ
		5	BLQ	BLQ
		1	BLQ	BLQ

Further, residue analysis showed that fungicide deposits were detected primarily in the litchi peel, while pulp residues were BLQ (below limit of quantification) at all sampling intervals across treatments. At 15 days before harvest (DBH), thiophanate methyl, azoxystrobin and the control were BLQ in both peel and pulp, whereas measurable peel residues were recorded for difenoconazole (0.247 mg/kg), copper oxychloride (1.125 mg/kg), and carbendazim (0.412 mg/kg) (Table 3.7).

At 10 DBH, peel residues increased and remained detectable for difenoconazole (0.514 mg/kg), azoxystrobin (0.208 mg/kg), copper oxychloride (1.834 mg/kg), and carbendazim (0.826 mg/kg), while thiophanate methyl and control remained BLQ.

At 5 DBH, peel residues were recorded for all fungicides except the control, with thiophanate methyl showing 0.347 mg/kg, difenoconazole 0.847 mg/kg, azoxystrobin 0.371 mg/kg, copper oxychloride 2.725 mg/kg, and carbendazim

1.136 mg/kg; pulp remained BLQ throughout. At 1 DBH, peel residues reached their maximum levels, particularly for copper oxychloride (4.05 mg/kg), followed by difenoconazole (1.478 mg/kg), carbendazim (1.375 mg/kg), azoxystrobin (0.814 mg/kg), and thiophanate methyl (0.714 mg/kg), whereas no residues were quantifiable in the pulp. Overall, residues increased as harvest approached and were consistently higher in peel than pulp, indicating minimal translocation of these fungicides into edible pulp under the tested conditions.

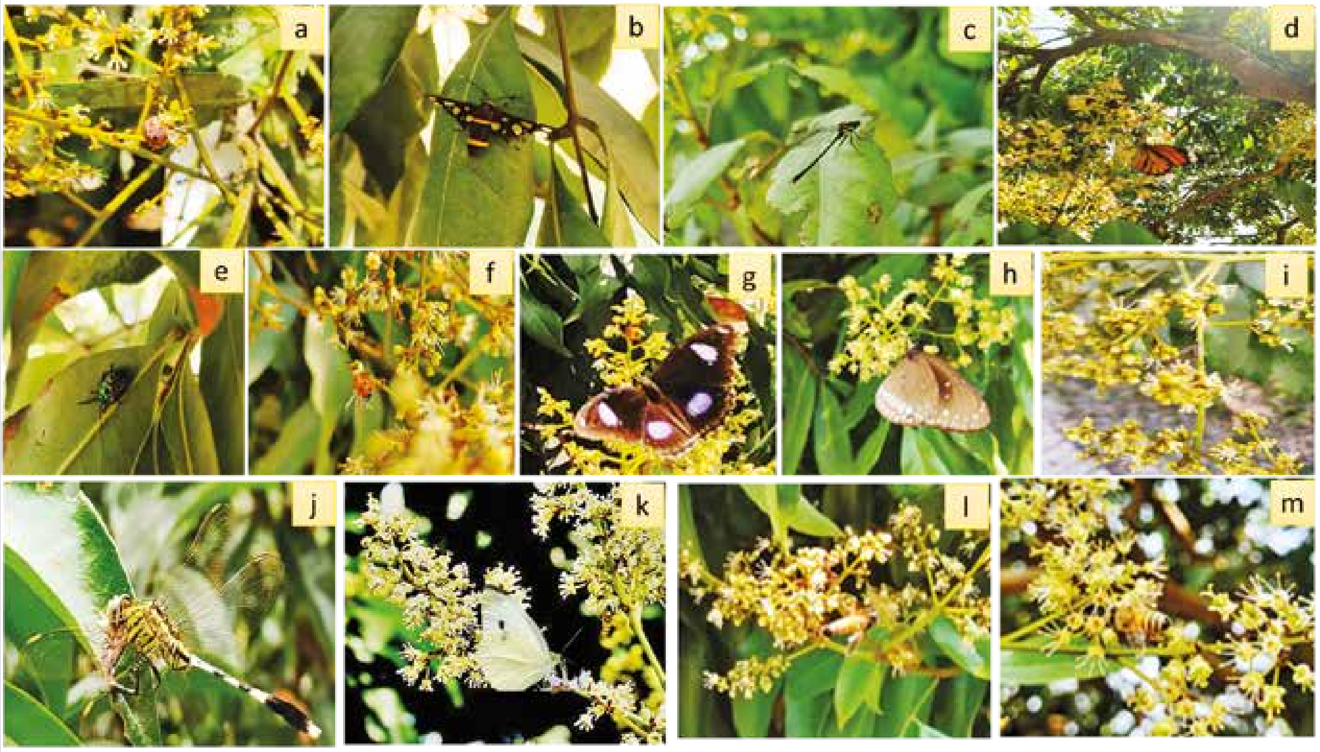
Table 3.7. Level of fungicide residue in litchi fruits, when sprayed at different days before harvest

S. No.	Name of the compound	Spray before harvest (days)	Average residues (mg/kg)	
			Peel	Pulp
1	T1 (Thiophanate Methyl)	15	BLQ	BLQ
		10	BLQ	BLQ
		5	0.347	BLQ
		1	0.714	BLQ
2	T2 (Difenoconazole)	15	0.247	BLQ
		10	0.514	BLQ
		5	0.847	BLQ
		1	1.478	BLQ
3	T3 (Azoxystrobin)	15	0.087	BLQ
		10	0.208	BLQ
		5	0.371	BLQ
		1	0.814	BLQ
4	T4 (Copper oxychloride)	15	1.125	BLQ
		10	1.834	BLQ
		5	2.725	BLQ
		1	4.05	BLQ
5	T5 (Carbendazim)	15	0.412	BLQ
		10	0.826	BLQ
		5	1.136	BLQ
		1	1.375	BLQ
6	T6 (Control)	15	BLQ	BLQ
		10	BLQ	BLQ
		5	BLQ	BLQ

3.6. Enhancing the livelihood of litchi farmers through beekeeping and assessing the agrochemicals in honey (National Bee Board)

Pollination Dynamics of *Apis mellifera* in Litchi (*Litchi chinensis*) Orchards: Influence of Floral Phenology and Weather Factors

Litchi (*Litchi chinensis Sonn.*) is a subtropical fruit crop that relies on insect-mediated pollination for optimal yield. This study, conducted during the 2025 flowering season (7–29 March, 2025) at ICAR-National Research Centre on Litchi, Muzaffarpur, Bihar, aimed to examine the floral phenology, insect visitation, and environmental factors influencing the pollination dynamics of *Apis mellifera (Fig. 3.12)*. Observations were made on ten randomly selected trees, with insect activity monitored at four daily intervals (8–10 AM, 10–12 PM, 12–2 PM, and 2–4 PM). A total of 13 insect species were recorded visiting litchi flowers, with *Apis mellifera*, *Apis dorsata*, and hoverflies (*Eristalis* spp.) being the primary pollinators. The highest settling rate of *A. mellifera* (45.78 ± 1.74) occurred during the peak appearance of M2 flowers (90.02 ± 4.66) on 20th March, indicating a strong temporal alignment between floral phenology and pollinator activity. Correlation analysis showed a significant positive relationship between M2 flowers and bee settling rate, particularly at 8–10 AM (r = 0.767**) and 10–12 PM (r = 0.747**). Environmental factors like cloud cover, temperature, and wind gusts also positively correlated with *A. mellifera* activity. The study highlights that afternoon hours, especially 12–4 PM, are ideal for bee foraging due to favorable environmental conditions. These findings suggest that beekeepers should place hives 5–7 days before the peak M2 flowering phase to optimize pollination efficiency and fruit set. This research provides valuable insights for enhancing litchi productivity through effective pollinator management.



a: Twelve spotted lady bird beetle, b: Handmaiden moth, c: Damsel fly, d: Monarch butterfly, e: Green Jewel bug, f: Seven spotted lady bird beetle , g: Blue moon butterfly, h: Common crow, i: Hover fly, j: Dragon fly, k: Cabbage butter fly, l: *Rock bee, m: European Bee*

Fig. 3.12. Incidence of diverse pollinators and foragers in litchi

Temporal Pollen Resource Integration in Pollinator-Friendly Litchi Agroecosystems

This study quantified spatio-temporal variation in pollen foraging by *Apis mellifera* across 11 litchi orchards in Muzaffarpur District, Bihar, during peak bloom (14th March–6th April, 2025). Wooden pollen traps were deployed on five healthy hives per orchard for 7 hours per day, with samples collected at 6-day intervals. Pollen pellets were sorted, weighed, and identified using DNA barcoding. Eleven plant species were confirmed in the bee-collected pollen spectrum, with sequences deposited in public databases.

A factorial randomized block design tested the effects of Place (11 orchards), Week (four weeks), and Pollen species (11 taxa) on pollen quantity and percentage. Significant effects were observed for all factors and interactions ($P < 0.01$). *Litchi chinensis* dominated the pollen profile, peaking during Weeks 2–3, coinciding with peak anthesis. Non-litchi species, such as *Bombax ceiba* and *Pithecellobium dulce*, occurred at lower but variable levels across sites and weeks. Spatial hotspots of litchi pollen were identified at Manikagaji, Sahila, and Prahaladpur.

The findings highlight strong spatial and temporal patterns in floral resource use during litchi bloom and demonstrate the reliability of DNA barcoding for identifying pollen sources. During peak flowering, *Apis mellifera* foraging was dominated by litchi pollen but diversified with local floral context and phenological stage. These results provide valuable guidance for apiary placement, timing of management interventions, and optimizing pollination services. They also offer a foundation for refining the regional floral calendar and managing supplemental floral resources to enhance colony nutrition and maximize litchi yield.

Recognizing the importance of continuous floral availability to sustain colonies beyond the short litchi bloom, the study explored the potential of planting diverse seasonal flora to promote non-migratory beekeeping in litchi-growing regions. By establishing and monitoring these species, researchers evaluated bee foraging preferences and the sequence of floral use across seasons. The findings demonstrated that bees readily adapted to the supplemental floral resources, as depicted in Figure 3.13 showing the diverse plant species visited by honey bees during the litchi and post-litchi periods.

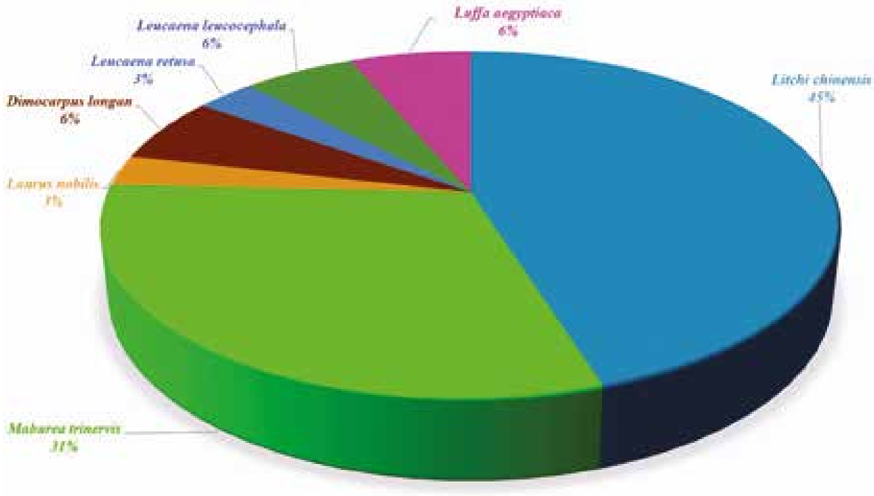


Fig. 3.13. Diverse types of pollen collected by *Apis mellifera* in litchi orchards

3.7 Entomofaunal Dynamics in Litchi Agri-Horticultural Systems: Diversity, Abundance, and Ecological Interactions (Bihar State Biodiversity Board)

Surveys conducted in litchi orchards across the districts of Muzaffarpur, Samastipur, Vaishali, and East Champaran revealed important information on pest incidence, natural enemies, and pollinator diversity in litchi ecosystems (Fig. 3.14). The major insect pests recorded were the litchi fruit and shoot borer, leaf roller, red weevil, litchi stink bug, and litchi mite. Among these, the fruit and shoot borer was found to be the most destructive pest, as its larvae damaged flowers, young shoots, and fruits. This led to symptoms such as distorted leaves, poor fruit retention, premature fruit drop, and overall reduction in orchard productivity. Leaf rollers and stink bugs also caused noticeable injury to foliage and developing fruits, while mites reduced plant vigor and fruit quality.

A wide range of beneficial natural enemies was present in the orchards. Parasitic wasps and predatory beetles were the most abundant and played a major role in suppressing pest populations. Their presence indicated a naturally occurring biological control system that can help reduce dependence on chemical pesticides.

The survey also recorded a rich diversity of floral visitors and pollinators, including honeybees, bumblebees, and hoverflies. *Apis mellifera* was identified as the dominant pollinator, with its foraging activity closely matching peak flowering periods. These findings highlight the importance of conserving both pollinators and natural enemies for sustainable litchi production and long-term orchard health.

Fig. 3.14. Survey of different Litchi orchards in Muzaffarpur, Samastipur, Vaishali and East Champaran conducted under BSBB

4. Integrated Postharvest Management to Reduce Losses, Improve Marketing and Product Diversification

4.1. Investigation and management of post-harvest losses in litchi

The present investigation was undertaken to evaluate the persistence, safety and functional role of *Bacillus subtilis* strain NRCL BS-01 on fruit surface, as well as assessing the effect of different pre-harvest treatments on post-harvest behaviour of fruits under ambient and cold storage conditions. The study aimed to understand microbial dynamics, biochemical changes and quality parameters influencing fruit deterioration, and to develop safe and effective interventions for extending shelf life.

Studies on formulation of *Bacillus subtilis* strain NRCL BS-01

(i) Development of suitable formulation for *Bacillus subtilis* (BS-01) for field application

Different formulations of *Bacillus subtilis* (BS-01) were evaluated to identify a suitable carrier system for maintaining cell viability under storage conditions. The treatments included Ringer solution, Ringer solution + trehalose (15 mM), SOC medium, $MgSO_4$ + skimmed milk (M-SKM), $MgSO_4$ + sucrose, and distilled water (control). The results indicated variable survival of bacterial cells under different formulations, with a gradual decline in viability over time under both room temperature and cold storage conditions. After successive refinement of formulations, the addition of Tween-20 and glycerol improved suspension stability and cell viability. Among the treatments, the formulation comprising distilled water + trehalose (2 mM) along with Tween-20 was found most effective in maintaining higher viable cell count over extended storage. This formulation sustained cell viability up to one year, indicating its suitability for field-level application of Bacillus subtilis (BS-01).

(ii) Retention of cells of *Bacillus subtilis* on fruit surface and viable count during storage

Progressive count of *Bacillus subtilis* before and after spray on fruit surface and during storage at different interval was assessed. Washing of three fruits in 100 ml distilled water were taken for study and 0.1 ml was plated onto nutrient agar (NA) plates. Results showed that cell count of *Bacillus subtilis* on sprayed fruit surface were almost 14,000 times more than on control fruits (12.7×10^6 cells per fruit compared to 900 in control) on the day of harvesting. This showed that spraying of BS formulation was successful in lodging fruit surface with *Bacillus subtilis* cells. Progressive count of *Bacillus subtilis* before and after spray on litchi fruit surface and during storage at different interval was taken

(iii) Progressive pH changes in BS-01 treated fruits during storage

To explore whether *Bacillus subtilis* colonization lowers the surface pH of litchi fruits and enhances post-harvest shelf life, an experiment was conducted. The hypothesis was that *Bacillus subtilis* colonization on the fruit surface, following a pre-harvest spray, may lead to a progressive decrease in pH. Hence, an experiment was conducted to study the effect of *Bacillus subtilis* (BS-01) colonization on surface pH of litchi fruits during storage. The pH of fruit surface was monitored at 0, 2, 4 and 6 days of storage at ambient temperature (25°C) and compared with untreated control.

The results indicated a progressive decrease in surface pH in BS-01 treated fruits over the storage period. The initial pH of fruit pericarp was recorded at 5.90 (Day 0), which gradually declined to 4.50 (Day 6). In contrast, control fruits showed relatively stable pH with only minor fluctuations during the storage period. The reduction in surface pH under BS-01 treatment indicates its potential role in modifying the fruit microenvironment, which may contribute to suppression of spoilage organisms and improvement in post-harvest shelf life.

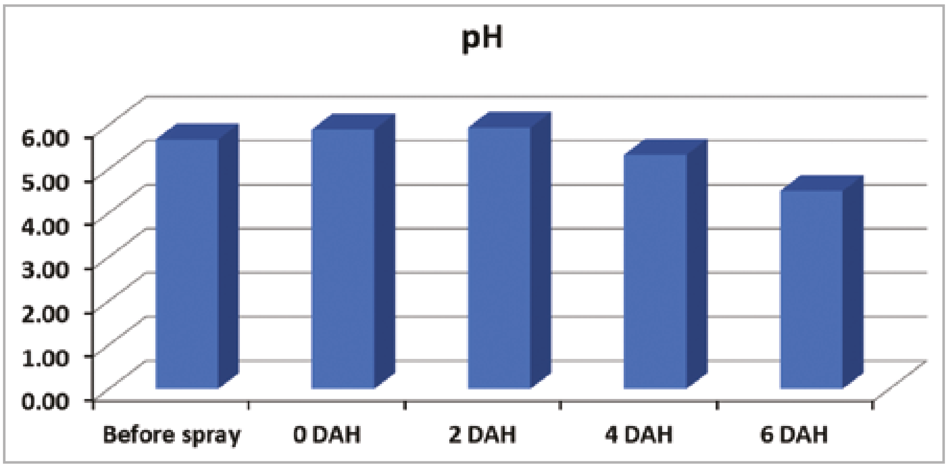


Fig. 4.1. Progressive pH values of the *Bacillus subtilis* (BS-01) treated fruits over a storage period 6 days at ambient temperature (25^{0}C)

Effect of different pre-harvest treatments on shelf life of litchi fruits

The experiment was conducted to evaluate the effect of different pre-harvest treatments applied 48 hours before harvest on post-harvest quality and shelf life of litchi fruits under ambient (25°C) and cold storage (4°C) conditions. Various biochemical and quality parameters were assessed during storage.

(i) Enzymatic activity (PAL, PPO and POD)

The activity of PAL, PPO and POD enzymes showed distinct trends during storage. The activities of PPO and POD increased progressively with storage duration under both ambient and cold storage conditions; however, the rate of increase was higher in control fruits as compared to treated samples. Fruits treated with BS-01 exhibited comparatively lower PPO and POD activity, indicating reduced enzymatic browning and slower deterioration. In contrast, control fruits showed higher enzyme activity, reflecting faster quality degradation. The activity of PAL decreased over the storage period, but the decline was relatively slower in BS-01 treated fruits compared to control, indicating better retention of phenylpropanoid metabolism and associated quality attributes (Fig. 4.2 & 4.3).

(ii) Total phenolic content

Total phenol content decreased gradually during storage under both conditions; however, significantly higher phenolic content was recorded in fruits treated with BS-01 and ethnomedicinal plant extracts compared to control and other treatments. The retention of higher phenolic content under these treatments indicates reduced oxidative degradation and better maintenance of fruit quality (Fig. 4.2 & 4.3).

(iii) Titratable acidity (TA) and total soluble solids (TSS)

Titratable acidity showed a declining trend with storage duration; however, the rate of decrease was comparatively lower in BS-01 treated fruits than in control, indicating delayed senescence. Total soluble solids (TSS) remained largely comparable among treatments initially, but showed a declining trend during prolonged storage, reaching up to 14.77°Brix in methionine-treated fruits (Fig. 4.4 & 4.5).

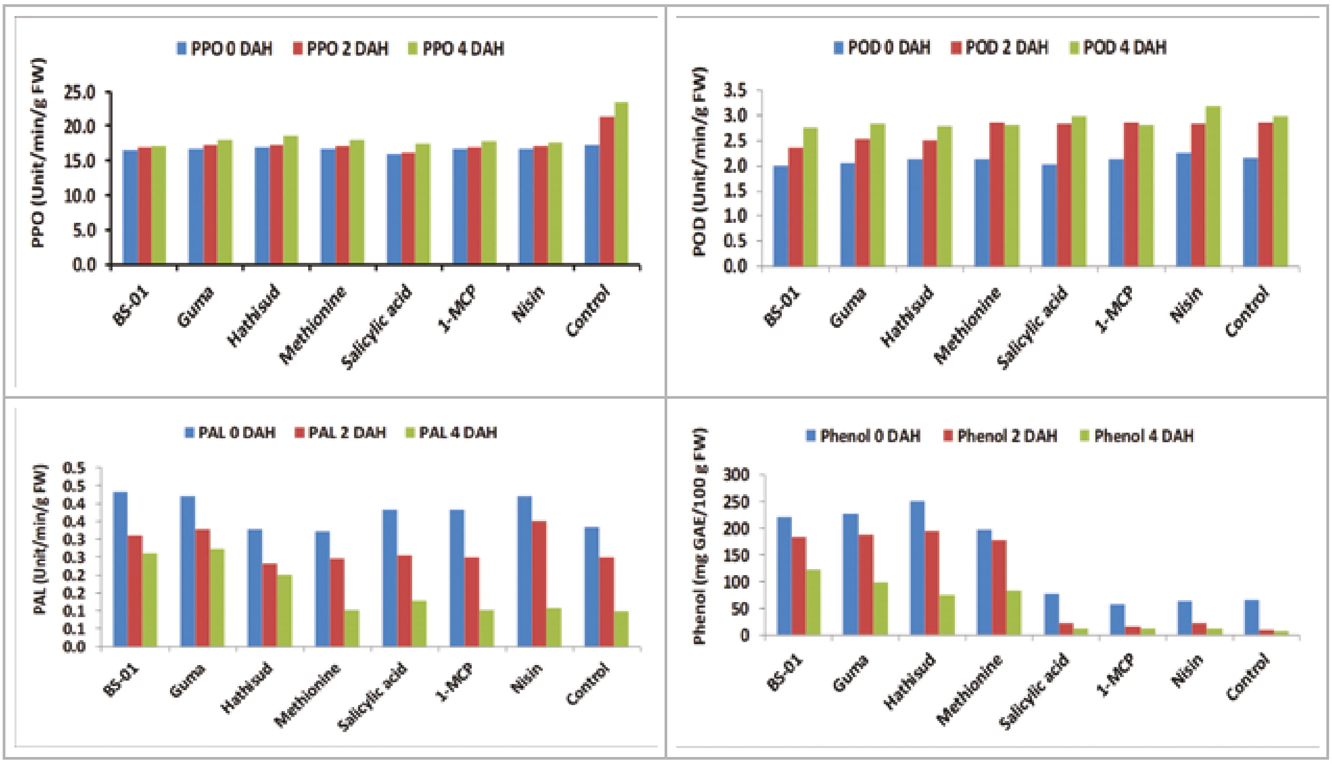
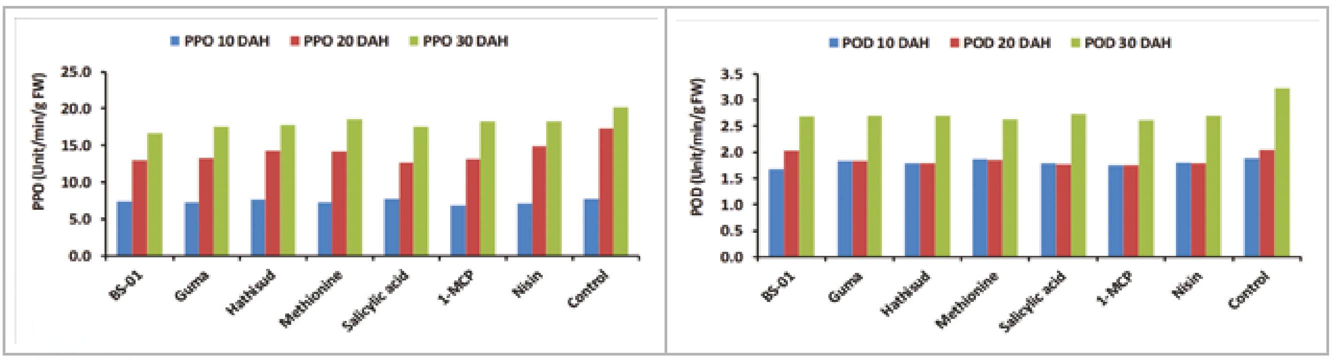


Fig. 4.2. **Effect of different pre-harvest treatments on different enzymatic activity (PPO, POD, PAL) and** total phenols of litchi fruits during ambient storage (25 °C)



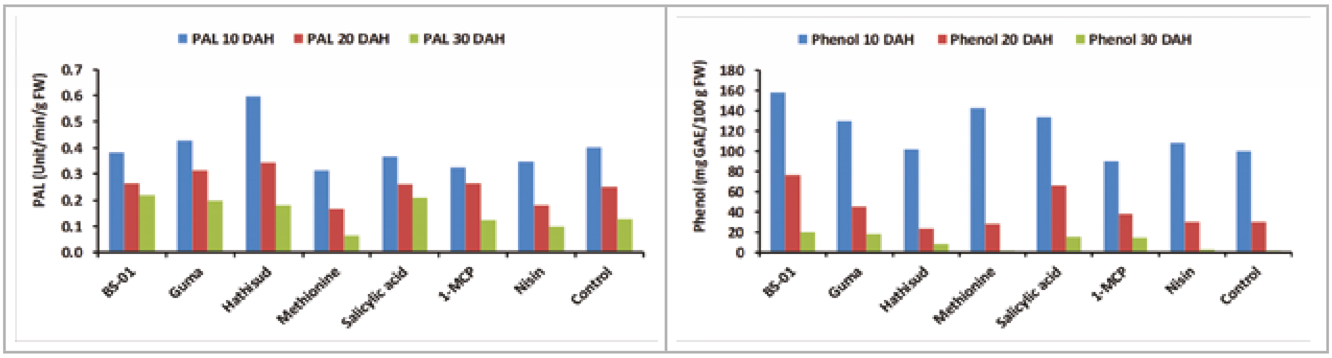


Fig. 4.3. **Effect of different pre-harvest treatments on different enzymatic activity (PPO, POD, PAL) and** total phenols of litchi fruits during storage at 4 °C

(iv) Anthocyanin content

Anthocyanin content decreased progressively during storage across all treatments. However, fruits treated with BS-01 and Hathisud extract recorded comparatively higher initial anthocyanin content and showed slower decline during storage than control. This indicates better retention of pericarp colour and reduced pigment degradation under these treatments (Fig. 4.4 & 4.5).

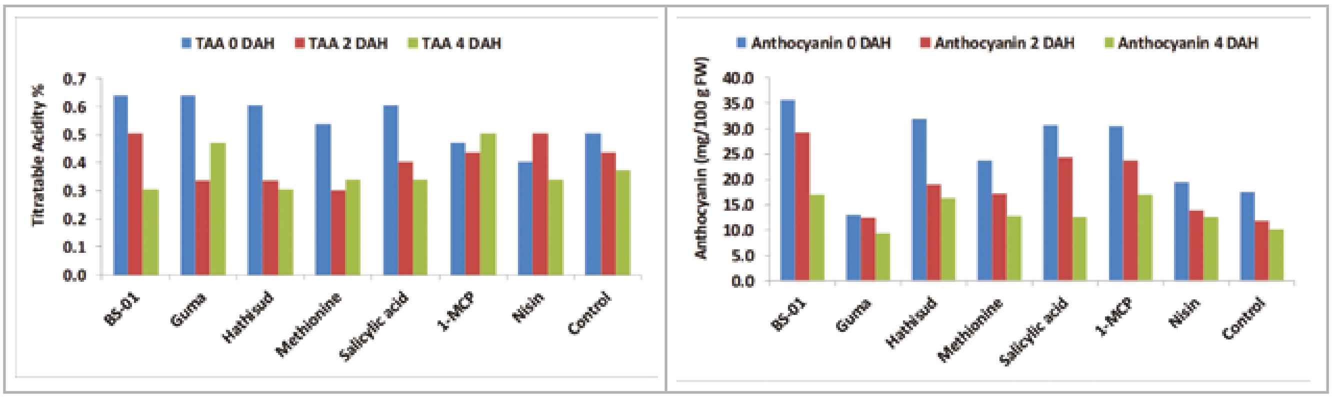


Fig. 4.4. Effect of pre-harvest treatments on titratable acidity (TA) and anthocyanin content of litchi fruits during storage at ambient conditions (25°C)

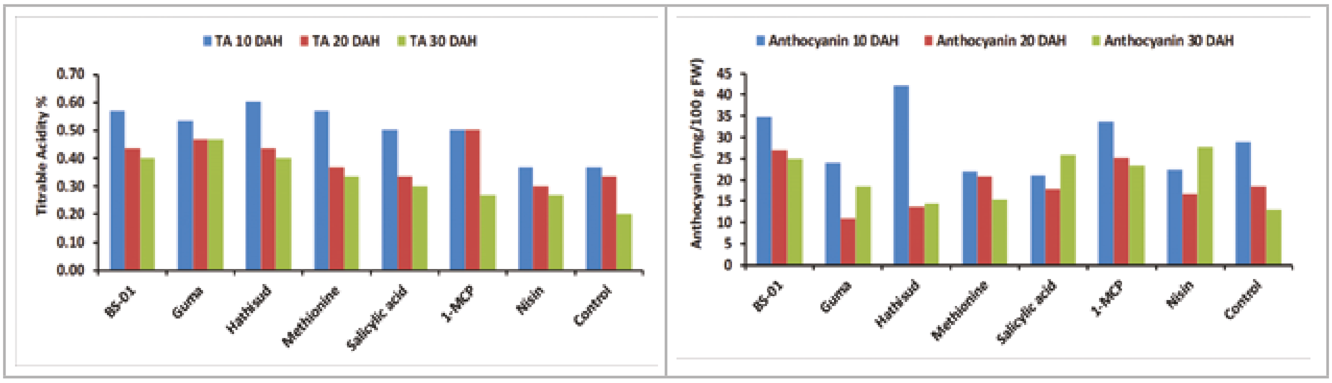


Fig. 4.5. Effect of pre-harvest treatments on titratable acidity (TA) and anthocyanin content of litchi fruits during storage at 4□

(v) Fruit decay and browning

Fruit decay and browning increased with storage duration, with comparatively higher values under ambient conditions (25°C) than cold storage (4°C). Among the treatments, BS-01 was the most effective, recording the lowest fruit decay and browning index throughout the storage period under both conditions, indicating consistent suppression of post-harvest deterioration.

At ambient storage, BS-01 treated fruits recorded mean fruit decay of 1.48% and browning index of 0.50 at 30 days, reflecting superior shelf life and quality retention. 1-MCP, nisin and salicylic acid exhibited moderate but stable efficacy, particularly at later storage stages, while Guma extract showed initial effectiveness but declined over time. In contrast, untreated control fruits recorded the highest decay and browning.

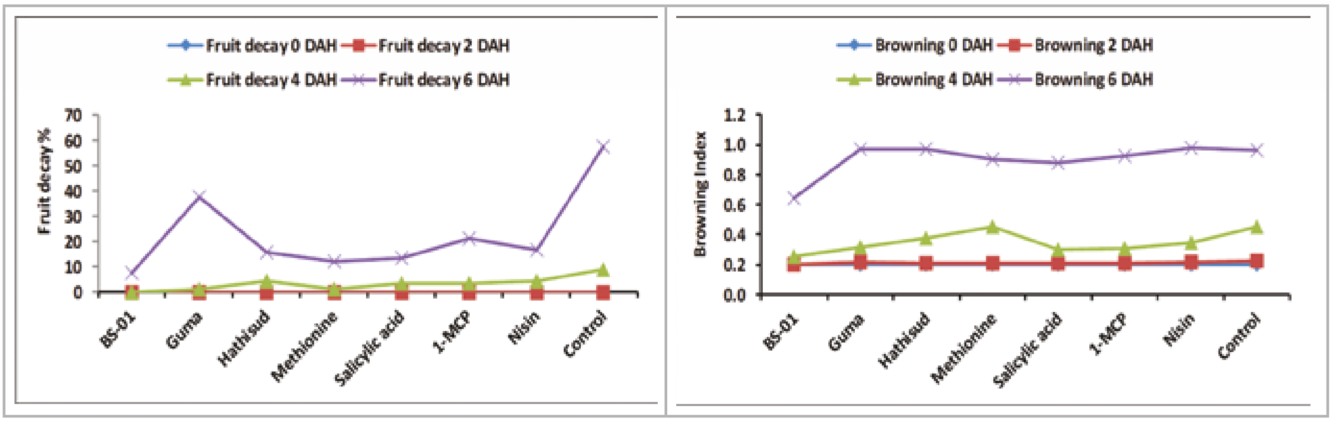


Fig. 4.6. Effect of pre-harvest spray treatments on fruit decay and browning of litchi fruits during storage at ambient conditions (25°C)

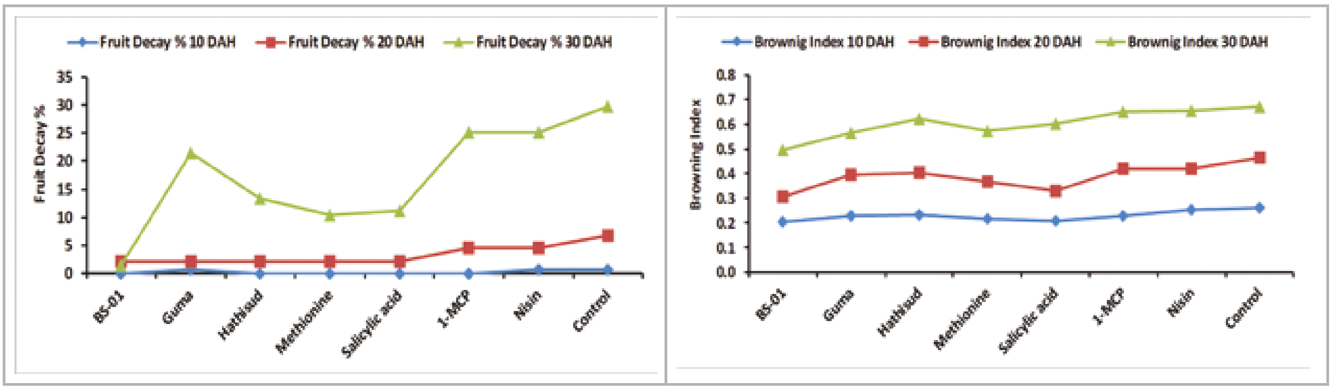


Fig. 4.7. Effect of pre-harvest spray treatments on fruit decay and browning of litchi fruits during storage at at ambient conditions (25°C)

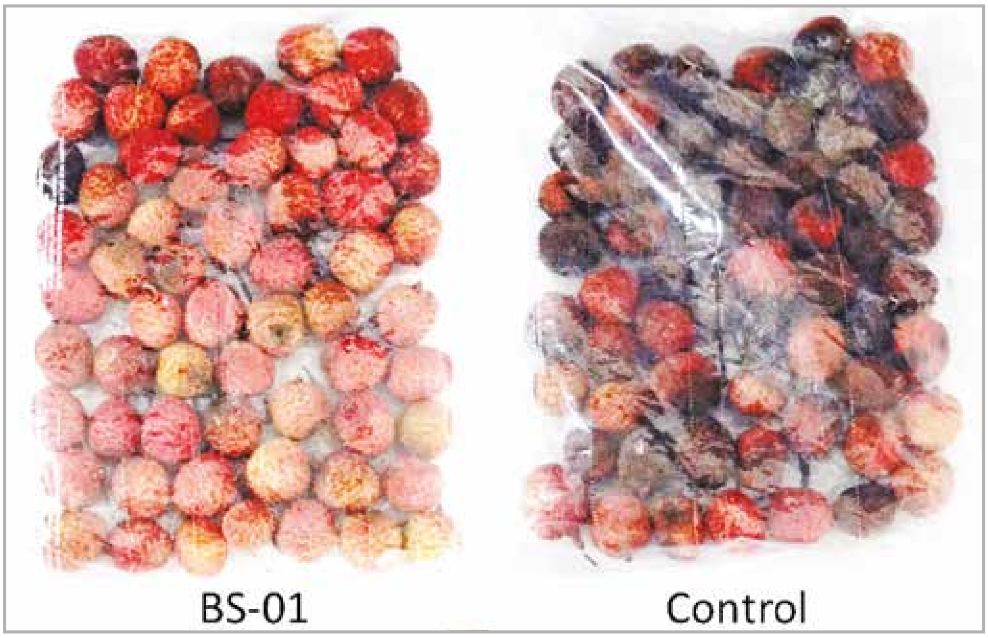


Fig. 4.8. Effect of BS-01 treatment on litchi fruits after 6 days of storage at room temperature

4.3. Post-harvest management and by-product utilization of litchi fruit

Preparation of litchi leather

For the preparation of leather following hydrocolloids were used

- Pectin (3% for gelling effect)
- CMC (0.5 -1% for better texture)
- Maltodextrin (15%): for flavour entrapment and preventing thermal damage
- Glycerol (1-3%): for elasticity

Fig 4.9. Litchi Leather

Table 4.1. Experimental Design for Optimizing CMC and Plasticizer (Glycerol) Ratios in Litchi Coating Solutions.

Treatments	Explanation
S1	0.5% CMC; 1% Glycerol
S2	1% CMC; 1% Glycerol
S3	0.5% CMC; 3% Glycerol
S4	1% CMC; 3% Glycerol

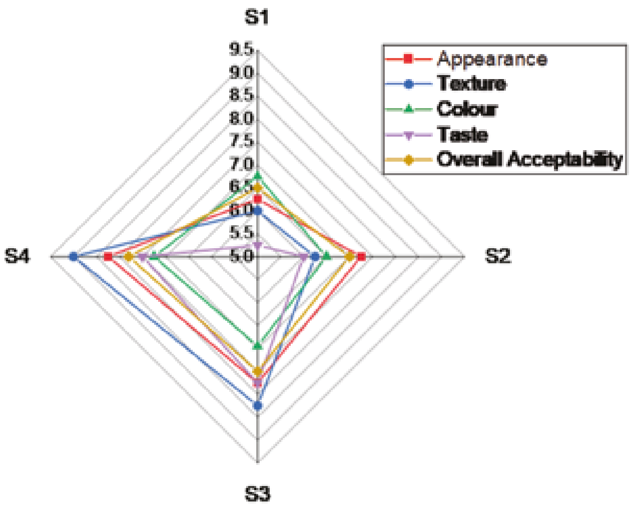


Fig 4.9. Radar curve shown here represents that the highest value of almost all the sensory attributes are achieved in S4 i.e. 3% glycerol and 1% CMC

- The thickness of leather was maintained as 3 mm in all the trails.
- The water activity in all the trails was found lesser than 0.6 (0.33-0.37) representing microbial safety of all the samples
- Colorimetric analysis showed lightest colour in S4 (L*=37) showing better sensory property

Comparative evaluation of physicochemical and functional properties of starch extracted from litchi (*Litchi chinensis*) seed slurry and powder

This study comparatively evaluated ultrasound-assisted starch extraction from litchi seeds using Wet-Slurry (T1) and Dry-Powder (T2) methods. The Dry-Powder approach (T2) demonstrated superior extraction efficiency, yielding significantly higher starch recovery (32.06± 0.09) and amylose content (22.86± 0.04) compared to T1. While both treatments maintained low moisture (<9.3) and water activity (a_w < 0.35), T2 produced a lighter starch (L* = 71.62) with a higher Hausner Ratio (1.31) and Carr Index (0.23), indicating distinct flowability characteristics. These results suggest that the dry-powder method is the more effective processing route for upcycling litchi seed waste into high-quality functional starch.

Table 4.2. Comparative Evaluation of Starch Extracted from Litchi Seed Slurry (T1) and Powder (T2).

Parameter	Unit	Seed Slurry (T1)	Seed Powder (T2)
Starch Recovery	%	30.19±0.04	32.06±0.09
Amylose Content	%	21.99±0.20	22.86±0.04
Moisture Content	% (wb)	9.28±0.10	9.06±0.14
Water Activity	-	0.34±0.00	0.32±0.00
Bulk Density	kg/m^3	392.08±1.09	362.45±5.22
Tapped Density	kg/m^3	464.69±1.30	474.94±6.84
Hausner Ratio	-	1.18±0.00	1.31±0.00

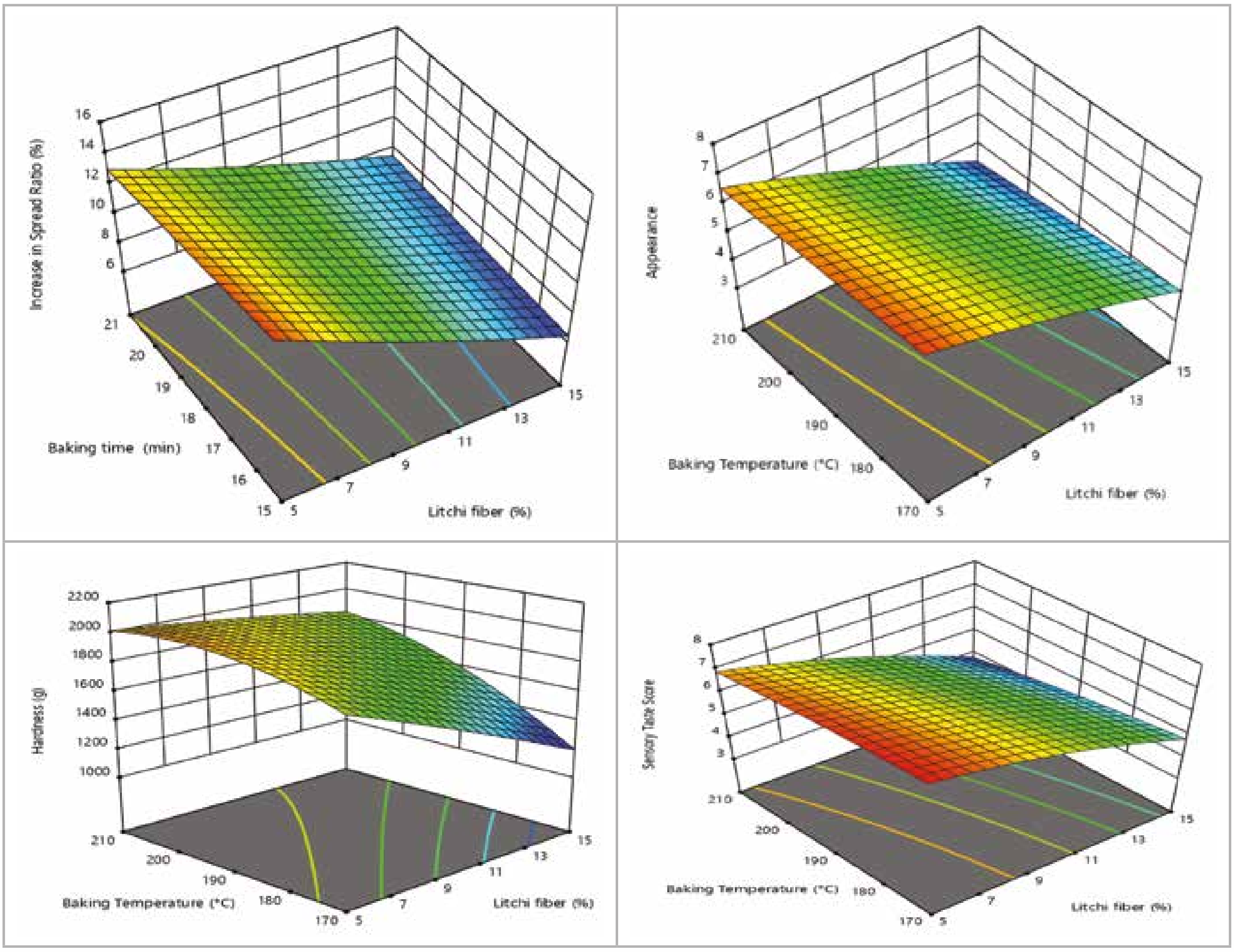
Parameter	Unit	Seed Slurry (T1)	Seed Powder (T2)
Carr Index	-	0.15±0.00	0.23±0.00
L (Lightness)*	-	67.78±0.61	71.62±0.30
a (Redness)*	-	9.95±0.08	9.67±0.11
b (Yellowness)*	-	21.44±0.09	22.26±0.20

Optimization of sensory parameters of litchi fiber riched cookies using RSM

This study utilized Response Surface Methodology (RSM) to optimize the sensory and physical properties of cookies enriched with litchi pomace fiber, focusing on the interaction between litchi fiber content (5–15%), baking temperature (170–210°C), and baking time (15–21 min). The 3D response surface plots reveal that while increasing fiber levels tends to elevate cookie hardness due to higher water-binding capacity, there is a specific equilibrium where sensory scores for taste, appearance, and texture are maximized. The optimization analysis identified a highly desirable solution (Desirability = 0.935) at a 5% litchi fiber concentration, baked at approximately 190.4°C for 15.3 minutes, demonstrating that litchi pomace can be effectively upcycled into a functional food ingredient without compromising consumer acceptability.

Table 4.3. The dependent variables/responses were taken as follows:

R1	Hardness
R2	Increase in Spread Ratio (%)
R3	Appearance
R4	Sensory Colour
R5	overall sensory score
R6	Sensory Taste Score
R7	Sensory texture



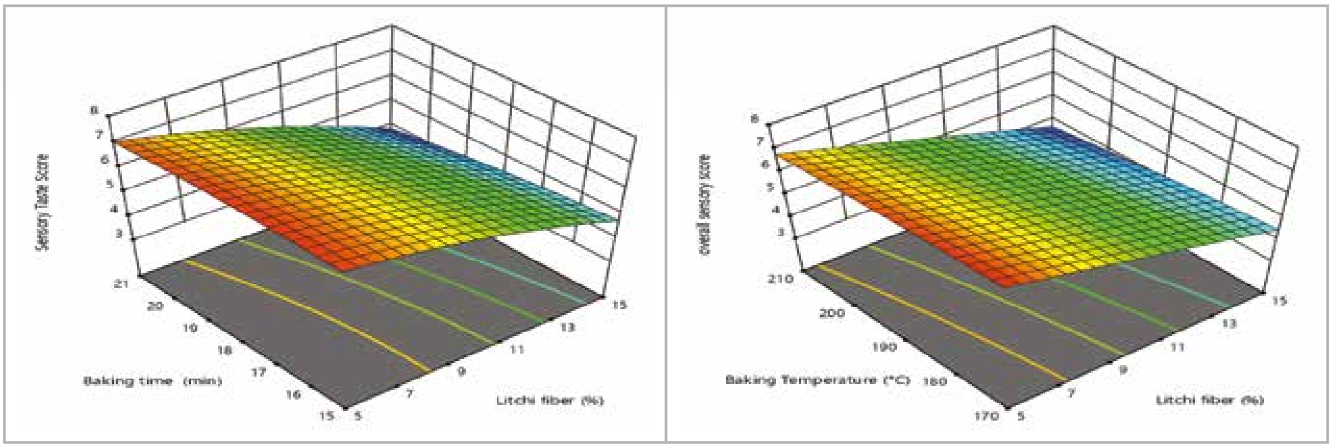


Fig. 4.10. RSM plots of different response variables as affected by input variables

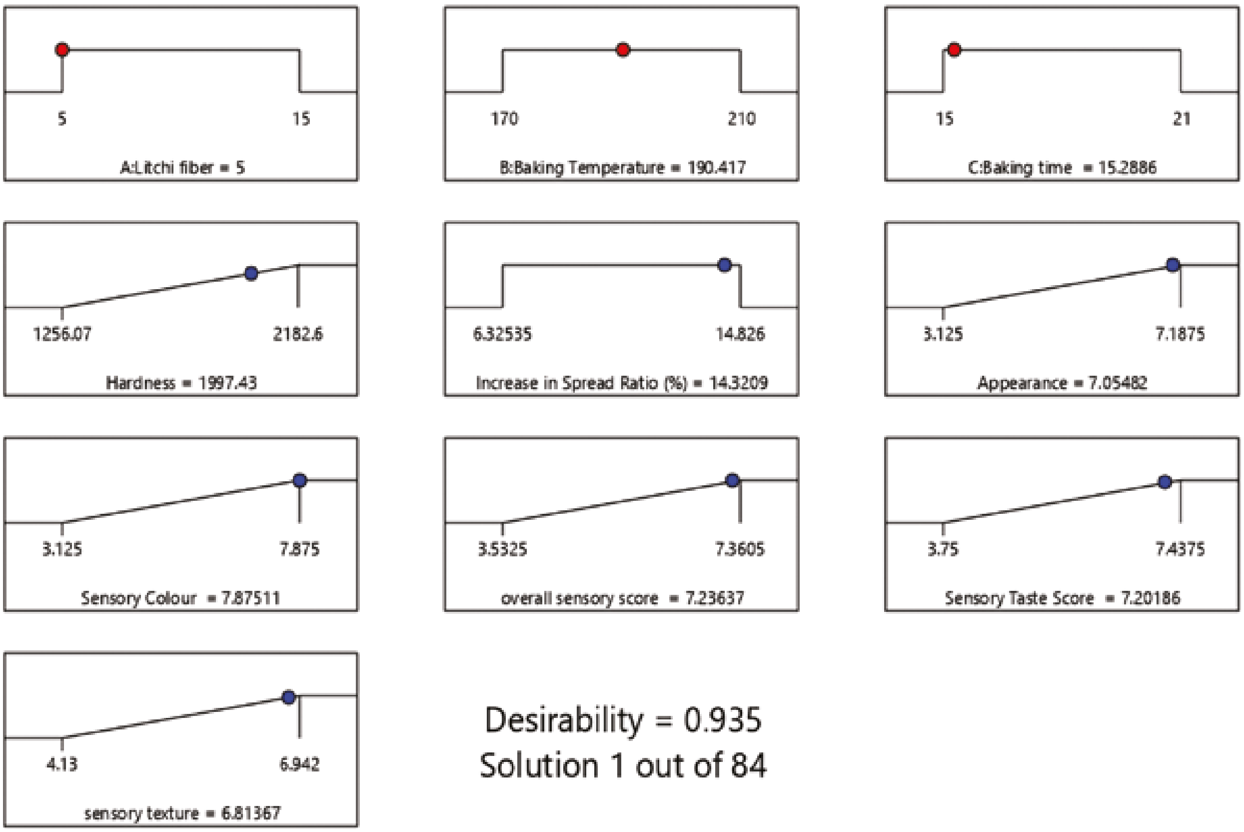


Fig. 4.11. Ramp plot showing the optimum response

Ultrasound assisted extraction of bioactive compounds from litchi seed

This experiment investigated the optimization of Ultrasound-Assisted Extraction (UAE) for recovering bioactive compounds from litchi seeds, specifically analyzing the impact of sonication power (20–100% amplitude) and solvent systems on Total Phenolic Content (TPC), Total Flavonoid Content (TFC), and Antioxidant Activity (% RSA). The results demonstrate a clear dose-response relationship where extractability increases significantly with power level before saturating at 80% amplitude, which yielded optimal concentrations of TPC (34.12± 0.03 mg GAE/g) and TFC (126.12± 1.06 mg QE/g). Furthermore, comparative solvent analysis revealed that 50% Aqueous Methanol and 50% Aqueous Ethanol were the most effective media for maximizing antioxidant recovery, whereas pure water and pure solvents showed markedly lower efficiency. These findings establish that a synergic combination of 80% sonication power and 50% aqueous alcohol provides a highly efficient, high-yield methodology for upcycling litchi seed waste into functional food ingredients.

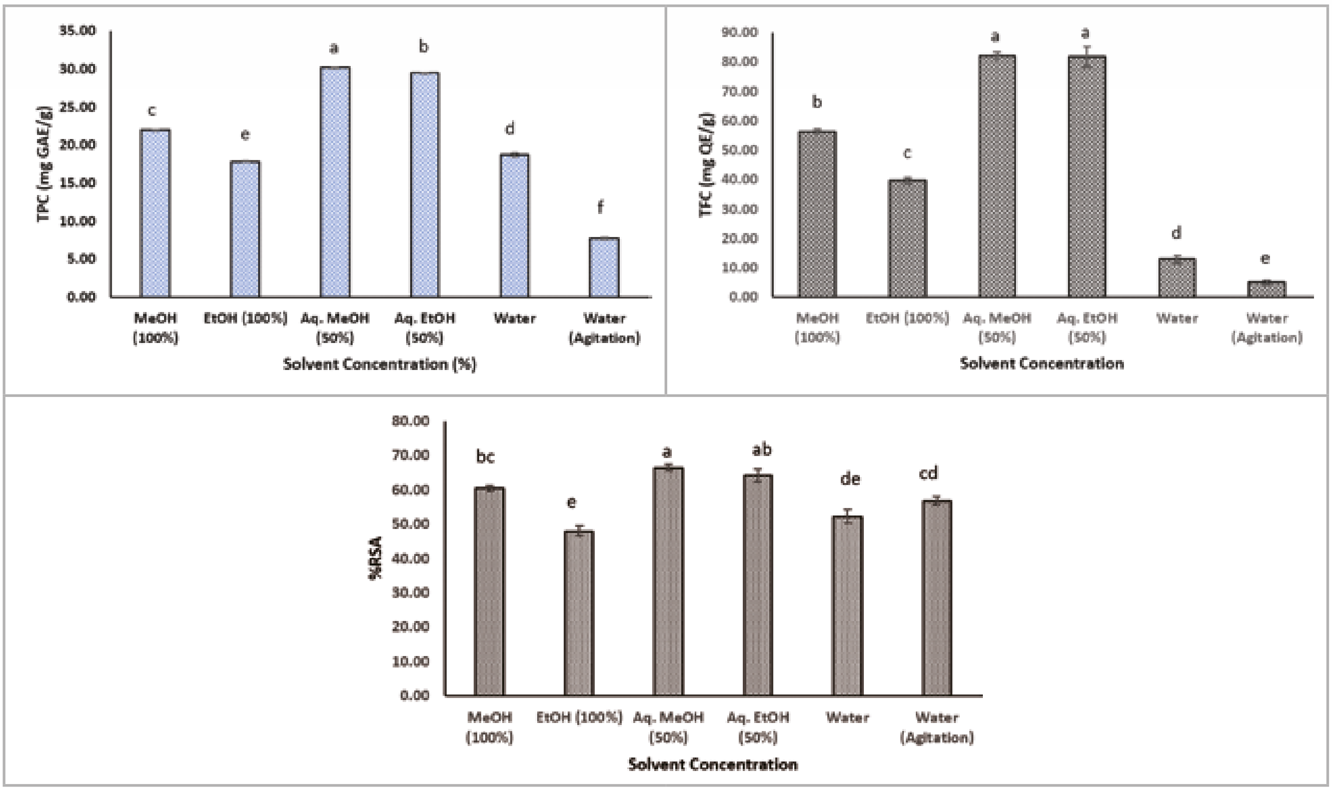


Fig 4.12. Graphical represantation of effect of different methods of extraction on the recevory of bioactive compounds

Table 4.4. Optimization of Ultrasound-Assisted Extraction (UAE) Power Levels for Total Phenolics, Flavonoids, and Antioxidant Capacity

Power Level	TPC	TFC	AOX
20%	14.33 ± 0.44^{d}	34.06 ± 0.53^{d}	36.00 ± 0.14^{d}
40%	28.01 ± 0.02^{c}	87.39±1.32c	50.15 ± 1.77^{c}
60%	32.90 ± 0.15^{b}	113.96 ± 1.32^{b}	53.95 ± 0.07^{b}
80%	34.12 ± 0.03^{a}	126.12 ± 1.06^{a}	58.85 ± 0.21^{a}
100%	34.23 ± 0.02^{a}	129.30 ± 1.32^{a}	59.70 ± 0.28^{a}

Preparation and evaluation of carbonated beverage

This experiment evaluated the development and 6-month storage stability of a litchi-based carbonated beverage using clarified and unclarified juices. Physicochemical analysis revealed that carbonation effectively preserved Vitamin C and Acidity levels compared to non-carbonated controls, with TSS remaining stable across all treatments. Sensory evaluation via radar charts identified S5 (unclarified, 1-time carbonation) as the initial favorite, while S6 (unclarified, 2-times carbonation) demonstrated superior long-term sensory stability, maintaining the highest balanced scores for taste, texture, and overall acceptability after 6 months. These results indicate that higher carbonation levels in unclarified litchi RTS successfully enhance both the nutritional retention and shelf-life quality of the beverage.

Fig 4.13. Bottle used for carbonation

Table 4.5. Physio-chemical analysis of Carbonated Beverage

Trials	Initial Data			After 6 months		
	TSS	Acidity	Vit C	TSS	Acidity	Vit C
S1 (Clarified juice without carbonation)	14.12±0.06	0.40±0.00	2.01±0.02	14.1±0.00	0.31±0.01	1.42±0.03
S2 (Clarified juice with 1 time carbonation)	14.12±0.06	0.41±0.00	1.96±0.12	14.2±0.01	0.39±0.01	1.67±0.21
S3 (Clarified juice with 2 times carbonation)	14.24±0.01	0.43±0.01	2.05±0.14	14.0±0.01	0.40±0.00	1.95±0.24
S4 (Unclarified juice without carbonation)	14.06±0.01	0.34±0.01	1.83±0.11	14.1±0.04	0.33±0.00	1.11±0.26
S5 (Unclarified juice with 1 time carbonation)	14.01±0.04	0.38±0.00	2.07±0.14	14.1±0.03	0.35±0.01	1.52±0.15
S6 (Unclarified juice with 2 times carbonation)	14.14±0.01	0.47±0.01	2.09±0.12	14.1±0.04	0.41±0.01	1.61±0.02

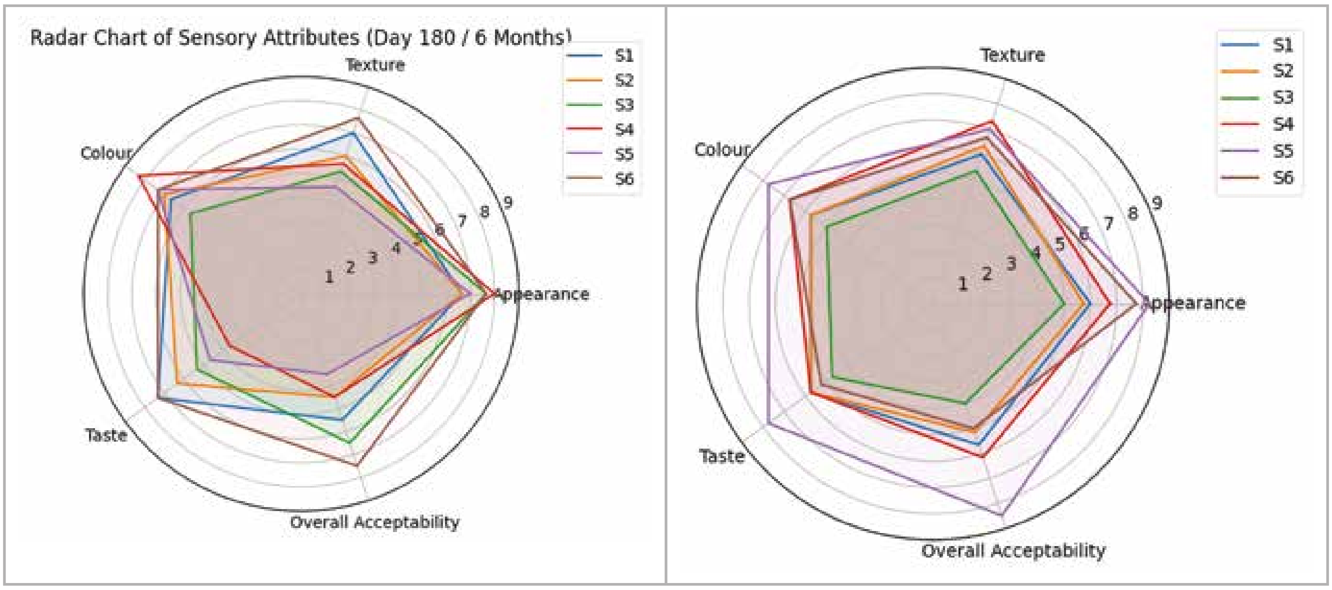


Fig 4.14. Sensory analysis of Carbonated Beverage

4.4. Development of packaging protocol for the long-distance transport of litchi

Effect of different packaging film on shelf life of litchi during road transportation

The study was conducted at ICAR-NRCL, Muzaffarpur, using 'Shahi' litchi fruits harvested at early, mid, and full maturity stages during May. Physiologically sound, graded fruits were sorted to remove defects and then secured into 100-fruit bunches using food-grade jute twine for subsequent transportation trials.

Table 4.6. Experimental Design and Packaging Treatments for the Shelf-life Extension of 'Shahi' Litchi Bunches.

Treatments	Packaging Description
T_1	Litchi fruits in bunches without film
T_2	Litchi fruits in bunches wrapped with butter paper
T_3	Litchi fruits in bunches enclosed in Vamsa film (nano silver embedded)
T_4	Litchi fruits in bunches enclosed in Uflex film
T_5	Litchi fruits in bunches enclosed in HDPE film
T_6	Litchi fruits in bunches enclosed in polypropylene film

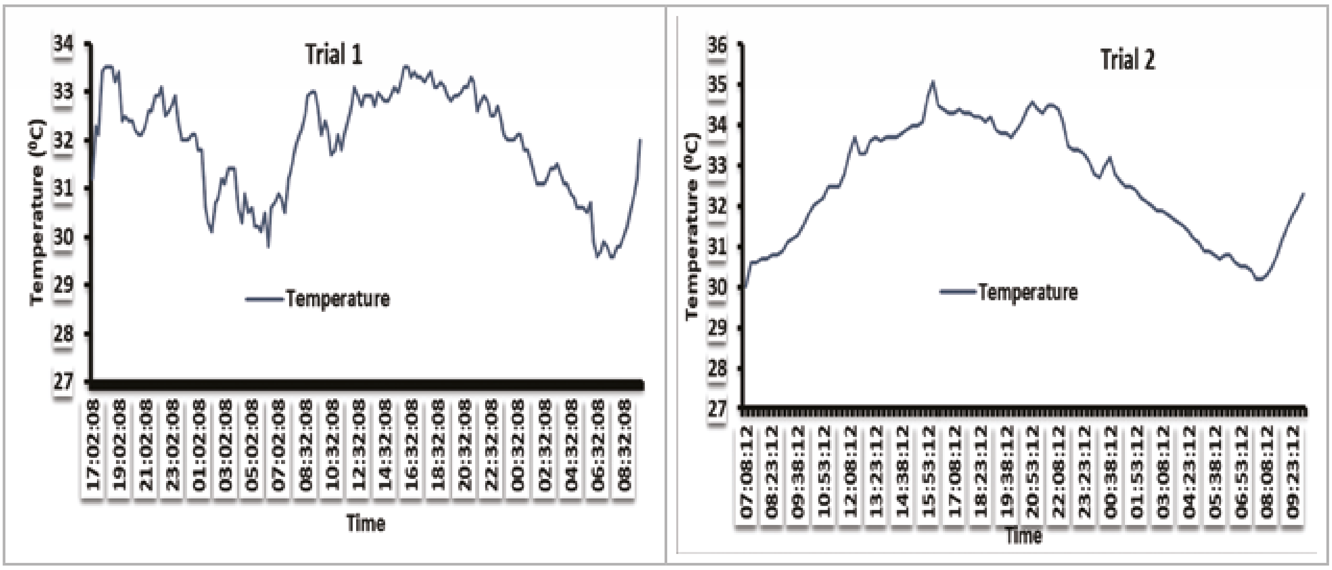


Fig 4.15 Change in temperature profile of package during transportation

Across both transportation trials, Treatment T4 consistently outperformed all others, showing the lowest physiological loss in weight (PLW), minimal discoloration, and near-zero decay. Conversely, T5 and T6 exhibited the highest susceptibility to browning and decay, indicating that T4 provides the most effective protection for maintaining fruit quality during transit. The results indicate that while TSS remained relatively stable across all treatments and trials, Treatment T4 was most effective at maintaining acidity levels during transit, particularly in Trial 2. The minimal fluctuation in TSS combined with T4's ability to prevent rapid acid degradation suggests this treatment is superior for preserving the characteristic flavor profile of 'Shahi' litchi during the 5-day transportation period. The results demonstrate that Treatment T4 was highly effective in maintaining fruit texture, recording significantly higher firmness (630–639 g) by Day 5 compared to other treatments. While Vitamin C levels remained relatively stable or showed slight increases across all groups, T4's ability to minimize textural softening indicates its superior performance in preserving the physical resilience of 'Shahi' litchi during the supply chain. The graphical analysis reveals that Treatment T4 effectively maintained fruit color stability, exhibiting the highest retention of lightness (L*) and the lowest total color change Δ E approx. 1 by Day 5. In contrast, other treatments showed significant darkening and higher Δ E values, indicating that T4 most successfully inhibited the browning and color degradation.

Table 4.7. Change in physiochemical properties of litchi in transportation trials

	Day 5				
	Treatments	**PLW (%)**	**Discolouration (%)**	**Decay (%)**	**Browning Index**
Transportation trial 1	T1	12.46±0.70^{c}	44.04±0.16^{b}	36.96±4.60^{ab}	2.43± 0.01^{c}
	T2	6.25±0.24^{d}	24.42±0.42^{e}	42.28±15.09^{ab}	2.16±0.01^{d}
	T3	4.97±0.06^{d}	28.18±0.99^{d}	26.70±1.91^{b}	2.05±0.00^{d}
	T4	2.03±0.27^{e}	1.33±0.15^{f}	1.66±0.34^{c}	1.35±0.01^{e}
	T5	17.37±0.70^{a}	67.32±0.26^{a}	45.78±0.47^{a}	2.83±0.06^{a}
	T6	15.71±0.52^{b}	33.54±0.34^{c}	32.08±1.03^{ab}	2.63±0.09^{b}
Transportation trial 2	T1	13.15±0.78^{b}	47.30±0.49^{c}	33.38±0.89^{b}	2.42±0.00^{c}
	T2	12.46±1.61^{bc}	20.92±0.12^{e}	23.86±0.02^{c}	2.16±0.02^{d}
	T3	9.18±1.18^{c}	27.08±0.77^{d}	27.93±0.90^{d}	2.05±0.00^{e}
	T4	2.17±1.29^{d}	2.75±0.18^{f}	0.18±0.31^{d}	1.35±0.01^{f}
	T5	17.93±1.26^{a}	70.23±1.12^{a}	43.33±0.62^{a}	2.90±0.06^{a}
	T6	18.62±0.88^{a}	66.04±1.62^{b}	44.12±0.25^{a}	2.76±0.00^{b}

Note: *Day 5 post-transportation data. PLW: Physiological Loss in Weight. Values are Mean ± Standard Deviation. Means followed by different superscript letters ($^{a-f}$) within the same column and trial are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test.*

Table 4.8. Change in physiochemical properties of litchi in transportation trials

		Day 0	Day 5	Day 0	Day 5
Transportation trial 1	**Treatments**	**TSS (°Brix)**		**Acidity**	
	T1	17.65±0.36^{a}	18.04±0.35^{a}	0.69±0.07^{a}	0.66±0.07^{a}
	T2	17.66±0.33^{a}	18.21±0.41^{a}	0.69±0.12^{a}	0.65±0.12^{a}
	T3	17.79±0.19^{a}	18.22±0.20^{a}	0.71±0.11^{a}	0.70±0.11^{a}
	T4	17.93±0.06^{a}	18.08±0.11^{a}	0.71±0.10^{a}	0.71± 0.09^{a}
	T5	17.55±0.32^{a}	17.86±0.37^{a}	0.68±0.10^{a}	0.67±0.10^{a}
	T6	17.24±0.12^{a}	18.10±0.10^{a}	0.76±0.01^{a}	0.72±0.01^{a}
Transportation trial 2	T1	19.20±0.20^{a}	19.56±0.20^{a}	0.36±0.00^{c}	0.26±0.00^{c}
	T2	19.23±0.55^{a}	19.57±0.48^{a}	0.34±0.00^{d}	0.27±0.00^{bc}
	T3	19±0.17^{a}	19.50±0.17^{a}	0.36±0.01^{bc}	0.32±0.02^{b}
	T4	19.06±0.20^{a}	19.53±0.32^{a}	0.39±0.00^{a}	0.38±0.01^{a}
	T5	19±0.10^{a}	19.23±0.41^{a}	0.33±0.00^{d}	0.25±0.02^{c}
	T6	19.10±0.18^{a}	19.30±0.03^{a}	0.38±0.00^{ab}	0.25±0.02^{c}

Note: *TSS: Total Soluble Solids. Values represent Mean ± Standard Deviation (n=3). Within each trial, means followed by the same superscript letter ($^{a-d}$) in a column are not significantly different (P > 0.05) according to Duncan's Multiple Range Test.*

Table 4.9. Change in physiochemical properties of litchi in transportation trials

		Day 0	Day 5	Day 0	Day 5
Transportation trial 1	Treatments	Vitamin-C		Firmness(g)	
	T1	18.80±0.3^{a}	19.10±0.30^{a}	653.33±19.85^{a}	577.66±9.07^{c}
	T2	18.60±0.2^{a}	18.93±0.25^{a}	682.66±3.51^{a}	612±9.16^{b}
	T3	18.73±0.25^{a}	18.93±0.25^{a}	675.66±14.74^{a}	613.33±14.04^{ab}
	T4	18.90±1.13^{a}	19.74±0.93^{a}	650.33±25.16^{a}	630±7.93^{a}
	T5	18.49±0.45^{a}	18.88±1.06^{a}	676.66±4.72^{a}	576.33±10.1^{c}
	T6	18.44±0.38^{a}	18.63±0.34^{a}	674.33±13.31^{a}	576±2.64^{c}
Transportation trial 2	T1	28.36±0.08^{c}	29.08±0.06^{c}	653.33±19.85^{a}	577.66±9.073^{b}
	T2	27.69±0.20^{d}	28.22±0.21^{d}	682.66±3.51^{a}	612±9.16^{a}
	T3	30.28±0.04^{b}	31.17±0.07^{b}	675.66±14.74^{a}	613.33±14.04^{a}
	T4	27.60±0.28^{d}	27.47±0.03^{e}	650.33±25.16^{a}	639±7.93^{a}
	T5	31.40±0.30^{a}	31.95±0.03^{a}	676.66±4.72^{a}	576.33±10.11^{b}
	T6	30.86±0.10^{ab}	31.34±0.33^{b}	663.66±17.03^{a}	551±19.28^{b}

Note: *Vitamin C (mg/100g); Firmness (g). Values are expressed as Mean ± Standard Deviation. Superscript letters ($^{a-e}$) within the same column and trial indicate significant differences (P < 0.05) based on Duncan's Multiple Range Test.*

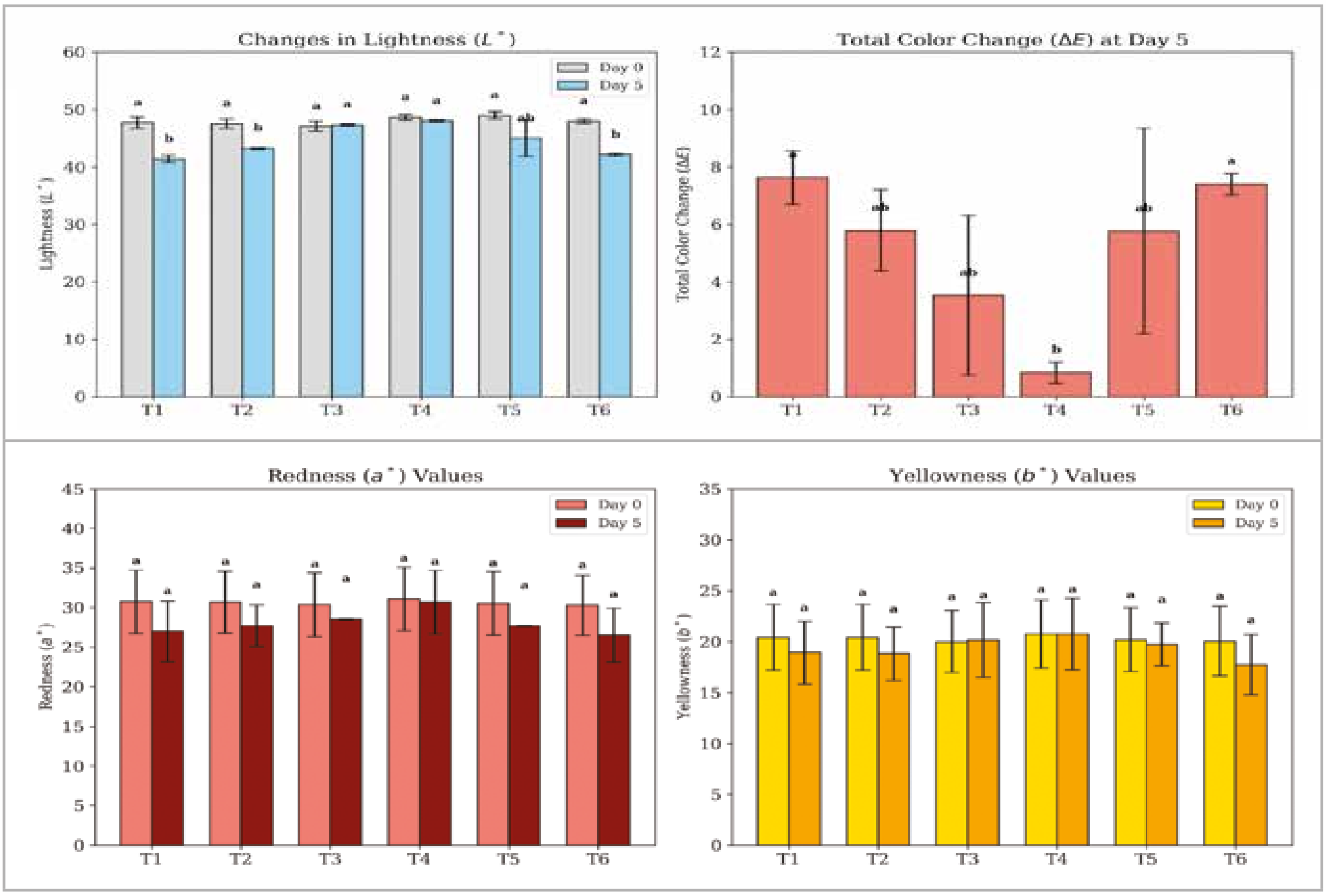


Fig 4.16. Change in colorimetric properties of litchi in first transportation trials

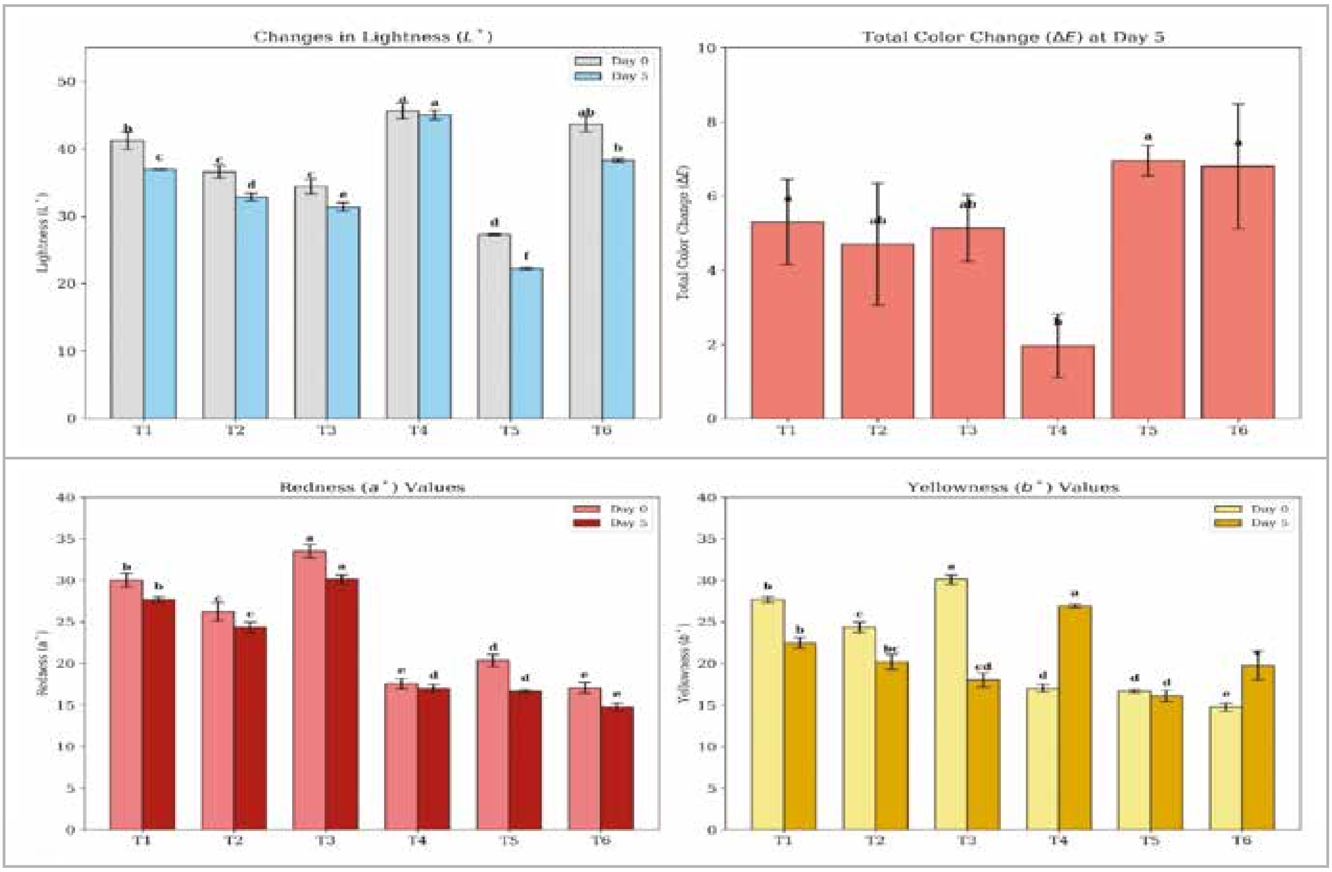


Fig 4.17 Change in colorimetric properties of litchi in second transportation trials

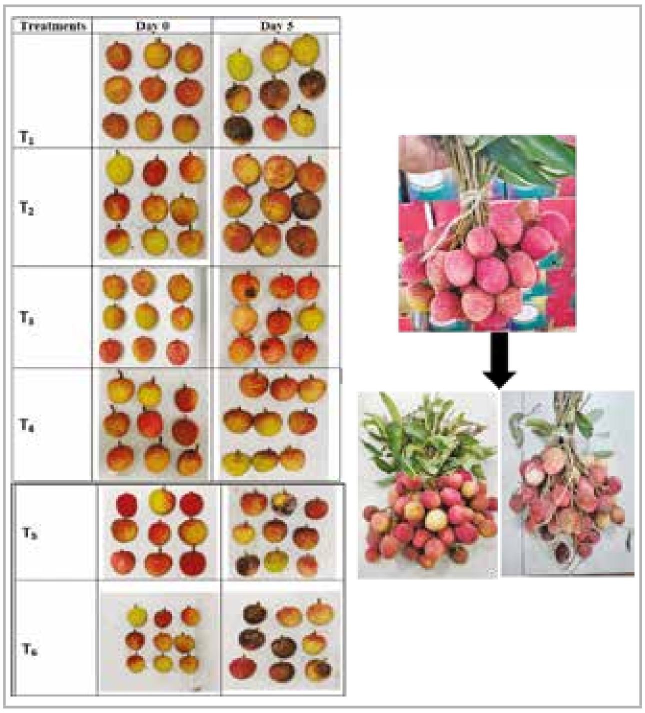


Fig 4.18. Effect of different MAP on the shelf-life of Shahi Litchi during transportation

Economic impact of the technology: After accounting for processing (5%), local/air/rail transport (20%), and postharvest losses (10%), about 4.55 lakh MT (65%) of litchi is transported via road. Out of this, 65% (~3 lakh MT) is A-grade litchi, targeted for distant markets. Use of laser-perforated biodegradable MAP film in road transport saves 60,000 MT of fruit by reducing spoilage and browning. The packaging cost associated with the film is ₹150 crore (₹5/kg). Hence, the net estimated profit will be ₹450 crore annually by using the technology.

4.5. Shelf-life enhancement and value addition of litchi through various post-harvest intervention

Effect of lac-based coating on shelf life of litchi

This study evaluated the efficacy of lac-based coating formulations (procured from ICAR-NISA) as a post-harvest intervention for litchi bunches, focusing on the performance of the NISA-03 formulation at a 3:1 dilution (T5) compared to an uncoated control (T0). The results demonstrate that the lac-based spray functions as an effective semi-permeable barrier, significantly reducing physiological loss in weight (PLW) from 30.67% in the control to 19.00% by Day 5 and enhancing the retention of Vitamin C (18.00 mg/100g). Furthermore, the T5 treatment successfully delayed pericarp browning and maintained superior fruit lightness (L*) and yellowness (b*) values throughout the storage period. While decay remained a challenge by the end of the 5-day trial, the lac-based coating proved instrumental in stabilizing TSS and acidity levels, suggesting that NISA-03 is a viable, eco-friendly coating for preserving the physicochemical integrity of litchi during ambient storage.

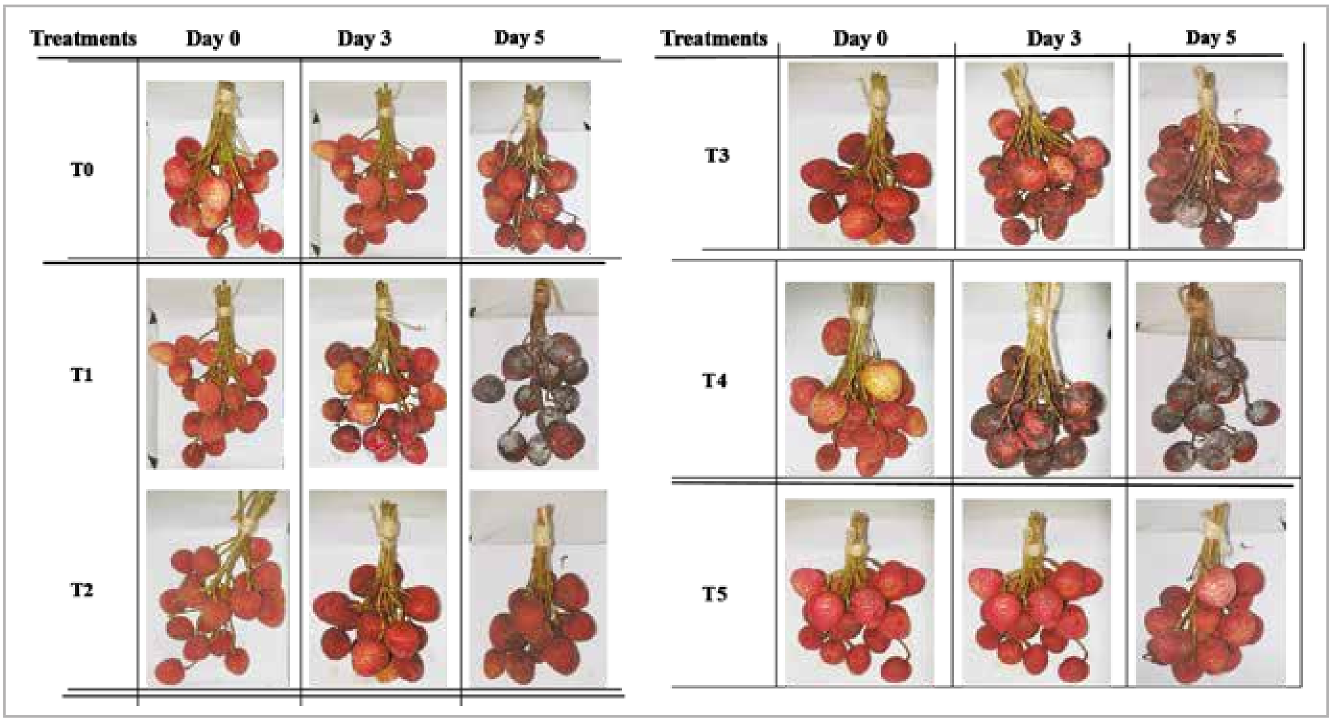


Fig 4.19 Change in physiochemical properties of litchi in Lac based Coating. T0: No Lac based coating (Distilled water sprayed), T1: NISA-05 with 50:50 dilution with water, T2: NISA-05 with 30:70 dilution with water, T3: NISA-06 with 50:50 dilution with water, T4: NISA-06 with 3:1 dilution with water, T5: NISA-03 with 3:1 dilution with water.

Table 4.10 Change in physiochemical properties of litchi in lac-based coating

Treatments		TSS	Acidity	Vit-C	PLW (%)	Decay (%)
Day 0	T0	20.17 ± 0.06	0.75 ± 0.04	29.33 ± 0.58	0	0
	T5	19.97 ± 0.21	0.79 ± 0.01	29.67 ± 1.53	0	0
Day 3	T0	18.57 ± 0.50	0.76 ± 0.05	19.00 ± 1.00	14.00 ± 1.73	7.51 ± 0.43
	T5	19.00 ± 0.17	0.79 ± 0.01	21.67 ± 1.15	8.67 ± 1.53	7.57 ± 0.54
Day 5	T0	17.37 ± 0.31	0.71 ± 0.09	14.67 ± 1.15	30.67 ± 4.04	23.46 ± 0.56
	T5	18.13 ± 0.15	0.74 ± 0.04	18.00 ± 1.00	19.00 ± 2.00	21.46 ± 1.11

Table 4.11 Changes in chromaticity parameters of litchi pericarp as influenced by lac coating formulation.

Treatments		L*	a*	b*
Day 0	T0	30.62 ± 0.63	20.45 ± 0.40	19.38 ± 0.57
	T5	35.13 ± 2.40	20.72 ± 1.32	20.05 ± 0.84
Day 3	T0	21.10 ± 0.07	12.75 ± 0.40	17.64 ± 0.37
	T5	28.66 ± 0.56	12.59 ± 0.28	18.54 ± 0.27
Day 5	T0	15.24 ± 1.36	6.09 ± 1.12	9.24 ± 0.31
	T5	17.22 ± 0.15	6.27 ± 0.47	13.93 ± 0.59

Note: *Data are presented as Mean± Standard Deviation (n=3). Values within the same column followed by different superscript letters (a, b, c, etc.) are significantly different (P < 0.05) according to Duncan's Multiple Range Test. L* indicates lightness, a* represents redness/greenness, and b* denotes yellowness/blueness.*

Effect of different hydrocolloid-based coating on Shelf life of Fresh litchi

This study evaluated the efficacy of various hydrocolloid-based coatings specifically Carboxymethyl Cellulose (CMC), Gum Arabic, and Sodium Alginate in extending the post-harvest shelf life of 'Shahi' litchi. The results indicate that hydrocolloid dipping significantly reduced physiological loss in weight (PLW) compared to the control, with S2 (2% CMC) and S3 (1% CMC + 1% Gum Arabic) showing the most promising results in maintaining fruit hydration and structural integrity over a 5-day period.

Table 4.12. Change in physio-chemical Properties of litchi (Shahi) on hydrocolloids dip

Treatments	% PLW		% Decay		Browning Index	
	Day 3	Day 5	Day 3	Day 5	Day 3	Day 5
S1	5.19±1.06^{a}	9.58±3.16^{a}	7.06±2.02^{a}	12.54±6.13^{a}	2.01±0.58^{a}	2.24±0.66^{a}
S2	3.55±0.29^{b}	7.34±0.59^{b}	8.90±1.41^{a}	17.37±4.30^{a}	2.00±0.14^{a}	2.20±0.15^{a}
S3	3.39±0.31^{b}	8.48±1.57^{ab}	7.48±1.05^{a}	11.21±3.32^{a}	1.71±0.15^{a}	1.89±0.17^{a}
S4	5.17±1.41^{a}	10.33±3.52^{a}	6.90±1.89^{a}	12.58±5.25^{a}	2.02±0.61^{a}	2.26±0.69^{a}
S5	3.58±0.55^{b}	8.14±1.70^{ab}	9.20±2.11^{a}	17.25±5.10^{a}	2.10±0.61^{a}	2.34±0.68^{a}
S6	3.93±0.44^{b}	8.79±1.25^{ab}	7.33±0.60^{a}	11.13±4.27^{a}	1.78±0.24^{a}	1.97±0.26^{a}
S7	3.96±0.66^{b}	9.27±1.15^{a}	10.31±2.62^{a}	18.72±7.28^{a}	1.87±0.10^{a}	2.06±0.11^{a}

S1: Control (water dip for 30 min), S2: CMC (2% dip) and 5 mL glycerol, S3: CMC:1% and Gum Arabic (1%) with 5 mL glycerol, S4: Gum Arabic (2%) and 5 ml glycerol, S5: Sodium Alginate (0.5%), S6: Sodium Alginate (0.25%) and CMC (1%), S7: Sodium Alginate (0.25%) and gum arabic (1%)

While most treatments showed a general decline in Vitamin C and an increase in browning and decay over time, the coated fruits (particularly those utilizing CMC and Sodium Alginate blends) exhibited better retention of firmness and lower browning indices compared to the untreated control (S1). These findings suggest that edible hydrocolloid coatings act as an effective semi-permeable barrier, slowing down respiration and moisture loss, thereby preserving the physicochemical quality of litchi during short-term storage.)

Fig 4.20. Dipping of litchi in hydrocolloids and moisture removal

Table 4.13. Change in physio-chemical Properties of litchi (Shahi) on hydrocolloids dip

Treatments	Vitamin C			Firmness		
	Day 0	Day 3	Day 5	Day 0	Day 3	Day 5
S1	1.08±0.07[a]	0.94±0.11[a]	0.74±0.13[a]	763.3±35.1[a]	863.3±77.7[a]	880.0±72.1[a]
S2	1.16±0.03[a]	1.01±0.04[a]	0.92±0.02[a]	773.3±46.2[a]	946.7±5.8[a]	951.7±5.8[a]
S3	1.15±0.03[a]	1.00±0.03[a]	0.91±0.06[a]	770.0±10.0[a]	950.0±40.0[a]	958.3±40.1[a]
S4	1.14±0.06[a]	1.01±0.02[a]	0.90±0.02[a]	776.7±23.1[a]	970.0±10.0[a]	976.7±7.6[a]
S5	1.11±0.01[a]	1.01±0.05[a]	0.62±0.39[a]	763.3±5.8[a]	970.0±10.0[a]	975.0±10.0[a]
S6	1.11±0.10[a]	1.01±0.06[a]	0.90±0.01[a]	780.0±26.5[a]	906.7±56.9[a]	921.7±52.0[a]
S7	1.08±0.07[a]	1.01±0.03[a]	0.96±0.05[a]	783.3±20.8[a]	946.7±15.3[a]	951.7±15.3[a]

Note: *Vitamin C (mg/100g); Firmness (g). Values are expressed as Mean ± Standard Deviation. Superscript letters ([a–e]) within the same column and trial indicate significant differences (P < 0.05) based on Duncan's Multiple Range Test.*

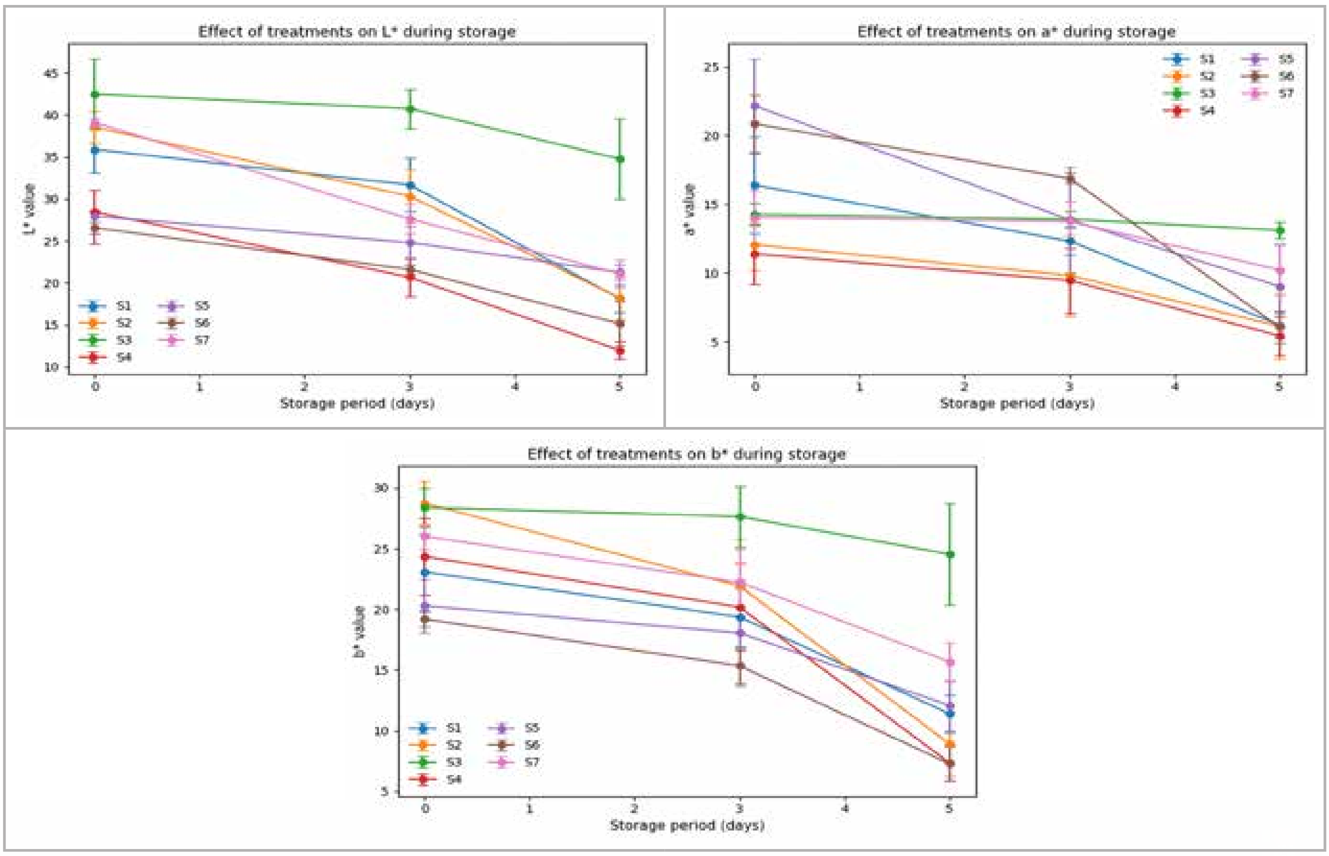


Fig 4.21. Change in physio-chemical properties of litchi (shahi) on hydrocolloids dip

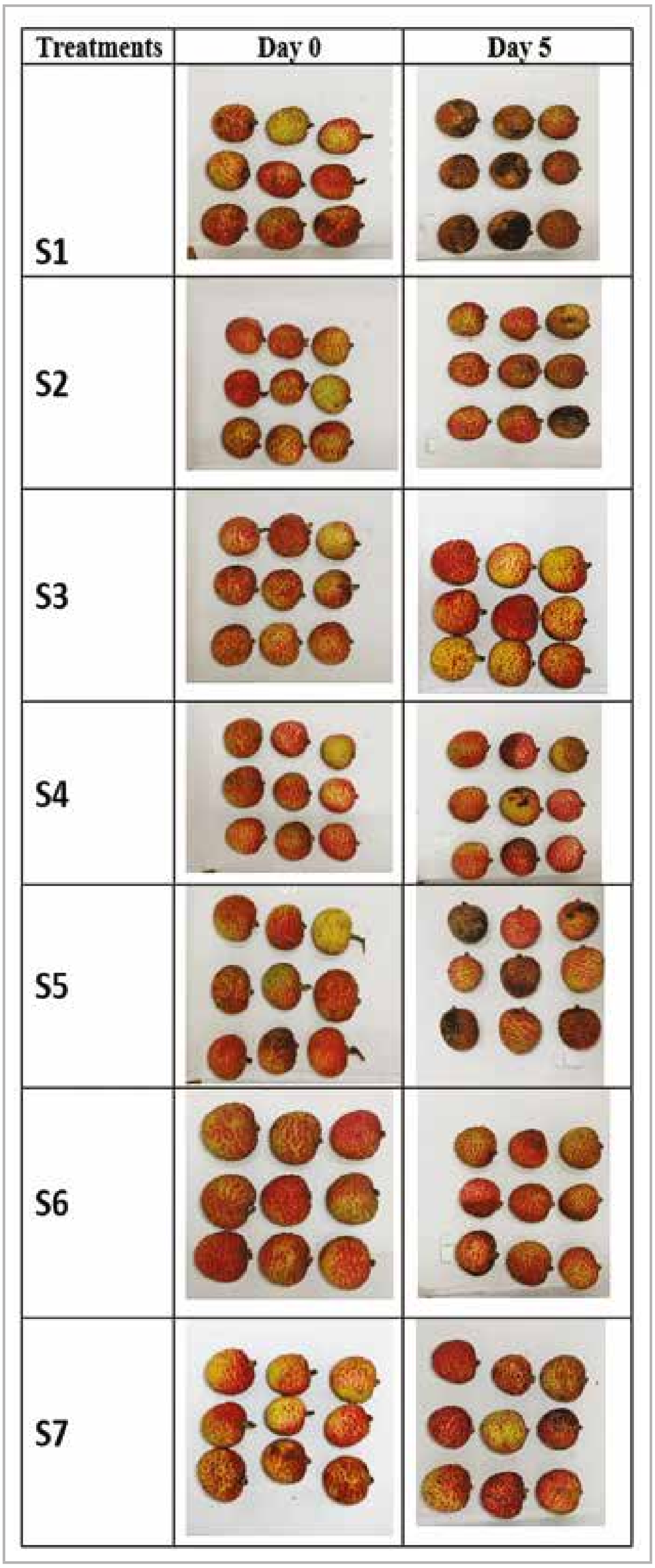


Fig 4.22. Effect of melatonin dip on shelf life of fresh litchi

Variation in physio-chemical properties of Shahi litchi during its marketing season

This study monitored the physicochemical variations of 'Shahi' litchi from May 17 to May 28 to determine the optimal harvest window for peak market quality. The results indicate that fruit maturity peaked between May 25 and May 28, characterized by high structural uniformity and sphericity (0.86–0.92). During this period, a significant color transition occurred as the a* value (redness) increased from 8.05 to 33.88, signaling full ripeness. Biochemically, the ripening process culminated in maximum Total Soluble Solids (21.47 °Brix) and Vitamin C levels (41.00 mg/100g), accompanied by a characteristic decline in titratable acidity and fruit firmness. These findings suggest that harvesting during the final week of May maximizes the nutritional profile and consumer-preferred sensory attributes of 'Shahi' litchi.

Fig 4.23. Change in Shahi litchi from 17th May to 28th May, 2025

Table 4.14. Change in Physical Properties of litchi (Shahi) on daily basis

Date	Length (mm)	Width (mm)	Thickness (mm)	Equivalent Diameter (mm)	Sphericity
17-May	31.94 ± 1.02^{b}	25.19 ± 0.29^{e}	26.92 ± 0.75^{bc}	27.87 ± 0.34^{cd}	0.87 ± 0.02^{bc}
18-May	34.27 ± 1.63^{ab}	27.36 ± 0.70^{cd}	27.88 ± 1.44^{ab}	29.67 ± 1.17^{abc}	0.87 ± 0.01^{bc}
19-May	33.33 ± 2.04^{ab}	29.50 ± 1.67^{ab}	29.08 ± 1.46^{ab}	30.58 ± 1.66^{ab}	0.92 ± 0.02^{a}
20-May	34.91 ± 0.95^{a}	29.26 ± 0.89^{ab}	28.06 ± 0.87^{ab}	30.60 ± 0.66^{ab}	0.88 ± 0.01^{bc}
21-May	34.93 ± 0.60^{a}	29.19 ± 1.44^{ab}	29.31 ± 1.30^{a}	31.03 ± 1.10^{ab}	0.89 ± 0.02^{abc}
22-May	35.10 ± 1.75^{a}	30.18 ± 0.65^{a}	29.29 ± 1.61^{a}	31.41 ± 1.05^{a}	0.90 ± 0.03^{abc}
23-May	33.10 ± 0.69^{ab}	28.05 ± 1.57^{bc}	27.00 ± 1.48^{abc}	29.26 ± 1.18^{bcd}	0.88 ± 0.03^{abc}
24-May	32.04 ± 2.40^{b}	26.19 ± 1.58^{de}	24.81 ± 2.50^{c}	27.50 ± 2.04^{d}	0.86 ± 0.03^{c}
25-May	34.79 ± 1.46^{a}	30.43 ± 0.83^{a}	29.07 ± 0.87^{ab}	31.33 ± 0.17^{a}	0.90 ± 0.04^{ab}
26-May	34.70 ± 0.88^{a}	29.12 ± 0.31^{abc}	29.14 ± 0.89^{ab}	30.87 ± 0.05^{ab}	0.89 ± 0.02^{abc}
27-May	33.10 ± 0.91^{ab}	29.57 ± 0.62^{ab}	28.77 ± 1.04^{ab}	30.42 ± 0.78^{ab}	0.92 ± 0.01^{a}
28-May	34.18 ± 1.66^{ab}	29.13 ± 1.22^{abc}	29.27 ± 1.31^{a}	30.77 ± 1.37^{ab}	0.90 ± 0.00^{ab}

Note: *Data are presented as Mean ± Standard Deviation. Values within the same column followed by different superscript letters ($^{a, b, c,}$ etc.) are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test.*

Table 4.15. Change in Colorimetric Properties of litchi (Shahi) on daily basis

Day	L*	a*	b*
17-May	48.96 ± 0.17^{a}	8.05 ± 1.33^{g}	38.86 ± 0.83^{a}
18-May	44.54 ± 4.40^{b}	10.11 ± 1.01^{g}	31.06 ± 1.35^{bc}
19-May	44.67 ± 2.98^{b}	16.70 ± 1.23^{f}	34.35 ± 4.21^{b}
20-May	40.50 ± 1.51^{c}	19.43 ± 1.22^{ef}	30.26 ± 4.76^{bc}
21-May	38.66 ± 2.68^{c}	21.23 ± 0.11^{de}	28.37 ± 2.89^{cd}
22-May	39.00 ± 1.84^{c}	23.08 ± 3.40^{cd}	24.43 ± 3.08^{de}
23-May	37.67 ± 0.89^{cd}	25.46 ± 2.88^{bc}	22.71 ± 2.19^{ef}
24-May	33.83 ± 2.42^{e}	27.97 ± 1.72^{b}	22.29 ± 1.10^{ef}
25-May	31.00 ± 0.76^{e}	33.12 ± 3.52^{a}	20.92 ± 0.59^{efg}
26-May	31.30 ± 0.99^{e}	33.07 ± 0.99^{a}	19.09 ± 1.75^{fg}
27-May	33.24 ± 1.23^{e}	34.31 ± 2.78^{a}	18.06 ± 1.00^{g}
28-May	34.13 ± 2.53^{de}	33.88 ± 1.08^{a}	19.20 ± 1.20^{fg}

Note: *L* (lightness), a* (redness/greenness), and b* (yellowness/blueness) values represent mean ± standard deviation. Superscript letters ($^{a–g}$) in the same column indicate significant differences ($P < 0.05$) based on Duncan's Multiple Range Test*

Table 4.16. Change in physio-chemical Properties of litchi (Shahi) on daily basis

Day	TSS (°Brix)	Vitamin C (mg 100 g^{-1})	Acidity (%)	Firmness (g)
17-May	15.37 ± 0.38^{e}	28.33 ± 0.58^{c}	2.60 ± 0.28^{a}	986.67 ± 32.15^{a}
18-May	15.93 ± 0.25^{e}	24.67 ± 1.53^{de}	1.78 ± 0.12^{b}	960.00 ± 52.92^{ab}
19-May	16.37 ± 0.21^{de}	20.33 ± 0.58^{f}	$1.60 \pm 0.12b^{c}$	880.00 ± 70.00^{bc}
20-May	17.37 ± 0.40^{cd}	21.33 ± 1.53^{ef}	1.44 ± 0.06^{c}	893.33 ± 20.82^{abc}
21-May	18.33 ± 0.42^{bc}	24.33 ± 0.58^{de}	1.08 ± 0.07^{d}	810.00 ± 55.68^{cde}
22-May	21.03 ± 0.86^{a}	26.33 ± 3.06^{cd}	0.95 ± 0.11^{d}	850.00 ± 95.39^{cd}
23-May	20.63 ± 0.55^{a}	26.00 ± 2.65^{cd}	0.91 ± 0.14^{d}	773.33 ± 70.95^{de}
24-May	20.57 ± 0.46^{a}	28.33 ± 1.15^{c}	1.01 ± 0.11^{d}	783.33 ± 76.38^{de}
25-May	18.97 ± 0.31^{b}	24.00 ± 4.00^{de}	1.00 ± 0.15^{d}	816.67 ± 28.87^{cde}
26-May	21.03 ± 0.55^{a}	28.33 ± 3.06^{c}	0.67 ± 0.00^{e}	733.33 ± 15.28^{e}
27-May	20.80 ± 1.54^{a}	35.00 ± 1.73^{b}	0.64 ± 0.06^{e}	736.67 ± 55.08^{e}
28-May	21.47 ± 0.68^{a}	41.00 ± 1.73^{a}	0.52 ± 0.01^{e}	726.67 ± 41.63^{e}

Note: *TSS: Total Soluble Solids; Vitamin C: Ascorbic Acid. Values are Mean ± Standard Deviation (n=3). Superscript letters ($^{a–f}$) within a column denote significant differences ($P < 0.05$) based on Duncan's Multiple Range Test.*

Optimization of Melatonin Concentration for Enhancing the Storage Stability of Punnet-Packed 'Shahi' Litchi

This experiment investigated the exogenous application of melatonin at concentrations ranging from 0.5 to 2.0 mM to enhance the post-harvest quality of 'Shahi' litchi stored in punnet boxes. The results demonstrate a significant dose-dependent effect on preserving the fruit's physiological and nutritional profile over a 5-day period. While the control (S1) showed rapid deterioration, the higher concentrations of melatonin, particularly S4 (1.5 mM) and S5 (2.0 mM), were highly effective in maintaining the red pericarp color (a* value) and significantly mitigating the loss of Vitamin C, which remained more than three times higher in S5 compared to the control by Day 5. Furthermore, melatonin treatment functioned as a potent anti-browning agent, with S3 (1.0 mM) and S5 (2.0 mM) achieving the lowest browning indices. Although TSS and acidity remained relatively stable across all trials, the marked reduction in weight loss and enzymatic browning suggests that melatonin dips effectively manage oxidative stress and moisture retention.

Table 4.17. Different treatments for concentration

S1: Control (water dip for 10 min)
S2: Melatonin dip for 10 min (0.5 mM)
S3: Melatonin dip for 10 min (1 mM)
S4: Melatonin dip for 10 min (1.5 mM)
S5: Melatonin dip for 10 min (2 mM)

Fig 4.24. Melatonin dipping of Shahi Litchi at different concentration

Table 4.18. Change in physio-chemical Properties of litchi (Shahi) on Melatonin dip

Trial	L*			a*			b*		
	Day 0	Day 3	Day 5	Day 0	Day 3	Day 5	Day 0	Day 3	Day 5
S1	28.13±1.70^{b}	21.10±0.07^{d}	16.14±0.56^{b}	23.38±0.70^{a}	12.75±0.40^{b}	6.09±1.12^{c}	17.32±0.33^{d}	17.14±0.70^{c}	9.24±0.31^{c}
S2	35.13±2.40^{a}	28.99±1.06^{ab}	19.55±0.61^{a}	18.21±3.59^{b}	11.69±0.28^{c}	6.27±0.47^{bc}	21.48±0.31^{bc}	20.12±0.89^{b}	13.93±0.59^{b}
S3	26.93±2.42^{b}	26.15±0.05^{c}	19.31±0.49^{ab}	14.03±1.50^{b}	11.78±0.40^{c}	7.49±1.14^{abc}	18.91±0.35^{cd}	16.89±0.67^{c}	14.11±1.02^{b}
S4	28.24±1.04^{b}	27.68±0.73^{bc}	19.32±2.52^{ab}	13.68±0.80^{b}	13.83±0.03^{a}	8.47±0.45^{ab}	24.79±0.66^{a}	24.44±0.52^{a}	18.60±0.62^{a}
S5	31.22±1.14^{ab}	29.65±0.42^{a}	21.93±0.64^{a}	15.59±0.20^{b}	13.34±0.39^{ab}	8.73±0.79^{a}	23.56±2.41^{ab}	20.90±0.54^{b}	18.60±0.36^{a}

Table 4.19. Change in physio-chemical Properties of litchi (Shahi) on Melatonin dip

	TSS			Vit-C			Acidity		
Trial	Day 0	Day 3	Day 5	Day 0	Day 3	Day 5	Day 0	Day 3	Day 5
S1	20.83±0.64^{a}	19.07±0.35^{a}	18.60±0.53^{a}	29.00±2.00^{a}	15.67±0.58^{d}	6.67±0.58^{d}	0.86±0.05^{a}	0.80±0.10^{a}	0.72±0.15^{a}
S2	20.57±0.64^{a}	18.70±0.35^{a}	18.33±0.60^{a}	29.00±1.00^{a}	21.33±0.58^{c}	13.00±1.00^{c}	0.85±0.03^{a}	0.83±0.01^{a}	0.91±0.05^{a}
S3	20.70±0.61^{a}	18.67±0.15^{a}	18.07±0.12^{a}	30.00±0.00^{a}	23.67±0.58^{b}	16.67±0.58^{b}	0.85±0.02^{a}	0.85±0.03^{a}	0.88±0.01^{a}
S4	20.63±0.40^{a}	18.73±0.57^{a}	18.47±0.25^{a}	27.67±1.53^{a}	26.00±1.00^{a}	18.00±1.00^{ab}	0.88±0.03^{a}	0.87±0.02^{a}	0.89±0.02^{a}
S5	20.97±0.51^{a}	19.43±0.31^{a}	18.60±0.30^{a}	28.67±1.53^{a}	26.33±1.15^{a}	21.00±2.00^{a}	0.85±0.04^{a}	0.83±0.01^{a}	0.85±0.04^{a}

Data are presented as Mean ± Standard Deviation (n=3). Values within the same column followed by different superscript letters (a, b, c, d) are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test

Table 4.20. Effect of melatonin dipping on %PLW and Browning Index

Treatments	% PLW		Browning Index	
	Day 3	Day 5	Day 3	Day 5
S1	10.89±0.04a	19.76±0.08b	2.72±0.06a	3.00±0.06a
S2	9.99±1.69a	20.12±0.45b	1.81±0.01c	2.01±0.01c
S3	9.88±0.71a	19.63±0.53b	1.53±0.02d	1.70±0.02d
S4	10.54±0.64a	20.95±0.93ab	2.04±0.06b	2.25±0.06b
S5	10.99±0.53a	22.84±1.22a	1.84±0.03c	2.03±0.03c

Note: *Data are presented as Mean ± Standard Deviation (n=3). Values within the same column followed by different superscript letters (a, b, c, d) are significantly different ($P < 0.05$) according to Duncan's Multiple Range Test. % PLW indicates Physiological Loss in Weight*

Treatments	Day 0	Day 5
S1		
S2		
S3		
S4		
S5		

Fig 4.25. Change in physio-chemical Properties of litchi (Shahi) on Melatonin dip

5. Litchi based farming system under changing climate scenario

5.1 Assessment of phenology in litchi grown under varying climatic conditions

Litchi (*Litchi chinensis* Sonn.) exhibits marked phenological variability among cultivars affecting productivity and climate adaptability. This study aimed to characterize and compare the phenological behavior of 'Shahi' and 'China' using the extended BBCH scale and to examine the influence of thermal indices on phenophase progression. Phenological observations were recorded from bud development to fruit maturity following the BBCH scale (Fig 5.1 and 5.3). Growing degree days (GDD) and chilling days were computed to assess temperature-driven responses.

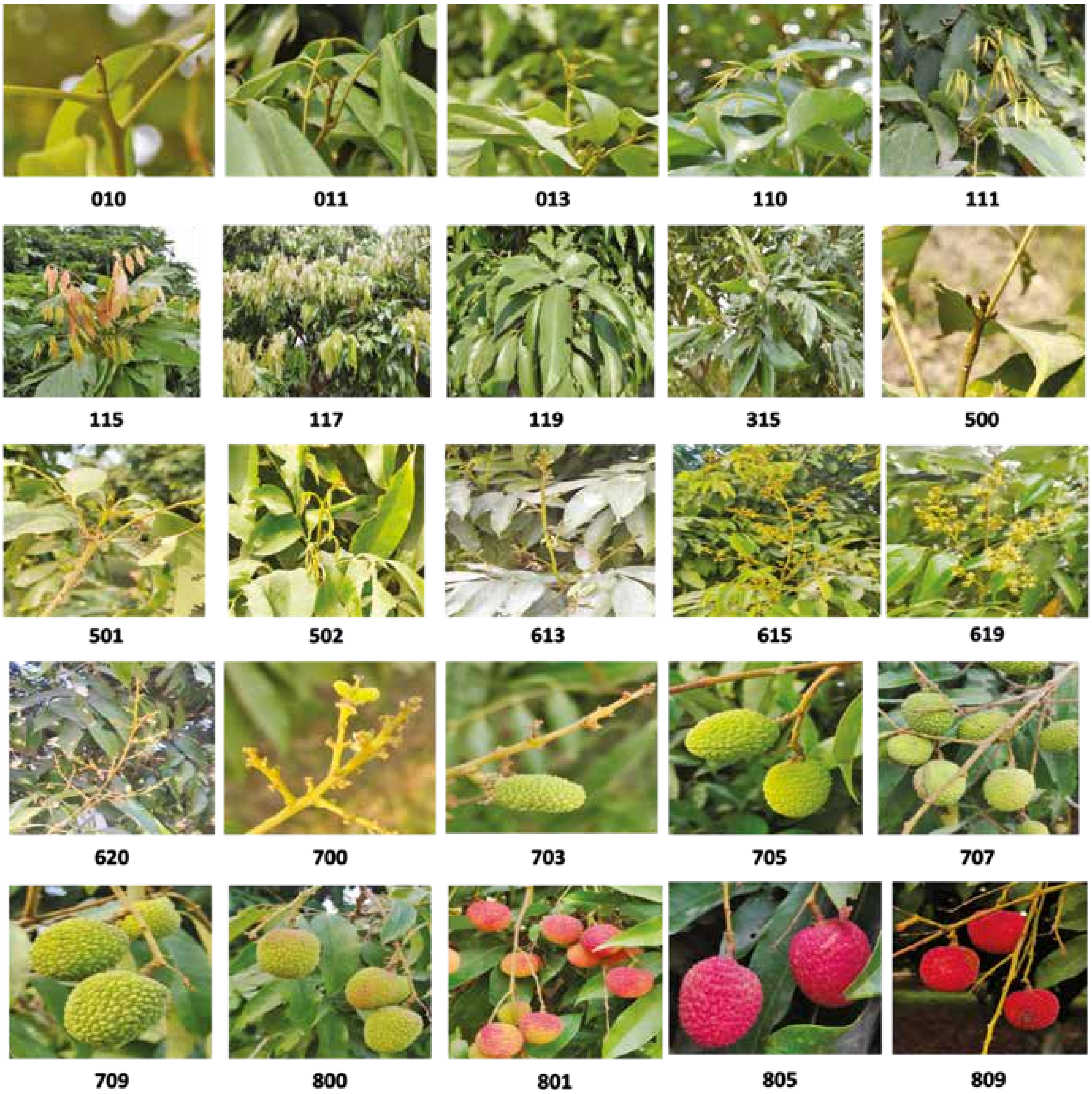


Fig. 5.1. Important phenophases of litchi cv. 'Shahi'

Clear cultivar-specific differences were observed in phenological timing and duration. 'Shahi' exhibited early bud break, shoot growth, and fruit maturity, whereas 'China' showed delayed but prolonged development. Although flowering intensity was comparable, 'China' recorded higher fruit set (89%) and retention (78%) than 'Shahi' (35% and 22%). Thermal accumulation was also greater in 'China' (1162.9 GDD) compared to 'Shahi' (955.5 GDD). Hence, 'China' demonstrated superior reproductive efficiency and yield potential despite delayed phenology. The BBCH scale enabled precise phenophase documentation, supporting better orchard management. These findings are useful for cultivar selection and climate-resilient litchi production planning in eastern India.

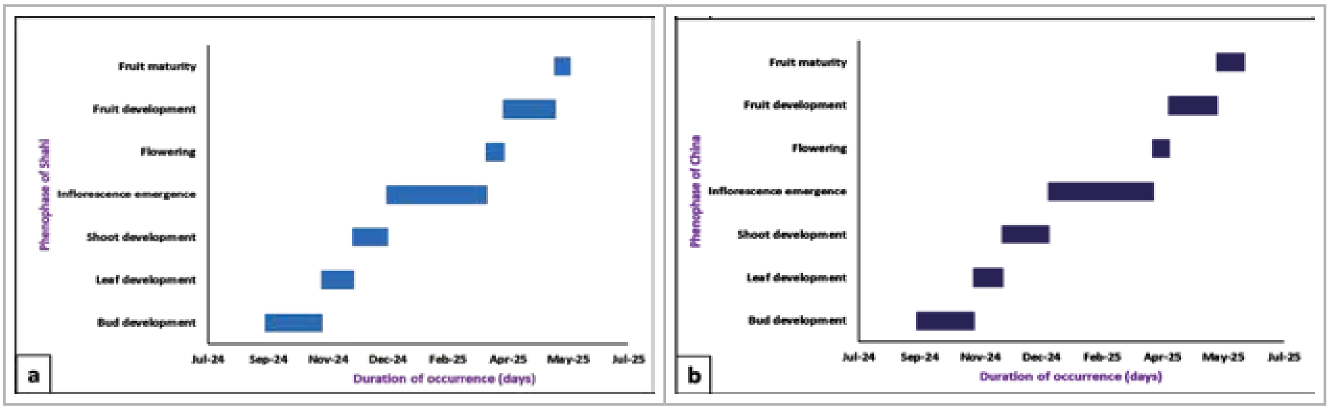


Fig. 5.2. Chronological progression of phenophases in litchi cv. 'Shahi' (a) and 'China' (b)

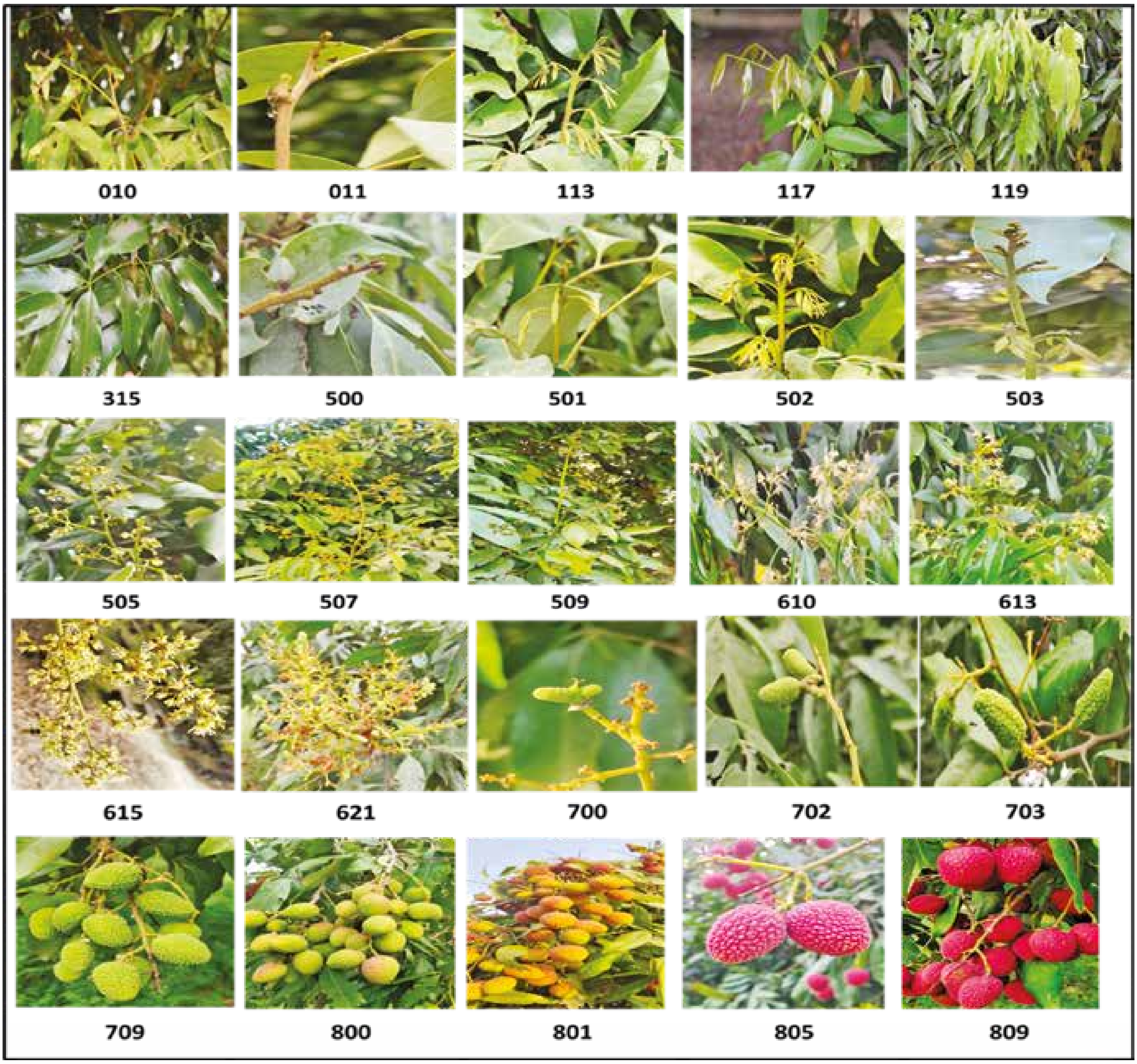


Fig. 5.3. Important phenophases of litchi cv. 'China'

5.2. Ecological foot printing of litchi production in India

The study analyzed 251 litchi-based farming households in Bihar to quantify ecological footprint, energy efficiency, sustainability, and resource-use patterns within integrated farming systems. Cluster analysis identified six distinct farmer typologies (Fig. 5.3), differentiated by landholding size, production intensity, diversification pattern, and economic orientation. Statistical validation using the Kruskal–Wallis test confirmed significant differences ($p < 0.001$) among clusters for both landholding size and net income, demonstrating strong structural heterogeneity among litchi-based farming systems.

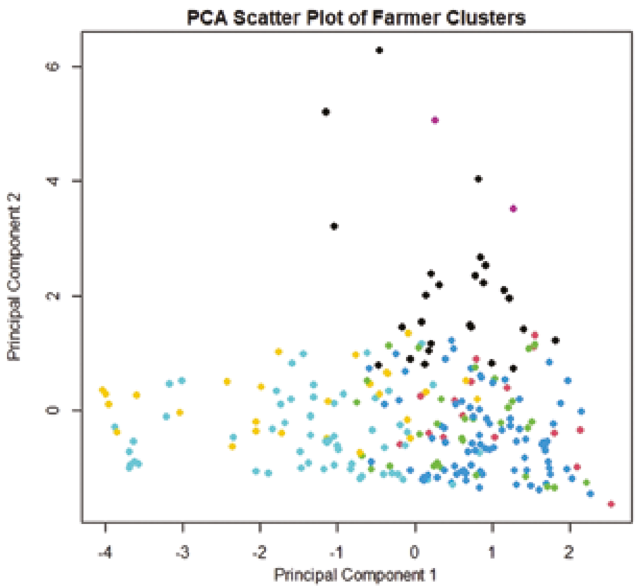


Fig 5.3. PCA scatter plot of farmer clusters

Farmer Typologies and Farming System Characteristics

Cluster 1: Very small farmers (0.74 ha) with low income and subsistence orientation; highly dependent on litchi orchards

Cluster 2: Small–medium farmers (1.4 ha) with moderate diversification and mixed crop income

Cluster 3: Medium farmers (2.08 ha) exhibiting balanced input–output structures and mixed orchard–oilseed systems

Cluster 4: Medium–large farmers (4.49 ha) characterized by fruit diversification and higher mechanization

Cluster 5: Large integrated farmers (6.94 ha) with diversified farming systems and strong commercial orientation

Cluster 6: Very large entrepreneurial farmers (8.84 ha) operating cereal–pulse dominated systems with large-scale management

Energy Efficiency and Carbon Footprint

Energy use efficiency increased progressively with farm size, ranging from 0.0008 in small farms to 1.56 in large farms. Diesel fuel accounted for 58% of total energy consumption, primarily for tractor operations and orchard management. Human labour contributed 27%, reflecting the labour-intensive nature of litchi orchards. Electricity constituted 15%, mainly used for irrigation pump sets. While chemical fertilizer (38%) is the major contributor in terms of indirect energy as shown in figure 5.4.

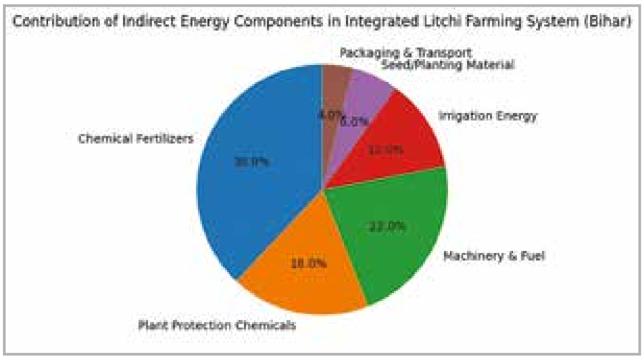


Fig. 5.4. Contribution of indirect energy components in integrated litchi farming system.

Carbon emissions varied substantially across clusters, with medium-scale systems showing the highest emissions due to higher input intensity. Small farms emitted approximately 2.4–2.5 t CO_2-eq ha^{-1} yr^{-1}, while large integrated farms emitted only 1.2–1.3 t CO_2-eq ha^{-1} yr^{-1}, indicating improved resource-use efficiency at larger scales. A one-unit increase in energy-use efficiency reduced emissions by approximately 1.4 t CO_2-eq ha^{-1} yr^{-1}, highlighting the importance of energy optimization in orchard systems.

Sustainability Assessment

Composite Sustainability Index based on Environmental, economic and energy indexes were calculated (Fig. 5.5). Composite sustainability index values increased steadily from 0.02 in Cluster 1 (very low sustainability) to 1.00 in Cluster 6 (excellent sustainability). Large integrated farms achieved higher sustainability due to improved resource management, diversification, and higher economic returns. Medium-scale diversified orchards also showed high sustainability performance due to efficient input-output balance.

Hence, orchard-intensive systems possess high potential for carbon mitigation through improved nutrient and plant protection management. Integrated farming systems with diversified enterprises demonstrated the best balance between productivity, sustainability, and emission reduction. Crop-dominated systems have low emissions but limited carbon sequestration potential unless diversified with perennial components. Fruit diversification increases absolute emissions per hectare but reduces emissions per unit income, indicating improved eco-efficiency of production systems.

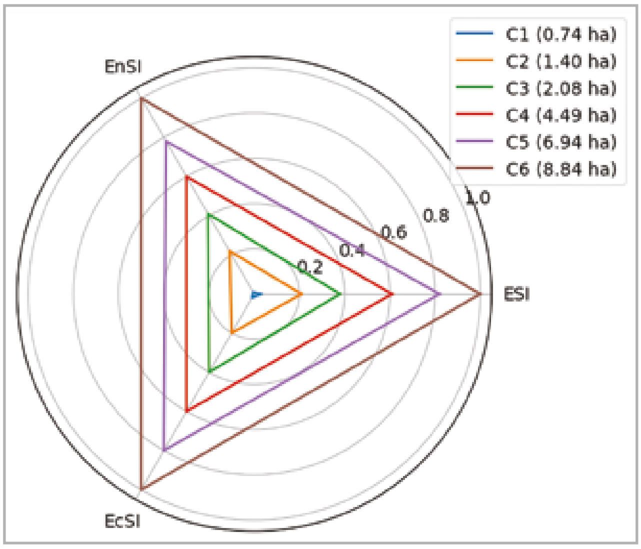


Fig. 5.5. Radar plot of sustainability dimensions integrated litchi-based farming system

6. Improving knowledge and skill of stakeholders for increasing production of litchi

6.1. Technological upscaling among tribal farmers (TSP)

Tribal Sub-Plan (TSP) project is an initiative for advancing litchi cultivation in tribal regions. Under this project for the financial year 2025–26, a focused intervention was implemented to promote litchi cultivation and strengthen the capacity of tribal farmers. The initiative emphasized both technological dissemination and livelihood enhancement in underutilized horticultural landscapes.

A total of 2,000 planting materials of the elite litchi cultivar 'Shahi' were provided to Krishi Vigyan Kendra (KVK), Tirap, Arunachal Pradesh for tribal farmers. This effort aimed to introduce high-quality litchi cultivar for enhancing orchard productivity and fruit quality in the region. To complement the distribution of planting materials, a hybrid training programme was organized at KVK Tirap, engaging around 42 tribal farmers. The training focused on scientific cultivation practices, including orchard establishment, nutrient management, and plant protection strategies. Participants were also provided with organic inputs and basic agricultural tools to facilitate immediate on-farm adoption of the recommended practices.

From a developmental perspective, this initiative represents a strategic step toward diversifying horticultural systems in tribal areas, where high-value fruit crops like litchi have remained largely underexploited. By integrating improved inputs with knowledge dissemination, the programme contributes to enhancing farmers' technical competencies, increasing productivity, and creating sustainable income opportunities. The activities were executed within an allocated budget of ₹5.00 lakh for the year. To ensure optimal utilization of funds, an additional 73 litchi saplings were procured. The plants are currently under hardening. These plants are scheduled for distribution during the

Fig. 6.1. Planting materials at KVK, Tirap, Arunachal Pradesh

6.2 Technological upscaling among Scheduled Caste farmers

Under SCSP project, a total of 12,130 litchi saplings were distributed through selected KVKs for onward supply to Scheduled Caste (SC) beneficiaries to support orchard establishment and horticulture-based livelihoods. Saplings were dispatched from ICAR-NRCL to four districts of Bihar: Nawada (5,250), Muzaffarpur (4,580), Begusarai (1,600), and Jamui (700), with allocations based on district-wise beneficiary coverage and planting material requirements.

Fig. 6.2. litchi saplings being distributed to Scheduled Caste (SC) beneficiaries to support orchard establishment and horticulture-based livelihoods

Transfer of Technology and Outreach Activities

Dissemination of technologies have been done through organizing training, demonstration, field day, Kisan Gosthis, lectures, showcasing NRCL's technologies in agriculture/ farmers fair and interaction with stakeholders. The details of formal training and other programmes pertaining to transfer technology and human resource development activities are summarized below.

1. Training programmes/field days organized

S. No.	Title of the training	Date	Number of participants	Sponsoring agency	Coordinators
1.	लीची की बागवानी में उत्तम कृषि पद्धतियाँ	6-8 Jan, 2025	20	BAMETI	Dr. Prabhat Kumar Dr. Abhay Kumar
2.	खाद्य प्रसंस्करण के माध्यम से उद्यमिता विकास	16-18 Jan, 2025	20	RKVY	Er. Ankit Kumar Dr. Sunil Kumar
3.	लीची की प्रूनिंग (छंटाई)	18 Jan, 2025	15	ICAR-NRCL	Dr. Sunil Kumar Dr. Ashok Dhakad
4.	Entrepreneurship development through value-added litchi products	20-22 Jan, 2025	20	BAMETI	Dr. Sunil Kumar Er. Ankit Kumar
5.	खाद्य प्रसंस्करण एवं प्रबंधन	10-12 Feb, 2025	20	RKVY	Dr. Sunil Kumar
6.	Advanced Entrepreneurship and Skill Development Programme (A-ESDP) on Processing and Post-Harvest Value Chain Management in Litchi	17-21 Feb, 2025	20	MSME	Dr. Sunil Kumar Er. Ankit Kumar Dr. Ipsita Samal
7.	Beekeeper -ver 3.0	19 Feb - 5 Apr, 2025	20	BAMETI	Dr. Ipsita Samal Dr. Sunil Kumar
8.	Beekeeper -ver 3.0	25 Feb - 11 Apr, 2025	20	BAMETI	Dr. Ipsita Samal Dr. Sunil Kumar
9.	लीची मे प्रबंधन तथा प्रसंस्करण	27 Feb - 1 Mar, 2025	20	RKVY	Dr. Sunil Kumar Er. Ankit Kumar
10.	A-ESDP on Technological Interventions in Litchi for Higher Productivity and Quality Fruit Production	3-7 Mar, 2025	20	MSME	Dr. Sunil Kumar Er. Ankit Kumar Dr. Ipsita Samal
11.	लीची मे प्रसंस्करण तथा उद्यमिता विकास	18-20 Mar, 2025	20	RKVY	Er. Ankit Kumar Dr. Sunil Kumar
13.	लीची की छत्रक प्रबंधन	18 Jun, 2025	16	ICAR-NRCL	Dr. Sunil Kumar
14.	EDP लीची में मूल्य संवर्धन	9-11 July, 2025	26	ICAR-NRCL	Er. Ankit Kumar Dr. Sunil Kumar Dr. Bhagya Vijayan
15.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	04-10 Aug, 2025	18	NNB	Dr. Bhagya Vijayan Er. Ankit Kumar
16.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	11-17 Aug, 2025	21	NBB	Er. Ankit Kumar
17.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	18-24 Aug, 2025	23	NBB	Dr. Ipsita Samal Dr. Sunil Kumar
18.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	25 Aug-1 Sept, 2025	25	NBB	Dr. Ipsita Samal Er. Ankit Kumar
19.	लीची की फसल की खेती, प्रसंस्करण एवं विपणन	9-13 Sept, 2025	30	ATMA Samastipur	Er. Ankit Kumar Dr. Bhagya Vijayan
20.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	08-14 Sept, 2025	20	NBB	Dr. Ipsita Samal Dr. Bhagya Vijayan

S. No.	Title of the training	Date	Number of participants	Sponsoring agency	Coordinators
21.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	15-24 Sept, 2025	20	NBB	Dr. Ipsita Sambal Dr. Sunil Kumar
22.	लीची में गार्डलिंग तकनीक का प्रचलन/प्रयोग	16 Sept, 2025	80	ICAR-NRCL	Dr. Sunil Kumar Er. Ankit Kumar
23.	लीची की खेती में उत्तम कृषि पद्धतियाँ	22-24 Sept, 2025	20	BAMETI	Dr. Bhagya Vijayan Dr. Ipsita Samal
24.	लीची की खेती एवं बाग प्रबंधन	25-27 Sept, 2025	20	BAMETI	Dr. Sunil Kumar Er. Ankit Kumar
25.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	06-12 Oct, 2025	22	NBB	Dr. Ipsita Samal Dr. Sunil Kumar
26.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	13-18 Oct, 2025	22	NBB	Dr. Ankit Kumar Dr. Sunil Kumar
27.	लीची बाग में कीट प्रबंधन	13-15 Oct, 2025	20	BAMETI	Dr. Prabhat Kumar, Dr. Bhagya Vijayan
28.	मधुमक्खी पालन के वैज्ञानिक दृष्टिकोण पर प्रशिक्षण	03-08 Nov, 2025	20	NBB	Dr. Bhagya Vijayan Er. Ankit Kumar
29.	लीची की खेती में उत्तम कृषि पद्धतियाँ	10-13 Nov, 2025	13	ICAR-NRCL	Dr. Bhagya Vijayan Dr. Ipsita Samal
30.	लीची की खेती में उत्तम कृषि पद्धतियाँ	13-15 Nov, 2025	16	ICAR-NRCL	Dr. Bhagya Vijayan Dr. Ipsita Samal
31.	लीची में मूल्य संवर्धन	18-20 Nov, 2025	20	BAMETI	Er. Ankit Kumar Dr. Bhagya Vijayan
32.	लीची की खेती में नवीनतम प्रगति	09-11 Dec, 2025	20	BAMETI	Dr. Sunil Kumar Er. Ankit Kumar
33.	लीची उत्पादन की वैज्ञानिक तकनीक एवं तुड़ाई उपरांत प्रबंधन	22-26 Dec, 2025	22	ATMA Begusarai	Dr. Bhagya Vijayan Er. Ankit Kumar



2. Institute Seminar/webinars organized

The talk series for the students and other litchi stakholders has been started, in which scientists from different fields were invited to interact.

S. No.	Title of Lecture	Date	Resource person
1.	Fruit Breeding: From Domestication to Genome Editing	24th Jan, 2025	Dr. Sunil Kumar, Scientist (Fruit Science)
2.	An insight into the host-pathogen interaction of necrotrophic fungal pathogens and its implications to disease management	18th April, 2025	Dr. Vinod Kumar, Principal Scientist (Plant Pathology)
3.	Bibliometric trends in current research: Present status, relevance and future prospects	23rd Sept, 2025	Dr. Ipsita Samal, Scientist (Entomology)
4.	Modified and controlled atmosphere packaging of fruit products	23rd Sept, 2025	Er. Ankit Kumar, Scientist (Agri. Structure & Process Engg.)

Institute seminar on "Fruit Breeding: From Domestication to Genome Editing" on 24th Jan, 2025 delivered by Dr. Sunil Kumar, Scientist (Fruit Science)

Institute seminar on topic entitled "Socio-ecological perspective of Life Cycle Assessment (LCA) in orchard crops" on 28th Nov, 2025 by Dr. Bhagya Vijayan, Scientist (Agricultural Extension)

3. Monthly Stakeholders' Interface Meetings organized

The institute organizes Farmer-scientists interface meet at monthly interval in which litchi growers/traders; processors participate in the deliberations on seasonal issues on litchi with scientists of the institute and representatives from Govt. of Bihar. During the year a total of Twelve number of monthly farmer scientist interface meetings were held at the centre in which more than 760 stakeholders participated.

4. Participation in Farmers' Fairs/Exhibitions

S. No.	Programme	Venue	Date	Participants
1.	Bagwani Mahotsav	Gandhi Maidan, Patna	03-05 Jan, 2025	Dr. Chaman Kumar Mr. A.P. Pandey Mr. Dharmdev Bharti
2.	Farmers' Progress Fair	KVK Piprakothi, East Champaran	8-10 Feb, 2025	Mr. Dharmdev Bharti Ms. Upagya Sah Mr. Amit Kumar
3.	Kishan Mela	Dr. RPCAU, Pusa, Samastipur	15-17 Feb, 2025	Ms. Upagya Sah Dr. Chaman Kumar Mr. A.P. Pandey
4.	Agricultural Fair and Exhibition	ICAR-NISA, Ranchi	20-22 Feb, 2025	Dr. Ashok Dhakad Mr. Rohit Kumar
5.	Kishan Mela	ICAR-RCER, Patna	20-22 Feb, 2025	Dr. Chaman Kumar Mr. Sanjan Kr. Bharti Mr. Ajay Kr. Rajak

S. No.	Programme	Venue	Date	Participants
6.	Viksit Krishi Sankalp Abhiyan	Bhagalpur	22-24 Feb, 2025	Dr. Bikas Das Mr. Dharmdev Bharti Mr. Amit Kumar
7.	Kishan Mela	KVK Piprakothi, East Champaran	4-6 March, 2025	Mr. Dharmdev Bharti Mr. A.P. Pandey Dr. Chaman Kumar
8.	Kishan Mela	BAU, Bhagalpur	11-13 March, 2025	Mr. A.P. Pandey Mr. Alok Kumar
9.	Farmer Fair – cum - Horticulture Exhibition	ATMA, Muzaffarpur	11-12 March, 2025	Dr. Chaman Kumar Mr. Dharmdev Bharti
10.	Bihar Diwas	Gandhi Maidan, Patna	22-24 March, 2025	Dr. Chaman Kumar Mr. Dharmdev Bharti Mr. A.P. Pandey
11.	Kishan Mela	ICAR-IARI, New Delhi	22-26 March, 2025	Dr. Chaman Kumar Mr. A.P Pandey
12.	Viksit Krishi Sankalp Abhiyan	All Blocks and panchayats of Muzaffarpur Dist.	29 May – 12 June, 2025	Dr. Bikas Das Dr. Abhay Kumar Dr. Prabhat Kumar Dr. Bhagya Vijayan Dr. Sunil Kumar Er. Ankit Kumar Dr. Ipsita Samal Mr. Dharmdev Bharti
13.	Agriculture, Livestock and Fisheries Development Fair	KVK Piprakothi, East Champaran	01-02 Dec, 2025	Mr. Dharmdev Bhari Dr. Chaman Kumar Dr. A.P. Pandey
14.	Agriculture Fisheries and Livestock Development Fair	KVK Piprakothi, East Champaran	17-19 Sept, 2025	Dr. Abhay Kumar Dr. Chaman Kumar Mr. A.P. Pandey Mr. Dharmdev Bharti
15.	Farmers Fair on Agriculture Growth through Advanced Technology Adoption	KVK, Jale, Darbhanga	21-22 Sept, 2025	Er. Ankit Kumar Dr. Chaman Kumar Mr. Dharmdev Bharti Mr. A.P. Pandey
16.	District Level Farmer Fair and Horticulture Exhibition	ATMA, Muzaffarpur	29-30 Dec, 2025	Dr. Bhagya Vijayan Dr. Chaman Kumar Mr. Dharmdev Bharti

5. Field demonstration conducted:

S. No.	Demonstration	Date	Place	No. of Participants
1.	Rejuvenation of senile litchi orchard	26 March, 2025	Vishali, Muzaffarpur, Bhagalpur, Samastipur, East Champaran	18
2.	Rejuvenation of senile litchi orchard	14 June, 2025	Nawada, Muzaffarpur	20
3.	Rejuvenation of senile litchi orchard	21 June, 2025	Manika, Muzaffarpur	33
4.	Trichoderma demonstration in young litchi orchards	06 July, 2025	Manika, Muzaffarpur	41
5.	Trichoderma demonstration in young litchi orchards	21 Aug, 2025	Mehsi, East Champaran	22
6.	Demonstration of strawberry as intercrop in litchi	26 Aug, 2025	Mushahari, Muzaffarpur	80
7.	Demonstration of strawberry as intercrop in litchi	12 Sept, 2025	Rohua, Mushahari, Khanti, Khatra	14
8.	Rejuvenation and canopy management	14-18 Sept, 2025	Mushahari, Nawada, Motipur, Katra, Bochhaha, Gayghat, Minapur, Muraul, Viashali, Sakra, Sitamari, Pusa, Kanti	64
9.	Rejuvenation and canopy management	16-21 Sept, 2025	Mushahari, Nawada, Motipur, Katra, Bochhaha, Gayghat, Minapur, Muraul, Viashali, Sakra, Sitamari, Pusa, Kanti	64
10.	Canopy management	24-28 Sept, 2025	Mushahari, Rohua, Bochhaha, Goraul, Pusa, Manganpur, Sadadpur, Manika	20
11.	Nutrient spray demonstration using Agri-drone	6-16 Oct, 2025	Pusha, Khanpur, Raghunathpur, Amma, Bishunpur Bakhari, Harpur Mahmada, Samastipur, Dhobgama	56
12.	Microbial consortium Demonstration	10-30 Nov, 2025	Mushahari, Muraul, Kurni, Katra, Khanti	102
13.	Intercrop demonstration in litchi orchard	5 Dec, 2025	Minapur, Muraul, Manika, Mushahari	40
14.	Apiary integration in litchi orchard	20 Dec, 2025	Mushahari, Minapur, Khati, Muraul	05

Agri-drone spraying in field crops

Intercrop demonstration in rejuvenated litchi orchard

Human Resource Development

Participation of Scientist Staff in Training/ Conference/ Seminar/ Symposia/ Workshop / Meeting

S. No.	Title	Venue and date	Participant(s)
1.	National Conference on Digital Technologies for Transforming the Horticulture Sector	ICAR-IARI, New Delhi 28-30 Jan, 2025	Dr. Ankit Kumar Dr. Sunil Kumar
2.	National Conference on Seed Chain Management in Eastern & North Eastern Hill Region: Challenges & Opportunities	CHES, Bhubaneswar 21-22 Jan, 2025	Dr. Bikas Das Dr. Sunil Kumar
3.	XII Group Discussion of ICAR- All India Coordinated Research Project on Fruits	BAU, Sabour, Bhagalpur 11-14, Feb, 2025	Dr. Bikas Das Dr. Sunil Kumar
4.	XVII Agricultural Science Congress	GBPUAT, Pantnagar 20- 22 Feb, 2025	Dr. Sunil Kumar
5.	National Horticulture Fair 2025	ICAR-IIHR, Bengaluru 27-28 Feb, 2025	Dr. Sunil Kumar
6.	National Seminar on Litchi Diversity and GI Based Litchi Honey	DrRPCAU, Pusa 24-25 May, 2025	Dr. Bikas Das Dr. Sunil Kumar
7.	International Conference on Agroecology and Pest management: Balancing Environment and Human Health	LNMU, Darbhanga 18-19 July, 2025	Dr. Bhagya Vijayan
8.	Training on Analysis of Experimental Data using R	ICAR-NAARM, Hyderabad 21–25 July, 2025	Dr. Prabhat Kumar
9.	Training on R for Soil Science	ICAR-NBSS&LUP, Nagpur 11–20 Nov, 2025	Dr. Prabhat Kumar
10.	Workshop on Scientific Writing and Data Analysis	Regional Horticultural Research Station, Tirupati, 12-15 Nov, 2025	Dr. Sunil Kumar
11.	9th International Conference on Advances in Agricultural, Biological and Biodiversity Conservation for Sustainable Development	University of Mysore 13–15 Nov, 2025	Dr. Abhay Kumar Dr. Prabhat Kumar
12.	Training of Master Trainers on Vigilance Perspectives	ICAR-NAARM, Hyderabad 17–19 Nov, 2025	Dr. Prabhat Kumar

Events Organized

25th Foundation Day

The 25th Foundation Day of ICAR–National Research Centre on Litchi, Muzaffarpur was celebrated on 6th June, 2025 at the Centre. Dr. Anjani Kumar, Director, ICAR-ATARI, Patna, graced the occasion as Chief Guest. The programme began with the lighting of the lamp followed by the ICAR song. Dr. Bikash Das, Director, NRCL, delivered the welcome address and highlighted the achievements of the Centre over the past two decades.

The event was attended by distinguished guests including Dr. Anup Das, Director, ICAR-RCER, Patna; Dr. Sushil Kumar Purbey, Director, ICAR-MGIFRI, Motihari; Dr. Pradeep Kumar Jatav, Deputy Director, National Horticulture Board, Bihar; and Ms. Suman Prabha, District Development Manager, NABARD, who shared their views on horticultural development and farmer empowerment.

During the technical session, a series of lectures were delivered addressing key challenges and opportunities in litchi research and development. Dr. Vinod Kumar spoke on present problems in litchi and future research directions, emphasizing the need for targeted research to address emerging issues. Dr. Sunil Kumar highlighted the current status, challenges, and Vision 2050 for litchi improvement, focusing on long-term sustainability and productivity enhancement. Dr. Ipsita Samal discussed insect pest management in litchi, presenting practical and simplified solutions for effective control. Dr. Sushil Kumar Purbey elaborated on future research perspectives in post-harvest management and value addition, underlining its importance for reducing losses and enhancing farmer income. Dr. Pradeep Kumar Jatav outlined schemes of the National Horticulture Board for empowering farmers in Bihar, while Ms. Suman Prabha highlighted various opportunities and support mechanisms available through NABARD for strengthening farmers' livelihoods. A scientist–farmer interaction session was organized to discuss current challenges and future research directions in litchi. Progressive farmers and stakeholders were felicitated for their outstanding contributions to litchi research and development.

The programme was coordinated by Dr. Vinod Kumar, Principal Scientist, with active participation of scientific, technical, administrative, and supporting staff of the Centre. The event concluded with a vote of thanks proposed by Dr. Bhagya Vijayan, Scientist, followed by group photography and lunch.

Glimpses of 25th Foundation Day celebration

Janjatiya Gaurav Varsh Pakhwada

The "*Janjatiya Gaurav Varsh Pakhwada*" was organized by ICAR–National Research Centre on Litchi (NRCL), Muzaffarpur from 1st to 15th November, 2025 to commemorate the 150th Birth Anniversary of Bhagwan Birsa Munda (*Janjatiya Gaurav Diwas*). The programme was coordinated by Dr. Vinod Kumar, Principal Scientist, with active participation of scientific, technical, administrative and supporting staff of the Centre.

The pakhwada commenced with an inaugural address by the Director, NRCL, along with display of banners and posters depicting the life and legacy of Bhagwan Birsa Munda. At NRCL, the pakhwada included a series of awareness and outreach activities such as display of posters on the life and legacy of Bhagwan Birsa Munda, documentary screenings, lecture on tribal communities and sustainable agriculture, exhibitions on tribal food and traditional knowledge, farmer interaction programmes, school awareness campaigns, plantation drive, and field visits for technology dissemination. The programme concluded with the celebration of Birsa Munda Jayanti and Janjatiya Gaurav Diwas.


Glimpses of *Janjatiya Gaurav Varsh Pakhwada*" organized by ICAR–NRCL, Muzaffarpur


Glimpses of *Janjatiya Gaurav Varsh Pakhwada*" organized by KVK, Tirap, Arunachal Pradesh (sponsored by ICAR-NRCL, Muzaffarpur)

A similar programme was also organized at KVK Tirap, Deomali, Arunachal Pradesh, under the sponsorship of NRCL, Muzaffarpur, with active participation of farmers from different parts of the district. During the inaugural session, Dr. Narendra Kumar, Senior Scientist & Head, highlighted the objectives of the programme. A series of technical sessions were conducted on horticultural technologies, including litchi cultivation techniques and value addition of millet-based products.

Subject matter specialists delivered lectures on important livelihood aspects, wherein plant protection aspects of litchi and other fruit crops were explained with emphasis on pest and disease management. Training programmes on pig farming and its scientific management were conducted to enhance farmers' income with low investment. Sessions on fisheries highlighted integrated farming approaches for better utilization of resources and increased profitability.

Hands-on learning was promoted through method demonstrations and field visits at the KVK farm, enabling farmers to gain practical exposure to improved agricultural practices. In addition, an exposure visits to an agriculture-based enterprise in Tinsukia, Assam was organized to familiarize farmers with modern farm inputs, mechanization, supply chains, and marketing strategies.

हिन्दी राजभाषा से सम्बंधित आयोजित बैठक एवं कार्यक्रम का विवरण

राजभाषा कार्यान्वयन समिति की तिमाही बैठक

पहली तिमाही बैठक	21/04/2025
दूसरी तिमाही बैठक	30/07/2025
तीसरी तिमाही बैठक	15/10/2025
चौथी तिमाही बैठक	13/03/2026

राजभाषा हिन्दी कार्यशाला

दिनांक	10/01/2025
मुख्य अतिथि: श्री नीरज कुमार मिश्रा, असिस्टेंट प्रोफेसर, हिंदी विभाग, आरडीएस कॉलेज, मुज० (बिहार)	
दिनांक	30/06/2025
मुख्य अतिथि: डॉ विनोद आज़ाद, विभागाध्यक्ष (हिन्दी),एसआरपीएस कॉलेज, मुजफ्फरपुर (बिहार)	
दिनांक	15/10/2025
मुख्य अतिथि: डॉ विनोद आज़ाद, विभागाध्यक्ष (हिन्दी),एसआरपीएस कॉलेज, मुजफ्फरपुर (बिहार)	

हिन्दी पखवाड़ा

आयोजन तिथि	**12/09/2025 से 25/09/2025**
आयोजित प्रतियोगिता	ऑनलाइन प्रश्नोतरी प्रतियोगिता, हिन्दी अनुवाद, हिन्दी टंकण, श्रुत लेखन, सुलेखन, निबंध, वाद-विवाद प्रतियोगिता, खेल प्रतियोगिता एवं कविता प्रतियोगिता (मौखिक)

हिंदी कार्यशाला में भाग लेने वाले प्रतिभागी

पुरस्कार वितरण एवं समापन समारोह

विश्व हिन्दी दिवस का आयोजन

आयोजन तिथि	**10/01/2025**
दिनांक 10/01/2025 को विश्व हिन्दी दिवस के उपलक्ष्य में एक कार्यशाला का आयोजन किया गया जिसमें व्याख्यान हेतु मुख्य अतिथि के रूप में श्री नीरज कुमार मिश्र, सहायक प्रोफसर, आर डी एस कॉलेज, मुजफ्फरपुर द्वारा हिन्दी पर अति सुन्दर व्याख्यान किया गया।	

नगर राजभाषा कार्यान्वयन समिति, मुजफ्फरपुर के तत्वाधान में संस्थान में आयोजित हिन्दी कार्यशाला, संगोष्ठी एवं प्रश्नमंच प्रतियोगिता

आयोजन तिथि	**27/06/2025**
कार्यक्रम के मुख्य बिंदु: संविधान सभा में हिन्दी के बारे में टिका टिप्पणी पर एक सुन्दर फिल्म का चित्रण "राजभाषा एवं तकनीक; कृत्रिम बुधिमत्ता" पर व्याख्यान प्रश्नमंच प्रतियोगिता का आयोजन एवं पारितोषिक वितरण हिन्दी के प्रयोग पर विस्तृत चर्चा	

Constitution Day

Constitution Day was celebrated at ICAR–National Research Centre on Litchi, Muzaffarpur on 26 November 2025 in compliance with the directives of the Government of India. The programme aimed to commemorate the adoption of the Constitution of India and to create awareness about its importance among staff members and young professionals. The event commenced with the playing of the National Song "Vande Mataram," followed by a welcome address by the Director, who highlighted the significance, values, and historical relevance of the Constitution and emphasized the responsibility of every citizen to uphold constitutional ideals. At 11:00 AM, all officials and staff members collectively recited the Preamble, reaffirming their commitment to justice, liberty, equality, and fraternity.

During the programme, participants shared their views on the importance of Constitution Day and the role of the Constitution in strengthening the democratic framework of the country. The staff also participated in the online Preamble reading through the Government portal and downloaded participation certificates. The celebration concluded with a collective resolve to promote constitutional values and contribute towards nation-building through dedicated professional efforts.

Vigilance Awareness Week 2025

Vigilance Awareness Week-2025 was observed from 27th oct to 2nd Oct 2025 at ICAR NRC on Litchi, Muzaffarpur, with active participation of employees to promote integrity, transparency, and accountability in official functioning. During the week, both e-pledge and physical integrity pledges were administered, with employees and stakeholders taking part in reaffirming their commitment to ethical conduct. Various activities such as walkathon, debate and discussion on vigilance awareness, and awareness programmes were organized within the institute. Banners and posters were displayed at different locations to disseminate vigilance messages, and pamphlets were used to sensitize staff. Additionally, awareness was spread through social media platforms including X, Facebook, and LinkedIn. The programme emphasized the importance of corruption-free governance and encouraged staff members to follow best practices in public service, thereby strengthening a culture of transparency and accountability in the organization.

Swachhata Pakhwada

ICAR–National Research Centre on Litchi, Muzaffarpur successfully organized Swachhata Pakhwada from 16th to 31st December, 2025 with active participation of scientists, technical, administrative staff, students, farmers and community members. The Pakhwada commenced with Swachhata Pledge Day on 16th December, 2025, led by the Hon'ble Director, involving mass administration of the Swachhata Pledge, awareness dissemination through IEC materials, digital platforms and a Swachhata-themed selfie booth. Subsequently, a series of day-wise thematic activities were carried out including Swachhata awareness programmes with school children, seminars and workshops on waste management and "waste to wealth", review and weeding out of old records, disposal of scrap items, e-office implementation and cleanliness drives in offices, campuses and residential colonies.

Special emphasis was laid on green initiatives, plantation drives, discouraging single-use plastics, recycling of waste water, sanitation awareness and community outreach through Shramdaan activities under Mera Gaon Mera Gaurav and other schemes. The Pakhwada also witnessed community involvement events such as symbolic human chain, signature campaigns, plogging rallies, Safai Mitra Suraksha Shivirs, engagement of VIPs/VVIPs and religious leaders, and focused drives at public places, markets, tourist and religious sites. Kisan Diwas (Farmer's Day) was celebrated as "Clean Green Utsav" with participation of farmers, sharing of best practices and felicitation of exemplary Swachhata initiatives. Competitive activities, webinars and cultural programmes were organized to foster healthy competition and awareness among students and youth. Overall, the programme significantly enhanced awareness on cleanliness, sanitation, waste management and sustainable practices, reinforcing the commitment of ICAR–NRCL towards the objectives of Swachh Bharat Mission through active institutional and community participation.

24th IRC Meeting

The 24th Institute Research Council (IRC) meeting of the of ICAR-NRCL, Muzaffarpur, was held on 16th January 2026 in the Committee room of the Institute under the chairmanship of Dr. Bikash Das, Director, ICAR-NRCL. Dr. Kundan Kishore, Dean, Pandit Deen Dayal Upadhyay College of Horticulture & Forestry, RPCAU was the invited at External Expert. Dr. Bhagya Vijayan, In-Charge PME Cell, welcomed the Chairman and all the members to the 24th IRC meeting. In his opening remarks, Dr. Bikash Das, Director & Chairman, IRC, appreciated the contribution of entire team of ICAR-NRC on Litchi towards augmenting farmer's income through various training programmes conducted at the Centre. He highlighted the need for unified efforts among litchi stakeholders to promote a circular economy.

The research projects of the institute are carried out under 6 broad core-areas and the progress of the research work under different core areas were presented by the respective Scientists. During the deliberation, a total of 26 institute-funded projects, 7 externally funded projects, 9 AICRP trials, and 2 collaborative projects were reviewed. The IRC, reviewed the progress of each project and suggested future course of action.

Ongoing Research Projects

A. Institute Funded

S. No.	Project title	Principal Investigator	Co-PIs
1. Conservation, characterization, and utilization of genetic diversity for improvement of litchi			
1.	Collection of indigenous and exotic germplasm, their characterization, evaluation, documentation and utilization	Dr. Abhay Kumar	Dr. Sunil Kumar Dr. Vinod Kumar Dr. Ipsita Samal Er. Ankit Kumar Dr. Suvalaxmi Palei
2.	Development of improved cultivars in litchi	Dr. Abhay Kumar	Dr. Sunil Kumar
3.	Characterization, evaluation and utilization of longan germplasm	Dr. Abhay Kumar	Dr. Sunil Kumar
4.	Molecular Finger-printing in litchi cultivars through microsatellite markers	Dr. Abhay Kumar	Dr. Sunil Kumar
5.	Mutation breeding for litchi improvement	Dr. Sunil Kumar	Dr. Abhay Kumar
6.	Mapping of gene(s)/QTLs for economically important traits in litchi through genome-wide association studies (GWAS)	Dr. Sunil Kumar	Dr. Abhay Kumar Dr. M. K. Dhakar Dr. K. U. Tribhuvan Dr. D. S. Bisht
2. Development and refinement of integrated production technologies for improved productivity of litchi			
7.	Investigation on mycorrhizal association and role of bio-fertilizers for sustainable production of litchi	Dr. Vinod Kumar	Dr. Prabhat Kumar
8.	Integrated soil health management for quality litchi production	Dr. Prabhat Kumar	Dr. Vinod Kumar
9.	Nutrient management in Litchi orchard using Diagnosis and Recommendation Integrated System	Dr. Prabhat Kumar	—
10.	Effect of Seasonal variation on leaf nutrient dynamics of litchi cultivar and Standardizing Litchi leaf sampling Technique for Alluvial plain of Bihar	Dr. Prabhat Kumar	—
11.	Effect of enriched biochar on soil properties and fruit yield in litchi orchard	Dr. Prabhat Kumar	—
3. Development and refinement of integrated crop protection technologies for improved productivity of litchi			
12.	Investigation and management of pre-harvest diseases of litchi	Dr. Vinod Kumar	Dr. Abhay Kumar
13.	Investigation and management of insect-pest complex of litchi	Dr. Ipsita Samal	Dr. Vinod Kumar Dr. J. S. Chaudhary
14.	Understanding spatio-temporal variation changes in host pest interaction	Dr. Ipsita Samal	Dr. Vinod Kumar Dr. Bhagya Vijayan Dr. Pratheepa M Dr. J. S. Chaudhary

S. No.	Project title	Principal Investigator	Co-PIs
15.	Exploring the potential of behaviour chemicals for the managment of litchi stink bug	Dr. Ipsita Samal	Dr. Vinod Kumar Dr. K. Subaharan Dr. J. S. Chaudhary
4 . Integrated Postharvest Management to Reduce Losses, Improve Marketing and Product Diversification			
16.	Investigation and management of postharvest losses in litchi	Dr. Vinod Kumar	—
17.	Postharvest management with respect to pericarp browning and fruit decay	Er. Ankit Kumar	Dr. Vinod Kumar
18.	Post harvest management and by-product utilization of litchi fruit	Er. Ankit Kumar	Dr. Sunil Kumar Dr. Bhagya Vijayan Dr. S. K. S. Yadav Dr. Alok Gupta
5. Improving knowledge and skill of stakeholders for increasing production of litchi			
19.	Socio-Economic Impact assessment of ICAR-NRCL technologies among litchi growers in India	Dr. Bhagya Vijayan	Dr. Sunil Kumar
20.	Ecological footprinting of litchi production in India	Dr. Bhagya Vijayan	Dr. Bikash Das Er. Ankit Kumar
6. Long term activities			
21.	Tribal Sub-Plan	Dr. Vinod Kumar	Dr. Bhagya Vijayan
22.	Scheduled Caste Sub Plan	Dr. Ipsita samal	Dr. Bhagya Vijayan
7. Pilot projects/observational trials			
23.	Management of fruit cracking in Litchi	Dr. Sunil Kumar	Dr. Bikash Das Er. Ankit Kumar Dr. Ashok Dhakad
24.	Natural farming in litchi	Dr. Sunil Kumar	Dr. Bikash Das Dr. Ashok Dhakad
25.	Evaluation of Conservation Agriculture practice in litchi	Dr. Sunil Kumar	Dr. Bikash Das Dr. Ashok Dhakad

B. Externally Funded

S. No.	Project title	Principal Investigator	Co-PIs	Funding Agency
1.	Developing national repository and facilities for DUS testing in Litchi	Dr. Abhay Kumar	Dr. Sunil Kumar	PPV&FRA
2.	National Agricultural Innovation project-Component II	Dr. Bhagya Vijayan	Dr. Vinod Kumar Dr. Abhay Kumar Dr. Prabhat Kumar Dr. Sunil Kumar Er. Ankit Kumar	NAIF

S. No.	Project title	Principal Investigator	Co-PIs	Funding Agency
3.	Participatory Development of Litchi based Climate Resilient Farming systems in Bihar	Dr. Bhagya Vijayan	Er. Ankit Kumar Dr. Bikash Das	RKVY
4.	Shelf-life Enhancement and Value Addition of Litchi through various Post-harvest Intervention	Er. Ankit Kumar	Dr. Bhagya Vijayan Dr. Sunil Kumar	RKVY
5.	Enhancing the livelihood of litchi farmers through beekeeping and assessing the agrochemicals in honey	Dr. Ipsita Samal	Er. Ankit Kumar Dr. Sunil Kumar	NBB
6.	Entomofaunal Dynamics in Litchi Agri-Horticultural Systems: Diversity, Abundance and Ecological Interactions	Dr. Ipsita Samal	Dr. Vinod Kumar	BSBB
7.	Development of Model Litchi Farms for Natural Farming Practices under NMNF – ICAR-IIFSR, Modipuram	Dr. Ipsita Samal	Dr. Bikash Das Dr. Bhagya Vijayan Dr Ashok Dhakad	NMNF

C. Trials under ICAR-AICRPs:

S. No.	Title of the trial	Principal Investigator	Co-PIs
ICAR-AICRP on Fruits			
1.	Creating variability in litchi (1.3.2.L.)	Dr. Sunil Kumar	Dr. Bikash Das
2.	Evaluation of small seeded litchi variety (MLT-1) (1.3.3.L.)	Dr. Sunil Kumar	Dr. Bikash Das
3.	Development of plant canopy architecture in litchi (2.3.5.L.)	Dr. Sunil Kumar	-
4.	Irrigation scheduling in litchi (3.3.3.L.)	Dr. Sunil Kumar	-
5.	Assessment of phenology in litchi grown under varying climatic conditions (4.3.7.L.)	Dr. Sunil Kumar	Dr. Bikash Das
6.	Using paclobutrazol and micronutrient application as a tool for productivity and fruit quality improvement of litchi under subtropical conditions (4.3.8.L.)	Dr. Sunil Kumar	-
7.	Survey for new and emerging inscet pests and their natural enemies in litchi (5.3.1.L.)	Dr. Ipsita Samal	-
8.	Crop phenology-based bio-intensive pest management module for litchi pest complex (5.3.5.L.)	Dr. Ipsita Samal	-
ICAR- AICRP on Biocontrol			
9.	Bio intensive pest management of Litchi fruit borer ,*Conopomorpha sinensis* in litchi	Dr. Ipsita Samal	-

List of Publications

Research Papers

- Bhat, A., Rana, V. K., Chandel, V. G. S., Shandil, D., Samal, I. (2025). Seasonal occurrence of *Conopomorpha sinensis* (Gracillariidae: Lepidoptera) infesting litchi (*Litchi chinensis*) in Himachal Pradesh. *The Indian Journal of Agricultural Sciences*, 95(7): 799–804.
- Bhoi, T. K., Dhillon, M. K., Samal, I., Singh, N. (2025). Phytochemicals in wild crucifers affect development and reproduction of mustard aphid (*Lipaphis erysimi*). *The Indian Journal of Agricultural Sciences*, 95(9): 1127-1132.
- Bhoi, T. K., Dhillon, M. K., Samal, I., Singh, N. (2025). Variation in aphid complex influx and predatory dynamics in wild crucifers. *The Indian Journal of Agricultural Sciences*, 95(8): 957-961.
- Bhoi, T. K., Mahanta, D. K., Samal, I., Dash, S., Singh, S., Komal, J. (2025). Effect of endophytic entomopathogenic fungi (EEPF) in biological control of Odontotermes obesus (Rambur 1842) and their synergistic impact on plant physiological responses. *The Microbe*, 7: 100411.
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- Dwivedi, R., Banjare, S., Jaiswal, S. K., Singh, A., Painkra, G. P., Tiwari, J. K., Samal, I., Bhoi, T. K., Mahanta, D. K. (2025). Standardization of DNA Extraction Protocol and Assessment of Molecular Genetic Variation in Honey Bees. *Entomological News*, 132(3): 379-388.
- Kabi, M., Palei, S., Kesawat, M. S., Routray, S., Rajendra, V., Naik, I. S., Kumar, R., Rahim, M. (2025). Engineering crop genomes: A review of editing tool evolution, applications, and future trajectories. *Ecological Genetics and Genomics*, 37: 100408.
- Komal, J., Gowrisankar, R., GV, V., Nadaf, H., Samal, I., Dinesh Kumar, P. V., Bhoi, T. K. (2025). Bibliometric trends and patterns in Tasar silkworm (*Antheraea mylitta*) research: A data report (1980–2024). *Frontiers in Insect Science*, 5: 1533267.
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- Kumar, V., Kumari, P., Samal, I., Singh, S., Kumar, A., Kumar, L. (2025). Efficacy, cost-effectiveness, and residue levels of fungicides for managing panicle blight, fruit blight and anthracnose diseases of litchi. *Crop Protection*, 198: 107391.
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Member of Advisory Committee of Students

Sl. No.	Advisory Committee	Name of the Scientist	Name of the student	Degree	University	Year
1.	Chairman	Dr. Bikash Das	Mageshwari D.	M.Sc. (Fruit Science)	ICAR- IARI, Jharkhand	2023-2025
2.	Chairman	Dr. Sunil Kumar	Nanneboyina Srikanth	M.Sc. (Fruit Science)	ICAR- IARI, Jharkhand	2023-2025
3.	Co-Chairman	Dr. Sunil Kumar	Mageshwari D.	M.Sc. (Fruit Science)	ICAR- IARI, Jharkhand	2023-2025
4.	Co-Advisor	Dr. Sunil Kumar	Jyoti Kumari	M.Sc. (Hort.) Fruit Science	IGKV, Raipur	2023-2025
5.	Member	Dr. Sunil Kumar	Happy Kumari	M.Sc. (Ag.) Entomology	Ch. Charan Singh University, Meerut	2023-2025
6.	Chairman	Dr. Ipsita Samal	Happy Kumari	M.Sc. (Ag.) Entomology	Ch. Charan Singh University, Meerut	2023-2025
7.	Chairman	Dr. Ipsita Samal	Madhur Jyoti	M.Sc. (Ag.) Entomology	Ch. Charan Singh University, Meerut	2023-2025
8.	Co-Advisor	Dr. Vinod Kumar	Rajeev Kumar	Ph.D. Zoology	LNMU, Darbhanga	2023-2026
9.	Chairperson	Dr. Sunil Kumar	Gaingamliu Kamei	M.Sc. (Fruit Science)	ICAR- IARI, Jharkhand	2024-2026
10.	Chairperson	Dr. Bikash Das	Menaga S.	M.Sc. (Fruit Science)	ICAR- IARI, Jharkhand	2024-2026

Awards and Honours

Dr. Abhay Kumar

- Young Scientist Award in recognition of outstanding contribution in the field of Plant Biotechnology during the 9th International Conference on "Advances in Agricultural, Biological and Biodiversity Conservation for Sustainable Development (ABCD-2025)" held at University of Mysore, Karnataka, India (13–15 Nov, 2025).

Dr. Prabhat Kumar

- Young Scientist Award in recognition of outstanding contribution in the field of Soil Science during the 9th International Conference on "Advances in Agricultural, Biological and Biodiversity Conservation for Sustainable Development (ABCD-2025)" held at University of Mysore, Karnataka, India (13–15 Nov, 2025).

Compilation, Editing and Documentation

S. No.	Title	Year of publication	Scientist involved
1.	ICAR-NRCL Annual Report 2025	2026	Dr. Abhay Kumar Dr. Ipsita Samal Er. Ankit Kumar
2.	EFC Memorandum (2026-2031)	2025	Dr. Vinod Kumar
3.	Technology and Publication Repository (Database), KRISHI	2025	Dr. Vinod Kumar
4.	Annual Report - 2024 of ICAR-All India Coordinated Research Project on Fruits	2025	Dr. Bikash Das Dr. Sunil Kumar
5.	4th QRT Proceedings and Action Taken Report	2026	Dr. Vinod Kumar
6.	24th IRC Proceedings, and Action Taken Report	2026	Dr. Bhagya Vijayan
7.	Compilation of Rajbhasa Hindi Patrika (Litchima) Vol 11	2025	Dr. Abhay Kumar

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	S. No.	Name	Designation
RMP		Dr. Bikash Das	Director
Scientific		Dr. Vinod Kumar	Pr. Scientist (Plant Pathology)
		Dr. Abhay Kumar	Sr. Scientist (Agri. Biotechnology)
		Dr. Prabhat Kumar	Scientist (Soil Science)
		Dr. Bhagya Vijayan	Scientist (Agri. Extension)
		Dr. Sunil Kumar	Scientist (Fruit Science)
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		Sh. Akchhay Kumar Yadav	Assistant
		Sh. Avinash Kumar Kashyap	Assistant
		Sh. Sawan Kumar	UDC (Sr. Clerk)
		Sh. Pawan Kumar	UDC (Sr. Clerk)
		Ms. Ekta	LDC (Jr. Clerk)
		Sh. Ritesh Kumar	LDC (Jr. Clerk)
Technical		Sh. Ashok Dhakad	Senior Technical Officer, (T-6)
		Dr. Ramashish Kumar	Technical Officer, T-5 (F/F)
		Ms. Upagya Sah	Senior Technical Assistant, T-4 (F/F)
		Sh. Ajay Kumar Rajak	Sr. Technician, T-2 (F/F)
		Sh. Somesh Kumar	Sr. Technician, T-2 (F/F)
		Sh. Lokesh Kumar	Sr. Technician, T-2 (L/T)
		Sh. Dharmendra Kumar	Technician, T-1 (F/F)
Supporting		Ms. Sunita Devi	Skilled Supporting Staff
		Sh. Shankar Ram	Skilled Supporting Staff

Recruitment, Promotion and Transfer

New entry during the year 2025:

- Dr. Suvalaxmi Palei joined to the post of Scientist (Fruit Science) at ICAR-NRC on Litchi, Muzaffarpur on 28th Oct, 2025.

Promotions:

- Dr. Bhagya Vijayan, Scientist (Agricultural Extension) promoted to the next higher grade to Research Level-11 with effect from 11th Nov, 2022.
- Dr. Sunil Kumar, Scientist (Fruit Science) promoted to the next higher grade to Research Level-11 with effect from 7th Aug, 2025.
- Dr. Ramashish Kumar, Senior Technical Assistant (T-4) promoted to the next higher grade Technical Officer (T-5) in the Pay Level-7 with effect from 30th July, 2025.

Budget Utilization and Revenue Generation

Financial Statement 2025-26

S. No.	Head-wise break up	RE 2025-26 (Rs. In lakh)	Release (Rs. In lakh)	Expenditure (Rs. In lakh)
(A). Recurring:				
a.	Establishment (including pension)	378.87	378.87	377.55
b.	T.A.	13.49	13.49	13.49
c.	Contingency	271.15	271.15	271.15
d.	HRD	0.36	0.36	0.36
e.	Loans and advances	5.00	5.00	0.50
	Total (A)	668.87	668.87	663.05
(B). Non-Recurring:				
a.	Equipment	26.69	26.69	26.69
b.	Works (Minor)	0.00	0.00	0.00
c.	Furniture & Fixture	10.98	10.98	10.98
d.	I.T.	9.08	9.08	9.08
e.	Vehicle	23.36	23.36	23.36
f.	Live Stock	0.00	0.00	0.00
g.	Land	0.00	0.00	0.00
	Total (B)	70.11	70.11	70.11
Grand Total (A+B)		**738.98**	**738.98**	**733.16**

Resource generation 2025-26

Items	Rs. (In lakh)
Sale of farm produce	33.53
Interest earned on short term deposits	27.69
Income generated from internal resources (including recovery of loans and advances)	80.00
Miscellaneous receipts	9.13
Total	**150.35**

Receipts and Expenditure Statement of Externally Funded Projects 2025-26

Externally funded Projects	Opening Balance (Rs. In lakh)	Receipt (Rs. In lakh)	Expenditure (Rs. In lakh)
AICRP-Fruits (ICAR)	0.07	12.50	12.50
AICRP-Bio Control (ICAR)	0.00	1.45	1.44
NAIF (ICAR)	0.32	3.75	3.75
DUS (PPV&FRA)	0.35	6.89	7.24
RFS (Seed & Plant)	39.55	33.98	40.87
RFS (Post Harvest Lab)	8.37	12.60	14.78
National Bee Board	0.00	126.35	126.35
Bihar State Biodiversity Board	9.31	0.00	7.24

Important Committees

Research Advisory Committee (RAC)

Chairman	Dr. B.M.C. Reddy, Former Vice Chancellor, SLKTS Horticultural University
Members	Dr. B.S. Tomar, Head, Vegetable Science, ICAR-IARI, New Delhi Dr. Kumbhkaran Rout, Former Dean, College of Agriculture, OUAT, Bhubaneswar R.T. Patil, Former Director, ICAR-CIPHET, Ludhiana Dr. Shivendra Kumar, Former Head, ICAR-RCER FSRCHPR, Ranchi Dr. Ranjit Kumar, Principal Scientist, ICAR-NAARM, Hyderabad
Members (Non-official)	Sh. Lokesh Narayan Sharma, Patna, Bihar Sh. Laltu Das, Murshidabad, West Bengal
Members (Ex-officio)	Dr. Bikash Das, Director, ICAR- NRC on Litchi, Muzaffarpur Dr. V. B. Patel, ADG (Fruits & Plantation Crops), ICAR, New Delhi
Member Secretary	Dr. Vinod Kumar, Pr. Scientist, ICAR- NRC on Litchi, Muzaffarpur

Institute Management Committee (IMC)

Chairman	Dr. Bikash Das, Director, ICAR- NRC on Litchi, Muzaffarpur
Members	Dr. A. K. Dubey, Pr. Scientist, ICAR-IARI, New Delhi Dr. A. K. Mall, Pr. Scientist, ICAR-IISR Regional Station, Motipur Dr. R. K. Laxman, Pr. Scientist, ICAR-IIHR, Bangalore Dr. V. B. Patel, ADG (Fruits & Plantation Crops), ICAR- New Delhi Sh. Rajat Das, Finanace & Account Officer, ICAR- RCER, Patna
Members (Non-Official)	Sh. Vivek Kumar, Muzaffarpur Sh. Vikrant Kumar Upadhyay, Dhanwad
Members (Ex-officio)	Director Horticulture, Directorate of Horticulture, Department of Agriculture, Bihar Director Horticulture, Directorate of Horticulture, Department of Agriculture, Jharkhand Vice Chancellor, Birsa Agricultural University, Ranchi
Member Secretary	Sh. Shubham Sinha, Administrative Officer, ICAR- NRC on Litchi, Muzaffarpur

Institute Research Council (IRC)

Chairman	Dr. Bikash Das, Director, ICAR- NRC on Litchi, Muzaffarpur
Members	Dr. Vinod Kumar, Pr. Scientist (Plant Pathology) Dr. Abhay Kumar, Sr. Scientist (Agri. Biotechnology) Dr. Prabhat Kumar, Scientist (Sr. Scale) (Soil Science) Dr. Bhagya Vijayan, Scientist (Agri. Extension) Dr. Sunil Kumar, Scientist (Fruit Science) Er. Ankit Kumar, Scientist (Agri. Structure & Process Engg.) Dr. Ipsita Samal, Scientist (Agri. Entomology) Dr. Suvalaxmi Palei, Scientist (Fruit Science)
Member Secretary	Dr. Bhagya Vijayan, Scientist (Agri. Extension)

Nodal Officers and Responsibilities

S. No.	Nodal Officers	Responsibilities
1.	Dr. Vinod Kumar	EFC, Liaison Officer (Reservation Roster), KRISHI Portal, TSP
2.	Dr. Abhay Kumar	ARMS, PIMS-ICAR, PMS, HRD Cell
3.	Dr. Prabhat Kumar	Vigilance Officer
4.	Dr. Bhagya Vijayan	PME
5.	Er. Ankit Kumar	ITMU, Academic
6.	Dr. Ipsita Samal	SCSP Project, Library, Institute Seminar
7.	Dr. Ashok Dhakad	Swachha Bharat Abhiyan
8.	Sh. Dileep Kumar	e-office, e-HRMS 2.0, SPARROW

ICAR-NRCL in Media

असम के 25 किसानों को प्रशिक्षण

रोग और कीट से लीची के पेड़ को बचाने की दी जानकारी

भाकृअनुप–राष्ट्रीय लीची अनुसंधान केंद्र, मुजफ्फरपुर द्वारा लीची फसल की खेती, प्रसंस्करण एवं विपणन विषय पर पाँच दिवसीय प्रशिक्षण कार्यक्रम का सफल आयोजन

मुजफ्फरपुर आसपास जागरण

राष्ट्रीय लीची अनुसंधान केंद्र में तीन दिवसीय प्रशिक्षण का हुआ समापन

लीची की खेती में आधुनिक तकनीक से रूबरू हुए किसान, बढ़ेगा उत्पादन

लीची के बाग में फूल और फल आने से पहले सिंचाई से करें परहेज

रिटंक बग, फ्लावर वेबर व झुलसा रोग से बचाएं

लीची पेय पदार्थों के सूक्ष्म प्रसंस्करण पर तीन दिवसीय प्रशिक्षण सम्पन्न 26 उद्यमियों ने सीखा लीची स्क्वॉश, आरटीएस और रसोगुल्ला निर्माण का गुर

लोकतंत्र की आवाज

रामजी कुमार

लीची की खेती में जैविक और संतुलित उर्वरक का करें उपयोग, होगा फायदा

प्रशिक्षण का समापन

लीची बागवानी के साथ मधुमक्खी पालन से किसानों की आय दोगुनी

लीची उत्पादन में आ रही चुनौतियों एवं उनके समाधान पर हुई चर्चा

लीची के निर्यात को बढ़ावा देने के लिए सरकार तत्पर : डिप्टी सीएम

उपमुख्यमंत्री ने किया बीज प्रसंस्करण संयंत्र का उद्घाटन

सिटी रिपोर्टर — राष्ट्रीय लीची अनुसंधान केंद्र, मुशहरी में

किसान एकीकृत कीट प्रबंधन के उ कर बढ़ा सकते हैं लीची की पैदावार

कार्यक्रम • राष्ट्रीय लीची अनुसंधान केंद्र में लीची के निर्यात और पैकेजिंग पर विशेष सत्र

उचित तापमान नियंत्रण और मॉडिफाइड एटमॉस्फेयर पैकेजिंग से लंबे समय तक रह सकती है लीची की ताजगी

लीची किसानों के बीच शोध प्रसारित करने की जरूरत

44 किसानों को कार्यक्रम में किया गया सम्मानित

बुजुर्ग लीची किसानों के बाग संभालेंगे युवा

लीची की खेती नहीं, उद्यम के रूप में लें : निदेशक

80

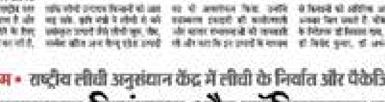
03

GURU NANAK DEV UNIVERSITY, AMRITSAR

लीची में मंजर बेहतर, झुलसा से खतरा

लीची तुड़ाई उपरांत बागों में आवश्यक कटाई–छंटाई एवं छ प्रबंधन की वैज्ञानिक विधि को सीख उत्साहित हुए लीची उत्पा

लीची की डाली-पत्तियां बेकार नहीं जाएंगी, बनेगी खाद



लीची की तुड़ाई के बाद अवशिष्ट का होगा उपयोग

भा.कृ.अनु.प.–राष्ट्रीय लीची अनुसंधान केन्द्र

ICAR-National Research Centre on Litchi

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118_(0526)_Anapurna Press and Process 6287999194