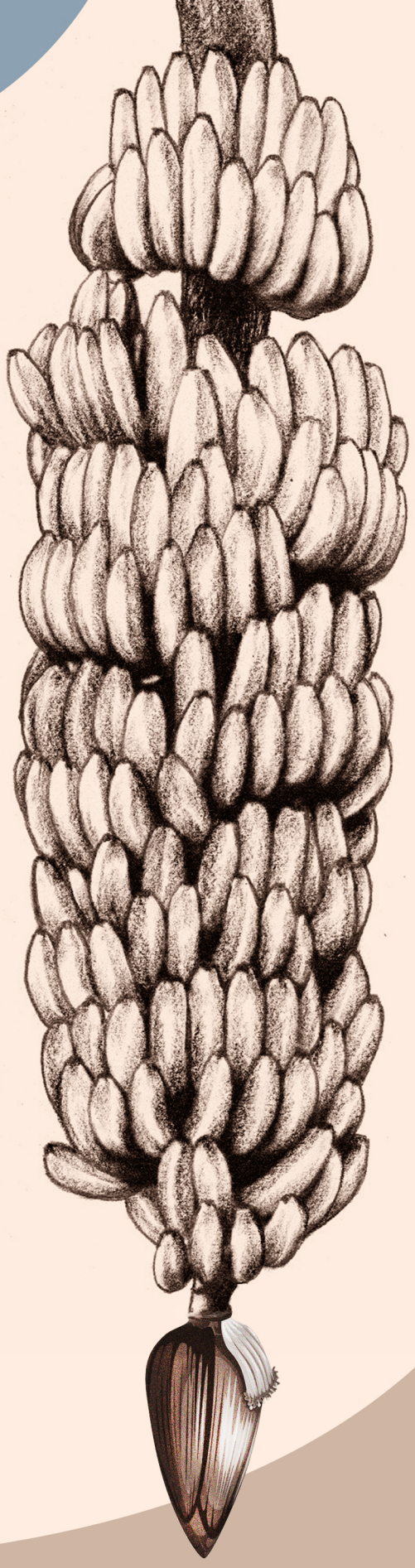

वार्षिक प्रतिवेदन

Annual Report 2023

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

Tiruchirappalli - 620 102, Tamil Nadu, India.

भाकृअनुप – राष्ट्रीय केला अनुसंधान केंद्र

तिरुचिरापल्ली - 620 102, तमिल नाडु, भारत

भाकृअनुप
ICAR

वार्षिक प्रतिवेदन
Annual Report
2023

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भारत 2023 INDIA

INTERNATIONAL YEAR OF
MILLETS
2023

NATIONAL RESEARCH CENTRE FOR BANANA
TIRUCHIRAPPALLI

भाकृअनुप – राष्ट्रीय केला अनुसंधान केंद्र
ICAR - National Research Centre for Banana

(An ISO 9001:2015 Certified Institute)
Tiruchirappalli - 620 102, Tamil Nadu, India

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Banana Diversity

PREFACE

As the Director of the esteemed ICAR-National Research Institute for Banana, it is with great pride and enthusiasm that I present this annual report encapsulating the ground-breaking research and transformative developments in the realm of banana cultivation and utilization in 2023. Our institute's unwavering commitment to advancing agricultural science and fostering innovation has culminated in a wealth of knowledge and achievements that are poised to revolutionize the banana industry.

Within the pages of this report, readers will embark on a journey through the intricate world of banana research, including crop improvement, production, postharvest technology, and crop protection. From the meticulous nutritional analysis of various banana products, shedding light on the nuanced differences in fat and sugar content among different flour types, to the cutting-edge genetic research unveiling the intricate genetic markers crucial for distinguishing between resistant and susceptible banana cultivars, our institute's endeavors have been nothing short of transformative.

In the realm of Crop Improvement, our institute has spearheaded pioneering initiatives, including the collection of 12 wild germplasm accessions and one cultivated variety, paving the way for enhanced genetic diversity and resilience in banana crops. One new dessert banana, Kaveri Kanchan, with high Provitamin A content, has been released for cultivation by SVRC and it is a potential alternative to cv. Nendran, widely cultivated in Kerala and Tamil Nadu.

The nutrient dynamics studies conducted have yielded invaluable insights into the macro and micronutrient concentrations in banana waste biomass and pseudostem sap, offering a holistic perspective on nutrient management strategies for sustainable crop production. Moreover, our experiments in crop production have yielded promising results, with innovative fertilization techniques and spacing configurations leading to remarkable increases in bunch weights for our newly released varieties such as Kaveri Saba and Kaveri Harita.

The postharvest technology section of this report underscores the critical role of pre-harvest treatments and optimal storage conditions in extending the shelf life of bananas. Studies have shown that implementing pre-harvest treatments such as ethylene gas exposure can delay ripening by up to 7 days, significantly enhancing the marketability of bananas. Furthermore, storage under controlled conditions with a temperature range of 13-15°C has been proven to extend the shelf life by an average of 10 days, ensuring the preservation of quality and freshness.

ICAR-NRCB has been at the forefront of developing and implementing effective pest management strategies, with a particular focus on combating Fusarium wilt disease through the strategic use of bioagents. Field trials have demonstrated a 30% reduction in disease incidence with the application of bioagents, highlighting their efficacy in disease control. Kaveri Microbial consortium (a biostimulant), No2Wilt (a microbial consortium for fusarium wilt) and Banana Weevil Killer (Beauveria formulation for managing weevil borers) have been developed and are being popularized.

The Centre organized numerous outreach and inter-institutional activities including new initiatives such as celebrating National Science Day as an ‘Open Day’ with 3000 students, Capacity

Development Programmes for stakeholders, conducting Farmers Exposure Visits, and coordinating events like the Viksit Bharat Sankalp Yatra. Additionally, events like the NRCB's 30th Foundation Day, Kisan Mela, and a Banana Stakeholders' Meet during the Governor's visit were held, engaging over 600 farmers and 200 stakeholders from the banana sector.

The highlight of the year was the successful conduct of VIROCON 2023, a unique National Conference under the One Health Concept, jointly organized by ICAR-NRCB and the Indian Virological Society, New Delhi, from December 1st to 3rd, 2023, in Tiruchirappalli, Tamil Nadu, with the focal theme of 'Advancements in Global Virus Research Towards One Health'. It attracted wide participation from researchers and students of plant, animal, aquatic and medical virology from India and abroad.

As we navigate the ever-evolving landscape of banana farming, the ICAR-NRCB remains steadfast in its mission to drive innovation, foster collaboration, and empower stakeholders across the banana industry. This report stands as a testament to our collective efforts, our relentless pursuit of excellence, and our steadfast commitment to shaping a more sustainable and prosperous future for banana cultivation.

I thank Dr. Himanshu Pathak, DG (ICAR) / Secretary, DARE; Dr. S.K. Singh, DDG (Hort.); and Dr. V.B. Patel, ADG (Hort.) for their inspired guidance and support for our activities.

(R. Selvarajan)

Director

INTRODUCTION

The ICAR-National Research Centre for Banana is a premier R&D institution that caters to the needs of banana farmers and other stakeholders, contributing immensely to the increase in production and productivity of Indian banana farmers. During 2023, in the realm of Crop Improvement, ICAR-NRCB has spearheaded pioneering initiatives, including the collection of 12 wild germplasm accessions and one cultivated variety, paving the way for enhanced genetic diversity and resilience in banana crops. One new dessert banana, Kaveri Kanchan, with high provitamin A content, has been released for cultivation by the SVRC, and it is a potential alternative to the widely cultivated cv. Nendran in Kerala and Tamil Nadu. Our experiments in crop production have yielded promising results, with innovative fertilization techniques and spacing configurations leading to remarkable increases in bunch weights for our newly released varieties, such as Kaveri Saba and Kaveri Harita.

The Centre has a research farm of 36.5 hectares and a laboratory complex on 3.23 hectares. The ICAR-NRCB also has a residential complex spread over an area of 0.80 hectares in the city. The Centre is located at 11.50ºN latitude and 74.50ºE longitude, 90 meters above mean sea level, and receives 800 mm of rainfall annually. The climate is warm and humid, with average minimum and maximum temperatures of 25ºC and 35ºC, respectively.

The Centre works on five major areas of research: Crop Improvement, Crop Production, Post-Harvest Management, Crop Protection, and Extension. The Institute has state-of-the-art research laboratories for tissue culture, biotechnology, soil science, water and nutrient management, physiology, biochemistry, entomology, nematology, plant pathology, post-harvest technology, and extension research. During the year, the Centre has adopted recent hi-tech cultivation practices such as automation, sensor-based irrigation systems, IoT-enabled disease detection systems, and the production of high-tech value-added products, including the utilization of drone technology. The Centre also initiated new line of research on 'Drone Technology Demonstration' with the financial support from DAC & F W, Govt. of India.

Further, the Centre has developed and implemented effective pest management strategies, with a particular focus on combating Fusarium wilt disease through the strategic use of bioagents. Field trials have demonstrated a 30% reduction in disease incidence with the application of bioagents, highlighting their efficacy in disease control. The Kaveri Microbial Consortium (a bio-stimulant), No2Wilt (a microbial consortium for Fusarium wilt), and Banana Weevil Killer (a Beauveria formulation for managing weevil borers) have been developed and are being popularized.

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The Centre organized numerous outreach and inter-institutional activities, including new initiatives such as celebrating National Science Day as an 'Open Day' with 3000 students, Capacity Development Programmes for stakeholders, conducting Farmers Exposure Visits, and coordinating events like the Viksit Bharat Sankalp Yatra. Additionally, events like the NRCB's 30th Foundation Day, Kisan Mela, and a Banana Stakeholders' Meet during the Governor's visit were held, engaging over 600 farmers and 200 stakeholders from the banana sector. The Centre signed MoAs / MoUs / MoCs with 10 research institutes / colleges / private companies for research collaborations and student exchange. Moreover, the Centre organized 25 on-campus capacity development programs and 8 off-campus training programs for banana farmers, FPOs, Government officials, public and private entrepreneurs under various schemes, including SC&SP program, ATMA-SSEPERS, NHM, etc

The Centre periodically conducts Institute Research Council meet and Research Advisory Council meet to review the ongoing research projects and also monitor the progress made on the RAC and QRT recommendations.

Vision

To be the world leader in production and productivity of bananas and plantains thereby meet the growing demand in India.

Mission

To become the global leader in banana production and productivity and export of banana

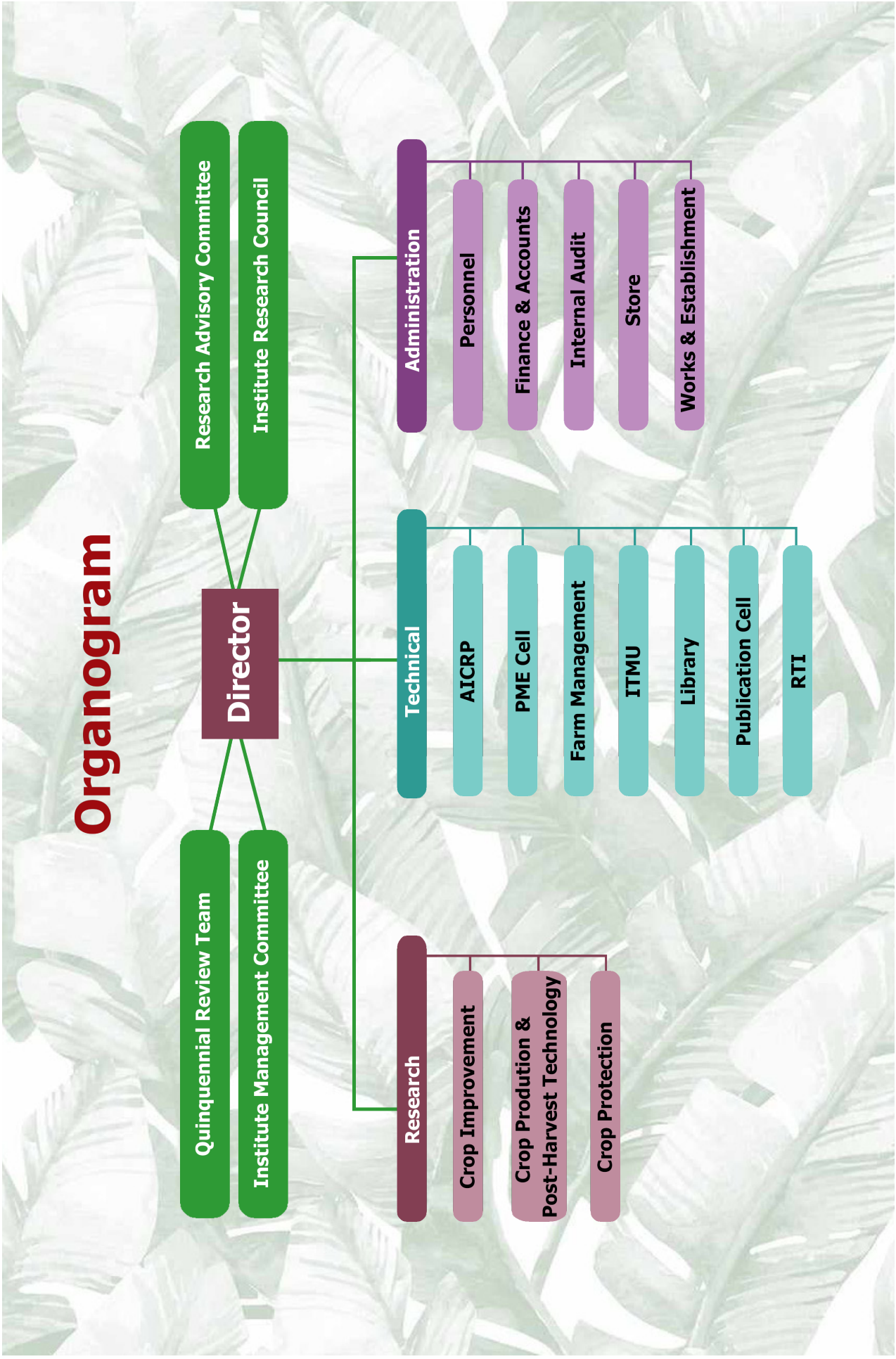
Mandate

- Basic, strategic and applied research on genetic resource management, crop improvement and production technologies for sustainable and enhanced production and utilization of banana.
- National banana gene bank management, coordination and validation of research for enhancing and sustaining the productivity of banana.
- Transfer of technology and capacity building of stakeholders for enhanced and sustained production of banana.
- Referral laboratory for monitoring the quality of micro-propagated banana plants.v

Budget details for the year 2023 (C.Y)

Head	Expenditure (in lakhs)
Equipment	69.42
IT	0.73
Works	10.90
Establishment	1002.78
TA	15.77
Research Expenses	42.16
Operational Expenses	145.25
Infrastructure	125.44
Communication	4.09
Repair of equipment, Vehicle	15.15
Other admn. (Other TA)	8.07
HRD	0.68
Publicity & Exhibition	3.47
Miscellaneous	22.55
P Loans & Advances	3.00
Total	**1469.46**
SCSP-Capital	**0**
SCSP-General	**19.32**
Grand Total	**1488.78**

A revenue of Rs. 73.98 lakhs was generated by the Centre during the year 2023.


Organogram
Research Advisory Committee
Institute Research Council
Director
Quinquennial Review Team
Institute Management Committee
Administration
Personnel
Finance & Accounts
Internal Audit
Store
Works & Establishment
Technical
AICRP
PME Cell
Farm Management
ITMU
Library
Publication Cell
RTI
Research
Crop Improvement
Crop Prodution & Post-Harvest Technology
Crop Protection

Executive Summary

Crop Improvement

- The 54th State Variety Release Committee and 40th State Seed Sub-Committee of Tamil Nadu have approved the release of progeny NCR 17 as Kaveri Kanchan. This variety is a dessert type with high carotenoid content (2423 µg/100g fresh pulp), resistant to fusarium wilt, and yields 20% more than Nendran. It is recommended for cultivation in Trichy, Theni, Pollachi, Coimbatore, Salem, and Tirunelveli districts of Tamil Nadu.

- Exclusive field gene banks with 351 indigenous and 121 exotic accessions have been newly established. A new demonstration block has been set up with eight promising lines identified at ICAR-NRCB, Trichy. The demonstration block includes 107 accessions of the core germplasm covering all cultivable types. Additionally, a new block with 77 accessions found to be resistant to Foc race 1/ TR4 has been raised at the Satellite Genebank in Agali.'

- Passport data for 2 germplasm accessions and 10 banana hybrids were submitted to ICAR-NBPGR, New Delhi, for IC numbers.

- Studies on carotenoid content in bananas yielded compelling results, with ITC 2390-2 standing out for its significantly elevated levels compared to conventional commercial cultivars like Nendran and Red Banana, hinting at its potential as a nutritionally enriched banana variety with possible health benefits.

- Studies on in vitro cultured bananas revealed intriguing phenomena, including the transient emergence of diverse variants such as green, variegated, red, and albino, which subsequently reverted to their original state, highlighting the dynamic nature of banana tissue culture.

- A field trial was conducted to assess the resistance of NRCBGNM1, a mutant line, against fusarium wilt. Genetic analysis of DIR 11 gene sequences between resistant and susceptible accessions was done to unravel crucial genetic insights into the mechanisms underpinning leafspot disease resistance in bananas.

- Developing diverse banana progenies from tetraploid pre-breeding lines was attempted for enhancing genetic diversity within banana cultivation, paving the way for the creation of novel banana varieties with improved traits.

- Investigations into regeneration systems for somatic embryos showcased promising outcomes, with the successful generation of plantlets demonstrating consistency and stability during field evaluations, underscoring the potential for scalable and sustainable propagation methods in banana agriculture.

Crop Production

Clump management studies

- The study on clump management in bananas, focusing on cv. Ney Poovan, explored the influence of varying sucker populations and nutrition levels for maximizing banana yield. Results indicated that the S1 treatment (Mother plant + 2 suckers) exhibited the highest bunch weight, with the first sucker producing 13.56 kg and the second sucker 10.23 kg.

Nutrient dynamics in banana

- In nutrient dynamics study, macro and micronutrient concentrations in banana waste biomass and pseudostem sap post-bunch harvest were studied, offering valuable insights into nutrient recycling and management strategies. Nitrogen levels varied from 0.70% to 1.19%, phosphorus from 0.14% to 0.17%, potassium from 1.36% to 2.06%, copper from 53.1 ppm to 73.4 ppm, manganese from 125.9 ppm to 260.0 ppm, zinc from 52.3 ppm to 63.3 ppm, and iron from 92.2 ppm to 146.3 ppm. These data underscore the nutrient-

rich nature of banana waste biomass and pseudostem sap, highlighting their potential for sustainable agricultural practices and soil fertility enhancement.

- Comparative studies on the efficacy of Nano-Banana Shakti with Normal-Banana Shakti at different concentrations of foliar sprays indicated the best combination for banana growth was Nano-Banana Shakti with 3% surfactant 1 suspension, with a 1% foliar spray resulting in the highest dry matter production of 14.5g in 90-day-old banana plants.

- Evaluation of Poly4 (Polyhalite) on banana plants under Alfisol conditions showed that using 50% RD-K as Poly4 led to higher bunch yields compared to 100% RD-K as MoP. The study indicated that the soil's conducive K:Ca:Mg ratio favoured Poly4 application, resulting in heavier banana bunches compared to conventional MoP fertilization. Potassium Adsorption Ratios (KAR) were lowest with Poly4, highlighting its efficacy in promoting banana growth.

Package of practices for export bananas

- The study on the integrated package of practices for the export of selected commercial and GI-tagged varieties, focusing on Cv. Ney Poovan, was conducted at NRCB-Farm and a farmer's field in Mudalaipatti village, Karur Dt. The research showcased significant improvements in growth and yield attributing characters with the application of 100% RDF as fertigation and pre-harvest treatments. Results indicated that the optimal treatment combination led to a remarkable bunch weight of 13.15 kg, accompanied by 13.50 hands and 180 fingers, surpassing the control group. Additionally, the study highlighted the reduced maturity period achieved through specific practices, underscoring the efficacy of integrated approaches in enhancing the export potential of selected banana varieties and promoting agricultural sustainability.

Effect of high temperature and moisture deficit stress

- Effect of high temperature and soil moisture deficit stresses in bananas was assessed in 53 banana genotypes with diverse genomes (AAB, ABB) under conditions of drought stress at the floral primordial initiation stage. The study revealed substantial reductions in bunch weight (25-50%) and fruit weight (22.25-39.90%) in most AAB genotypes under drought conditions, with significant decreases in the number of hands, fruits per bunch, and fruits per hand. Moreover, the research highlighted the adverse effects of soil moisture deficit stress on various growth parameters, indicating that foliar-primed drought-stressed plants treated with ASA exhibited enhanced growth metrics, while excessive moisture levels resulted in diminished plant height and leaf numbers in specific cultivars.

Nutraceutical content analysis

- The analysis of anthocyanins in various banana genotypes indicated Cyanidin was the predominant anthocyanin compound, constituting a substantial portion (66–75%) in different banana varieties. The major fructan fraction identified in rhizome was 1,1-nystose, with concentrations spanning from 361 µg/g DW to 420 µg/g DW across diverse banana cultivars.

- The starch composition of fully matured banana fruits was studied and the total starch content exhibited a range of 81% to 87% across different banana varieties. Notably, Ney Poovan showcased the highest starch content, while Pachanadan displayed the lowest levels. Furthermore, the amylose fraction in bananas varied significantly among cultivars, with plantain and cooking banana varieties containing amylose levels exceeding 35%, while dessert bananas featured slightly lower amylose content, ranging from 5% to 10%.

Banana value added products

- The analysis of banana starch modification through ultrasonication and plasma-activated water unveiled a rich tapestry of physico-chemical transformations, showcasing a notable decrease in swelling power by 25% and a significant increase in solubility by 30% in the modified flour compared to its native counterpart.

- In studies on banana bread formulation, the incorporation of banana starch catalyzed a captivating shift in color profiles, with moisture content exhibiting a dynamic range from 11.85% to 24.72% in the crumb and 7.14% to 16.46% in the crust, underscoring the profound impact of this ingredient on both visual aesthetics and textural attributes.

- Fortification of stem juice with banana fig underpinned a nutritional renaissance, as pioneering coatings like soy protein and date syrup orchestrated a symphony of enhanced protein content by 15% and reduced sugar levels by 20%, heralding a transformative paradigm shift in the landscape of functional foods.

- The encapsulation of Lactobacillus plantarum within porous banana starch emerged as a beacon of biotechnological advancement, showcasing elevated viability by 40% and acid resistance by 35%, with modified starch emerging as the vanguard of encapsulation efficacy.

Crop Protection

Insect pest management

- Among various new insecticides evaluated against banana scarring beetle, fipronil 5% SC, spinosad 45% SC, and chlorpyriphos 20% EC demonstrated 100% mortality rates within 1 day after application.

- In laboratory bioassays, the Banana Weevil Killer bioformulation exhibited LC50 values of 2×104 and LC90 values of 6×109 with R2 values of 0.872 using the sheath dipping method, and LC50 values of 4×104 and LC90 values of 1×107 with R2 values of 0.988 with the insect spray method on the 7th day after treatment.

- In field evaluation also, fipronil 5% SC and thiamethoxam 25% WG caused 100% mortality against pseudostem weevil when injected directly into the pseudostem.

- Chemical treatments, including bleaching powder and Carbendazim injections, extended the shelf life of bananas to 9 days, compared to control fruits showing symptoms by the 3rd day. The entomopathogenic fungal formulations EPF 22, EPF 28, and EPF 50 broths effectively managed banana pseudostem weevils, with specific formulations attracting weevils and leading to increased mortality rates.

Disease management

- For fusarium wilt management, three specific combinations, including biocontrol agents and organic amendments, demonstrated exceptional efficacy in suppressing Fusarium wilt in cv. Grand Nain. Remarkably, these combinations achieved an impressive disease score of only 0.2 on a severity scale of 0-5 when applied to Foc-inoculated plants, highlighting their potent disease-suppressing capabilities compared to the control group, which scored 4.5.

- In comprehensive screening of a total of 300 mutated plants against both Foc races 1 and TR4, a putative Fusarium wilt-resistant line against Foc race 1 was identified at a radiation dose of 40 Gy.

- Recombinant monoclonal antibodies specifically targeting the Banana Bunchy Top Virus (BBTV) were developed. By standardizing ELISA-based diagnostic techniques, accuracy and efficiency of virus detection in banana plants was enhanced. The extraction of total DNA from BBTV-infected samples and subsequent cloning into an expression vector paved the way for the successful expression of recombinant BBTV-CP, a critical milestone in the development of improved diagnostic tools for detecting and managing banana viruses.

Outreach activities

- The outreach and inter-institutional activities included various initiatives such as celebrating National Science Day with 3000 students, organizing Capacity Development Programmes for stakeholders, conducting Farmers Exposure Visits, and coordinating events like the Viksit Bharat Sankalp Yatra.

- Additionally, events like the NRCB's 30th Foundation Day, Kisan Mela, and a Banana Stakeholders' Meet during the Governor's visit

were held, engaging over 600 farmers and 200 stakeholders from the banana sector.

- ICAR-National Research Centre for Banana actively participated in the prestigious Mega state level "AGRI EXPO 2023" held during 27-29 July 2023 at CARE Engineering College in Tiruchirappalli and bagged the Top Stall award.

- ICAR-NRCVB organized various training programs for women farmers from various districts of Tamil Nadu and other states. During the year, the total number of women beneficiaries was 3680. Under the ATMA program, training sessions were conducted on Integrated Nutrient Management (INM), value addition techniques, and various government schemes such as PM Kisan, KCC, and RKVY.

- On October 2nd, 2023, the Governor's office arranged a special function to honour freedom fighters, extending an invitation to ICAR NRCB to host an exhibition stall. NRCB stall featured an impressive display of NRCB technologies alongside products contributed by 13 different banana stakeholders, showcasing the breadth and depth of our contributions to the banana industry.

Important National / International Conferences and Workshops

- VIROCON 2023, a unique National Conference under the One Health Concept, was jointly organized by ICAR-National Research Centre for Banana, Trichy, and the Indian Virological Society, New Delhi, during December 1–3, 2023, in Tiruchirappalli, Tamil Nadu, with the focal theme of 'Advancements in Global Virus Research Towards One Health'. Totally 444 delegates from India and abroad including scientists, students and research scholars representing 70 institutes participated in the conference. There were 19 Technical Sessions in which presentations were made under various thematic areas, besides four workshops on the sidelines in which 146 farmers and other stakeholders participated.

- ICAR-NRCB, Tiruchirappalli, in collaboration with Alliance of Bioversity International and CIAT, Italy, a CGIAR institute, organized an International workshop on 'Phenotyping for Drought Tolerance' at ICAR-NRCB, Tiruchirappalli from March 7th to 11th, 2023.

- ICAR-NRCB and Jain Irrigation System Ltd., Jalgaon, Maharashtra, jointly organized a workshop on "Hi-tech banana cultivation in changing climate scenario" on June 1, 2023, in Barwani, Madhya Pradesh.

Revenue Generated

A Gross revenue of Rs. 73.98 lakhs was generated by the Centre during January to December 2023.

कार्यकारी सारांश

फसल सुधार

तमिलनाडु की 54वीं राज्य किस्म विमोचन समिति और 40वीं राज्य बीज उप–समिति ने एक संकर किस्म एनसीआर 17 को कावेरी कांचन नाम से जारी किए जाने को मंजूरी दी है। यह किस्म, उच्च कैरोटीनॉयड सामग्री (लगभग 2400 µg/100g ताजा वजन) वाली एक मिठासयुक्त किस्म है, जो *फ्यूजेरियम विल्ट* के विरुद्ध प्रतिरोधी है, और इस किस्म में नेंद्रन किस्म की तुलना में 20 प्रतिशत अधिक उपज प्राप्त हुई है। इसे तमिलनाडु राज्य के त्रिची, थेनी, पोलाची, कोयंबटूर, सेलम और तिरुनेलवेली जिलों में खेती के लिए अनुशंसित किया गया है।

• एक नया विशिष्ट फील्ड जीन बैंक स्थापित किया गया है जिसमें 351 स्वदेशी और 121 विदेशी एक्सेसनों (परिग्रहणों) को शामिल किया गया है। भाकृअनुप–एनआरसीबी, त्रिची में 08 आशाजनक वंशावलियों (लाइन) की पहचान करके एक नया प्रदर्शन ब्लॉक स्थापित किया गया है। इस प्रदर्शन ब्लॉक में केले की खेती लायक सभी किस्मों को शामिल करते हुए मुख्य (कोर) जर्मप्लाज्म के 107 परिग्रहण शामिल किए गए हैं। इसके अतिरिक्त, *अगाली* स्थित सैटेलाइट जीन बैंक में 77 एक्सेसनों (परिग्रहणों) के साथ एक नया ब्लॉक तैयार किया गया है, जिसे *फोक रेस* 1/टीआर4 के विरुद्ध प्रतिरोधी पाया गया है।

• दो जननद्रव्य के परिग्रहणों (जर्मप्लाज्म एक्सेसन) और केले की 10 संकर किस्मों के पासपोर्ट डेटा को भाकृअनुप–एनबीपीजीआर, नई दिल्ली को प्रस्तुत किया गया।

• केले में कैरोटीनॉयड सामग्री पर किए गए अध्ययनों से आकर्षक परिणाम मिले, जिसमें प्रमुख वाणिज्यिक किस्मों जैसे नेंद्रन और रेड बनाना की तुलना में आईटीसी 2390–2 में उल्लेखनीय रूप से उच्च स्तर की कैरोटीनॉयड तत्व पाए गए जिससे केले की इस किस्म में संभावित स्वास्थ्य लाभों के साथ–साथ पोषण की प्रचुर क्षमता का भी संकेत मिलता है।

• *इन विट्रो* (पात्र) में उगाए गए केले पर किए गए अध्ययनों से रोचक घटनाएं सामने आईं, जिसमें हरे, अलग–अलग प्रकार के, लाल और एल्बिनो जैसे विभिन्न प्रकार के विभेद प्राप्त हुए जो बाद में अपनी मूल स्थिति में वापस आ गए, जो केले की खेती में ऊतक संवर्धन की गतिशील प्रकृति को रेखांकित करते हैं।

• *फ्यूजेरियम विल्ट* के विरुद्ध एक म्यूटेंट (उत्परिवर्ती) वंशक्रम NRCBGNM1(NRCB Sel.14) की प्रतिरोधी क्षमता का आकलन करने के लिए संचालित फील्ड परीक्षणों में केले की फसल जो वर्तमान में वानस्पतिक अवस्था के अंतिम चरण में थी में केवल 4.85 प्रतिशत का संक्रमण प्रदर्शित किया जबकि गैरउपचारित (कंट्रोल) किस्म ग्रैंड नैने में 33.33 प्रतिशत संक्रमण देखा गया।

• पत्ती धब्बा प्रतिरोधी जीन DIR 11 (Ma08_g19750) डिरिजेंट जीनद्ध का प्रतिरूपण (क्लोनिंग) और लक्षणवर्णन किया गया। अनुक्रमों की जांच में 73, 99 तथा 380 पोजिशनों पर प्रतिरोधी एवं ग्रहणशील परिग्रहणों के बीच तीन कॉमन सिंगल न्यूक्लियोटाइड बहुरूपता (एसएनपी) का पता चला। इन सभी एसएनपी ने प्रोटीन अनुक्रम के भीतर अमीनो एसिड में विशिष्ट परिवर्तनों को अंजाम दिया।

• केले की खेती में आनुवंशिक विविधता को बढ़ाने के लिए प्रजनन–पूर्व (प्री–ब्रीडिंग) विभिन्न टेट्राप्लोइड वंशावलियों से केले की विविध संततियों को विकसित करने का प्रयास किया गया जिससे बेहतर विशेषताओं वाली केले की नई किस्मों को विकसित करने का मार्ग प्रशस्त हुआ।

• प्रजनन–पूर्व वंशावलियों के रूप में टेट्राप्लोइड्स की क्षमता का मूल्यांकन किया गया। मादा जनकों (पैरेंट) के रूप में उपयोग में लाए गए 10 *पिसांग अवाक*–आधारित टेट्राप्लोइड संततियों (प्रोजिनीज) में से, सभी संकरणों (क्रॉस) में बीजों का बनना (सीड सेट) देखा गया। चार *पिसांग अवाक* टेट्राप्लोइड संततियों को जब रोज़ एवं कलकत्ता

4 के साथ नर जनकों (मेल पैरेंट) से क्रॉस कराने पर इनसे पौधे उत्पन्न हुए, जिसके परिणामस्वरूप 40 प्रोजिनी प्राप्त हुईं।

• स्यूडोस्टेम बोरर प्रतिरोधिता की जांच के लिए टेट्राप्लोइड प्री–ब्रीडिंग वंशावलियों की लगातार दो वर्षों के दौरान किए गए खेत परीक्षणों (फील्ड स्क्रीनिंग) में, सात संततियों (प्रोजिनी 0187, 0189, 0731, 0734, 0816, 0817 तथा 0819) को प्रतिरोधी पाया गया।

• नर पुष्प कलिकाओं के एक्सप्लांट (कर्तोतक) का उपयोग करके त्रिवेंद्रम से सजावटी टाइप के केलों के लिए एक प्रत्यक्ष पुनरुद्भवन नवाचार (डाइरेक्ट रिजेनेरेशन प्रोटोकाल) स्थापित किया गया। संकर पौधों (कलकत्ता 4 ग नेय पूवन टेट्राप्लोइड) के लिए *इन विट्रो* पुनर्जनन प्रोटोकॉल का मानकीकरण किया गयज्ञं

फसल उत्पादन

केले के क्लम्प के प्रबंधन पर अध्ययन

• केले की खेती में नेय पूवन किस्म पर विशेष ध्यान देते हुए केले के क्लम्प प्रबंधन पर किए गए अध्ययनों में केले की अधिकतम उपज प्राप्त करने के लिए अलग–अलग सकर्स की संख्या और पोषण के विभिन्न स्तरों के प्रभाव का पता लगाया गया। परिणामों में एस1 उपचार (मदर प्लांट + 2 सकर्स) में गुच्छे का सर्वाधिक वजन देखा गया तथा पहले सकर से 13.56 किग्रा तथा द्वितीय सकर से 10.23 किग्रा फलों का उत्पादन प्राप्त हुआ।

केले में पोषक तत्वों की गतिशीलता

• पोषक तत्वों की डायनेमिक्स (गतिशीलता) पर किए गए एक अध्ययन में, गुच्छों की कटाई के बाद केले के अपशिष्ट बायोमास (शुष्क वजन के आधार पर) और स्यूडोस्टेम के रस में सूक्ष्म एवं प्रमुख पोषक तत्वों की सांद्रता का अध्ययन किया गया जो पोषक तत्वों के पुनर्चक्रण एवं प्रबंधन नीतियों के बारे में उल्लेखनीय अंतर्दृष्टि प्रदान करता है। नाइट्रोजन का स्तर 0.70 प्रतिशत से 1. 19 प्रतिशत, फॉस्फोरस 0.14 से 0.17 प्रतिशत, पोटेशियम 1.36 प्रतिशत से 2.06 प्रतिशत, तांबा 53.1 पीपीएम से 73.4 पीपीएम, मैंगनीज 125.9 पीपीएम से 260.0 पीपीएम, जिंक 52.3 पीपीएम से 63.3 पीपीएम और आयरन 92.2 पीपीएम से 146.3 पीपीएम के बीच पाया गया। ये आंकड़े केले के अपशिष्ट बायोमास में पाए जाने वाले पोषक तत्वों की प्रचुरता को रेखांकित करते हैं, जो टिकाऊ कृ षि पद्धतियों और मिट्टी की उर्वरता बढ़ाने के लिए इसकी क्षमता पर प्रकाश डालते हैं।

• पत्तियों पर नार्मल –बनाना शक्ति के साथ नैनो–बनाना शक्ति की विभिन्न सांद्रताओं का छिड़काव करने पर उसकी प्रभावकारिता पर किए गए तुलनात्मक अध्ययन से पता चला कि केले की वृद्धि के लिए सबसे अच्छा संयोजन 3 प्रतिशत सर्फेक्टेंट 1 सस्पेंशन सहित नैनो–बनाना शक्ति था, जिसका पत्तियों पर 01 प्रतिशत छिड़काव करने पर 90–दिन पुराने केले के पौधों में 14.5 ग्राम का अधिकतम शुष्क पदार्थ प्राप्त हुआ।

केले के निर्यात हेतु पैकेज ऑफ प्रेक्टिस

• राष्ट्रीय केला अनुसंधान केंद्र के फार्म और करूर जिले के मुदलाईपट्टी गांव में एक किसान के खेत में कुछ चुनिंदा वाणिज्यिक और जीआई–टैग युक्त किस्मों के निर्यात के लिए विशेषकर केले की ''नेय पूवन'' किस्म को ध्यान में रखते हुए एकीकृत पैकेज ऑफ प्रेक्टिस पर अध्ययन किया गया। इस अध्ययन में 100 प्रतिशत आरडीएफ के साथ फर्टिगेशन और फसल की कटाई–पूर्व उपचार करने पर फसल के विकास और उपज में उल्लेखनीय सुधार पाया गया। इन परिणामों में इष्टतम उपचार संयोजन के कारण 13.15 किग्रा वजन के गुच्छे की प्राप्ति हुई जिसमें 13.50 हैंड और 180 फिंगर थीं, जो गैरउपचार (कंट्रोल) की तुलना में काफी अधिक थी।

• केले की फसल पर 100 प्रतिशत आरडीएफ तथा बनाना शक्ति + गुच्छा छत्र + गुच्छे पर छिड़काव (पोटेशियम सल्फेट) का फसल की

कटाई पूर्व उपचारों का उनके जीवनकाल (शेल्फ–लाइफ) और गुणवत्ता विशेषताओं पर होने वाले प्रभाव का अध्ययन किया गया। 85 प्रतिशत परिपक्वता स्तर पर काटे गए गुच्छों को वैक्यूम पैक + एथिलीन स्क्रबर से उपचारित करके 13.5 डिग्री सेल्सियस पर संग्रहीत किया गया, जिसके फलस्वरूप स्वीकार्य गुणवत्ता मापदंडों (टीएसएस 24.33^0 ब्रिक्स; अम्लता – 0.36 प्रतिशत; कुल शर्करा – 19.61 प्रतिशत) के साथ अधिकतम 58 दिनों का शेल्फ–लाइफ़ देखा गया। जबकि अच्छे गुणवत्ता मापदंडों (टीएसएस –26.11^0 ब्रिक्स; अम्लता – 0.34 प्रतिशत; कुल शर्करा – 20.74 प्रतिशत) सहित गैरउपचार (कंट्रोल) वाले फलों का जीवनकाल (शेल्फ–लाइफ) केवल 7 दिनों का पाया गया था।

उच्च तापमान और कम नमी का प्रभाव

• केले की फसल में फूलों के निकलने की प्रारंभिक अवस्था में सूखे के तनाव की दशाओं में उच्च तापमान और मिट्टी में कम नमी का प्रभाव एएबी और एबीबी जीनोम से संबंधित केले के 53 जीनोटाइपों का मूल्यांकन किया गया। इस अध्ययन में सूखे की स्थिति में अधिकांश एएबी जीनोटाइपों में गुच्छे के वजन (25–50 प्रतिशत) और फलों के वजन (22.25–39.90 प्रतिशत) में पर्याप्त कमी के साथ ही हैंड की संख्या, प्रति गुच्छे में फलों की संख्या और प्रति हैंड फलों की संख्या में भी उल्लेखनीय कमी देखी गई। इसके अलावा, इस अनुसंधान में पौधे के विकास मापदंडों पर मिट्टी में कम नमी से उत्पन्न तनाव से होने वाले प्रतिकूल प्रभावों पर भी प्रकाश डाला जो यह दर्शाता है कि एएसए के साथ उपचारित पत्तियों की प्रमुखता वाले सूखा–तनावग्रस्त पौधों के वृद्धि मैट्रिक्स में वृद्धि देखी गई जबकि नमी के अत्यधिक स्तर के कारण विशिष्ट किस्मों में पौधे की ऊंचाई और पत्तियों की संख्या में कमी पाई गई।

पोषण (न्यूट्रास्युटिकल) सामग्री का विश्लेषण

• केले के विभिन्न जीनोटाइपों में एंथोसायनिन के विश्लेषण से पता चलता है कि साइनाइडिन एक प्रमुख एंथोसायनिन यौगिक है जिसका केले की विभिन्न किस्मों में एक बड़ा भाग (66–75 प्रतिशत) होता है। केले के प्रकंद में प्रमुख फ्रुक्टेन अंश 1,1–निस्टोज़ की पहचान की गई जिसकी सांद्रता केले की विभिन्न किस्मों में 361 µg/g ॅ से 420 µg/g ॅ के बीच थी।

• पूरी तरह से पके हुए केले के फलों की स्टार्च संरचना का अध्ययन किया गया और केले की विभिन्न किस्मों में कुल स्टार्च अंश को 81–87 प्रतिशत के रेंज में पाया गया। केले की नेय पूवन किस्म में सबसे अधिक स्टार्च पाया गया जबकि पंचनंदन में स्टार्च अंश को सबसे कम स्तर पर पाया गया। इसके अलावा, केले की विभिन्न किस्मों में एमाइलोज अंश में काफी अंतर देखा गया जिसमें प्लेनटेन और कुकिंग बनाना किस्मों में एमाइलोज का स्तर 35ः से अधिक था, जबकि डिजर्ट बनाना में एमाइलोज की मात्रा कम थी जिसे 5 से 10 प्रतिशत के बीच पाया गया।

मूल्य संवर्धन

• अल्ट्रासोनिकरण और प्लाज्मा–सक्रिय पानी द्वारा केले के स्टार्च संशोधन के विश्लेषण में भौतिक–रासायनिक परिवर्तनों को देखा गया जिसमें केले से बने पारंपरिक आटे (नेटिव काउंटरपार्ट) की अपेक्षा संशोधित आटे में फुलाव शक्ति में 25 प्रतिशत की उल्लेखनीय कमी और घुलनशीलता में 30 प्रतिशत की उल्लेखनीय वृद्धि पाई गई।

• केले से ब्रेड (डबलरोटी) बनाने के लिए किए गए एक अध्ययन में, केले के स्टार्च को शामिल करने पर अलग–अलग रंगों की संरचना प्राप्त हुई, जिसमें नमी की मात्रा ने क्रम्ब में 11.85 से 24.72 प्रतिशत और क्रस्ट में 7.14ः से 16.46 प्रतिशत तक की गतिशील रेंज को प्रदर्शित किया जो दृश्य सौंदर्य और टेक्सचर (बनावट) के लक्षणों पर इसके महत्वपूर्ण प्रभाव को दर्शाता है।

• सोया प्रोटीन, चाय के अर्क, शहद और खजूर के सिरप के 10 प्रतिशत घोल जैसे अलग–अलग फंक्शनल कोटिंग्स के साथ केले के अंजीर को सुदृढ़ करने से इसके पोषण मूल्य में वृद्धि हुई, सोया प्रोटीन के उपयोग से प्रोटीन अंश में वृद्धि

हुई जबकि खजूर के रस ने संभावित रूप से खनिज सामग्री को बढ़ाया। लेपित नमूनों में शर्करा अंश को कम करने में पाँच गुना जबकि प्रोटीन सामग्री में दो गुना वृद्धि देखी गई।

• देशी एवं संशोधित केले के स्टार्च को शामिल करके *लैक्टोबैसिलस प्लांटारम* के संपुटीकरण (एनकैप्सुलेशन) का प्रयास किया गया। छिद्रयुक्त (पोरस) संशोधित स्टार्च में बेहतर संपुटीकरण दक्षता और कम घुलनशील कैप्सूल पाए गए जिसमें 40: (12cfu/g) तक बढ़ी हुई वाएबिलिटी और अम्ल प्रतिरोधिता पाई गई।

फसल सुरक्षा

केले के नाशकीट तथा उनके प्राकृतिक शत्रु

• सीओएक्स1 अनुक्रमण के माध्यम से 02 लेपिडोप्टेरान नाशीकीटों एवं 08 मिलीबग का आणविक लक्षण वर्णन किया गया और इनके जीनबैंक एक्सेसन नम्बर प्राप्त किए गए।

• *एनागाइरस* प्रजाति और *एलोट्रोपा* प्रजाति से संबंधित दो परजीवाभ्यों (पेरासिट्वॉयड) को जैक बियर्डस्ले मिलीबग पर पहली बार दर्ज किया गया।

• पूर्वोत्तर भारत और दक्षिण भारत से केले के पारितंत्र में पाए जाने वाले परभक्षी कोक्सीनेलिड की दो नई जेनेरा (वंशक्रमों) और प्रजातियाँ – *नियोप्लाटिनास्पिस वैंडेनबर्गे* पूरनी एवं *स्लिपिंसकिसिमनस केरालेंसिस* पूरनी का लक्षणवर्णन किया गया। केले की फसल में एक जंपिंग स्पाइडर, *अफ्राफ्लैसिला एडवाथुरेंसिस* (अरानेई: साल्टिसिडे) को विज्ञान जगत में नया पाया गया।

कीट प्रबंधन

• केले के वयस्क स्कारिंग बीटल के विरुद्ध प्रयोग किए गए विभिन्न नए कीटनाशकों के मूल्यांकन में, फिप्रोनिल 5: SC स्पिनोसैड 45% SC और क्लोरपाइरीफोस 20: EC को प्रयुक्त करने पर 1 दिन के भीतर शतप्रतिशत मृत्यु दर पाई गई।

• प्रयोगशाला परीक्षण (बायोएसे) में शीथ डिपिंग विधि का उपयोग करके *बनाना वीविल किलर* बायोफ़ॉर्मूलेशन ने LC 50 मान के 2×10^4 और LC 90 मान के 6×10^9 के साथ आर 2 मान 0.872 का प्रदर्शन किया जबकि इंसेक्ट स्प्रे विधि में उपचार के बाद 7वें दिन में LC 50 मान के 4×10^4 और LC 90 मान के 1×10^7 के साथ आर2 मान 0.988 का प्रदर्शन किया।

• खेतों पर किए गए मूल्यांकन में भी, फिप्रोनिल 5: SC और थाइमेथोक्सम 25: WG को स्यूडोस्टेम में सीधे इंजेक्ट करने पर स्यूडोस्टेम वीविल के विरुद्ध शतप्रतिशत मृत्यु दर प्रदर्शित की।

• एन्टोमोपैथोजेनिक फंगल फॉर्मूलेशन जैसे कि EPF 22, EPF 28 और EPF 50 ने केले के स्यूडोस्टेम वीविल को प्रभावी ढंग से प्रबंधित किया, जो वीविल को आकर्षित करने वाले विशिष्ट फॉर्मूलेशन की मदद से कीटों की मृत्यु दर में वृद्धि करते हैं।

रोग प्रबंधन

• केले के कीट एवं रोगों के प्रबंधन हेतु अनुशंसित रासायनिक उपचारों का परीक्षण फसलोपरांत (पोस्ट हार्वेस्ट) रोग नियंत्रण और अवशेष स्तरों के लिए किया गया और इसके परिणामस्वरूप फसलोपरांत होने वाली बीमारियों में लगातार कमी आई, फलों के जीवनकाल (शेल्फ लाइफ) में वृद्धि तथा गुणवत्ता में सुधार पाया गया। उपचारित फल 9 दिनों तक एन्थ्रेक्नोज से मुक्त रहे, जबकि गैरउपचारित फलों में तीसरे दिन से लक्षण दिखाई दिए। उपचारित फलों में क्राउन रॉट 7वें दिन शुरू हुआ, जबकि गैर उपचारित फलों में इसे तीसरे दिन देखा गया। रासायनिक उपचारों से शेल्फ लाइफ 9 दिनों तक बढ़ गई, जबकि गैरउपचार में इसे 4–5 दिन पाया गया।

• *फ्यूजेरियम विल्ट* प्रबंधन के लिए जैव नियंत्रण एजेंटों और जैविक संशोधनों को शामिल करके 03 विशिष्ट संयोजनों ने ग्रैंड नैने प्रजाति में

फ्यूजेरियम विल्ट को रोधित करने में असाधारण प्रभावकारिता का प्रदर्शन किया। उल्लेखनीय रूप से, इन संयोजनों को एफओसी–संरोपित पौधों पर प्रयुक्त करने पर 0–5 के सीविएरीटि स्केल (गंभीरता पैमाने) पर केवल 0.2 का रोग स्कोर हासिल किया, जो गैरउपचारित ग्रुप की तुलना में उनकी शक्तिशाली रोग–दमन क्षमताओं को उजागर करता है, जिसका स्कोर 4.5 था।

• 40 जीवाई पर गामा विकिरण से उपचारित पौधों की पॉट स्क्रीनिंग में, एफओसी रेस 1 के विरुद्ध एक संभावित *फ्यूजेरियम* विल्ट प्रतिरोधी वंशक्रम की पहचान की गई, जिसका *इन विट्रो* संवर्द्धन शुरू किया गया है। एफओसी रेस 1 और टीआर 4 के विरुद्ध 300 म्यूटेंट (उत्परिवर्तित) पौधों की जांच की जा रही है, जबकि 1000 पौधों का एक और सेट सैकेंडरी हार्डनिंग स्टेज (द्वितीयक सख्त अवस्था) में है।

• विशेष रूप से केले के बंची टॉप वायरस (बीबीटीवी) को लक्षित करने वाला एक रिकांबिनेंट मोनोक्लोनल एंटीबॉडी विकसित किया गया। एलिसा–आधारित निदान तकनीकों के मानकीकरण द्वारा केले के पौधों में वायरस का पता लगाने की सटीकता और दक्षता को बढ़ाया गया। बीबीटीवी–संक्रमित नमूनों से कुल डीएनए का निष्कर्षण और उसके बाद एक्सप्रेशन वेक्टर में क्लोनिंग ने रिकांबिनेंट बीबीटीवी–सीपी के सफलतापूर्वक एक्सप्रेशन (अभिव्यक्ति) का मार्ग प्रशस्त किया, जो केले में वायरसों का पता लगाने और उसके प्रबंधन के लिए बेहतर नैदानिक साधनों (टूल्स) के विकास में एक मील का पत्थर साबित होगा।

संपर्क (आउटरीच) गतिविधियाँ

• बाहरी संपर्क और अंतर–संस्थानीय गतिविधियों में विभिन्न प्रकार की पहलें शामिल की गईं जिनमें लगभग 3,000 आगंतुकों एवं छात्रों के साथ राष्ट्रीय विज्ञान दिवस का आयोजन, हितधारकों के लिए क्षमता विकास कार्यक्रमों का आयोजन, किसानों के संपर्क दौरे आयोजित करना और *विकसित भारत संकल्प यात्रा* जैसे कार्यक्रमों का समन्वय करना सम्मिलित है।

• इसके अतिरिक्त, राष्ट्रीय केला अनुसंधान केंद्र (एनआरसीबी) के 30$^{वें}$ स्थापना दिवस, *किसान मेला* और राज्यपाल के संस्थान आगमन के दौरान केले की खेती से संबंधित हितधारकों की बैठक जैसे कार्यक्रम आयोजित किए गए, जिसमें केला सेक्टर से सम्बद्ध 600 से अधिक किसान और 200 हितधारक शामिल हुए।

• भाकृअनुप–एनआरसीबी ने तिरुचिरापल्ली के केयर इंजीनियरिंग कॉलेज में 27 से 29 जुलाई, 2023 तक आयोजित प्रतिष्ठित राज्य स्तरीय मेगा ''एग्री एक्सपो 2023'' में भाग लिया और शीर्ष स्टॉल पुरस्कार जीता।

• भाकृअनुप–एनआरसीबी ने तमिलनाडु और अन्य राज्यों के विभिन्न जिलों की महिला किसानों के लिए अनेक प्रशिक्षण कार्यक्रम आयोजित किए। प्रतिवेदित वर्ष में, महिला लाभार्थियों की कुल संख्या 3,680 थी। एटीएमए कार्यक्रम के दौरान, एकीकृत पोषक तत्व प्रबंधन (आईएनएम), मूल्य संवर्धन तकनीकों और पीएम किसान, केसीसी और आरकेवीवाई जैसी विभिन्न सरकारी योजनाओं पर प्रशिक्षण सत्रों का आयोजन किया गया।

• भाकृअनुप–एनआरसीबी ने स्वतंत्रता सेनानियों को सम्मानित करने के लिए 2 अक्टूबर, 2023 को राज्यपाल कार्यालय द्वारा आयोजित विशेष समारोह में अपनी प्रौद्योगिकियों और उत्पादों का प्रदर्शन किया। एनआरसीबी के स्टॉल में 13 केला हितधारकों द्वारा प्रस्तुत उत्पादों के साथ–साथ प्रौद्योगिकियों का प्रभावशाली प्रदर्शन किया गया, जो केला उद्योग में इस संस्थान के योगदान को दर्शाता है।

प्रमुख राष्ट्रीय एवं अंतरराष्ट्रीय सम्मेलन और कार्यशाला

• भाकृअनुप–राष्ट्रीय केला अनुसंधान केंद्र, त्रिची और भारतीय वायरोलॉजिकल सोसायटी, नई

दिल्ली द्वारा तमिलनाडु के तिरुचिरापल्ली में 1–3 दिसंबर, 2023 के दौरान संयुक्त रूप से वन हेल्थ कॉन्सेप्ट के तहत एक विशिष्ट राष्ट्रीय सम्मेलन वाइरोकॉन 2023 का आयोजन किया गया, जिसका मुख्य विषय था 'वन हेल्थ की दिशा में वैश्विक वायरस अनुसंधान में प्रगति'। इस सम्मेलन में 70 संस्थानों के वैज्ञानिकों, छात्रों और शोधार्थियों सहित भारत और विदेश से कुल 444 प्रतिनिधियों ने भाग लिया। इस दौरान 19 तकनीकी सत्र आयोजित किए गए, जिनमें विभिन्न थीमेटिक (विषयगत) क्षेत्रों के अंतर्गत प्रस्तुतियाँ दी गईं, इसके अलावा चार कार्यशालायों का भी आयोजन किया गया जिनमें 146 किसानों और अन्य हितधारकों ने भाग लिया।

• भाकृअनुप–एनआरसीबी, तिरुचिरापल्ली ने एलायंस ऑफ बायोवर्सिटी इंटरनेशनल तथा सीआईएटी, इटली, जो सीजीआईएआर का एक संस्थान है के सहयोग से संस्थान में 7 से 11 मार्च, 2023 तक 'सूखा सहिष्णुता के लिए फेनोटाइपिंग' पर एक अंतर्राष्ट्रीय कार्यशाला का आयोजन किया।

• भाकृअनुप–एनआरसीबी, तिरुचिरापल्ली तथा जैन इरिगेशन सिस्टम लिमिटेड, जलगाँव, महाराष्ट्र ने संयुक्त रूप से 1 जून, 2023 को मध्य प्रदेश के बड़वानी में "बदलते जलवायु परिदृश्य में हाई टैक (उच्च तकनीक) केले की खेती" पर एक कार्यशाला का आयोजन किया।

राजस्व उत्पन्न

रुपये का सकल राजस्व. जनवरी से दिसंबर 2023 के दौरान केंद्र द्वारा 73.98 लाख रुपये का राजस्व अर्जित किया गया।

4.RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

4.1.1 Improvement and management of banana genetic resources in the Indian sub-continent

Collection

During the reporting period, 12 wild germplasm accessions were collected from a secondary source, namely ICAR-NBPGR, Vellanikkara, Kerala, in the form of seeds and suckers, and one cultivated variety, Nanjangud Rasabale, from a farmer's field in Devarasanahalli, Mysuru (Table 1).

Table 1. Germplasm accessions collected

S. No.	Name	Source
1.	*Musa kattuvazhaiana, M. thomsonii, M. sikkimensis* (2 types), *M. ochracea, M. acuminata, M. balbisiana* (5 types), *M. indandamanensis*	ICAR-NBPGR, Vellanikkara, Kerala
2.	Nanjangud Rasabale	Farmer's field, Devarasanahalli village, Mysuru, Karnataka

Morphotaxonomic characterization

Morpho-taxonomic characterization was conducted for eight accessions collected from Kittur Rani Chennamma College of Horticulture, Arabhavi, Karnataka, during the previous year, utilizing the IPGRI Musa descriptors. This process led to the identification of genomes and subgroups (Table 2).

Table 2. List of accessions characterized

S. No.	Name	Identified genome
1.	Budubale	ABB
2.	Shanbale	ABB
3.	Bargibale	AAB
4.	Karibale	AAB
5.	Mitli	AB
6.	Sakkarabale	AAB
7.	Budumitika	AAB
8.	Rajapuri	AAB

Under AICRP (Fruits), morpho-taxonomic characterization has been completed for 72 accessions maintained at the Bhubaneshwar center, leading to the identification of 40 duplicates. IC numbers have been assigned to the remaining 32 accessions. Similarly, IC numbers have been assigned to 78 germplasm accessions maintained at Mohanpur center.

Molecular characterization

Attempts were made to identify SSR markers to distinguish the Cavendish clones. Initially, four trait-specific markers, four AGMI markers, and eight NRSIP markers were tested on four Cavendish clones, namely Grand Nain, NRCB selection 14, TBM 9, and Williams. Out of the 16 markers tested, only NRSIP 2 could distinguish TBM 9 from the rest of the Cavendish clones (Fig. 1).

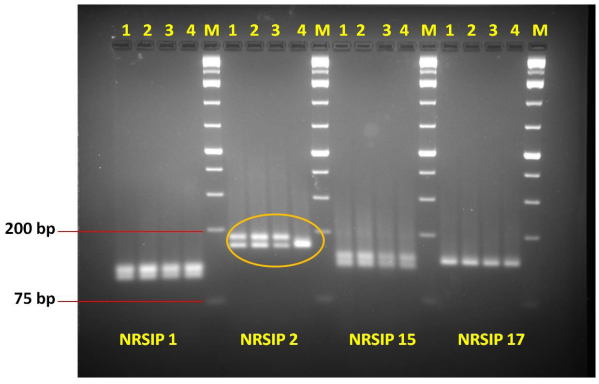


Fig. 1. Screening of SSR markers for distinguishing the four Cavendish clones.

Cloning and characterization of leaf spot resistant gene DIR 11 isoforms

The Ma08_g19750 dirigent gene, significantly up-regulated in resistant wild BB types like Bhimkol and Attikol (BB) compared to susceptible varieties Jahaji and Manjahaji (AAA) (Fig. 2), was isolated and cloned. Examination of the sequences revealed three common single nucleotide polymorphisms (SNPs) between resistant and susceptible accessions at positions 73, 99, and 380. These SNPs led to specific alterations in amino acids within the protein sequence, as shown in Table 3.

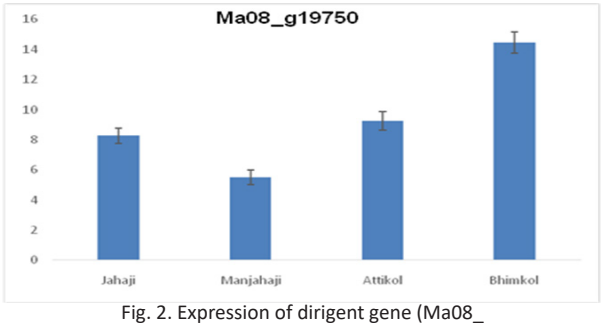


Fig. 2. Expression of dirigent gene (Ma08_g19750)

The sequences of the DIR 11 gene (Ma08_g19750) in resistant and susceptible accessions were compared with those available in the public domain. A phylogenetic tree was constructed using MEGA software, revealing that all banana sequences formed a distinct cluster closely related to wheat (Fig. 3).

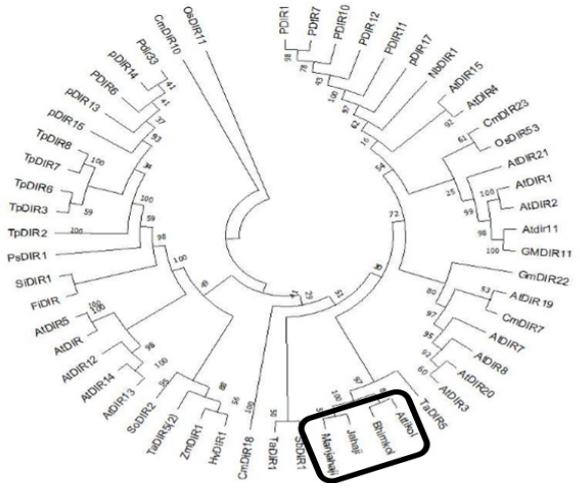


Fig. 3. Phylogenetic tree of dir11 genes constructed using MEGA software

Table 3. SNPs identified in dirigent 11 gene between the leaf spot resistant and susceptible cultivars

Position of amino acid	Susceptible cultivar	Resistant cultivars
25th position	S (Serine)	G (Glycine)
33rd position	M (Methionine)	I (Iso-leucine)
67th position	G (Glycine)	A (Alanine)

Establishment of new blocks

Exclusive field genebanks with 351 indigenous and 121 exotic accessions have been newly established. A new demonstration block has been set up with eight promising lines identified at ICAR-NRCB, Trichy. The demonstration block includes 107 accessions of the core germplasm covering all cultivable types. Additionally, a new block has been raised at the Satellite Genebank in Agali with 77 accessions found to be resistant to Foc race 1/TR4.

Registration

Passport data for two germplasm accessions and 10 banana hybrids were submitted to ICAR-NBPGR, New Delhi, for IC numbers. Total and beta-carotenoid contents were estimated in promising ITC accession 2390-2 and compared with commercial cultivars Grand Nain, Red Banana, and Nendran. Accession 2390-2 had carotenoid levels ten-fold greater than Grand Nain and was comparable to Nendran, surpassing even Red Banana (Table 4).

Table 4. Estimation of carotenoids in ITC 2390-2 at different stages of ripening

Total carotenoids (µg/100g) FWB

Description	Ripening stage	GRAND NAINE	2390-2	NENDRAN	RED BANANA
Unripe	Stage 2	89.49	**963.5**	972.32	731.05
	Stage 3	95.32	**1118.53**	1012.36	763.25
Mid ripe	Stage 4	102.87	**1121.36**	1197.36	846.47
Ripe	Stage 5	176.23	**1206.33**	1223.02	982.36
Over ripe	Stage 7	278.76	**1251.62**	1413.21	1286.98

β-carotene (µg/100g) FWB

Description	Ripening stage	GRAND NAINE	2390-2	NENDRAN	RED BANANA
Unripe	Stage 2	60.49	**863.49**	834.08	664.93
	Stage 3	75.30	**923.41**	992.24	687.23
Mid ripe	Stage 4	98.87	**936.58**	976.31	752.69
Ripe	Stage 5	143.94	**973.26**	1013.23	842.36
Over ripe	Stage 7	185.39	**987.46**	1243.26	1028.16

Performance evaluation of TBM 12 at Theni

TBM 12 is another promising dwarf mutant from the same population of TBM series. The same was evaluated in two farmers' fields at Theni. It was found to be 1 meter shorter than Grand Nain, with an average bunch weight of 20 kilograms.

Regeneration systems in banana Field evaluation of somatic embryo derived plantlets of cvs. Red Banana and Grand Nain

Germinated somatic embryos (GSE) from SERV were sent to: M/s. Dhanam Agro-tech Biotech in Krishnagiri and BRS, Kovvur for plantlet production. Red Banana GSE (200g) yielded 2800 plantlets, while Grand Nain GSE (120g) yielded 700. Field evaluation at farmer's field in Salem revealed no phenotypic variations (Fig. 4).

T1 Baltic peat T2 Baltic Peat T3 Kelpeat

Fig.4. Different stages of SERV derived Red Banana TC plants

Development of plantlet from NCR 17 ECS and mutated ECS of Grand Naine using bioreactor

A total of 222 Grand Naine mutant plantlets were developed from mutated ECS through bioreactor and being used for *Foc* screening under pot culture. A total of 1000 plantlets of NCR 17 have been obtained from biorector using ECS and they were distributed to the Farmers at Goa with the help of ICAR-Central Coastal Agricultural Research Institute.

Screening of ITC accessions under pot culture against *Foc* race 1 and TR 4

Pot culture screening of ten ITC accessions showed that seven accessions (Palang. Tha-18, Cocos, Maiden Plantain, Kluai Tiprod, SH3640 and ITC 553 (2390/2)) were moderate resistance, four accessions (Paliama, FHIA 3, Pisang Raja, and Fogamou) were susceptible and one was *M.ac.ssp.malacensis* highly susceptible reactions for *Foc* TR 4. Pot culture screening of five ITC accessions showed that *M.ac.ssp. malacensis*, Vudai wai wai were moderate resistance, Palang was susceptible and Pisang Raja and Kluai Namwakhom were highly susceptible to *Foc* race 1.

Screening of Local land races and somaclonal variant of land race (Kaveri Sugantham) against Foc race 1

Kaveri Sugantham and Manoranjitham were found to be susceptible; Sabri was found to be moderately resistant and Namarai was found to be highly susceptible for *Foc* race 1 under pot culture condition.

Multiple shoot induction in zygotic embryos of hybrid progenies

In vitro regeneration protocol for hybrid seedlings (Calcutta 4 X Ney Poovan tetraploid) was standardized. Modified MS with BAP, Kinetin, IAA, and Adenine sulfate, produced 30 shoots after the sixth subculture. These were rooted in the same medium with IBA and NAA.

Development of haploids through anther culture

Anther culture was attempted in four cultivars (Bhimkol, Athiakol, Neypoovan, and Grand Nain). The optimal bract number for anthers with uni-nucleate, highly vacuolated pollen was determined. Among five callus induction media tested, MA1, modified MA1, and modified Nitsch media showed promising results. Only Bhimkol callus inoculated in MA4 media regenerated into plantlets through indirect organogenesis. Currently, they are in the phase of shoot multiplication (Fig. 5).

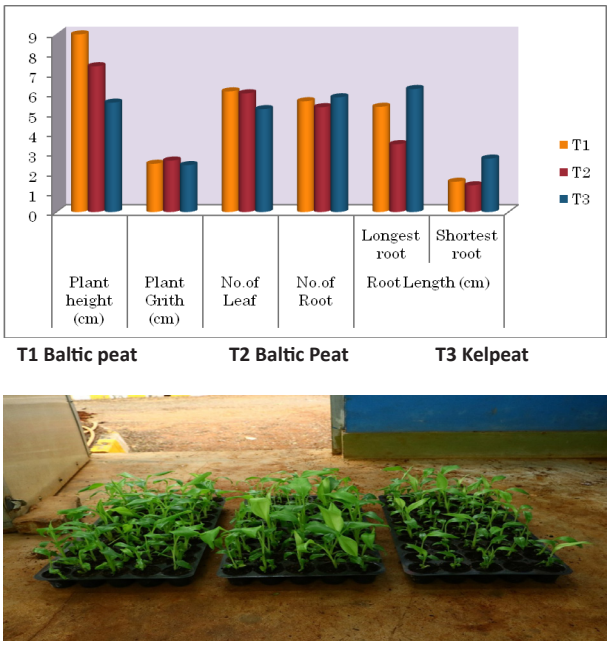
Fig.5. Development of haploids through anther culture

Direct regeneration protocol for the variegated ornamental banana

A direct regeneration protocol was established for ornamental types from Trivandrum using male flower bud explants. Meristematic clumps formed in MS media with BAP and IAA, regenerating into shoots with reduced IAA concentration. Higher BAP levels (5 ppm) produced variants (green, variegated, red, albino) *in vitro*, but they reverted to normal in the later stages of *in vitro* multilplication.

Effect of different substrates on hardening of tissue cultured bananas

Among the substrates tested for hardening, Baltic peat outperformed Kelpeat in growth parameters such as plant height and leaf number. However, Kelpeat showed better root growth (Fig. 6).



T1 Baltic peat T2 Baltic Peat T3 Kelpeat

Fig.6. Effect of different substrates on hardening of tissue cultured bananas

Preliminary trials on hydroponics method of hardening

Tissue culture-derived banana plantlets are prone to soil-borne pathogens. Therefore, preliminary attempts were made using the hydroponics method of hardening (refer to Fig. 7a, 7b, 7c). This method offers several benefits, including uniform water and nutrient distribution, while consuming only 1/10th of the water used in the conventional method. Additionally, it reduced the duration of hardening by 15 days and costs by 35%.

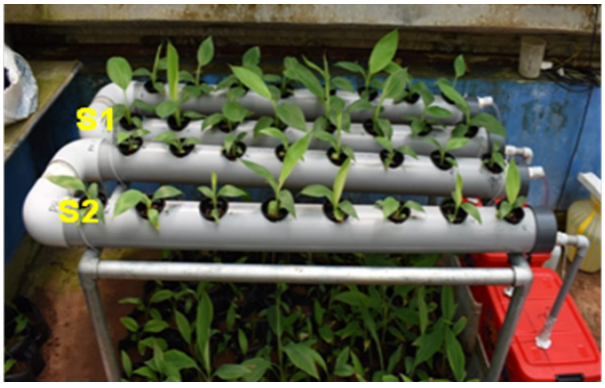


Fig. 7a. Hydroponics model

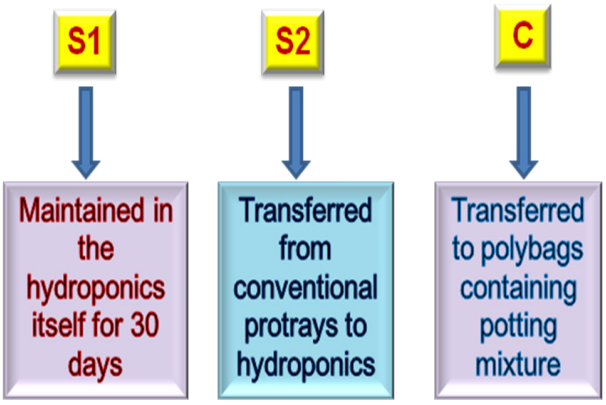


Fig.7b. Different methods of hardening

Fig. 7c. Variation in growth parameters under three different methods of hardening

Fig.7. Hydroponics method of hardening of tissue culture plantlets

4.1.2 Improvement of banana through conventional breeding

Release of Provitamin A rich dessert banana for Tamil Nadu State

The 54th State Variety Release Committee and 40th State Seed Sub-Committee of Tamil Nadu have recommended the release of progeny NCR 17 as Kaveri Kanchan. This variety is a dessert type with high carotenoid content (2423 µg/100g fresh pulp), resistant to fusarium wilt, and yields 20% more than Nendran. It is recommended for cultivation in Trichy, Theni, Pollachi, Coimbatore, Salem, and Tirunelveli districts of Tamil Nadu due to its unique features (Fig. 8).

Fig.8. Bunch and fruits of Kaveri Kanchan, a new variety from ICAR-NRCB

New progenies developed from various cross combinations

A total of 60 new progenies of various combinations have been newly planted and are currently being maintained, while 207 new progenies resulting from 34 cross combinations are in the secondary hardening stage.

Potential of tetraploids as pre-breeding lines

In ten Pisang Awak-based tetraploid progenies used as female parents, seed set was achieved in all crosses. However, only four Pisang Awak tetraploid progenies produced plants when crossed with cv. Rose and Calcutta 4 as male parents, resulting in 40 progenies (see Table 5 & Fig. 9).

Table 5. Progenies developed from tetraploid pre-breeding lines

Cross combinations using Tetraploid female parent	No. of progenies
Pro. 496 (Udhayam x Cheng-dawt) x cv. Rose	2
Pro.665 (Saba x PL) OP	2
Pro. 868 (Saba x PL) OP	1
Pro.765 (Bhatmonahar x PJ) OP	16
P 441 (Marabale x Calcutta 4) x Calcutta 4	19
Total	**40**

Fig. 9. Bunches of tetraploid pre-breeding lines Pro. 496

Pseudostem borer resistant tetraploid pre-breeding lines

Field screening of tetraploid pre-breeding lines for pseudostem borer over two consecutive years revealed that seven progenies (Pro. 0187, Pro. 0189, Pro. 0731, Pro. 0734, Pro. 0816, Pro. 0817, Pro. 0819) did not get borer infestation (Fig.10).

Fig.10. Bunch trait of pseudostem borer resistant tetraploid pre-breeding lines

Pot culture screening of progenies against *Foc* race 1

Out of 64 progenies screened against Foc race 1 under pot culture, 20 showed immune reactions, 17 were resistant, 13 displayed moderate resistance, and 14 were susceptible/highly susceptible. Seven of the immune progenies also exhibited immunity at the hotspot (Fig. 11) and except two (Pro. 009-3X and Pro.756-4X) all the progenies were diploids. Pro.837 showed high resistance, Pro. 932 and Pro.933 showed FoC resistance, Pro.836 showed moderate resistance, and Pro. 913 showed susceptibility under the hotspot area.

Reaction of progenies against Foc race 1 at hotspot and in pot culture

S.No	Progeny No	Parentage	Ploidy	*Foc* Race 1		Weevil %
				Hot spot	Pot	
1	009	Matti x Anaikomban	3x	I	I	-
2	822	Udhayam x P.Lilin	4x	-	I	0
3	110	Karpuravalli x Calcutta -4-1	2x	I	I	50
4	111	Karpuravalli x Calcutta -4-1	2x	I	I	33.3
5	113	Karpuravalli x Calcutta -4-1	2x	I	I	41.7
6	117	Karpuravalli x Calcutta -4-1	2x	I	I	25
7	756	Karpuravalli x Calcutta -4-1	4x	I	I	12.5
8	867	Karpuravalli x Calcutta -4-1	4x	-	I	12.5
9	901	Nendran x Cultivar rose	2x	-	I	-
10	913	Ennabenian Op	4x	S	I	0
11	878	Dole Op	2x	I	I	-
12	811	Kothia x C4 Op	3x	-	I	0
13	836	Kothia x Calcuta-4-1	2x	MR	I	-
13	837	Kothia x Calcuta-4-1	2x	HR	I	-
15	838	Kothia x Calcuta-4-1	2x	-	I	-
16	906	Poovan x Calcutta 4	3x	-	I	0
17	908	Poovan x Calcutta 4	4x	-	I	0
18	932	P-480 (Kothia x Calcutta 4) Op	2x	R	I	-
19	933	P-647 (Kothia x Calcutta 4)Op	3x	R	I	-
20	017	Anaikomban x Lairawk	2x	-	I	-

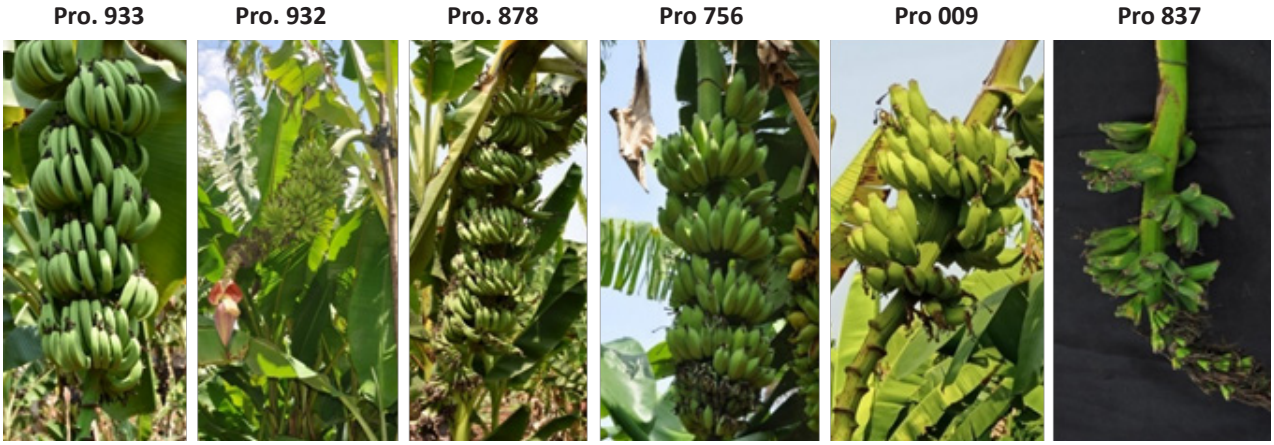


Fig.11. Bunches of hybrid Progenies immune/ resistant to *Foc* both at hotspot and in pot culture

Reaction of a cooking type elite progeny 0959 for *Foc* race 1 and TR4

Pro. 959, a promising cooking type progeny, was highly susceptible to Foc race 1 under pot culture screening. However, it exhibited field resistance to Foc TR4 in the hotspot area of Bihar district, recording an average bunch weight of 28 kg.

Reaction of cv. Rose x Calcutta 4 progenies against *Foc* race 1

Out of the 10 progenies in the newly added cv. Rose x Calcutta 4 mapping population tested against Foc race 1 under pot culture, one progeny (Pro. 924) exhibited immunity, while seven progenies (Pro. 919, 920, 1922, 923, 925, 929, and 930) showed a resistant reaction with a score of 2.

Field screening of progenies against pseudostem weevil (*Odoiporus longicollis*)

BSW infection was observed in seven tetraploid progenies: Pro. 0734 (Udhayam x Pisang Lilin), Pro. 0819 (Udhayam x Calcutta 4), Pro. 0189 (Udhayam x Calcutta 4-1), Pro. 0817 (Karpuravalli x Calcutta 4-1), Pro. 816 (Bankela x Pisang Lilin), Pro. 0731 (Saba OP), as well as in three triploids: Pro. 0160 (Bankela x Pisang Lilin), Pro. 0685, and Pro. 0691 (Saba x Pisang Lilin), and four diploids: Pro. 0791 and Pro. 0820 (Udhayam x Pisang Lilin), Pro. 0429 (cv. Rose x Pisang Lilin), and Pro. 0009 (Matti x Anaikomban) (refer to Fig. 12).

Fig.12. Progenies of various ploidy levels showing resistant reaction against BSW

4.1.3 Development of trait specific markers for *Fusarium* wilt resistance through association mapping studies in banana (*Musa* spp.)

Phenotyping was done for eight accessions through pot screening, including three Cavendish varieties, three Sabri accessions, one *Rhodochlamys* member, and one Nendran type. Disease scores ranged from 2 to 5, with Williams among the Cavendish varieties being susceptible, along with all three Sabri accessions.

Genotyping of 153 mini-core accessions was conducted using fusarium wilt race 1 specific SSR markers. Preliminary results showed alignment between phenotyping and genotyping data for most accessions.

4.1.4 Improvement of cv. Grand Nain (Cavendish–AAA) for *Fusarium* wilt resistance through non-conventional breeding

Field evaluation of NRCBGNM 1 (NRCB Sel.14) in wilt infested and wilt free fields at Theni

Large scale evaluation of NRCBGNM 1 (NRCB Sel.14) at Theni (wilt free) indicated that the performance was on par with cv. Grand

Nain with respect to growth and yield related parameters.

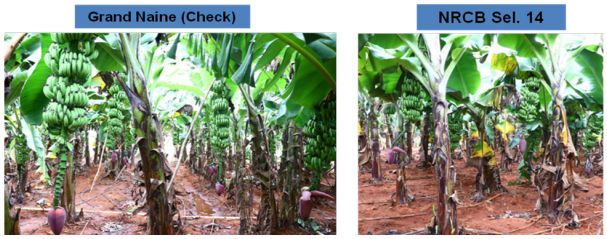


Fig.13. Performance of NRCBGNM1 (NRCB Sel.14) in wilt free soils

Simultaneous evaluation of NRCBGNM 1 (NRCB Sel.14) was conducted in a wilt-infested field in Theni. The crop, currently in the late vegetative stage, showed only 4.85% infection, compared to the 33.33% observed in the Grand Nain control.

Fig.14. Performance of NRCBGNM 1 (NRCB Sel.14) in wilt infested soils

Phase I and II evaluation of putative resistant mutant lines against *Foc* race 1 in the sick plot at Theni

Phase II evaluation of seven mutant lines in the race 1 sick plot at Theni showed minimal infection (16.66%) compared to 46.66% in the Grand Nain control. In Phase I, four putative resistant mutant lines in the sick plot exhibited slow growth but remained 100% symptom-free. In field evaluation of all the seven mutant lines in the TR 4 sick plot at Bihar, the internal disease score ranged 2.25–3, indicating that they are moderately resistant.

Validation of fusarium wilt resistance using trait specific markers

Mutant lines which were found to be resistant to either race 1 or TR 4 under pot culture were screened using respective race 1 and TR 4 specific markers. Results indicated that race 1 resistant mutants behaved similarly both under pot culture and molecular

Fig. 15. Performance of four putative resistant mutant lines for *Foc* race1

screening; however, TR4 resistant mutants which were resistant under pot culture were found to be susceptible in molecular screening.

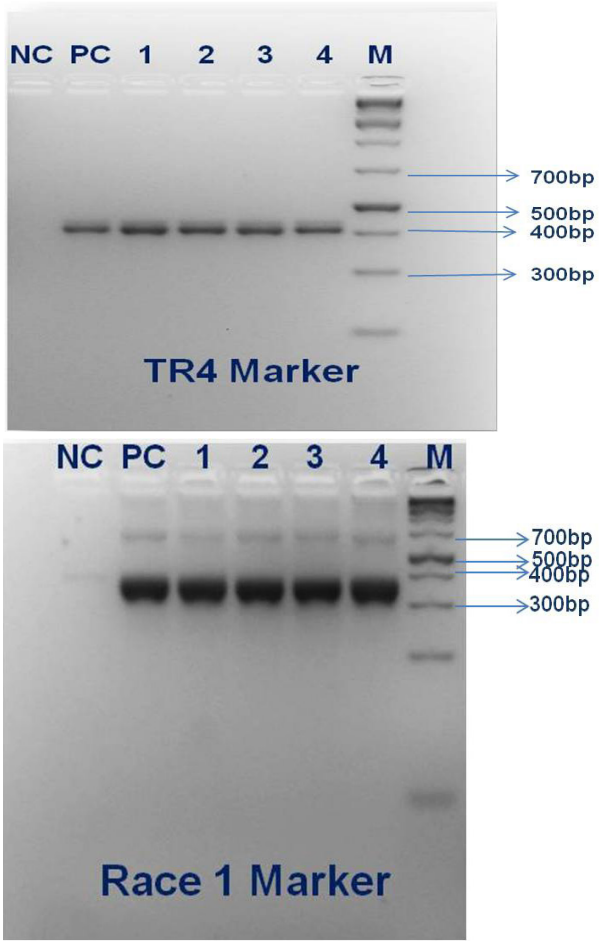


Fig. 16. Validation of fusarium wilt specific markers in Race 1 resistant population; NC: negative control; PC: positive control (G9); 1&2: NRCBGNMG-1 (R1); 3&4: NRCBGNMG-2(R1); M: 1Kb plus ladder

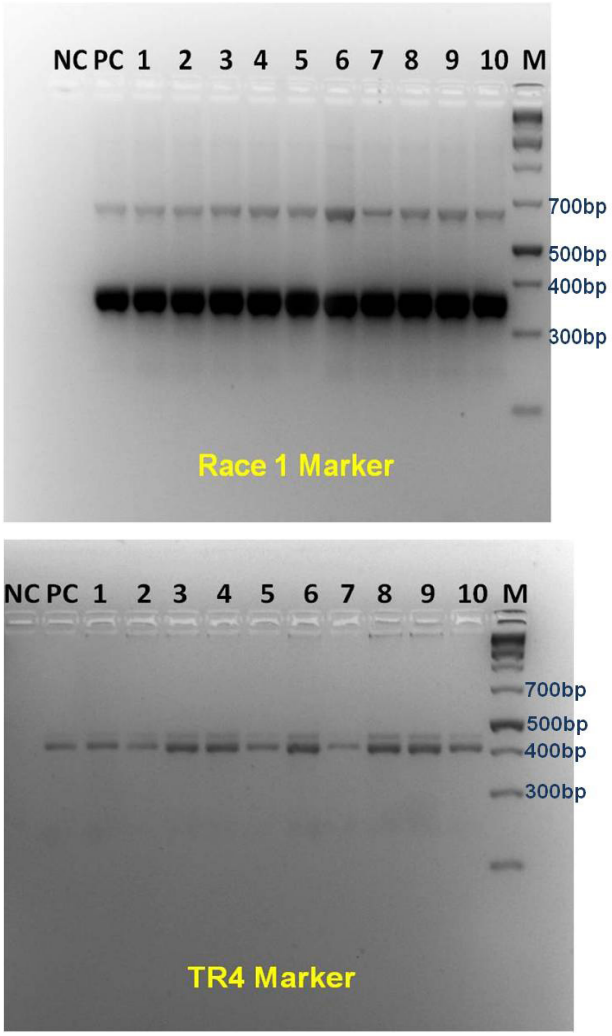


Fig. 17. Validation of fusarium wilt specific markers in TR 4 resistant population; NC: negative control; PC: positive control (G9); 1&2: NRCBGNMD-3 (TR4); 3&4: NRCBGNME-1(TR4); 5&6: NRCBGNME-3(TR4); 7&8: NRCBGNME-13(TR4); 9&10: NRCBGNME-15(TR4); M: 1Kb plus ladder

4.1.5 Production of doubled haploids for improvement of bananas (*Musa* spp.)

Out of 285 Calcutta 4 x Ney Poovan tetraploid progenies, 95% are diploid and resemble the female parent. The remaining 5% (16 progenies) are unique types, not resembling either parent. Among these, 9.1% are highly polleniferous, 18.5% are moderately polleniferous, and 10% did not produce pollen. Additionally, 61% of progenies have not yet flowered.

4.1.6 Identification of resistant gene candidate(s) in banana for race 1 and TR4

The full-length putative rga2 gene (approximately 7.0 kb) from Grand Nain, cv. Rose, and *M. itinerans* has been amplified and cloned. Additionally, the promoter region (2000 bp) of rga2 from Grand Nain, cv. Rose, Calcutta 4, and *M. itinerans* was amplified. The RGA3 gene (2.78 kb) was also amplified and cloned from Grand Nain, cv. Rose, and *M. itinerans*. Furthermore, the candidate resistance gene (Ma10_t00570) against Foc race 1 was cloned from Grand Nain.

Additionally, a genic SSR marker associated with *Foc* race 1 was validated across ornamental bananas, and *Musa acuminata* ssp. *zebrina*, reported as a resistant cultivar against *Foc* race 1, exhibited a resistant banding pattern (Fig. 18).

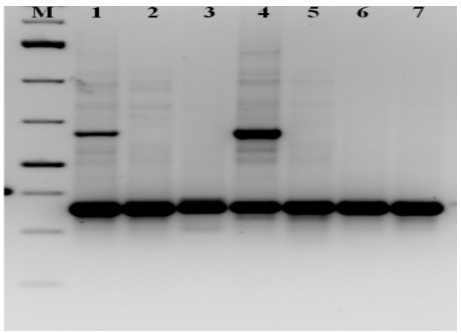


Fig. 18. Screening of ornamental banana with Genic SSR marker associated with Foc race1 resistance

Expression patterns of genes involved in plant-pathogen interaction and hormone signaling pathways were analyzed in Foc race 1 and TR4 resistant and susceptible cultivars. This led to the identification of nudix hydrolase as a susceptibility factor, amplified from Foc race 1 and different cultivars. Guide RNA was designed for gene editing of the dmr6 gene.

Totally 247 miRNAs from *M. acuminata* were used to identify miRNA targets in NBS and dmr6 genes, with 90 miRNAs targeting 104 NBS genes and 24 targeting 6 dmr6 genes. CircRNAs from Foc race 1 and TR4-affected *Musa* spp. were identified via RNA-Seq data, studying their role in regulating genes for wilt stress tolerance through circRNA-miRNA-mRNA interactions (Fig. 19)

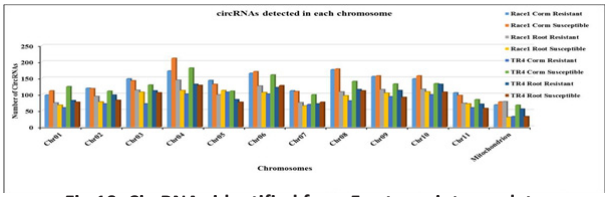


Fig.19. CircRNAs identified from Foc trascriptome data

4.2 CROP PRODUCTION, POSTHARVEST TECHNOLOGY & EXTENSION

Crop Production

4.2.1 Studies on Nutrient Dynamics in Banana

Nutrient dynamics studies on the ranges of macro and micronutrient concentrations in banana waste biomass (on a dry weight basis) and in the pseudostem sap after bunch harvest, in Grand Nain are presented in Table 6.

Table 6. Concentrations of nutritional elements in the waste biomass and pseudostem sap of cv. Grand Nain

Nutritional element	Concentration (on dry weight basis)	Concentrations in Pseudostem sap
Nitrogen	0.70 – 1.19 %	0.140 – 0.238 %
Phosphorus	0.14 – 0.17 %	0.028 – 0.034 %
Potassium	1.36 – 2.06 %	0.272 – 0.412 %
Copper	53.1 – 73.4 ppm	10.63 – 14.67 ppm
Manganese	125.9 – 260.0 ppm	25.18 – 51.99 ppm
Zinc	52.3 – 63.3 ppm	10.47 – 12.65 ppm
Iron	92.2 -146.3 ppm	18.45 – 29.26 ppm

4.2.2 Developing agro-techniques for ICAR-NRCB released varieties

Kaveri Saba

In Kaveri Saba (ratoon-1), two fertilizer levels (F1: 200:30:300g NPK and F2: 200:30:400g NPK per plant) and two spacing configurations (S1: 1.8 x 1.8 m^2 and S2: 1.5 x 1.5 x 2 m^2) were tested. Data on plant yield parameters are provided in Table 7. S1 had a significantly higher average bunch weight of 18.1 kg compared to S2, which recorded only 13.2 kg. As the bunch weight did not vary significantly with fertilizer levels, the treatment S1F1 is recommended for farmers.

Table 7. Effect of fertilizer levels and spacing on yield parameters of Kaveri Saba

No. of fingers				No. of hands/ bunch				Peduncle girth (cm)				Bunch weight (kg)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	59.0	57.4	58.1	S1	8.9	8.6	8.8	S1	19.7	19.5	19.6	S1	17.8	18.4	18.1
S2	56.2	60.3	58.2	S2	8.9	9.1	9.0	S2	21.9	19.7	20.8	S2	13.7	12.7	13.2
Mean	57.5	58.9			8.9	8.9			20.8	19.6			15.8	15.6	

Kaveri Harita

In Kaveri Harita (ratoon-1), the same fertilizer levels and spacing pattern were applied. Data on plant yield parameters are provided in Table 8. S1 had a significantly higher average bunch weight of 17.6 kg compared to S2, which recorded only 16.6 kg. Also, F1 had a bunch weight of 18.0 kg, significantly more than F2 (16.2 kg). The treatment S1F1 is recommended for farmers.

Table 8. Effect of fertilizer levels and spacing on yield parameters of Kaveri Harita

No. of fingers				No. of hands/bunch				Peduncle girth (cm)				Bunch weight (kg)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	59.3	64.5	61.9	S1	8.6	9.1	8.9	S1	16.3	17.3	16.8	S1	17.0	18.1	17.6
S2	59.3	51.6	55.5	S2	8.6	8.1	8.4	S2	16.6	16.8	16.7	S2	18.9	14.3	16.6
Mean	59.3	58.1			8.6	8.6			16.5	17.0			18.0	16.2	

Kaveri Kalki

In Kaveri Kalki (ratoon-1), the same fertilizer levels were used, but three different spacing patterns were adopted (S1: 1.8 x 1.8m2, S2: 2.1 x 2.1m2, S3: 2.4 x 2.4m2). Data on yield parameters are provided in Table 9. Although no significant variations in bunch weight were observed due to fertilizer levels, S1 recorded a significantly higher bunch weight of 17.7 kg compared to S2 (16.0 kg) and S3 (14.5 kg). The treatment S1F1 is recommended for farmers.

Table 9. Effect of fertilizer levels and spacing on yield parameters of Kaveri Kalki

No. of fingers				No. of hands/bunch				Peduncle girth (cm)				Bunch weight (kg)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	103.6	100.9	102.2	S1	10.1	8.8	9.5	S1	26.7	25.6	26.1	S1	18.0	17.4	17.7
S2	94.7	108.8	101.7	S2	9.0	9.2	9.2	S2	22.4	23.7	23.0	S2	15.1	16.8	16.0
S3	104.8	109.5	107.1	S3	8.9	8.1	8.5	S3	22.8	21.4	22.2	S3	15.5	13.7	14.5
Mean	101.0	106.3			9.4	8.7			23.9	23.6			16.2	16.0	

4.2.3 Development of Clump Management Technology for Enhancing Productivity of banana

Ney Poovan (AB)

The treatments included three levels of sucker population (S1: Mother plant (MP) + 2 suckers, S2: Mother plant + 3 suckers, S3: Mother plant + 4 suckers) and three levels of nutrition (N1: 125% RDF/clump, N2: 150% RDF/clump, N3: 175% RDF/clump). The S1 treatment yielded the highest bunch weight of 13.56 kg for the first sucker and 10.23 kg for the second sucker. Bunch weight in the third sucker varied from 6.28 kg (S3N1) to 8.1 kg (S2N3). Overall, bunch weight increased with increasing fertilizer dose, with the highest recorded in N2 (175% RDF per clump).

Among three different numbers of plants maintained per clump, allowing the mother plant with 3 suckers per clump (MP + 3 suckers i.e., S2), the highest cumulative bunch weight was 41.5 kg/clump, resulting in the highest total yield of 71.04 t/ha. Applying 175% RDF (N3) led to the highest cumulative bunch weight of 40.7 kg/clump and the highest bunch yield of 70.6 t/ha. The treatment combination of S2N3 recorded the highest total bunch weight of 43.1 kg/clump and the highest yield of 74.8 t/ha. However, the bunch grade has declined gradually in the second and third sucker plants.

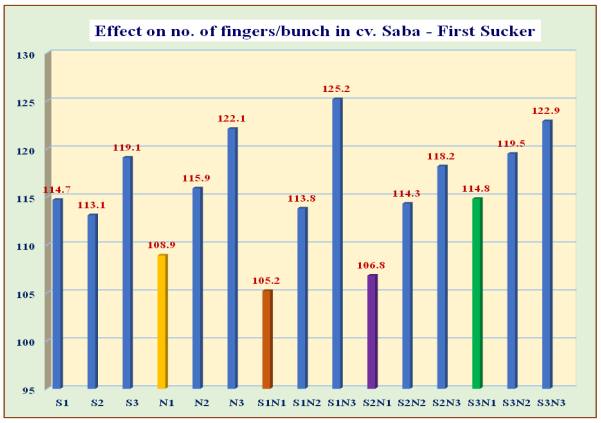
Kaveri Saba (ABB)

In cv. Kaveri Saba, maintaining the mother plant with three suckers per clump (S3) resulted in a shorter flowering period, taking only 314.0 days. Among the treatment combinations, S3N3 flowered in 306.6 days, similar to S2N1 and S2N2.

For the first sucker, S1N1 flowered earliest (355.8 days), while S3N1 took longest (384.2 days). S1N3 had the shortest fruit maturity time for both mother plant (90.7 days) and first sucker (94.3 days). Delayed maturity (102.0 days and 103.1 days) occurred in S3N1. Mother plant bunch weight ranged from 15.4 kg (S3N1) to 18.3 kg (S2N3), while first sucker's ranged from 22.7 kg (S3N1) to 26.1 kg (S1N3 & S2N3). In the first sucker, the bunch weight decreased gradually with the increasing number of suckers per clump but increased with the increasing dose of fertilizers as the highest level of 175% RDF recorded the highest bunch weight both in the mother plant (17.75 kg) as well as first sucker plant (25.6 kg).

The number of hands per bunch in the mother plant ranged from 6.8 (S3N1) to 7.8 (S3N3), while in the first sucker plant, it ranged from 9.1 to 10.9 hands/bunch. Applying 175% RDF (N3) resulted in the highest fingers/bunch for both the mother plant (96.2 fingers) and the first sucker (122.1 fingers/bunch).

Overall, in cv. Saba, the plants of the fourth daughter sucker in treatment S3 (MP + 4 daughter suckers) were found very tall with a height of over 3.2m and continued to be in vegetative growth and no flowering was recorded in majority of the plants. This suggests that the spacing adopted in the experiment is not suffient enough to maintain more than three suckers per clump and necessitates still a wider spacing to accommodate more suckers per clump.



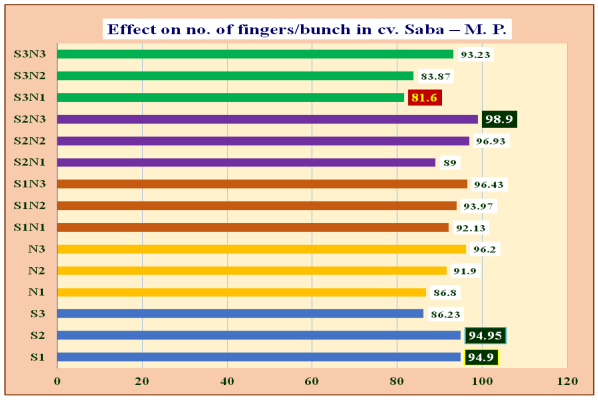


Fig. 20. Effect on number of fingers/bunch in cv. Saba in mother plant and in first sucker

4.2.4 DBT- Banana Shakti Nanoformulations - Effective delivery system of the micronutrient mixture for improved banana cultivation

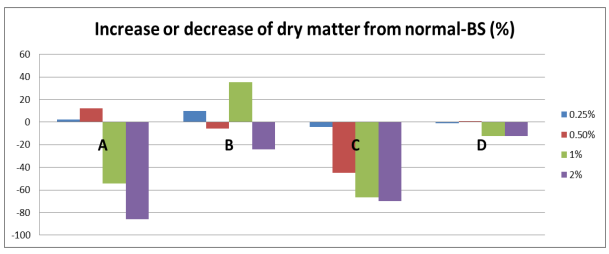
In the present study, a pot culture study compared the efficacy of Nano-Banana Shakti (Fe–4.3%, Zn–4.9%, B-1%, Mn–4.2%, & Cu–2.2%) with Normal-Banana Shakti at graded concentrations of foliar sprays in banana. Treatments A to E (Fig. 21) were implemented in the experiment. The treatments are (A) Nano-BS without any surfactant (B) Nano-BS with 3% surfactant 1, (C) Nano-BS with 3% surfactant 2, (D) Nano-BS with 1.5% surfactant 1 + 1.5% surfactant 2 and (E). Normal-BS (Control)

Each suspension (A-D) with Nano-BS at concentrations of 0.25%, 0.5%, 1%, and 2% was sprayed on banana leaves weekly, each replicated four times. Treatment-E served as control, sprayed with Normal-BS at the same concentrations, also replicated four times. An absolute control without any foliar spray was also maintained.

Table 10. Total Dry Weight of 90-day Grand Nain plant grown in pot culture

Spray Solution Conc.	Treatments					Mean
	A	B	C	D	E	
0.25%	12.4	13.3	7.0	12.0	12.1	**12.4 c**
0.50%	13.7	11.5	6.7	12.3	12.2	11.3 c
1%	4.9	**14.5**	3.6	9.4	10.7	8.6 b
2%	1.7	9.1	3.6	10.5	12.0	7.4 a
Mean	8.6 b	**11.7 c**	6.2 a	10.8 c	11.4 c	
Note: Mean values in a row or column followed by same letters are not significantly different						

The best combination for banana growth was found to be Nano-Banana Shakti with 3% surfactant 1 suspension. A 1% foliar spray of this nano-suspension yielded the highest dry matter production, reaching 14.5g in 90-day-old banana plants. The percent increase or decrease of dry matter production due to Nano-Banana Shakti treatments from control (Normal Banana Shakti) and absolute control (without banana Shakti) is depicted in the graph (Fig. 21).



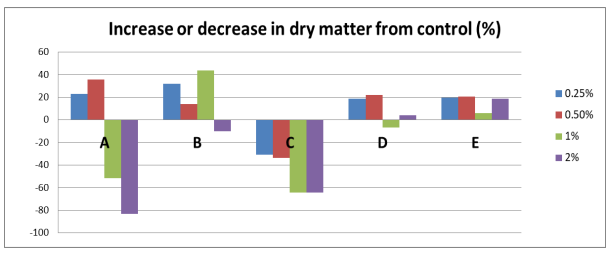


Fig. 21. Percent increase or decrease of DMP from the control and absolute control

4.2.5 Effect of high temperature and soil moisture deficit stresses on banana

In a field experiment, 53 banana genotypes of different genomes (AAB, ABB) were evaluated for soil moisture deficit stress (drought) at the floral primordial initiation stage. Most AAB genotypes showed significant reductions (25-50%) in bunch weight under drought, with Kanthali (ABB) recorded a maximum reduction of 36.13%. Similarly, the number of hands and fruits per bunch decreased significantly (15.36–31.25% and 20–36.95%, respectively) in most AAB genotypes, while some ABB genotypes, like Bhat Manohar, exhibited reduction in the number of fruits per hand (27.75%). Soil moisture deficit stress also significantly decreased fruit weight (22.25-39.90%) in both AAB and ABB genotypes, with most ABB genotypes showing lesser reduction (0.144 – 13.97%).

In a controlled pot experiment, ASA foliar-primed drought-stressed plants exhibited significantly better growth parameters, including plant height, girth, and biomass. In another experiment maintaining excess moisture revealed reductions in plant height and number of leaves, particularly in cultivars like Nendran and Grand Nain, where plants were weakened and toppled without recovery.

Post Harvest Technology

4.2.6 Integrated package of practices for export of selected commercial and GI tagged varieties

An experiment was conducted in NRCB-Farm and at a farmer's field in Mudalaipatti village, Kulithalai Tk, Karur Dt., using Cv. Ney Poovan. Significant differences were observed for growth, yield, and yield attributing characters in the trial conducted at NRCB farm. Application of 100% RDF as fertigation with pre-harvest treatments of Banana Shakti [@ 3, 5, and 7th month after planting], + Bunch cover + potassium sulphate [as bunch spray twice, once after removing male bud and another after one month of the first spray] resulted in the maximum bunch weight of 13.15 kg with 13.50 hands and 180 fingers, compared to the control (bunch weight of 12.06 kg with 12.00 hands and 169 fingers). However, the minimum maturity period (104.44 days@100% maturity; 88.77 days@85% maturity) was registered with 100% RDF as soil application without Banana Shakti + Bunch cover + Potassium sulphate, followed by 100% RDF as soil application with Banana Shakti + Bunch cover + Potassium sulphate (105.56 days@100% maturity; 89.73 days@85% maturity), which were comparable. Similar significant differences were observed in the trial conducted at the farmer's field in Mudalaipatti village.

Effect of 100% RDF and pre-harvest treatments of Banana Shakti + bunch cover + bunch spray (Potassium sulphate) on the shelf-life and quality attributes was studied. Bunches harvested at 85% maturity level and treated with vacuum pack + ethylene scrubber stored at 13.5°C exhibited a maximum shelf-life of 58 days with acceptable quality parameters (TSS – 24.330Brix; acidity – 0.36%; total sugars – 19.61%). The control had a shelf-life of 7 days with better quality parameters (TSS – 26.110Brix; acidity – 0.34%; total sugars – 20.74%).

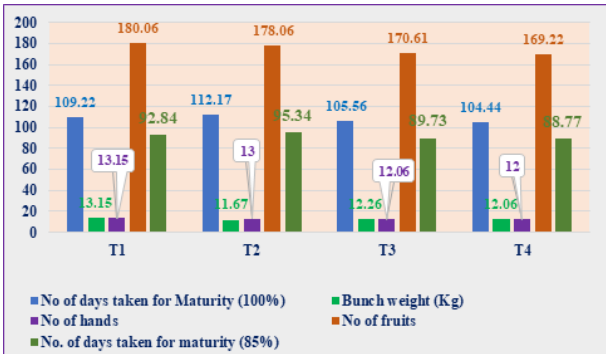


Fig. 22. Yield parameters of 'Ney Poovan' field trial at NRCB farm

T1 =100% RDF fertigation with Banana shakti +Banana Bunch Cover (Non woven Fabric) + Potassium Sulphate

T2 =100% RDF fertigation without Banana shakti +Banana Bunch Cover (Non woven Fabric) +Potassium Sulphate

T3 = 100% RDF soil with Banana shakti +Banana Bunch Cover (Non woven Fabric) +Potassium Sulphate

T4= 100% RDF soil without Banana shakti +Banana Bunch Cover (Non woven Fabric) +Potassium Sulphate

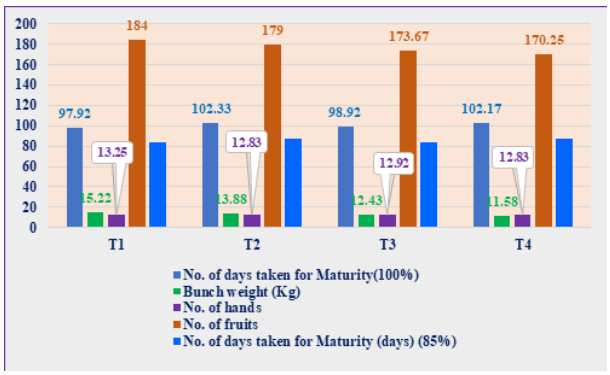


Fig. 23. Yield parameters of 'Ney Poovan' Field Trial at Farmer's Field, Mudalaipatti

T1 =100% RDF fertigation with Banana shakti +Banana Bunch Cover (Non woven Fabric) + Potassium Sulphate

T2 =100% RDF fertigation without Banana shakti +Banana Bunch Cover (Non woven Fabric) +Potassium Sulphate

T3 =100% RDF soil with Banana shakti +Banana Bunch Cover (Non woven Fabric) +Potassium Sulphate

T4=100% RDF soil without Banana shakti +Banana Bunch Cover (Non woven Fabric) +Potassium Sulphate

100% RDF Fertigation with BS+BC+ K_2SO_4

100% RDF Fertigation without BS+BC+ K_2SO_4 (Control)

Fig. 24 Bunches harvested at NRCB farm (Ney Poovan-TC plants)

100% RDF soil with BS+BC+K2SO4

100% RDF soil without BS+BC+ K2SO4

Fig. 25. Bunches harvested at Farmer's Field (Ney Poovan-TC plants)

4.2.7 Novel smart delivery systems for developing high value nutraceutical foods using banana and exploring non-food applications

Dual modification of banana flour and its physico-chemical and functional characteristics

The banana flour underwent modification using variations in ultrasonication power (USP) and plasma-activated water (PAW). Post-treatment, the L*, a*, and b* values of unmodified flour decreased significantly, while the whiteness index increased. Solubility and swelling power of modified banana flour indicated changes in starch chain interactions, affecting granule swelling and solubility. Modified flour showed decreased swelling power compared to native flour, while solubility levels increased significantly compared to native starch.

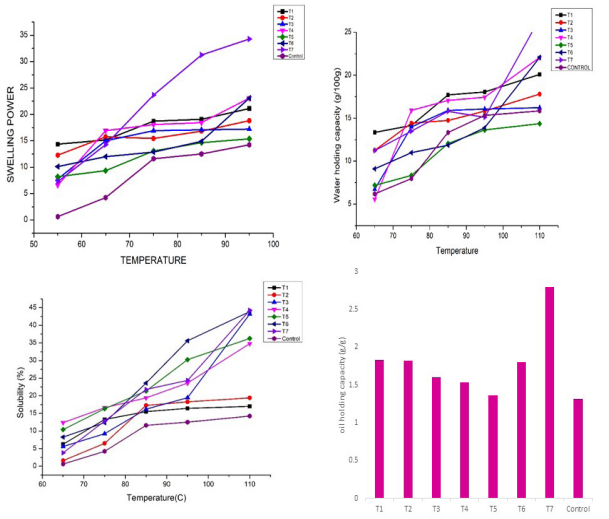


Fig.26. Functional properties of dual modified banana flour

T1-50% USP 30min-PAW; T2-100% USP 30min-PAW; T3-50% USP 30min-0.1% CA; T4-100% US 30min-0.1% CA; T5-Homogenization 30min- 0.1% CA; T6 Homogenization +Distilled water and T7-100% USP 30min+Distilled water; T8-Control.

Development of bread using native and modified banana starch and its effect on storage life

The study explored the impact of adding banana starch to banana bread compared to xanthan gum and corn starch. Color plays a crucial role in consumer preference. Bread samples with banana flour differed significantly from maida in both crumb and crust color, shifting from white to brown with

lower L* values. Moisture levels ranged from 11.85% to 24.72% in the crumb and 7.14% to 16.46% in the crust. Modified starches showed slower moisture transfer during baking. Carbohydrate content ranged from 65.87% to 72.89%, increasing with banana flour and starch substitution. Protein content varied from 0.08% to 0.66%, while fat content ranged from 0.48% to 1.3%, with lower fat content in breads with xanthan gum. Bread hardness was highest with corn starch.

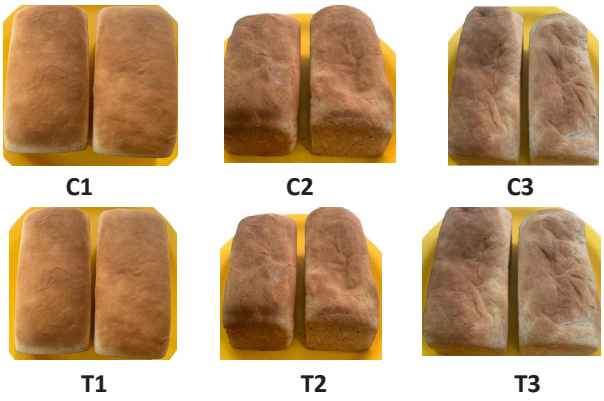


Fig. 27. Breads prepared with banana flour and starch

C1-Maida flour; C2-Banana flour; C3-Banana flour + xanthan gum; T1-Banana flour+ corn starch; T2-Banana flour+ banana starch; T3-Bananaflour + modified starch

Fortified low calorie central core stem juice

The study analyzed the physical parameters of the central core and the juice content of cv. Karpuravalli, suggesting sucralose as an alternative for those with specific caloric needs. Among the sweeteners, cane sugar recorded the highest TSS at 8.04 °Brix, followed by Stevia, sucralose, and Aspartame. Juice blended with Sucralose and Aspartame showed higher acceptance than the control. Sucralose exhibited low starch hydrolysis and high viscosity at 1.57 cp. Substituting 16g of Stevia for 80g of cane sugar reduced calorie intake while maintaining sweetness. Preservation at 7°C and 15°C for 10 days-maintained quality, meeting consumer demands. Ultrasonication at 45°C for 15 minutes extended shelf life up to two months without discoloration, even without preservatives.

Table 11. Physico-chemical parameters of central core stem juice blended with different sweeteners

Parameters	Raw Juice	Cane sugar	Aspartame	Stevia	Sucralose
TSS ºBrix	2.72 ± 0.01	8.04 ± 0.04	1.85 ± 0.03	1.86 ± 0.02	1.86 ± 0.05
pH	5.63±0.01	5.26 ± 0.01	5.85 ± 0.03	6 ± 0.07	5.65 ± 0.03
Acidity	0.23± 0.01	0.22 ± 0.01	0.06 ± 0	0.06 ±0.01	0.06 ± 0.01
Moisture	96 ± 0.57	91 ± 0.57	96 ± 1	96 ± 1	96 ± 1.52
Viscosity	1.56 ± 0.57	1.46 ± 0.01	1.57 ± 0.02	1.46 ± 0.01	1.46 ± 0.01

Influence of using porous banana starch for encapsulation of *Lactobacillus plantarum*

Encapsulation with modified banana starch yielded higher and less soluble capsules. All freeze-dried encapsulated samples had low water activity (<0.25±0.02). Porous and convective encapsulation with native and modified banana starch were compared for encapsulating *Lactobacillus plantarum*. The highest viability (12 cfu/g) and acid resistance of *L. plantarum* were observed in porous modified banana starch. Encapsulation in capsules coated solely with starch led to nearly complete release of probiotics in the small intestine, causing cell death before reaching the target site.

Table 12. Physico-chemical analysis of encapsulation of *Lactobacillus plantarum* using porous banana starch

	Yield (%)	Solubility (%)	Water activity (aw)	pH	Titratable acidity (%)
T1	52.4±1.12	62.53±1.05	0.23±0.01	3.88±0.02	0.36±0.03
T2	62.15±1.32	62.46±1.12	0.24±0.01	3.18±0.03	0.31±0.05
T3	53.58±1.25	61.55±1.19	0.20±0.01	3.73±0.01	0.34±0.01
T4	83.65±1.61	60.61±1.09	0.22±0.01	3.90±0.01	0.30±0.03

T1-Single encapsulation with native banana starch; T2-Porous encapsulation with native banana starch; T3-Single encapsulation with modified banana starch; T4-Porous encapsulation with modified banana starch.

Banana fig fortification with different functional coatings

Ripe Nendran and Karpuravalli bananas were coated with a 10% solution of soy protein, tea extract, honey, and date syrup, then dried in PCM dryers until reaching a moisture content of 22-24% dry weight. The fortified bananas exhibited increased nutritional value, with soy protein boosting protein content and date syrup potentially enhancing mineral content. Coated samples showed a five-fold increase in reducing sugar content and a two-fold increase in protein content. Honey and date syrup coatings enriched the flavor profile and served as natural sweeteners, improving total and reducing sugar content. Overall, this process resulted in bananas with enhanced nutritional, sensory, and functional attributes.

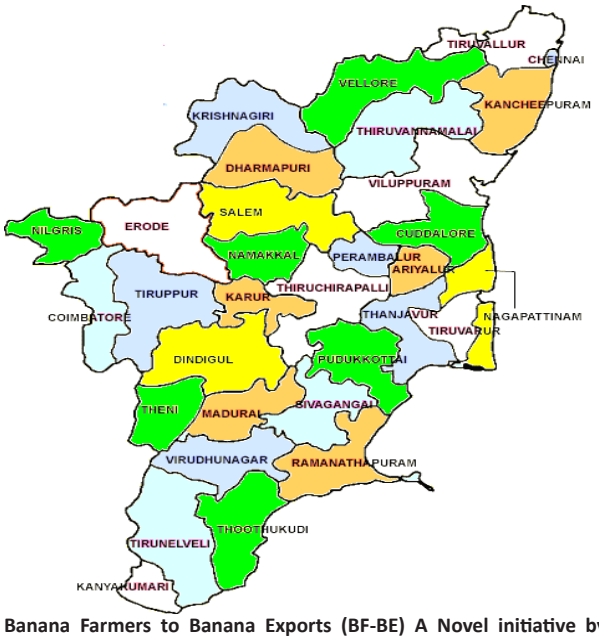
Extension – Outreach Programmes

4.2.8 Effective utilization of different extension methods and mass media for holistic transfer of banana technologies for different stakeholders in banana production system

Objective 1. to upscale the training activities to the different stakeholders

During the reported time several Capacity Development Programmes (CDP) have been conducted for different stakeholders.

Capacity Development Programme (CDP)	Nos.	Beneficiaries
One day CDP for farmers (ATMA, NHM, FPO, etc.)	16	516
Two days CDP for farmers (ATMA, NHM, FPO, etc.)	4	140
Three days CDP for farmers (ATMA, NHM, FPO, etc.)	6	207
One day exposure visit for farmers	28	843
Students CDP (PEV/Industrial visit/Study tour)	79	5015
Off–campus training (With KVK, FPOs etc.)	13	500
Officials visit	12	96
Total	**124**	**6215**



Banana Farmers to Banana Exports (BF-BE) A Novel initiative by ICAR–NRCB with collaboration of centrally sponsored ATMA SEPERS Scheme

Fig. 28. Capacity Development Programmes

Objective 2. To upscale the banana technologies through mass media and print media

Details	Nos.
No of News stories reported in dailies	12
No of dailies, YouTube covered NRCB News	127
No. of news stories reported in ICAR – NEWS (Online)	10
No. of video programmes prepared for different occasions	5
No. of news stories reported in ICAR – NRCB Portal	10
No. of events uploaded in FB, Twitter	13

ICAR-NRCB In Mass Media

Objective 3. To coordinate the Inter Institutional Activities

National Science Day was celebrated on February 28, 2023, under the theme 'Global Science for Global Well-being.' The event attracted nearly 2000 students from various schools and colleges in and around Tiruchirappalli. In addition, over 1000 farmers and members of the general public attended.

The NRCB's 30th Foundation Day and Kisan Mela were organized on August 21, 2023. An exhibition stall was set up as part of the festivities. More than 600 farmers participated in the function. During the Governor's visit, a Banana Stakeholders' Meet was organized on August 26, 2023. Over 200 stakeholders from the banana sector took part in an interactive meeting.

National Science Day observed as Open Day

Farmers-Scientist Interface during Foundation Day

Farmers-Scientist Interface during National Level Workshop- VIRO-CON 2023

Farmers-Scientist Interface during Governor's visit

Viksit Bharat Sankalp Yatra

Visit of the Honorable Governor of Tamil Nadu to ICAR-NRCB on 26th August 2023

His Excellency, the Governor of Tamil Nadu, visited the ICAR-National Research Centre for Banana on 26th August, 2023. The highlight of the day was the Honourable Governor's interaction with Banana Stakeholders' which saw the participation of a diverse group of stakeholders from the banana industry. Over 200 stakeholders, including progressive banana farmers, Agricultural Science Central and State officials, banana exporters, entrepreneurs, educators, KVK, FPO personnel, and various other stakeholders, gathered for this interaction meeting. The event provided a platform for in-depth discussions on various aspects of the banana industry.

4.3 PHYSIOLOGY AND BIO CHEMISTRY

4.3.1 Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower

Characterization of anthocyanins in flower bracts of banana cultivars of NE region

A total of 21 banana genotypes were collected from Jorhat, Assam, and Tura of West Garo Hills, Meghalaya, North Eastern region. The average total monomeric anthocyanin pigment contents in the first 10 bracts of male flower buds of these genotypes were estimated and quantified. Among these genotypes, Dudhsagar contained the highest amount at 69 mg/100 g bracts, followed by Borkal Baista (57 mg), Honda (54 mg), and Suti Jahaji (53 mg). Jahaji possessed the lowest amount at 13 mg/100 g of bracts, followed by Simulu Manohar (26 mg) (Fig. 29). Individual anthocyanin compounds in bracts of these 14 genotypes from the North Eastern Region were profiled using RP-HPLC and identified using standard compounds (Fig. 30 a and b). As the anthocyanidin compound cyanidin is predominant in most commercial bananas and banana genotypes, the cyanidin content (%) in these banana genotypes was quantified based on the peak area of the individual compounds (Table 13). Borkal Baista, Simulu Manohar, Honda, Jatikol, Tani, Bhoji Manohar, and Bangrier bracts predominantly (above 75%) contained cyanidin as the major anthocyanin compound. The highest anthocyanin-containing genotype, Dudhsagar, contained 66% cyanidin. To compare the efficiency of anthocyanin pigment extraction from banana flower bracts, anthocyanins were extracted

by two methods: hand grinding and ultra-sonication-assisted extraction (UAE), and total monomeric anthocyanins were estimated using the pH differential method. The UAE method yielded 15-20% higher anthocyanin pigments from flower bracts of five of the commercial banana varieties tested (Fig.31).

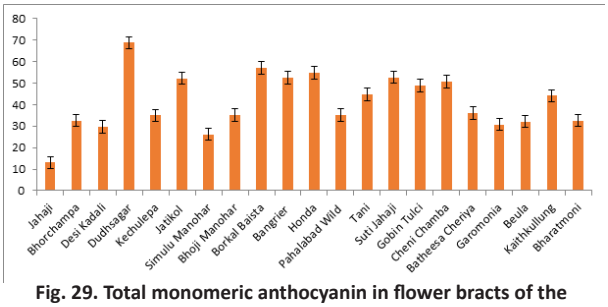


Fig. 29. Total monomeric anthocyanin in flower bracts of the varieties in North Eastern region

Table 13. Cyanidin (%) contents in flower bracts of NE region bananas

NE Banana Genotype	Cyanidin (%)
Jahaji	64.69
Bhorchampa	34.56
Desi Kadali	28.5
Dudhsagar	65.67
Kechulepa	30.39
Jatikol	76.91
Simulu Manohar	79.67
Bhoji Manohar	73.71
Borkal Baista	82.9
Bangrier	74.46
Honda	77.18
Pahalabad Wild	15
Tani	74.27

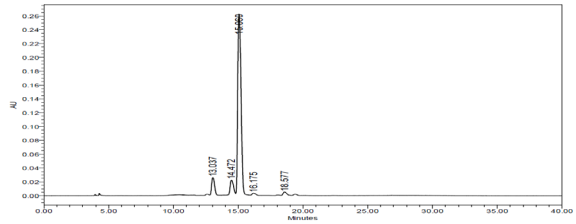


Fig. 30a. Chromatogram of anthocyanins identified in bracts of Borkal Baista

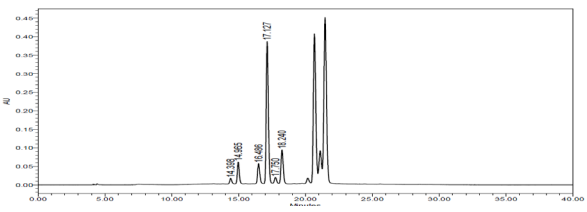


Fig. 30b. Chromatogram of anthocyanins identified in bracts of Dudhsagar

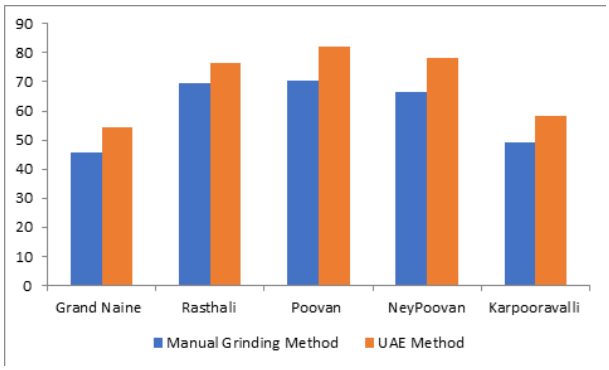


Fig. 31. Comparison of anthocyanin extraction methods

The antioxidant activity of anthocyanins in the flower bracts of 13 banana genotypes from the North Eastern region was assessed using Trolox Equivalent Antioxidant Capacity (TEAC) and Oxygen Radical Antioxidant Capacity (ORAC) assays to ascertain their nutraceutical potential. In both TEAC and ORAC assays, genotypes with high cyanidin contents exhibited notable results. Specifically, in the TEAC assay, Borkal Baista, Simulu Manohar, Honda, Jatikol, Tani, Bhoji Manohar, and Bangrier demonstrated higher antioxidant activity levels, with more than 90 TE/g DW, attributed to their cyanidin compound content of 70 mg and above. Similarly, in the ORAC assay, these same genotypes exhibited higher antioxidant activity, ranging from 175 µmol TE/g DW to a maximum of 215 µmol TE by Borkal Baista (Fig. 32).

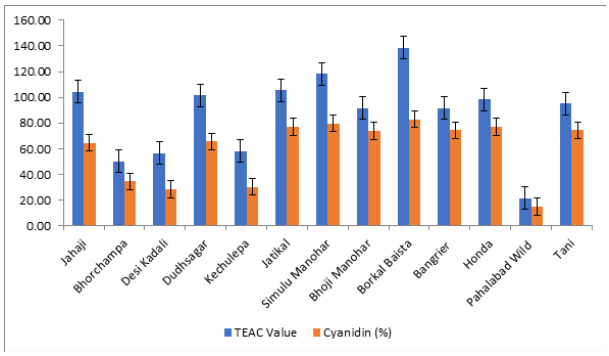


Fig. 32. Total antioxidant (TEAC) assay (µmol TE / 100 g FW) of anthocyanins

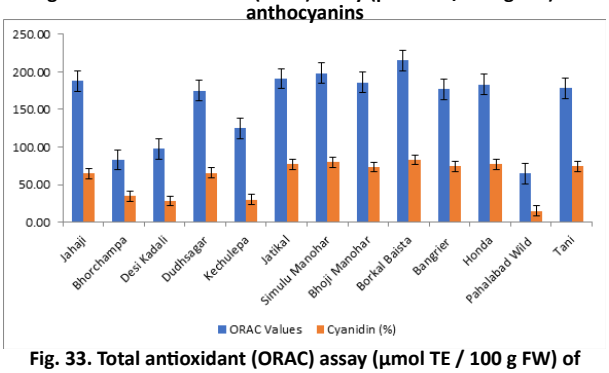


Fig. 33. Total antioxidant (ORAC) assay (µmol TE / 100 g FW) of anthocyanins

Fructans types in fruit pulp of commercial bananas

Analyses and quantification of fructan types in the pulp and rhizome of 14 commercial banana cultivars were conducted. Three major fructan types were identified in banana pulp: inulin-type, 1,1-nystose, and 1-kestotriose. Generally, among these three types, 1-kestotriose is the predominant fructan in banana pulp. However, in plantain and cooking bananas such as Nendran, Monthan, and Kaveri Saba, the inulin-type fructan contents were higher than the other two types, measuring at 118.6, 122.5, and 95 µg/g DW of pulp, respectively (Fig. 34).

Analysis of the fructans type in rhizome of these banana cultivars showed that 1,1-nystose was major fraction. The plantain and cooking bananas, *viz*. Nendran, Monthan and Kaveri Saba contained 403, 420 and 361 µg / g DW of 1.1-nystose in rhizome (Fig. 35).

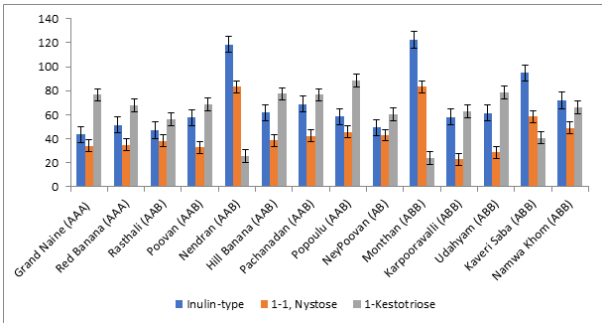


Fig. 35. Fructans type in rhizome of commercial banana cultivars

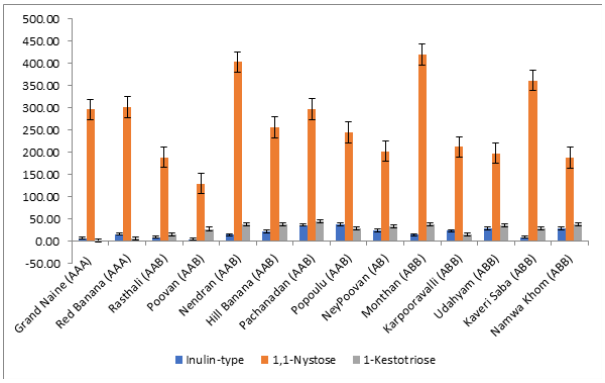


Fig. 34. Fructans type in pulp of commercial banana cultivars

Starch content in bananas

The estimation of total starch and its amylose and amylopectin composition in fully matured banana fruits of 10 commercial banana cultivars revealed variations in total starch content, ranging from 81% to 87%. Ney Poovan exhibited the highest starch content, while Pachanadan had the lowest. Among these, the amylose fraction constituted more than 35% in plantain and cooking banana cultivars Nendran, Monthan, and Kaveri Saba. Dessert bananas contained 5-10% less amylose content (Fig. 36).

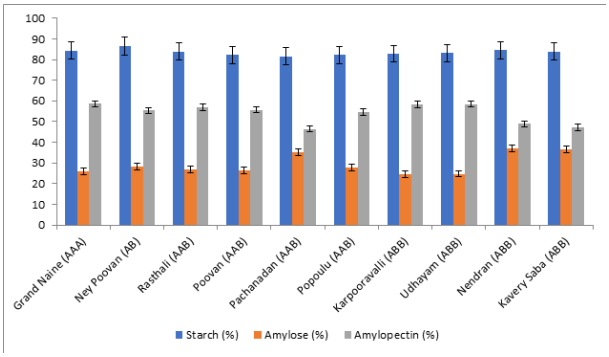


Fig. 36. Total starch and composition of some of the commercial bananas

4.4 CROP PROTECTION

4.4.1 Pest mapping in bananas and plantains in India

Molecular characterization by way of COX1 sequencing was done for two lepidopteran pests of banana (*Eupterote orientalis* and *Olepa ricini*) and eight mealybugs (*Ferrisia virgata, Dysmicoccus brevipes, Dysmicoccus neobrevipes, Pseudococcus jackbeardsleyi, Planococcus minor, Planococcus lilacinus, Maconellicoccus hirsutus, Phenacoccus solenopsis*) and GenBank accession numbers obtained. Two parasitoids belonging to *Anagyrus* sp. and *Allotropa* sp. were recorded on the Jack Beardsley mealybug for the first time. Two new genera and species of predatory coccinellids found in banana ecosystem, *Neoplatynaspis vandenbergae* Poorani and *Slipinskiscymnus keralensis* Poorani, were described from Northeastern India and South India, respectively. A jumping spider, *Afraflacilla adavathurensis* (Araneae: Salticidae), collected on banana, was described as new to science.

Localized outbreaks of skipper (*Erionota torus*) were observed in Trichy district, Tamil Nadu, during February–March 2023 during the fag end of the winter on the popular cultivars Nendran, Ney Poovan, Poovan, Karpooravalli, Rasthali, Udhayam, and Grand Nain. Early larval parasitism by *Elasmus brevicornis* Gahan (Hymenoptera: Eulophidae) was seen in all the locations surveyed. Moderately high to very

high levels of parasitism of II-III instar larvae (as high as 93%) was recorded in all locations, resulting in complete control of the pest within one month. A hyperparasitoid, *Pediobius* sp. (Hymenoptera: Eulophidae) was recorded on the pupae of *E. brevicornis* and caused moderate to heavy parasitism (39-80%), which was likely to have interfered with the efficacy of *E. brevicornis.* Very high levels of parasitism (up to 80%) by *Aphelinus gossypii*-group (Hymenoptera: Aphelinidae) was observed on banana aphid with the peak incidence during October-November 2023. The parasitoid preferred III-IV instar nymphs and few adult aphids were also found to be parasitized.

Scymnus (*Pullus*) *syoitii* Sasaji, a Japanese species, was found to be the only predator of banana root mealybug complex (*Geococcus johorensis*, *Geococcus* sp. and *Rhizoecus* sp.). This is a first record for India and the first report of this predator from outside Japan.

4.4.2 Identification and field evaluation of new and safe insecticides for use in IPM of banana insect pests with particular reference to corm weevil and sucking pests

In vitro bioassays and pot culture experiment of new insecticide molecules

Fipronil, in both SC and granule formulations, emerged as the most effective candidate against corm weevil, with LC values of 0.004% and R2 values of 0.81, respectively. A pot culture experiment was conducted using three methods: sucker treatment and granular application, as well as drenching (pouring 100 ml of insecticide solution). All three treatments proved effective against the corm weevil.

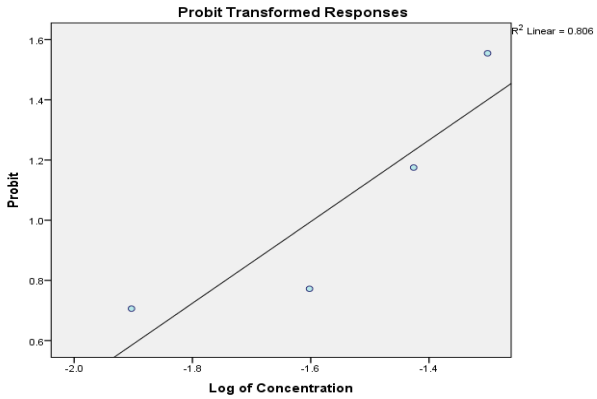


Fig.37. Probit analysis

Fig.38. Covered poly bags to restrict the movement of corm weevil

Fig.39. Sucker treatment

Fig.40. Fipronil granule treatment *vs* Control

4.4.3 Eco-friendly management of banana pseudostem weevil and banana scarring beetle

In vitro bioassays of botanicals, new insecticide molecules and entomopathogenic fungus against Banana Scarring Beetle

Fifteen treatments, comprising insecticides and botanicals, were tested against scarring beetle using the dipping method (leaf and fruit dip method). Mortality data were recorded from 2 hours up to 5 days after treatment. Fipronil 5% SC, Spinosad 45% SC, Chlorpyriphos 20% EC, Lambda Cyhalothrin 5% EC, and Fipronil 0.3% G demonstrated 100 percent mortality within 1 day after treatment (Fig. 41)

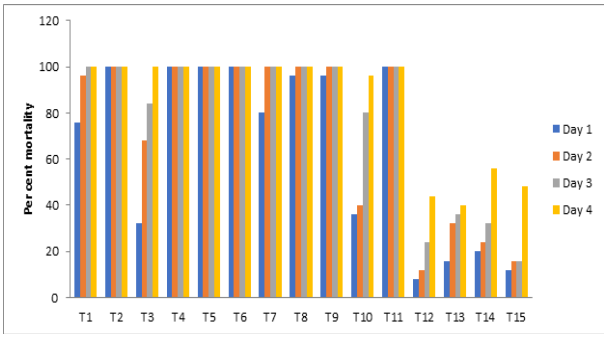


Fig. 41. Effect of new insecticides on fruit scarring beetle

Field evaluation of potential new insecticides for the management of BPSW

Selected insecticides, namely Fipronil 5% SC and Thiamethoxam 25% WG, were evaluated using three different methods: swabbing, injection, and leaf whorl application against BPSW. Both insecticides proved effective against pseudostem weevil and pseudostem injection resulted in 100% mortality **(Table 14)**

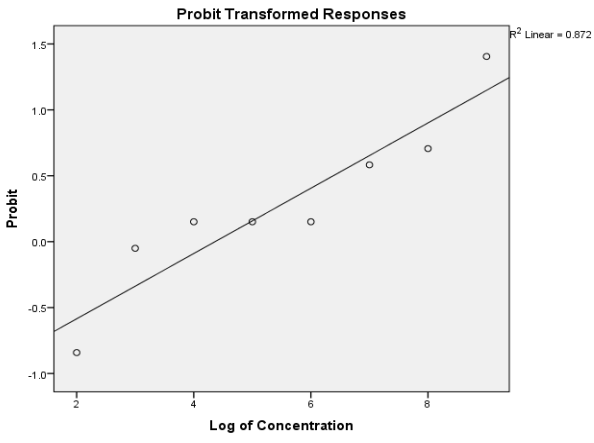
Table 14. Evaluation of the potential newer insecticides under field conditions

Treatments	Methods	Weevil incidence (Nos)			
		Thadiyankudisai	Kanalkadu	Manjalparrapu	Manalur
Fipronil 5% SC	Injection	0^a (0.71)	0^a (0.71)	0.00	0
Fipronil 5% SC	Swabbing	-	-	2.18	3.6
Fipronil 5% SC	leaf whorl application	-	-	0.00	-
Thiamethoxam 25% WG	Injection	0^a (0.71)	0^a (0.71)	0.00	0
Thiamethoxam 25% WG	Swabbing	-	-	7.40	5
Thiamethoxam 25% WG	leaf whorl application	-	-	0.00	-
Control		7.05^b (1.85)	3.15^b (1.37)	16.80	10.2
	CD(0.05)	0.771	0.505	NS	NS

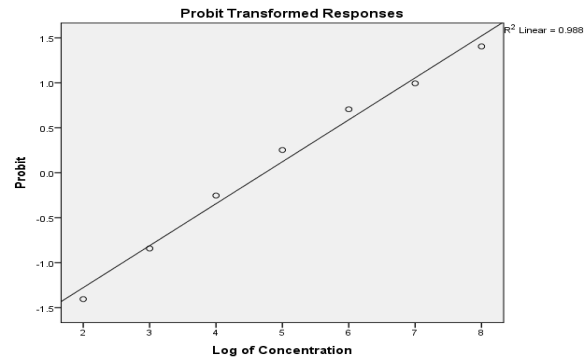
**Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05*

Probit analysis of entomopathogenic fungus formulation against pseudostem weevil (BPSW)

Banana weevil killer (NRCB EPF *B. bassiana* 22) in various concentrations was evaluated against *O. longicollis* in laboratory bioassays. The Banana weevil killer exhibited the highest efficacy, with LC50 values of 2×10^4 and LC90 values of 6×10^9, and R2 values of 0.872 when using the sheath dipping method. Similarly, with the insect spray method, it showed LC50 values of 4×10^4 and LC90 values of 1×10^7, and R^2 values of 0.988 on the 7th day after treatment (Fig. 42).



a. sheath dipping method



b. insect spray method

Fig.42. Probit analysis of entomopathogenic fungus formulation

Trapping of banana weevils in disc on stump traps

Trapping of banana weevils in Disc on Stump traps using the pseudostem and leaf sheath juices of susceptible banana varieties revealed significantly higher captures of pseudostem weevils in Nendran pseudostem juice (63.4 individuals) and Nendran leaf sheath juice (41.4 individuals) compared to the control (22.2 individuals) **(Table 15).**

Table 15. Trapping of banana weevils in Disc on Stump traps

Treatments	Number of weevils trapped
T_1 - Nendran stem juice	63.40[a] (7.84)
T_2 - Nendran sheath juice	41.40[b] (6.41)
T_3 - Water	23.40[c] (4.80)
T_4 - Control	22.20[c] (4.70)
CD	**0.88**

**Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05*

Evaluation of effective EPF formulations under field conditions against BPSW

EPF 22, EPF 28, and EPF 50 broths, along with insecticides such as fipronil and thiamethoxam, were applied to the disc on stump trap. Among the six treatments, EPF 22 and EPF 50 attracted a higher number of weevils with increased mortality compared to other treatments (Table 16).

Table 16. Evaluation of the effective EPFs using disc on stump trap under field conditions

Treatments	Number of weevils attracted
T_1 - EPF 22	9.57[a] (4.70)
T_2 - EPF 28	3.86[b] (2.01)
T_3 - EPF 50	8.14[c] (2.90)
T_4 - Fipronil	1.43[c] (1.31)
T_5 - Thiomethaxam	2.29[c] (1.55)
T_6 - Water alone	2.00[c] (1.52)
CD	**0.758**

**Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05*

The EPF-22 formulation was made in both liquid and powder form. This formulation was applied to disc on stump trap as well as longitudinal trap methods (**Fig. 43)** more weevils were attracted to the disc on stump trap method with the EPF-22 liquid formulation compared to other treatments **(Table 17).**

Fig. 43. Application of *B. bassiana* in different trap methods

Table 17. Evaluation of *B. bassiana* NRCB EPF 22 using different trap methods under field conditions

Treatments	Pseudostem weevil		Corm weevil	
	Weevils trapped (Nos)	Per cent mortality	Weevils trapped (Nos)	Per cent mortality
T_1 - Disc on stump Trap (*B. bassiana* Liquid Formulation)	12.33[a] (3.34)	83.15[a] (63.82)	0.33 (0.83)	8.33 (7.21)
T_2- Longitudinal Trap (Bb Liquid Formulation)	1.17[c] (1.23)	50.00[bc] (38.70)	0.33 (0.86)	16.67 (13.50)
T_3- Disc on stumpTrap (Bb Powder Formulation)	6.67[b] (2.56)	77.00[ab] (62.04)	1.00 (1.23)	25.00 (26.10)
T_4- Longitudinal Trap (Bb Powder Formulation)	0.83[c] (1.23)	33.33[c] (32.40)	0.50 (0.91)	25.00 (19.80)
T_5- Only Disc on stumpTrap	6.33[b] (2.44)	23.54[cd] (22.85)	0.17 (0.95)	0.00 (5.81)
T_6- Only Longitudinal Trap	0.67[c] (1.08)	0.00[d] (0.91)	0.33 (0.93)	0.00 (0.91)
CD (0.05)	**0.68**	**25.09**	**NS**	**NS**

**Figures in parentheses are square root √ (X+0.5) transformation values; Means are significant at p< 0.05*

Mass production of Banana Weevil Killer (*Beauveria bassiana* NRCB EPF 22)

Beauveria bassiana is a new strain isolated from an infected banana scarring beetle from Katihar, Bihar. A *B. bassiana* culture plate was prepared using Sabourad Dextrose Agar media, and one week later, a loop of mature conidial spores added to the Sabourad Dextrose Broth solution. Fifteen days after broth preparation, jaggery, yeast, skim milk agar powder, glycerol, sugar, ascorbic acid, and tween 20 were added in the required quantity and kept for 21 days. Afterwards, the number of cells (colony-forming unit) was counted using the pour plate technique as well as a hemocytometer. The recorded cell count is 2.77 x 109 CFU/ml. Shelf life was also calculated after six months; it was found 2. 60 x 109 CFU/ml.

A bioformulation called Banana Weevil Killer, containing *Beauveria bassiana*, was developed to combat banana pseudostem and corm weevils. It effectively controls all stages of the banana pseudostem and corm weevil life cycle, including eggs, larvae, pupae, and adults (Fig. 44).

Fig. 44. Banana Weevil Killer, a bioformulation of *Beauveria bassiana*

4.4.4 Integrated management of Tropical race 4 of Fusarium wilt disease in banana

Field evaluation of consortia of phosphate solubilizing bacteria

The second-year field trial in the ratoon crop at the ICAR-NRCB farm assessed various levels of phosphorus and P-solubilizing bacterial combinations (PS1-*Enterobacter hormaechii subsp. sakuensis* + PS2- *Leclercia adecarboxylate*) in cv. Ney Poovan. The application of 100% SSP + PS1 + PS2 resulted in a 225.47% increase in available phosphorus at the 4thmonth and a 276.42% increase at the 12thmonth after planting. Similarly, 100% RP + PS1 + PS2 saw a 214.80% increase at 4 months and 251.04% at 12 months. Furthermore, 100% RP + PS1 + PS2 led to an 86.18% and 153.8% increase in acid and alkaline phosphatase enzyme activity, respectively, followed by 100% SSP + PS1 + PS2 with 72.92% and 145.2% increases in activity, respectively, compared to the control. Furthermore, the application of 100% SSP + PS1 + PS2 resulted in increased plant height (25.35%), girth (23.15%), total number of leaves (17.65%), petiole length (23.74%), leaf area (38.88%), bunch weight (119.03%), fruit weight (58.50%), peel weight (13.20%), pulp weight (75.17%), TSS (10%), and acidity (12%).

Multilocational field evaluation trials of bioagents for the management of Fusarium wilt

In a field experiment at Katihar district, Bihar five bioagent combinations were tested for managing Fusarium wilt disease (TR4) in Grand Nain banana. Treatment T2 (Endophytic *Bacillus flexus* + Rhizospheric *T. asperellum*) and T5 (Endophytic *Bacillus subtilis* subsp. *inaquosorum* + Rhizospheric *Bacillus haynesii*) showed the lowest wilt disease scores (0.68 and 1.28, respectively) compared to the untreated control (4.32) on a 0-5 scale.

In a field study at KK Patti, Cinnamanur block of Theni district, using cv. Grand Nain for managing Foc R1, treatment T2 (rhizo. *T. asperellum* + endo. *Bacillus flexus*) and T5 (endo. *Bacillus subtilis* subsp. *inaquosorum* + Rhizo *Bacillus haynesii*) showed the lowest internal wilt disease scores of 0.5 and 0.8, respectively, compared to the untreated control (5) on a 0-5 scale.

In a field evaluation at Hampi village, Hospet, Vijayanagar district of Karnataka (R1), using cv. Ney Poovan to manage Foc R1, consortia T5 and T2 achieved the lowest internal wilt disease scores of 1.3 and 0.6, respectively, compared to the untreated control, which scored 4.6 on a disease scale of 0-5.

A roving survey in India for characterization of *Foc* isolates

West Bengal

West Bengal survey was conducted during March 2023, 31 Foc-infected banana samples were collected from 19 villages. Wilt incidence ranged from 0% to 50%, with the highest (50%) observed in Cavendish varieties like Singapuri and Grand Nain in Nadia district, and in Chini Champa (Mysore–AAB) in Murshidabad district.The characterization of Foc isolates via VCG analyses identified VCG 01213/16 of Race 4 and 0124 and 0125 of Race 1. Fusarium wilt incidence was highest in plantations infected with Tropical Race 4. Genetic diversity analyses using the elongation factor 1 α gene revealed nine different Foc strains and extensive genetic diversity among TR4 isolates.

Uttar Pradesh

A roving survey across 11 districts of Uttar Pradesh, including Kushinagar, Maharajganj, Gorakhpur, and others, showed Fusarium wilt incidence ranging from 0% to 90%. The highest incidence of 90% was recorded occurred in cv. Grand Nain (AAA) in Lakhimpur village of Kheri district. Characterization of 40 Foc isolates via VCG analyses identified VCG 01213/16 of Race 4 and 0125 and 01220 of Race 1 in cv. Grand Nain. Notably, 14 Foc R1 isolates (VCG 0125 and 01220) caused severe wilt in cv. Grand Nain across Uttar Pradesh. Furthermore, VCG 01220 from cv. Monthan could also infect cv. Grand Nain. SIX gene analysis revealed SIX 2, SIX 8, and SIX 9 amplification only in VCG 01213/16 (Foc TR4), while SIX 4 and SIX 6 were amplified in VCGs 0124 and 01220 (Foc R1). Genetic diversity analyses using EF-1α gene sequences showed four different subclusters, indicating wide genetic diversity among Foc isolates in Uttar Pradesh.

Bihar

In Bihar, a roving survey covered 7 districts, with Fusarium wilt incidence ranging from 2% to 36.66%. The most severe incidence occurred in

Katihar and Purnia districts. Characterization of all 21 Foc isolates via VCG analyses identified VCG 01213/16 (Race 4) and 0124, 0125, and 01220 (Race 1) in cvs. Grand Nain and Robusta, both belonging to the Cavendish group. Genetic diversity analyses using EF-1α gene sequences revealed five sub-clusters containing both Foc R1 (VCG 0124 and 0125) and Foc TR4, indicating wide genetic diversity among Foc isolates in Bihar.

Gujarat

A survey for Fusarium wilt conducted in 35 banana fields (total no. of plant=107700) in Surat district during February 2023 indicated that the wilt incidence was ranging from 0.3-50%. A high incidence Fusarium wilt (22.22-50%) in certain fields was having the history of occurrence of Fusarium wilt previous years.

Table 18. Survey for Fusarium wilt disease in banana in Surat district, Gujarat

Place/field	No of plants observed	No of plants infected	Fusarium wilt (%) (2022-23)
1	5400	350	6.48
2	5500	2500	45.45
3	1950	600	30.77
4	4200	15	0.36
5	1650	05	0.30
6	2000	15	0.75
7	5400	1500	27.78
8	2500	120	4.80
9	4000	86	2.15
10	2200	50	2.27
11	4000	80	2.00
12	2300	500	21.74
13	1800	600	33.33
14	3500	15	0.42
15	2500	250	10.00
16	2400	100	4.17
17	4000	410	10.25
18	2000	40	2.00
19	2000	20	1.00
20	3000	130	4.33
21	1700	50	2.94
22	2500	200	8.00
23	2400	1200	50.00
24	4500	520	11.56
25	800	150	18.75
26	4000	100	2.50
27	2500	40	1.60
28	4000	100	2.50
29	4500	80	1.78
30	3000	50	1.67
31	2400	300	12.50
32	2400	350	14.58

Development and evaluation of consortia of bioagents for the management of *Foc* TR4

A total of 127 microbial isolates, including 63 bacteria and 64 fungi, were obtained from rhizospheric soil, corm, and root samples of 13 banana accessions. Screening identified three combinations that achieved nearly 100% suppression of Fusarium wilt in cv. GrandNain

1) Rhizo. *Trichoderma* sp. (isolated from Pisang berlin rhizo. soil)+Rhizo. *Trichoderma asperellum* (isolated from Poovan rhizo. soil).

2) Endo. *Bacillus subtillis* (isolated from cv. Matti) + Rhiz. *B. subtilis* (isolated from cv. Safed velchi) and 3) *B. subtilis s.sp. inaquasorum* + Rhi. *T. asperellum.*

Soil application of these combinations resulted in a disease score of only 0.2 on a 0-5 scale, compared to 4.5 in *Foc*-inoculated control plants.

4.4.5 Survey, etiology and management of rhizome rot of banana

Survey for rhizome rot

A survey undertaken in June 2023 in Krishnampatti and Erasai, Theni District, Tamil Nadu indicated that rhizome rot incidence in tissue culture plants (cv. Grand Naine) ranged from 14.6% to 38.5% and 13.33% to 30.00%, respectively. In Tiruchirappalli (ICAR-NRCB farm), Ney Poovan and Grand Naine tissue culture plants recorded rhizome rot incidence ranging from 6.66% to 23.33% and 3.33% to 26.66%, respectively.

Efficacy of PGPR isolates on rhizome rot disease, growth and yield in banana under field conditions

Among eight PGPR isolates tested (BCB 2-4, BCNA 5-3, H4BC1, H6BC2, H6BC3, H7BC2, H8BC1, H8BC2, and JP-4), four isolates—BCNA 5-3, H6BC2, H6BC3, and JP-4—exhibited significantly lower rhizome rot incidence (0.53%) compared to the control (49.80%). PGPR isolates H6BC3, JP-4, and BCNA 5-3 showed notably higher plant height, girth, leaf length, and breadth compared to other isolates and the control after 3 months. Based on 16rDNA sequencing, the isolate JP-4 was identified and characterized as *Bacillus subtilis.*

GC-MS analysis of volatile organic compounds produced by PGPR isolates

Principal component analysis of metabolites from GC-MS analysis showed that samples JP4 and BCNA 5-3 shared similar chemical components. Sample H7-BC2 had the majority of unique chemical components, while samples H8-BC1, H8-BC2, H6-BC2, H6-BC3, and H4-BC1 shared major similar chemical components.

4.4.6 Management of postharvest diseases of banana

Effect of pre-harvest application of chemicals (pesticides) on postharvest diseases, residues and fruit quality

Various chemicals recommended for managing banana pests and diseases were tested for post-harvest disease control and residue levels during the 2022-23 season. Treatments included bleaching powder, Cartap hydrochloride, carbendazim injections, drenching, and different sprays at various stages. Imidacloprid injections were also evaluated on ratoon bananas (cv Grand Naine) at ICAR-NRCB farm, alongside suitable controls. Observations showed that chemical treatments consistently reduced post-harvest diseases, extended shelf life, and improved fruit quality. Treated fruits remained anthracnose-free for 9 days, while control fruits showed symptoms by the 3rdday. Crown rot began on the 7thday for treated fruits, compared to the 3rdday for the control. Shelf life was extended to 9 days with chemical treatments, compared to 4-5 days in the control. Control fruits detached from the crown and rotted completely by the 6th and 7th day, respectively.

a b

Fig. 45. Pre-harvest chemicals applied (a) and non-applied (b) hands on 8th day of storage at room temperature

4.4.7. Molecular approaches to understand the host-virus-vector-environment interactions and the management of banana viruses

Survey on occurrence of CMV

Surveys were undertaken in 10 villages located on the Tapi River banks in Jalagon district of Maharashtra and Burhanpur district of Madhya Pradesh, revealing that the infectious chlorosis caused by CMV re-emerged in epidemic proportions in TC plants of cv. Grand Naine. The maximum CMV disease incidence ranged between 48.91% and 74.8%, and the minimum incidence was between 9.57% and 12.7% in banana orchards located in Jalgaon and Burhanpur districts, respectively.

Yield loss management through fertilizers in cucumber mosaic virus affected banana

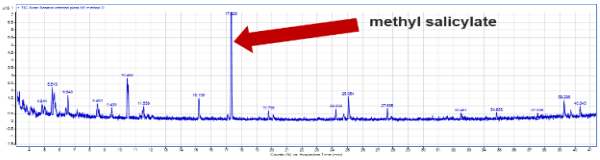
A study was conducted to evaluate the effect of nutrient management on banana yield in CMV-infected orchards and to estimate the yield loss due to CMV infection. In this experiment, a 125% increased dose of the recommended dose of fertilizer (RDF) along with three foliar sprays of “Banana Shakti” micronutrient mixture increased flowering and bunch formation by 50%, and bunch weight also increased by 29.68%. Even though the number of bunches and bunch weight can be slightly increased by nutrient management, it has been observed that flowering and bunch

formation are delayed by 20 to 60 days in CMV-infected banana plants. Furthermore, the percentage of infected plants producing marketable bunches was about 4.93%, and a total yield loss of 28% due to CMV infection was observed.

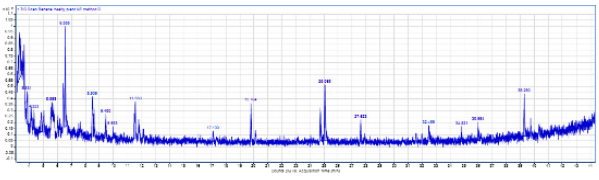
Study of host-virus-vector interaction in banana

An experiment identified 73 volatile organic compounds (VOCs) emitted in BBTV-infected and healthy banana plants, assessing their impact on *P. nigronervosa* behavior. Partial least squares discriminant analysis (PLS-DA) highlighted 15 compounds distinguishing infected aphids, healthy aphids, and healthy plants. Cluster analysis revealed distinct chemical profiles among samples. Methyl salicylate predominated in infected plants, while Bicyclo [2.1.1] hexan-2-ol, 2-ethenyl- was prevalent in healthy ones. Notably, infected plants emitted higher levels of 7-Benzoylheptanoic acid and NI 25. This study suggests potential VOC-based approaches for managing *P. nigronervosa* in banana, with preliminary findings indicating increased aphid attraction to infected plants.

Screening of ICAR-NRCB varieties against BBTV



BBTV infected plant AE Method GCMS Chromatogram Chromatogram



Healthy plant AE Method GCMS Chromatogram

Two NRCB varieties, Kaveri Kanchan and Kaveri Vamana, were screened for resistance against BBTV. Non-viruliferous banana aphids were exposed to infected plants for 24 hours to acquire the virus, then transferred to healthy tissue culture plants for 48 hours of feeding. After treatment with imidacloprid, plants were monitored weekly. BBTD symptoms appeared in newly emerging leaves around 27-35 days after inoculation. All 10 plants inoculated exhibited BBTV symptoms, indicating susceptibility of both varieties.

Screening of cv. Kaveri Vamana against BBTV

Development of banana bunchy top virus resistant banana lines

In this study, BBTV-resistant Nendran (Musa AAB) lines were developed using the RNAi method. A ligation-independent cloning (LIC)-based RNAi vector replaced conventional ones, simplifying construction. The rep gene of BBTV was targeted, with a 200 bp partial sequence amplified and spliced into the LIC vector using adaptors. Cloned in *E. coli*, the construct was confirmed by sequencing. Agrobacterium transformation employed the EHA105 strain. Co-cultivation with Nendran embryogenic cells followed, and putatively transformed plants were screened for BBTV resistance. Nine out of 48 plants showed resistance against BBTV.

Screening of *Musa* accessions for resistance against BBTV

A total of 85 diploid accessions, including 26 AA, 36 BB, and 23 AB were screened for resistance against BBTV for three times in successive years in an insect- proof greenhouse using viruliferous banana aphids (*Pentalonia nigronervosa*). Twenty-five BB accessions remained symptomless, and BBTV was not detected in any of these plants by PCR. Two BB accessions showed symptoms after one year. Thirty accessions were PCR positive but didn't express symptoms throughout the experimental period. In contrast to BB accessions, 100% banana accessions having AA and AAA genome showed susceptibility and expressed bunchy top disease symptoms. The PCR-negative BB plants remain symptomless. The BB accessions showed a high level of resistance and possibly immunity to BBTV and are expected to provide a resource for conventional and marker-assisted breeding.

4.4.8. Investigations on *Musa* nematodes' diversity, biology, behaviour, interactions & its management

Field evaluation of biocontrol agents against plant nematodes infecting cv. Nendran

Field evaluation of Fusarium wilt suppressive biocontrol agents, including endophytic *Trichoderma asperellum* (Prr-2) and *Bacillus flexus* (Tvpr1), against rootlesion nematode *Pratylenchus coffeae* infecting cv. Nendran showed significant reduction in root population when biocontrol agents were applied alone or as consortia. Combined application of both agents reduced root nematode population by more than 75% compared to the control and increased bunch weight by up to 33% (Table 19, Fig. 46).

Table 19. Effect of application of biocontrol agents on the banana nematode (*Pratylenchus coffeae*) and bunch weight

Treatments	Treatment details	*P. coffeae* nematode population/g root			Bunch weight (Kg / plant)
		During flowering stage	During bunch formation stage	During harvest	
T_1	*T. asperellum* @ 50g / plant at planting; 2, 4 and 6 MAP	20.3 (1.3)^{b}	24.7 (1.38)^{b}	43.9 (1.6)^{b}	11.9^{b}
T_2	*B. flexus* @ 50g / plant at planting; 2, 4 and 6 MAP	17.0 (1.2)^{bc}	22.4 (1.35)^{bc}	30.0 (1.5)^{bc}	12.1^{b}
T_3	$T_1 + T_2$	15.0 (1.2)^{bc}	15.85 (1.19)^{cd}	16.6 (1.2)^{c}	13.4^{a}
T_4	Cartap hydrochloride @ 10g / plant at planting; 2, 4 and 6 MAP	12.5 (1.1)^{c}	12.13 (1.05)^{d}	15.9 (1.2)^{d}	13.6^{a}
T_5	Control	44.5 (1.6)^{a}	62.58 (1.80)^{a}	109.2 (2.0)^{a}	10.2^{c}
CD (P=0.05)		7.1 (0.1)	8.28 (0.2)	26.4 (0.2)	0.7

*** Figures in parentheses are log transformed values**

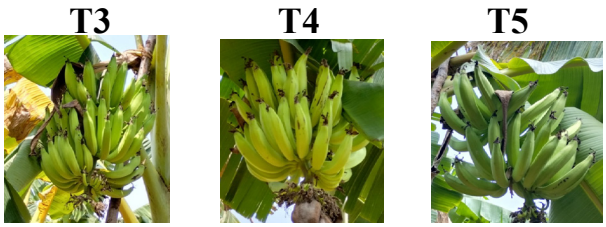


Fig. 46. Bunches of banana cv. Nendran treated with bioagent combinations (T_3) and cartap hydrochloride (T_4) with a control

Nematode incidence and damage

Post-cyclonic "toppling" occurred on cv. Popoulu due to root damage by root lesion nematode (*Pratylenchus coffeae*) at NRCB farm, Tiruchirappalli (Fig. 47). Combined attack of corm weevil and root lesion nematodewas observed on cv. Nendran at NRCB farm, Tiruchirappalli (Fig. 48). Burrowing nematode (*Radopholus similis*) incidence was noted on Poovan roots in Thirukkattuppalli, Thanjavur District, Tamil Nadu (Fig. 49), and root galls from root knot nematode (*Meloidogyne* sp.) were observed on Sirumalai cultivar in Sirumalai, Dindigul District, Tamil Nadu.

Fig. 47. Toppling of cv. Popoulu due to root damage caused by root lesion nematode

Fig. 48. Combined damage of corm weevil and root lesion nematode on cv. Nendran

Fig. 49. Damaged root system of cv. Poovan due to burrowing nematode

Evaluation of ITC accessions for resistance to root lesion nematode, *Pratylenchus coffeae*

Out of 10 ITC accessions evaluated for their response to root lesion nematode under inoculated conditions, only Calcutta 4 (0249) and Microcarpa (0253) were found resistant, while the others were susceptible (Fig. 50).

Calcutta 4 | Microcarpa | Nendran (Susceptible check)

Fig. 50. Evaluation of ITC accessions for resistance to root lesion nematode

Production of doubled haploids for improvement of bananas (*Musa* spp.)

A new *in situ* screening method for banana pseudostem weevil (BPSW) was conducted on seven plants each of androgenic Ney Poovan tetraploids and normal diploids (see Fig. 51). BPSW infection was observed in all tetraploids, with higher numbers of pupae (5) and adults (10) compared to only two infected plants and four larvae in diploid NeyPoovan. This suggests that Ney Poovan tetraploids are more susceptible than the diploid Ney Poovan.

GCMS analysis revealed higher levels of certain compounds (Hexaonic acid, 2-methyl-, 1-hexanol, 2-ethyl- and phenol content) in diploid Ney Poovan that activate defense mechanisms. Carboxylic acid group such as Pentanoic acid, 3-methyl- and Octanoic acid which act as flavouring agents as well as tetradecanoic acid which acts as lipid anchor in bio-membranes (Insect attractant) were higher in androgenic Ney Poovan tetraploids.

Fig.51. *In situ* screening of BPSW in diploid and tetraploid Ney Poovan

4.5 EXTERNALLY FUNDED PROJECTS

4.5.1 IITA-collaborative project: Improvement of Banana for smallholder farmers in the Great Lakes region of Africa - enhancing Banana production by developing Fusarium Wilt-resistant varieties and benefit sharing with African smallholders

(S. Uma, S. Backiyarani, M.S. Saraswathi and R. Thangavelu)

A total of 16 hybrids received from IITA partners were screened at the TR4 hotspot area in Falka village, Katihar, Bihar State, India, of which nine were found to be highly resistant. IITA 75, a stable high-yielding variety resistant to Foc Race 1 and moderately resistant to TR4, was evaluated in farmers' fields across Theni, Nagarcoil, Salem, and Tuticoirn districts of Tamil Nadu State, as well as in the Trivandrum district of Kerala, performing well in all locations (Table 20 a and b).

Table 20a. Reaction of the hybrids to Fusarium wilt disease

Reaction	No. of hybrids	Name of the hybrids
Highly resistant	9	IITA 4, NARITA 21, 8, 12, 23, TMB 10, 3, 24, 26
Resistant	4	IITA 1, 53, 146, NARITA 14
Moderately resistant	2	IITA 10 , IITA 75

Table 20 b. Performance of IITA 75 (PITA 16) at different locations of Tamil Nadu

Place	Mean of morphological and Yield traits						
	Plant Height (cm)	Girth (cm)	Duration (Months)	No. of Hands	No. of Fruits	Fruit length (cm)	Bunch weight (kg)
Theni	320±15	108±10	12±0.5	9±1	16±2	18±2	27±1.5
Nagarcoil	325±10	106±8	13±1	9±0	18±6	16±3	25±3.5
Salem	315±20	109±15	12±0.5	9±1	15±3	18±3	24±2.0
Tuticorin	310±10	108±10	12±0.5	8±2	17±5	19±1	26±3.0
Trivandrum	320±15	110±5	13±1	9±1	18±4	20±2	28±2.5

Commercializing rapid multiplication technologies and new models that drive private sector investment into VPC seed systems

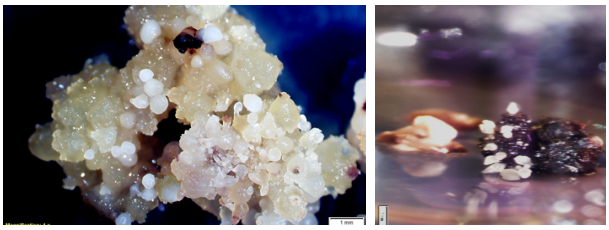
Two East African Hybrid Banana (EAHBs), Matoke and Muzuzu, were cultured in a temporary immersion bioreactor system developed by ICAR-NRCB at SERV. Matoke showed superior responses compared to Muzuzu in terms of shoots per explant, multiplication rate, and shooting quality throughout subculture cycles. The SERV system demonstrated the capacity to produce 0.8-fold and 0.5-fold higher shoot multiplication rates for Matoke and Muzuzu, respectively, compared to the semisolid system. Moreover, the shoots per explant wereapproximately 1.7-fold higher than that in the semi-solid medium (12-13 shoots per explant).

Fig. 51. Fifth subculture of Matoke in semisolid (Left) and SERV (Right) Fifth subculture of Muzuzu, in semisolid (Left) and SERV (Right).

4.5.2 Induced Polyploidy: A tool to improve sterile bananas

(Dr. S. Kalpana, Women Scientist – A (DST))

To develop tetraploids through chromosome doubling, embryogenic cell lines of Pisang Lilin, cv. Rose, Calcutta 4, Kunnan and Bhimkol buds available at ICAR-NRCB farm were initiated for callus induction. Embryogenic calli were obtained in Kunnan and Bhimkol and are transferred to ECS medium for development of suspension culture.



Kunnan embryogenic calli | Bhimkol embryogenic calli

4.5.3 Efforts towards the development of Fusarium Wilt resistance in Banana using CRISPR/Cas9

(C. Jeyabharathy, Women Scientist – A (DST)

To develop fusarium wilt (Foc TR4) resistance through precise targeting of the endogenous susceptible factors of the host genes, two transcription factors namely LBD20 and ATAF2 which are the susceptibility factors to the root infecting fungal pathogen *F.oxysporum* were identified in banana using banana genome hub. These genes were amplified from Grand Nain using specific primers and sequenced to design guide RNA. Simultaneously, for checking the expression level of LBD20 and ATAF2 in the *Foc* TR4 challenged resistant (cultivar Rose) and

susceptible cultivar (Grand Naine, Matti). Root samples were collected from *Foc* TR4 challenged resistant and susceptible cultivar at 2nd, 4th, 6th, 8th day.

DBT – BIRAC funded project

4.5.4 Biofortification and development of disease resistance in banana

Component 1: Transfer and evaluation of Indian banana with Provitamin A (PVA) constructs

(S. Backiyarani, M. Mayil Vaganan and S. Uma)

RCGM approval has been obtained to receive transgenic events from NABI, Mohali, and transfer ICAR-NRCB's transgenic events to NABI, Mohali; TNAU, Coimbatore; NAU, Gandevi; and AAU, Dhubri. Five tissue culture plants of the top 10 events overexpressing the psy2a gene were moved to each of the four Event Selection Trial (EST) centers. At the ICAR-NRCB EST site, 20 PVA events (10 from NABI and 10 from NRCB) were planted on 28.07.2023, all showing uniform vegetative growth (Fig. 52).

Fig. 52. Event selection trial at ICAR-NRCB

Component 2: Transfer and evaluation of Indian bananas with iron gene constructs

(M. Mayil Vaganan, I. Ravi and K. J. Jeyabaskaran)

Five elite iron events of cv. Grand Naine, carrying OsNAS1 and OsNAS2 genes, were multiplied using suckers as explants and maintained *in vitro*. They were acclimatized by hardening for conducting event selection trials at five locations across the country. Five plants each of the five transgenic events, along with five untransformed control Grand Naine plants, were transferred to four identified Event Selection Trial (EST) Locations: Tamil Nadu Agricultural University, Coimbatore; National Agri-Food Biotechnology Institute, Mohali; SCS College of Agriculture (AAU), Dhubri Dt., Assam; and Fruit Research Station (NAU), Gandevi, Navsari Dt., Gujarat, during July and August 2023. These plants were planted at the identified EST site of the Experimental Farm of the Centre on 28th July 2023.

PPV & FRA funded DUS project

4.5.5 ICAR-Framing crop specific DUS guidelines for Banana (*Musa* spp.)

(M.S. Saraswathi and S. Backiyarani)

DUS characterization has been completed for two farmer's varieties, Thottu Chingan and Kudhiraival Chingan and the data submitted. DUS characterization is ongoing for the farmer's variety Neykadali. Kerala Agricultural University has filed the application for registration of the farmer's variety (PPV & FRA/PVP No. DL3107230001/Banana/1157 dt.03.08.2023), and planting material has been received and established in the DUS field.

BRNS funded project

4.5.6 High-throughput screening for induced mutations in banana cv. Grand Naine (AAA) with Fusarium wilt (TR4) resistance

(M.S. Saraswathi, S. Uma, R. Thangavelu, S. Backiyarani and Himanshu Tak)

Results of *in vitro* screening showed optimal doses of fusaric acid at 0.025 and 0.050 mM, based on fresh weight gain over control and % shoot survival, respectively. Among different methods of induced mutagenesis using physical/chemical mutagens, treating somatic embryos in the maturation stage yielded better results compared to treating cells in suspension. Double treatment of somatic embryos with chemical followed by physical mutagens or *vice versa* led to a drastic reduction in germination. Pot screening of gamma irradiated (40 Gy) population (100

nos.) led to the identification of one putative mutant resistant to *Foc* race 1.

4.5.7 Development and utilisation of diagnostics to viruses of banana
(R. Selvarajan and C. Anuradha)

Developing recombinant monoclonal antibodies to BBTV and standardizing ELISA based diagnostics

Total DNA was extracted from a BBTV-infected sample using the CTAB method, followed by PCR amplification of the BBTV CP gene. The amplified gene was then cloned into the His-tagged prokaryotic expression vector, pET-28a, allowing for the expression of recombinant BBTV-CP. After transformation into Escherichia coli BL21 (DE3) cells, selected clones expressing the recombinant coat protein were induced for protein expression using IPTG. The expressed BBTV-CP protein was subsequently purified using Ni-NTA agarose resin column under denaturing conditions. Its purity and identity were confirmed through western blotting using a specific antibody against BBTV.

This purified BBTV-CP protein was then utilized as an immunogen to produce monoclonal antibodies against BBTV using hybridoma technology. To determine the optimal working dilutions of these monoclonal antibodies (MAbs) and to develop a detection method, an ACP-ELISA assay was performed. This assay not only allowed for the determination of the optimal dilutions of MAbs but also demonstrated the specificity of the developed ACP-ELISA protocol.

The specificity assay showed that BBTV could be reliably detected in BBTV-infected samples using the developed ACP-ELISA method. However, there were negative reactions with samples from other viruses such as BBrMV, BSMYV, and CMV, as well as with healthy banana samples. This highlights the specificity of the assay for BBTV detection, making it a valuable tool for disease diagnosis and surveillance

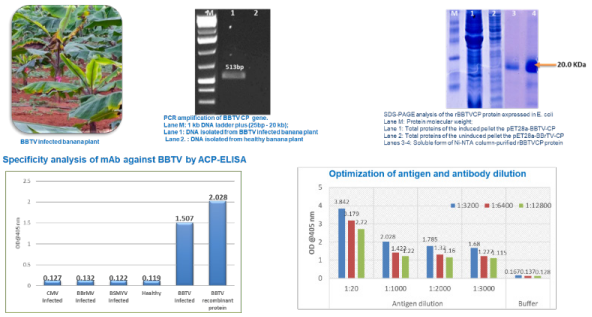


Fig. 53. Development of monoclonal antibodies for detection of banana bunchy top virus (BBTV)

Ready to use TAS-ELISA kits for detection of banana bract mosaic virus (BBrMV) and cucumber mosaic virus (CMV)

The recombinant coat proteins of BBrMV and CMV have been successfully expressed in a bacterial expression system and are currently being utilized to produce monoclonal antibodies using hybridoma technology. These monoclonal antibodies are then incorporated into triple antibody sandwich enzyme-linked immunosorbent assay (TAS-ELISA) kits. These TAS-ELISA kits have been developed and used for testing tissue culture banana plantlets against BBrMV and CMV.

NABARD Funded project

4.5.8 Establishment of banana macropropagation units in Tiruchirappalli District, capacity building and improvement of livelihood opportunities of farmers
(S. Uma, R. Karthic, S. Backiyarani and M.S. Saraswathi)

A total of 12 nurseries were established in various panchayat blocks in Tiruchirappalli. The performance of the disseminated technology in rural areas was evaluated, with each nursery capable of yielding 2000 plants within three months. These units can able to supply pplants to the small and marginal farmers at an affordable cost.

Foreign funded projects

A1553-CGIAR fund INIT-03 - Conservation and use of genetic resource (gene banks)

4.5.9 Study I: Evaluation of ITC accessions for their reaction to Fusarium wilt Race 1 & TR4 (R. Thangavelu and S. Backiyarani)

Evaluation of ITC accessions against For R1

Evaluation of 110 ITC accessions against Foc R1 in a glasshouse revealed eight were resistant, 58 moderately resistant, 32 susceptible, and 12 highly susceptible. Field evaluation of 103 ITC banana accessions at Theni, Tamil Nadu, showed that 44 were highly resistant, 13 resistant, 11 moderately resistant, eight susceptible, and 27 highly susceptible to Foc R1. Accessions resistant to R1 in both glasshouse and field conditions included PC-12-05 AAAB, Paka -AA, FHIA-23- AAAA, FHIA-02 -AAAB, Williams -AAA, TJau Lagada - AA, and GCTCV-119 -AAA.

Evaluation of ITC accessions against For TR4

Evaluation of 114 ITC accessions against Foc TR4 in glasshouse conditions revealedone was immune, 30 were resistant, 60 moderately resistant, 15 susceptible, and 8 highly susceptible to Foc Tropical Race 4. Field evaluation of 99 ITC accessions in Bihar showed that 88 were immune, nine highly resistant, 19 resistant, 22 moderately resistant, 24 susceptible, and 7 highly susceptible to Foc TR4. Common accessions resistant to TR4 in both glasshouse and field conditions include FHIA-23-AAAA, Pisang Mas -AA, GCTCV 215-AAA, Pisang Jari Buaya -AA, cv. Rose – AA, Blue Torres Strait Island -ABB, Guineo-AAA, Pisang Nangka -AAB, Pisang Berangan -AAA, PV-03-44 -AAAB, Tjau Lagada-AA, FHIA 21 -AAAB, Zebrina- AA, Safet Velchi- AB, Pisang Cici Alas -AA, Leite -AAA, Kluai Lep Mu Nang -AA, and Musa laterita (Rho) 627.

4.5.10 Study II: International Workshop on 'Phenotyping for drought tolerance' (I. Ravi and C. Karpagam)

ICAR–National Research Centre for Banana (ICAR-NRCB) and Alliance Bioversity International and CIAT co-hosted the "Phenotyping for drought tolerance" workshop from March 7th to 11th, 2023. There were five international trainees from different countries (Indonesia, Papua New Guinea, Sri Lanka, The Philippines, and Mauritius (Self-financed). From India (workshop host country) 11 participants (One participant from private industry, Jain Irrigation, (Self-financed) were participated in this workshop. Dr. A.K. Singh, Deputy Director General (Horticulture Sciences), ICAR, and Dr. Sebastien Carpentier, Senior Scientist, Alliance Bioversity International and CIAT, emphasized the importance of identifying drought-tolerant cultivars. The inaugural lecture was delivered by Dr. R Chandra Babu, Ex. Vice Chancellor of Kerala Agriculture University, India. Subsequently, the workshop was conducted with regular lectures and practical in the field as well as in lab. The main resource persons are Dr. I Ravi (Plant Physiologist) from ICAR-NRC for Banana and Dr. Sebastien Carpentier from Alliance Bioversity International and CIAT. Besides six eminent researcher who are working in drought aspects of different crops were invited to share their knowledge through online and off line. The workshop aimed to train researchers in identifying such genotypes under field conditions, featuring lectures, practical sessions, and visits to banana farmer's fields. The feedback was overwhelmingly positive, with 93% of participants rating the workshop as "very good".

4.5.11 Study III: Status of adoption behaviour of ITC accessions in India under the Banana production system and the constraint analysis in the dissemination process – An analytical study

(C. Karpagam and S. Backiyarani)

The secondary data collected over the period indicates that Popoulu (AAB, Plantain) has been identified as a higher yielding variety with dual-purpose capabilities, suitable for both dessert fruit and chips production. It has been recommended for cultivation in several states including Karnataka, Odisha, Tamil Nadu, Assam, Kerala, Andhra Pradesh, and West Bengal. Trials with introduced clones of Popoulu conducted at seven AICRP centers showed significant and favorable results, as indicated by the B:C ratio. Comparisons with Manjeri Nendran-II and the check variety Nendran revealed that Popoulu was preferred more as a dessert fruit. Based on these findings, it is recommended that Popoulu (AAB, Plantain) be cultivated for its higher yield potential in both dessert fruit and chips production.

To promote wider adoption of the ITC accession, the Banana Research Station in Kannara, Kerala, has achieved success in developing tissue culture plants for "Popoulu." These plants have been distributed to AICRP centers specializing in banana research for further evaluation.

In preparation for commercializing products from various banana varieties, the Banana Research Station in Kannara has conducted assessments on the ITC Accession for its growth and yield. Additionally, it has been evaluated for its suitability in chips preparation

Survey

During the survey period, a questionnaire titled "Status of ITC Accessions in India within the Banana Production System" was distributed via Google Form to ICAR-AICRP (F) Banana centers nationwide. An online workshop involving 30 experienced scientists was conducted on July 14, 2023, to discuss adoption behavior and constraints related to ITC accessions. Thirteen scientists submitted filled interview schedules, which were analyzed to generate a final report.

Table 21. Usage of ITC accessions

Name of the Institute	ITC accession	Source of ITC accession	From where it was obtained	Purpose of collection
TNAU, Coimbatore	Popoulu	Polynesian islands	BRS, Kannara	AICRP trial purpose
Bidhan Chandra Krishi Viswavidyalaya (BCKV)	NRCB Selection-10, Popoulu	ICAR-NRCB	ICAR-NRCB	Evaluation trial under ICAR-AICRP on Fruits
Mahatma Phule Krishi University	Phule Pride	Grand Nain population	Experimental Block of Banana Research Station, Jalgaon	To develop cultivar with dwarf stature
Bidhan Chandra Krishi Viswavidyalaya	NRCB Sel-10 [selection from Namwa Khom (ABB)] and Popoulu	ICAR-NRCB	ICAR-NRCB	Evaluation trials under ICAR-AICRP on Fruis
Dr. YSRHU-HRS, Kovvur	Pisang Lilin, cv. rose, Popoulu, Kaveri kalki, Kaveri saba	ICAR-NRC Banana	Trichy	Germplasm and MLT experiments
KRC college of Horticulture, Arabhavi (UHS, Bagalkot)	Pisang Lilin, Popoulu, Kaveri kalki, Kaveri Saba	NRCB, Trichy, BRS, Kannara	NRCB, Trichy, BRS, Kannara	Research purpose
TNAU, Coimbatore	Pisang Lilin	Banana germplasm at TNAU, Coimbatore	NRCB, Trichy	Breeding
Banana Research Station, Kannara, Kerala Agricultural University	Popoulu	NBPGR	NBPGR	Germplasm introduction

DAC & FW, Govt. of India Sponsored Project

4.5.12 Sub Mission on Agricultural Mechanisation (SMAM) for implementation of its component no.1 under Drone Technology Demonstration

(C. Karpagam, M. Loganathan, I. Ravi and K.J. Jeyabaskaran)

The project, launched in January 2023, aims to demonstrate drone spray technology for banana cultivation. ICAR-NRCB provided technological support for fungicide application via drones in Theni district. Awareness meetings were held in Thirukurungudi and drone demonstrations in Trichy, Theni, and Namakkal Districts. Two drones were allocated to NRCB, with the main goal being to elevate banana farming practices through farmer awareness and drone technology adoption.

Fig. 54. Drone Technology Demonstration at Thottiyam, Trichy

Fig. 55. Drone Technology Demonstration at Kalakkadu, Tirunelveli

Fig. 56. Drone Technology Demonstration at Theni

Fig. 57. Drone Technology Demonstration at Paramathi Velur, Namakkal

Table. 22. Details of drone technology implementation by National Research Center for Banana

S. No	Date	Place and District	Total Area Sprayed (ac)	No. Farmers
1	10.01.23	Kalakadu, Tirunelveli	24	100
2	23.01.23	Thottiyam, Tiruchirappalli	15.15	60
3	21 &22.02.23	Theni	46	50
4	27.02.23	Theni	10	50
5	22 &23.03.23	Paramathi Velur, Namakkal	13.52	70
6	January 2023	NRCB, Tiruchirappalli	5	-
	Total		**113.67**	**330**

ICAR Funded Projects

4.5.13 Network Project on Precision Agriculture

(I. Ravi, R. Selvarajan, K.J. Jeyabaskaran and P. Suresh Kumar)

To determine the optimum moisture level under varied nutrient conditions in banana, a field experiment was conducted at the ICAR-NRCB research farm. Drip irrigation-controlled water application, while moisture levels were monitored using the gravimetric method and interpolated with a soil moisture release curve generated through a pressure plate apparatus. The results revealed that soil moisture deficit stress (-0.3 MPa and -0.5 MPa) and nitrogen stress affected flowering time in cv. Grand Nain. Soil moisture deficit stress delayed flowering by 13-15 days compared to the irrigated control, while N0 and N50 (RDF) treatments showed early flowering by 15-17 days compared to N100 (RDF) treatments.

The varied levels of potassium (K) application did not influence the time of flowering. Yellowing of the plant canopy was observed through drone aerial imaging. Bunch weight was significantly reduced by 14.74–18.24% in soil moisture deficit treatments compared to the irrigated control (-33 KPa). Interestingly, N50 and N75 applications recorded significantly higher yields compared to N100 under soil moisture deficit stress.

IoT-based soil moisture sensors and an automated irrigation system, installed by M/s. Digite Infotech Pvt. Ltd. Mumbai, have been implemented in the experimental field. This system is designed to automate irrigation based on root zone moisture levels set at 33, 50, and 75 KPa.

4.5.14 ICAR-LBSOYSA. Utilization of banana wastes for the development of synbiotic & approaches and to enhance the farmers' income

(P. Suresh Kumar)

Development of gluten free extruded product from rhizome

Puffed snacks were prepared using a twin-screw extruder, incorporating various combinations of rice and maize flour along with banana rhizome flour (5–15%) in different ratios. The addition of banana rhizome flour led to enhanced fiber content (6-fold increase) and mineral content (K, Mg, Ca, and Na). The natural colour of banana rhizome contributed to the visual appeal of the final product, resulting in an improved brownness index.

Fig. 58. Banana rhizome based hot extruded products

Coacervation based encapsulation of laminarin and fish oil utilizing banana starch and faba bean protein

Banana starch (BS) and faba bean protein (FBP) were combined synergistically as a polysaccharide-protein complex in the encapsulation process of laminarin and fish oil. BS, known for its high amylose content and encapsulation properties, acted as the anionic component, while FBP, a cationic protein with exceptional emulsifying properties, served as the cationic component. Emulsion formation was facilitated using ultrasound, followed by freeze-drying for encapsulation. The separation percentage notably increased with decreasing ultrasound (US) treatment duration. The most stable emulsion was achieved at US 50:30M, followed by US 100:30M. US 50% for 30 min exhibited a viscosity curve similar to US 100% for 10 min, displaying higher viscosity than emulsions produced through conventional methods and US 50% for 10 min.

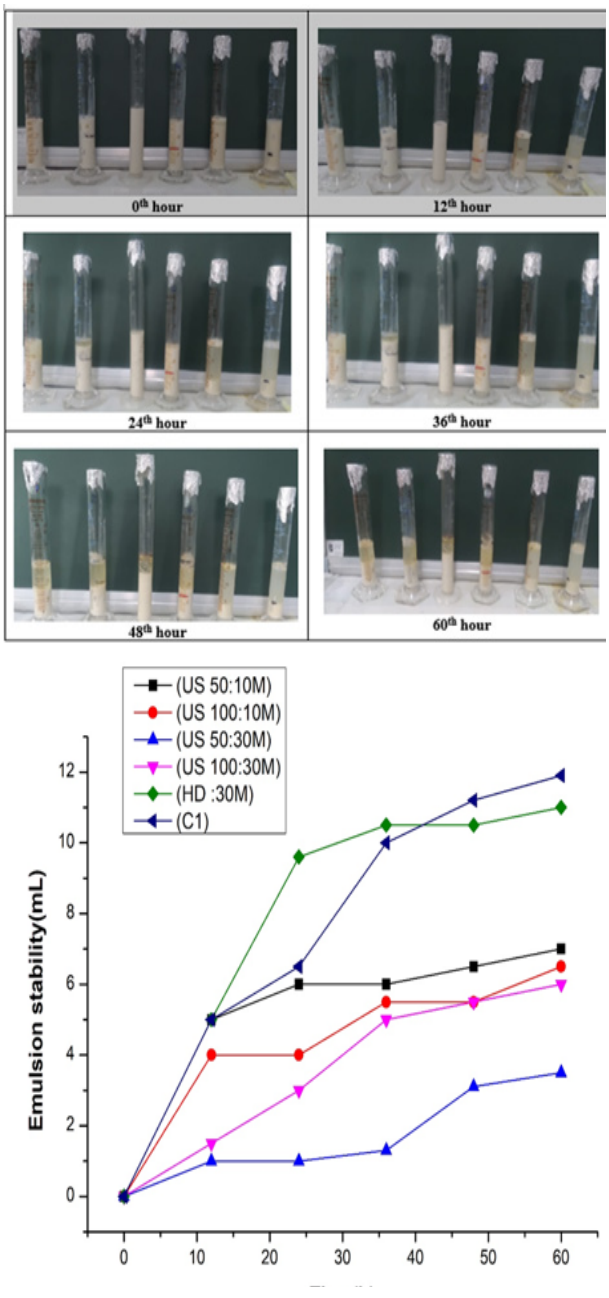


Fig. 59. Emulsion stability of coacervation based encapsulation of laminarin and fish oil

The application of ultrasound in emulsion preparation slightly reduced the friction coefficient for less intense treatments, with similar profiles observed at US 50% for 10 and 30 min, as well as US 100% for 10 min. Emulsion droplets without ultrasound were non-uniform, whereas increasing ultrasound power resulted in more uniform, smaller emulsion droplets. The combination of BS and FBP demonstrated the ability to stabilize laminarin and fish oil by inducing spatial repulsion to prevent flocculation and coalescence.

Table. 23. Characteristics of encapsulated powder

	Yield (%)	Moisture (%)	Water activity (a_w)	Chroma	WI	FFA (%)
USP 50:10M	83.13±0.02^{a}	2.71±0.36^{c}	0.19±0.11^{b}	24.10±1.05	75.3±0.72	1.32±0.03
USP 100:10M	84.70±0.23^{a}	2.55±0.08^{c}	0.16±0.01^{c}	23.76±2.03	75.65±0.15	1.30±0.11
USP 50:30M	83.78±0.76^{b}	2.96±0.26^{c}	0.14±0.00^{d}	21.72±1.89	77.64±0.46	1.45±0.06
USP 100:30M	84.23±0.17^{a}	2.41±0.18^{b}	0.16±0.01^{c}	22.66±2.46	76.75±1.06	1.56±0.02
(HD: 30M)	74.20±0.36^{a}	3.67±0.09^{b}	0.14±0.00^{d}	21.79±1.68	77.52±0.56	1.05±0.03
C1	66.27±0.2^{c}	5.01±0.25^{a}	0.31±0.01^{a}	20.28±2.68	89.32±0.67	0.28±0.01

Effect of addition of dietary fiber from central core stem on rheological and textural characteristic of ice cream

Incorporating dietary fiber (DF) from banana central core stem along with banana starch significantly altered the characteristics of ice cream. This synergistic combination led to a noticeable decrease in the ice cream melting rate, resulting in prolonged melt times and improved rheological and textural properties. The prolonged melting time was attributed to the enhanced water absorption capacity of DF. Furthermore, the increase in overrun (%) due to the addition of DF showed a direct correlation with the formation of larger air pockets, contributing to enhanced smoothness and an improved overall melting rate of the ice cream.

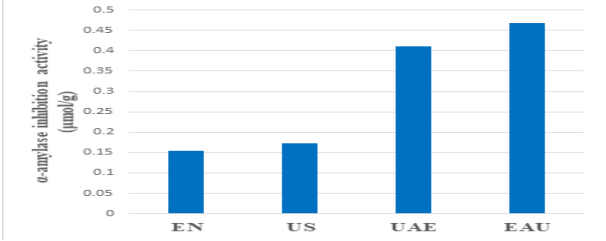


Fig. 60. α-amylase inhibition activity of DF extracted by different extraction methods

*EN- Enzymatic method, US- Ultrasonication method, UAE- Ultrasound assisted Enzymatic method, EAU- Enzymatic- Ultrasound method

4.5.15 ICAR – NAIF-Establishment of Agri Business Incubation Centre under ICAR-National Agriculture Innovation Fund (Component – II)

(K.N. Shiva, P. Suresh Kumar, V. Kumar, K.J. Jeyabaskaran and D. Ramajayam)

Between March and December 2023, 21 incubatees utilized ABI Incubation facilities to produce items like banana flower pickle, banana stem pickle, banana stem juice, banana grits and millet-based snack bars. ABI Incubation unit earned Rs.42,000 through membership fees from 21 incubatees. Additionally, 34 Entrepreneurship Development Programmes and Agri-business Development/Awareness Programmes were conducted. About 462 stakeholders visited the ABI.

ICAR-NRCB imparts training to farmers, stakeholders and Self Help Groups (SHG)

4.5.16 ICAR-NASF: Development of postharvest handling and smart packaging methods for the export of Traditional banana varieties and digital health monitoring of banana

(P. Suresh Kumar, K.N. Shiva, V. Kumar, R. Thangavelu and S. Uma)

Detection of arsenic traces in artificially ripened fruits using D-glucose functionalized silver nano particles

D-glucose functionalized silver nanoparticles (d-Ag NP) were synthesized for detecting arsenic traces in fruits. Silver nitrate, trisodium citrate, hydrogen peroxide, and sodium borohydride were combined, resulting in the formation of silver nanoparticles (Ag-NP). Glucose was then added for functionalization. Upon interaction with arsenic standards, the colour of d-Ag NP changed from golden yellow to dark navy blue, a change retained even after 24 hours. UV absorbance confirmed the interaction of d-Ag NP with arsenic.

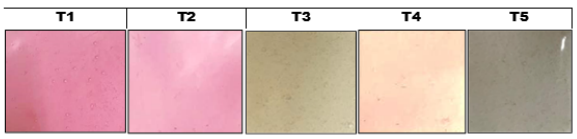
Study on the effect of green chemicals on shelf life of banana fruits

Green chemicals like Lac formulations, Hexanal, Aloe vera Gel, Gallic Acid, and Chitosan (1%) were compared to Carbendazim treatment for their effect on banana shelf life. Carbendazim-treated fruits lasted the longest. Lac formulation and gallic acid kept TSS lower for up to 50 days. However, Aloe vera gel and chitosan led to a rapid increase in TSS after 40 days. Fruit firmness declined steadily over time, with the greatest reduction seen in untreated fruits (20 days), followed by Aloe vera gel-treated ones.

Development of banana bract extract based smart packaging indicators

Anthocyanin extracted from banana flower bract was used in film-forming solutions with modified banana starch, PVA, and glycerol to create smart packaging labels. The films, varying in hydrophilicity based on formulation, showed promising results. The formulation with 5% banana bract extract exhibited the highest thickness, water vapor transmission rate, and pH activation, making it ideal for pH indicator packaging for chicken meat. In testing on meat samples, color changes in the smart pH indicator films corresponded to pH variations. These biodegradable films, incorporating banana bract extract, offer environmentally friendly options for consumers seeking products with better preservation quality.

Fig. 61. Change in colour of banana bract extract with varying pH



Colour of the smart packaging indicator film

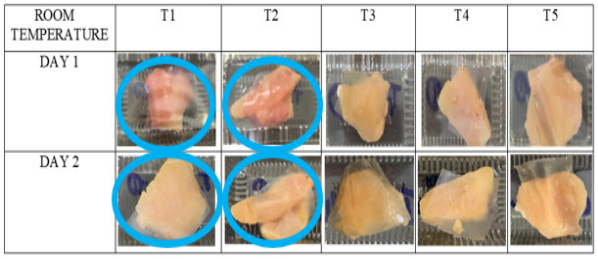


Fig. 62. Change in film colour indicating meat freshness

T1 – Modified banana starch (2g) + Anthocyanin; T2 – Modified banana starch (5g) + Anthocyanin; T3 – Banana starch (2g) + Anthocyanin; T4 – Banana starch (5 g) + Anthocyanin; T5 – Corn Starch + Anthocyanin

4.5.17 Development of smart foods, bio-composites, green packaging and bio-energy from agro residues

(P. Suresh Kumar, K.N. Shiva, M. Mayil Vaganan)

Greener technology for extraction of cellulose

Banana pseudostem (BPS) containing 40-60 wt% cellulose and 10-25 wt% lignin showed a promise as a natural alternative to synthetic fibers. Glycerol Organosolv Process (GOP) for lignocellulosic biomass pre-treatment was employed for enhancing cellulose hydrolysis. Ultrasound treatment further improves lignin removal from GOP-treated banana pseudostem fibers (BPF). Response Surface Methodology (RSM) optimizes GOP and ultrasound process variables for lignin and hemicellulose removal, and cellulose yield. GOP achieves 57% lignin removal at 200°C, 120 min, and 80% w/w glycerol concentration, while ultrasound achieves 92% removal at 250 W, 60 min, and 30% w/w glycerol concentration. The extracted cellulose is used to create starch-cellulose and polyvinyl alcohol (PVA)-cellulose composite biofilms, showing excellent mechanical properties and thermal stability

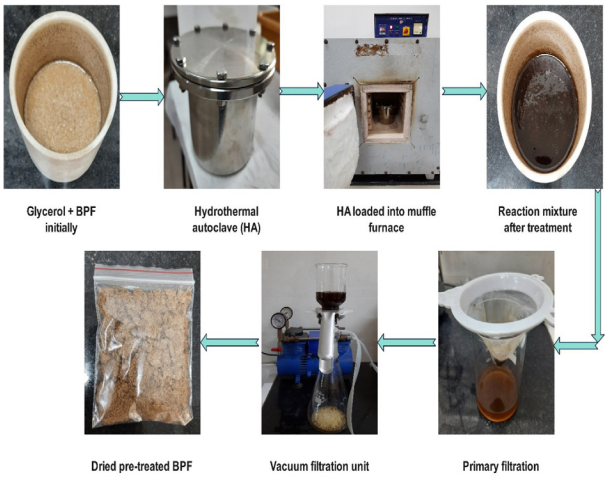
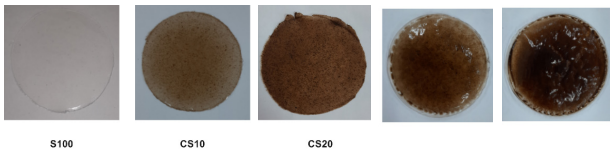


Fig.63. Greener technology for extraction of cellulose



S100 Corn starch; CS10-10% Cellulose and 90% corn starch; CS20-20% Cellulose and 80% corn starch; CP10-10% Cellulose and 90% PVA; CP20-20% Cellulose and 80% PVA

Fig. 64. Biofilms prepared from cellulose

4.5.18 Evaluation of ITC accessions for their reaction to Fusarium wilt Race 1 and Tropical Race 4

(R. Thangavelu)

Evaluation of ITC accessions against Foc R1

The evaluation of ITC accessions against *Foc* R1 under glass house indicated that out of 110 ITC accessions eight accessions were found to be resistant, 58 showed moderately resistant, 32 were susceptible and 12 were found to be highly susceptible to *Foc* R1. Out of 103 ITC banana accessions evaluated for their reaction to *Foc* R1 under field condition at Theni in Tamil Nadu indicated that 44 were found to be highly resistant, 13 were resistant, 11 were moderately resistant, eight were susceptible and 27 were found to be highly susceptible. The accessions found resistant to R1 both under glass house and field conditions were PC-12-05 AAAB (1260), Paka -AA (1254), FHIA-23- AAAA (1265), FHIA-02 -AAAB (0505), Williams -AAA (0570), TJau Lagada - AA (0090) and GCTCV-119 -AAA (1282).

Evaluation of ITC accessions against Foc TR4

In the case of Evaluation of ITC accessions against *Foc* TR4 under glass house condition, the results showed that out of 114 accessions, one was immune, 30 were resistant, 60 were moderately resistant, 15 were susceptible and 8 were found highly susceptible to *Foc* Tropical race 4. Similarly, the field level evaluation of 99 ITC accessions in Bihar indicated that 88 were immune, nine were highly resistant 19 were resistant, 22 were moderately resistant 24 were susceptible and 7 were highly susceptible to *Foc* TR4. However, the common accessions found to be resistant to TR4 under both glass house and field conditions are FHIA -23 -AAAA(1265), Pisang Mas -AA (0653), GCTCV 215-AAA (1271), Pisang Jari Buaya -AA (0312), cv. Rose – AA (0712), Blue Torres Strait Island -ABB(0338), Guineo-AAA (0005), Pisang Nangka -AAB (1062), Pisang Berangan -AAA (1287), PV-03-44 -AAAB (1262), Tjau Lagada-AA (0090), FHIA 21 -AAAB (1306), Zebrina- AA (1177), Safet Velchi- AB (0245), Pisang Cici Alas -AA – (0415), Leite -AAA (277), Kluai Lep Mu Nang -AA (533), *Musa laterita* (Rho) 627.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Radio talks

Name of the Scientist	Topic	Date of broadcast	Channel
C. Karpagam	Banana Extension & Government Schemes and Support for Small and Marginal Farmers.	July 19, 2023	Kodai FM Vanavil
	National Research Centre for Banana Foundation Day.	August 21, 2023	All India Radio, Tiruchirappalli
	Viksit Bharat Sankalp Yatra (VBSY) Programme in Trichy district.	December 28, 2023	All India Radio, Tiruchirappalli

5.2 Television talks

Name of the Scientist	Topic	Date of telecast	Channel
R. Selvarajan	Copyrights on TC plants	07.09.23	Puthiyathalaimurai
	About NRCB technologies	22.09.23	Puthiyathalaimurai
	About VIROCON	01.12.23	DD Tamil, Sun News, Thanthi Dinamalar and Tamilan
K.N. Shiva	NRCB's contribution towards Value addition	13. 05.23	DD Malayalam
I. Ravi	International workshop on Phenotyping	12.03.23	Sun News TV, Puthiyathalamurai TV, Maalai Murasu Seithikal–TV, Sathiyam TV
C. Karpagam	About NRCB Stall at Pusumai Vikadan mela	30.04.2023	Tamilan TV
	About NRCB Exhibition and Kisan mela during NRCB foundation Day	21.08.2023	Makkal TV, Puthiyathalaimurai TV and Jaya TV
	About NRCB Extension activities	22.09.2023	Puthiyathalaimurai TV
	Outreach on importance of VIROCON 2023	01.12.2023	Thanthi TV, Sun News TV, Sathiyam TV, Tamilan TV and Dinamalar TV

5.3 Exhibitions conducted / participated

Name of the event	Organizer & Venue	Date	Name of the staff participated
Banana Stakeholders Meet 2023	EDII-PHBIF, HC&RI, Periyakulam, Tamil Nadu	25 January, 2023	R. Selvarajan K.N. Shiva
National Science Day 2023	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	28 February, 2023	All Staff of NRCB

Farm Fest 2023 cum 33rd Flower, Vegetable and Fruit show	Department of Agriculture & Farmers welfare, AFT grounds, Puducherry	10-12 February, 2023	C. Karpagam A. Mohanasundaram P. Ravichamy
National Horticulture Fair 2023	ICAR-IIHR, Hessaraghatta, Bangalore, Karnataka	22-25 February, 2023	V. Kumar P. Ravichamy
Agri Expo 2023	Pasumai Vikatan, Kalaiarangam Marriage Hall, Tiruchirappalli, Tamil Nadu	28-30 April, 2023	C. Karpagam K. N. Shiva P. Suresh Kumar M. Loganathan D. Ramajayam A. Mohanasundaram P. Ravichamy R. Pitchaimuthu N. Marimuthu M. Bathrinath
Tamil Nadu Stale Level "Agri Expo- 2023" – Velan Sangamam	Ministry of Agriculture and farmers Welfare, Govt. of Tamil Nadu, held at CARE Engineering College, Tiruchirappalli, Tamil Nadu	27-29 July, 2023	C. Karpagam V. Kumar R. Thangavelu K. N. Shiva P. Suresh Kumar M. Loganathan D. Ramajayam A. Mohanasundaram P. Ravichamy R. Pitchaimuthu M. Bathrinath
ICAR-NRCB's 30th Foundation Day and *Kisan Mela*	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	21 August, 2023	All Scientists of NRCB
Banana stakeholders Meet	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	26 August, 2023	All Scientists of NRCB
Freedom Fighters Day Celebration at Raj Bhavan	Raj Bhavan, Chennai, Tami Nadu	2- 5 October, 2023	R. Selvarajan C. Karpagam S. Harishwar S. Ajith Kumar C. Sivananth
Small ICOP (Nasha Mukht Bharat Abhiyan), Festember-2023	NIT, Tiruchirappalli, Tamil Nadu		K. N. Shiva P. Ravichamy
XVI Agriculture Science Congress 2023 and ASC Expo	Organized by ICAR-CMFRI and NAAS, held at Kochi, Kerala	10-13 October, 2023	R. Selvarajan P. Suresh Kumar S. Harishwar S. Ajith Kumar

GRAMEEN MAHOTSAV	HDFC, Tiruchirappalli, Tamil Nadu	13 October, 2023	K. N. Shiva P. Ravichamy M. Bathrinath
Industrial Expo-2023	ICAR-IIHR, Bengaluru	13 October, 2023	P. Suresh Kumar
X Indian Horticulture Congress	Assam Agriculture university, Jorhat	30 October, 2023	P. Suresh Kumar
VIROCON Banana Expo-2023	Hotel courtyard marriott Hotel, Tiruchirappalli, Tamil Nadu	1-3 December, 2023	C. Karpagam P. Ravichamy P. Durai V. Selvaraj S. Harishwar S. Ajith Kumar

Farm Fest 2023 at AFT grounds, Puducherry

"Agri Expo 2023" organized by PASUMAI VIKATAN

Agri Expo-2023 organized by Ministry of Agriculture and Farmers Welfare, Govt. of Tamil Nadu

NRCB's 30th Foundation Day & Exhibition

Stakeholders Interactive Meet

Banana Exhibition, Governor's office

National Science Day 2023

XVI Agriculture Science Congress 2023, Kochi

6. EDUCATION AND TRAINING

6.1. Education – Students guided by NRCB Scientists

Chairperson	Degree	Project title	Student Name
S. Backiyarani	M. Sc. (Life Sciences)	Cloning and molecular characterization of type III polyketide synthase genes from banana cultivar Yangambi KM 5	A. Shobana
	M. Sc. (Biotechology)	Cloning and analysis of disease resistant gene in eumusae leafspot resistant and susceptible banana cultivars	K. Bhuvaneswari
M.S. Saraswathi	B. Tech (Biotechnology)	Studies on expression of Dirigent protein 11 isoforms in Eumusae leafspot resistant and susceptible cultivars of North Eastern India	R. Rajasoundarya
	M. Tech.	Soil-less acclimatization of shoot tip derived plantlets & exogenous application of Salicylic acid for enhanced salinity stress tolerance	S. Sujith
	M. Sc (Biotechnology)	Cloning and characterization of Dirigent 11 gene from *Musa* spp. of North Eastern origin	S. Ajay
	M. Sc. (Biotechnology)	*In vitro* screening of banana cv. Grand Nainefor Foc resistance using toxins	S. Pavithra
	M. Sc. (Biotechnology)	Cloning and Characterization of downy mildew resistance 6 (*dmr6*) gene from banana	P. Jeyaprakash
I. Ravi	M. Sc. (Food Sci. & Technology)	Development of banana starch based edible coating to extend shelf life of dessert banana	Keerthana
	M. Sc. (Food Sci. & Technology)	Development of fortified banana fig with minerals & sweetened peel with ginger flavour	Anjana. S. Anand
P. Suresh Kumar	M. Sc. (Food Processing)	Development of smart packaging indicators using banana anthocyanin and starch	Keerthana, D
	M. Sc. (Food Processing)	Microencapsulation of probiotic bacteria with banana starch	Vanipriya C
	M. Sc. (Food Processing)	Effect of starch and modified starch bread during storage	Harshitha S
	M. Sc. (Food Processing)	Banana rhizome flour addition in technical and functional properties of extruded products	Dharshana S
	M. Sc. (Food sci. & Technology)	Isolation and characterization of Non starch polysaccharides from banana pomace & puree	Hiba Rasmin
	M. Sc. (Food sci. & Technology)	Comparison of different dryers and infusion materials for the development of fortified banana fig	Sreethu Jith

M. Mayil Vaganan	M. Sc. Biotech.	*In vitro* multiplication & molecular characterization of three elite iron transgenic events of Grand Naine (*Musa* spp.) genetically modified with OsNAS genes	N. Vijaya Bharathi
	M. Sc. (Food Sci. and Tech.	Development of nutraceutical banana squash infused with anthocyanins from banana (Monthan) flower bracts & its characterisation	K. P. Shifa
Shiva, K. N.	M.Sc. (Food Processing)	Standardization and Development of Banana and Millet Grits based Snack Bar	T. Anumeka
A.Mohana Sundaram	Ph. D	Bio-ecology of *Eublemma amabilis* Moore & evaluation of certain entomopathogenic fungi for its management	Binita Borah
	M. Sc.	Establishment of *Beauveria bassiana* as endophyte in rice seedlings through differential application methods to assess the biocontrol potential against rice leaf folder	A. Arun
	M. Sc.	Studies on assessment of natural decontaminant for insecticide residues in vegetables	G. S. Rubesh

6.2. Training for Capacity Development for farmers and Students and other Stakeholders

6.2.1. On-Campus Trainings

World IP Day: "Women and IP: Accelerating Innovation and creativity"	P. Suresh Kumar	45	26 April 2023
IP awareness program	P. Suresh Kumar	49	18 July 2023
PPV&FRA awareness program	M.S. Saraswathi	40	20 July 2023
IP awareness program	P. Suresh Kumar	120	10 August 2023
Advanced Agricultural Engineering Technologies - Training cum demonstration of machinery for banana processing	K.N. Shiva P. Suresh Kumar Pramod S. Shelake	30	21 September 2023
Advanced Agricultural Engineering Technologies - Training cum demonstration of machinery for banana processing	K.N. Shiva P. Suresh Kumar Pramod S. Shelake	25	15 November 2023

World IP Day

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Demonstration of Drone technology for managing leaf spot disease in banana in Kalakkadu, Tirunelveli District	R. Selvarajan C. Karpagam R. Thangavelu M. Loganathan	300	08-09 January 2023
Demonstration of Drone technology for spraying Banana Shakti in Erasai, Kokilapuram, Appepatti, and Gudalur of Theni District	C. Karpagam M. Loganathan R. Selvarajan	150	08-09 February 2023
Demonstration of Drone technology for spraying Banana Shakti in Thottiyam, Trichy	C. Karpagam	120	23 January 2023
Demonstration of Drone technology for spraying Banana Shakti in Theni	C. Karpagam	150	21–22 February 2023
Demonstration of Drone technology for spraying Banana Shakti in Paramathy Velur, Namakkal	C. Karpagam S. Harishwar	175	22–23 March 2023
“Hi-tech banana cultivation in changing climate scenario” organized jointly by ICAR-NRCB and JISL at Badwani	R. Selvarajan K. J. Jeyabaskaran M. Loganathan	300	1 June, 2023
Hands-on training on “Integrated pest management in banana” organized at Kumaramanagalam, Kulithalai, Karur Dt.	M. Loganathan A. Mohanasundaram	50	11 August, 2023
Advances in Banana cultivation and integrated management of Fusarium wilt and other biotic stresses in Kushinagar, UP	R. Selvarajan R. Thangavelu K. J. Jeyabaskaran M. Loganathan	180	27 September, 2023
NRCB’s contribution towards Value addition in banana and role of ITMU and ABI	K.N. Shiva	500	May 5, 2023
Training under VBSY at Sekkanam panchayat, Vaiyampatty block, Trichy.	C. Karpagam P. Sureshkumar S. Ajith kumar S. Harishwar	500	December 29 , 2023

Capacity Development Programme

Off campus Training

On campus Training

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
Best Stall Award for Extension Exhibition at Farmers Mela	Best Stall Award at the 'National Horticulture Fair-2023' organized by ICAR-IIHR, held at ICAR-IIHR, Hessaraghatta, during February 2023."
	Best Stall Award at the Tamil Nadu State Level 'Agri Expo-2023' held at CARE Engineering College, Tiruchirappalli, organized by the Ministry of Agriculture & Farmers' Welfare, Government of Tamil Nadu, during July 2023."
	Best Stall Award at the XVI Agriculture Science Congress Expo-2023 held in Cochin during October 2024, organized by the Government of Kerala."
R. Selvarajan	Dr. B. P. Pal Memorial NABS-Best Scientist Award for 2021 during the 13th NABS National Conference held at Periyar University, Salem, Tamil Nadu, on January 25, 2023.
	Plaque of honour for outstanding contribution to plant protection sciences from the Indian Phytopathological Society (IPS) and the University of Mysore.
Selvarajan R, Balasubramanian V, Sundaram S, Fhilmar Raj JM	Best Oral Presentation Award at the National Symposium held jointly at ICAR-CTCRI, Thiruvananthapuram, Kerala, in September 2023.
Selvarajan R, Balasubramanian V, Soundarya D, Backiyarani, S	Best Poster Presentation Award at VIROCON-2023, organized by ICAR-NRCB and the Indian Virological Society, New Delhi, held in Tiruchirappalli, Tamil Nadu, in December 2023.
Selvarajan R, Balasubramanian V, Sundaram S, Fhilmar Raj JM, Parkavi R, Anuradha.C.	Best Poster Presentation Award at VIROCON-2023, organized by ICAR-NRCB and the Indian Virological Society, New Delhi, held in Tiruchirappalli, Tamil Nadu, in December 2023.
Selvarajan R, Makesh Kumar T, Balasubramanian V and Fhilmar Raj JM	Best Poster Presentation Award at VIROCON-2023, organized by ICAR-NRCB and the Indian Virological Society, New Delhi, held in Tiruchirappalli, Tamil Nadu, in December 2023.
Selvarajan R, Balasubramanian V, Sundaram S, Fhilmar Raj JM, Parkavi R, Anuradha C	Best Poster Presentation Award for the research paper titled 'Development of Sensitive Detection of Cucumber Mosaic Virus Infecting Banana with a Monoclonal Antibody-Based Triple Antibody Sandwich-Enzyme Linked Immunosorbent Assay' at VIROCON-2023, jointly organized by ICAR-NRCB and the Indian Virological Society, New Delhi, held in Tiruchirappalli, Tamil Nadu, in December 2023."
A. Kiruthika, R. Sasikala, Balasubramanian V, Sundaram S, Sangita, V. Loganathan, M. Selvarajan R,	Best Poster Presentation Award at the National Symposium jointly organized by ICAR-CTCRI and the Indian Phytopathological Society, New Delhi, held during 11-12 September 2023.

Anuradha C, Selvarajan R, Chandrasekar A, Prashina Mol P, Balasubramanian V, and Uma S.2023	Best Oral Presentation Award at VIROCON-2023, jointly organized by ICAR-NRCB and the Indian Virological Society, New Delhi, held in Tiruchirappalli, Tamil Nadu, in December 2023."
P. Giribabu	'Professor M.S. Swaminathan Best Scientist Award' 2022-23 from the Bose Science Society, Pudukkottai, Tamil Nadu, on 28 February 2023.
	Certificate of Appreciation from the 'State of India's Birds 2023' for making a valuable contribution to documenting 139 bird species for the State of India's Birds Report 2023
	Second place in the men's chess event at the ICAR South Zone Sports Tournament 2023, organized by ICAR-IIHR, Bengaluru, during 13-16 December 2023.
A. Mohanasundaram	Second prize in the Hindi Elocution competition organized by the Town Official Language Implementation Committee Divisional Railway Manager, Trichy, on 17 February 2023.
	AVIAN Award for Plant Protection-2023 at the AVIAN Trust Awards-2023 ceremony held on 16 December 2023.
C. Anuradha	Prof. M.S. Swaminathan Best Scientist Award 2022-23 from the Bose Science Society and Tamil Nadu Scientific Research Organisation
	INSC Research Excellence Award – 2023 by Institute of Scholars
	Best Oral Presentation Award at the International Conference on New Generation Horticulture for Prosperity, held in Bhubaneswar, Odisha, India, in January 2023.
	Best Oral Presentation Award at VIROCON-2023, jointly organized by ICAR-NRCB and the Indian Virological Society, New Delhi, held in Tiruchirappalli, Tamil Nadu, in December 2023.
P. Suresh Kumar, Ravindra Naik	Best Oral Presentation Award at International Symposium on Engineering Interventions for Making Millets a Global Food, organized by ISAE, New Delhi, and UAS Raichur, November 6-8, 2023.
Suresh Kumar P, Amelia Keran D, Pushpavalli S, and Shiva KN	Best Technology Award in 2023 for their work on the 'Preparation of Low-Cost Foam Mat Dried Ripe Banana Powder' during the ICAR Foundation Day celebration.
Shuprajhaa. T, Suresh Kumar P, Sheeba K. N, Dhayalini K	Best Paper Award at the Second International Conference on Electrical, Electronics, Information, and Communication Technologies in 2023.

Best Stall Award at Trichy-2023

Best Stall Award at Kochi-2023

ICAR- Best technology, preparation of low-cost foam mat dried ripe banana powder

7.2. Important and Special Recognitions Received by the Scientists

Dr. R. Selvarajan, Director
Organizing Secretary, VIROCON-2023
Organizing Secretary, Pre-Conference National workshop of VIROCON 2023
Organising Secretary, National Workshop on “Paradigm in Production and Utilization of Banana”
International Coordinator, International Workshop by ICAR–NRCB, Alliance of Bioversity International and CIAT, Italy.
Chief guest, College Day function at Cauvery College for Women, in March 2023.
Chief guest, Conference on Law and Agriculture held in Tiruchirappalli in May 2023.
Chief guest, National Technology Day organized by NIFTEM, in May 2023.
Chief guest, BIOFEST 2023 organized by Bishop Heber College, in March 2023.
Chief guest, Conference on improved production technologies organized by UHS
Chief guest, Workshop on “Sirumalai,” a GI tagged banana, in December 7th, 2023
Chief guest, FIRMA 2023, organized by Bishop Heber College, in September 2023
Chief guest, National Dialogue on Diseases Transmitted from Plants to Humans
Member (DG Nominee) for CAS/ promotion of scientists ICAR-NRC on Seed Spices, in January 2023
Member (DG Nominee) for ASRB interview New Delhi, in May 2023
Coordinator for Agriculture sector, ICAR-CRP on vaccine and diagnostic project
Member (DBT), Institute biosafety committee, ICAR- CTCRI, Thiruvananthapuram, Kerala
Member, State variety release committee, Govt. of Tamil Nadu
Secretary (Plant Virology), Indian Virological Society, New Delhi
Member, Editorial Board, Virus Disease Journal published by in IVS, New Delhi
Member, National organizing committee for International Seminar conducted by ICAR-IIHR, Bengaluru
Member, Advisory committee for National symposium organized by ICAR-CTCRI
Member, Selection Committee of Senior Scientist & Head in ICAR-KVK, CENDECT
Convenor, Programme committee in VIROCON-2023
Panellist, National workshop on “ Plant Virus Disease Management” organized during VIROCON-2023
Chairman, Technical Session 2 during Platinum Jubilee Conference organized by IPS and UoM
Chairman, Session V, 10th Indian Horticulture Congress organized by the IAH
Chairman, Session II, National symposium on Plant Health Management at ICAR-CTCRI
Co-Chair, Session IX, 10th Indian Horticulture organized by the IAHS
Co-Chair, Session V, International Seminar by the SPH and ICAR-IIHR, Bengaluru
Co-Chair, Session 7, during VIROCON-2023
Co-Chair, Panel discussion1, Global Conference organized by CHAI, ICAR-NRCB, JISL &ASM
Moderator, Agri Marketing Expo 2023 organized by DoAM&AB, Govt. of TN..
Co-Chair, Panel Discussion-2, National Workshop organised by CHAI, ICAR-NRCB, JISL &ASM
Invited talk, 2nd Conference of WSV at Riga Stradins University, Riga, Latvia.

Sharing insights on Gender and Plant Health in the workshop organized by the IPC, Nairobi, Kenya
External examiner for the evaluation of M.Sc. and PhD thesis from TNAU, AU, and UD.
Doctoral committee member, VIT, KAU and SRM University
Editor, Virus disease, springer, IVS- New Delhi
Dr. J. Poorani, Principal Scientist
Member (DG's nominee) for promotion of scientists in the discipline of Entomology, ICAR-SBI and ICAR-IISR
External Reviewer for Ph.D. Thesis submitted to University of Calicut, Calicut
Peer Reviewer for research articles, Zootaxa; Austral Entomology
Convenor, VIROCON 2023; Convenor, Secretariat, VIROCON 2023; Chairperson, Publication Committee, VIROCON 2023; Convenor, Technical Session 4: Host-Virus-Vector Interplay (Plant Virology), VIROCON 2023
Dr. R. Thangavelu, Principal Scientist
Member in Board of studies of Srimad Andavan Arts and Science college
Member in the Selection Committee of Senior Scientist & Head in ICAR-KVK, CENDECT
Co-chair, National symposium at ICAR-CTCRI, in September 2023
External examiner for the evaluation of thesis from the Sultan Qaboos University, Sultanate of Oman
Lead talk at the National symposium at ICAR-CTCRI, in September 2023
Panellist in Consultative Meeting on GI Banana organised by Government of Karnataka
Convenor of Session 6, in VIROCON-2023 during during 1-3 December 2023
Dr. M. Loganathan, Principal Scientist
Co-Convenor, "VIROCON-2023" organised by IVS & ICAR-NRCB, in December 2023.
Convenor of Session I during VIROCON-2023 organised by IVS & ICAR-NRCB, in 2023.
Convenor, National Workshop on "Plant Virus Disease Management" during VIROCON 2023
Panellist, National Workshop on "Plant Virus Disease Management "during VIROCON 2023
Panellist in Consultative Meeting on GI Banana organised by Government of Karnataka
Keynote talk "Hi-tech banana cultivation" organised by ICAR-NRCB and JISL at Badwari
Panellist, Panel discussion on "IoT and AI–Managed" held at ICAR-NRCB on 21.08.24.
Doctoral committee member for VIT students
External Member for guiding M.Sc. Research from AC& RI, Trichy.
Member for CAS/ promotion of scientist ICAR-DCR, Puttur
External Examiner for evaluation of M.Sc & thesis of TNAU, AU, UAS and CAU
Accreditation for guidance of PG/Ph.D students and research work as Faculty of Dr. YSRHU
Dr. A. Mohanasundaram, Senior Scientist
Managing Editor - SANRAG e-Newsletters, January, 2023 and July, 2023
Editor - Agriculture and Food (e-newsletter)
Reviewer, Indian Journal of Entomology and Journal of Non-Timber Forest Products
Attended the Board of studies meeting of Zoology, Bishop Heber College, Tiruchirappalli
External expert for Viva-Voce of Ph. D. students from Forest Research Institute, Kerala
Convenor for two technical sessions in 'VIROCON 2023'

Selection committee for the post of YP and JRF
S.Backiyarani
Evaluated the Ph.D. thesis from K.P Mangalore University
Evaluated the M.Sc (Biotechnology) thesis from TNAU
Accreditation for guidance of PG/Ph.D students and research work as Faculty of Dr. YSRHU
V.Kumar
External Examiner, M.Sc. /Ph.D. programs by TNAU, Coimbatore, T. N
External Examiner, M.Sc./Ph.D. programs by UHS, Bagalkot, Karnataka
External Examiner for Ph.D. Viva-voce by Dr YSRHU, Andhra Pradesh
M.S. Saraswathi
Evaluated one Ph.D (Fruit Science) thesis from Indian Agricultural Research Institute, New Delhi
External Examiner for Ph.D. final viva-voce at IARI
External Examiner for Ph.D. qualifying viva-voce at IARI
Evaluated M.Sc. theses for HC&RI, TNAU, Coimbatore, and Dr.YSRHU
Panellist, Consultative Meeting on GI Banana organised by Government of Karnataka
Rapporteur, Technical session for National Seminar held at IISR, Lucknow
Convenor for Medical and Aquatic Virology sessions of VIROCON 2023
P. Suresh Kumar
Member, CAS/ promotion committee of staff of NIFTEM
Member, “Expert Group” for implementing the PM-DevINE project
Rapporteur, Scientific Panel in 28th meeting of Scientific Panel of Fruits and Vegetables
External expert,Selection Committee of RA/SRF/Project Associate-I on contract basis at NIFTEM-T
Member,Scientific Panel on Fruits & Vegetables and their Products, FSSAI, GoI
Member, CAS/Promotion committee of the teaching faculties: 14 Scientists of NIFTEM-T
Member, Cost fixation committee. 26 Technologies. 8th November 2023. NIFTEM, Thanjavur
Reviewer, 19 Horticulture and food processing related journals.
K.N.Shiva
Nominated as member to participate in the 26th SAC Meeting held at ICAR-KVK, Cuddalore
Guest of honour during inaugural function of ECCENTRIC ORGANIC PVT LTD
Guest of honour during BANANA STAKEHOLDERS MEET organized by HC & RI,
Nominated as member to participate in the 20th SAC meeting held at ICAR-KVK Salem
Nominated as SMS for the XGroup Discussion of AICRP-Fruits Review Meeting.
Chief Guest,National Conference organized by Sengamala Thayaar Educational Trust
Convenor, World IP Day–organized by ICAR-National Research Centre for Banana,
Nominated as member of IMC to ICAR- Indian Institute of Spices Research, Kerala
Team Leader by ICAR-NRCB for conducting Re-examination of ICAR-IARI, Technician (T-1)
External member for CAS/ proforma of TO at NIFTEM-T
Recognized as PG/Ph.D. Guide by Dr. YSRHU, A.P.
Chairman, Workshop organized by Public Policy Research Institute (PPRI), Kerala
Expert during Regional Review Workshop on Horticulture related issues

Convenor, Technical Session in VIROCON–2023
Chef De Mission for ICAR-NRCB Sports Contingent (12) in the South Zone Sports Tournament
M. Mayil Vaganan
National Coordinator of International Workshop held at ICAR-NRCB
Coordinator of Phase Two Training-Orientation Programme
Chairperson of VIP Coordination and Hospitality Committee of VIROCON-2023
Convenor, Technical Session during VIROCON-2023
External Examiner for Ph. D. thesis from Bharathidasan University
I. Ravi
External Examiner for Ph. D. thesis from Osmania University
External Examiner for Ph. D. thesis from Acharya N.G.Ranga Agricultural University, Andhra Pradesh
C. Anuradha
Professional member of InSc international publishers.
Recognized as chairman, co-chairman and member of PG/Ph.D programmes of Dr. YSRHU
Member in Selection committee for selecting the post of YP–I under the ICAR–AICRP
Member, Selection committee of YP I for breeding project
Member, selection committee of Project Scientist under DBT-QUT project
Member, Selection Committee of YP II for TC plants project
Member, Selection Committee of YP I for the external project
Member, Selection Committee of YP I for the Institute In-house project t
Reviewer, 3Biotech related journals
Life member of Bose Science Society, life member of INSC
Fellow, Bose Science Society
Co-Convenor of VIROCON-2023
Convenor for Pre-Conference National workshop of VIROCON 2023
Convenor, Publication committee, VIROCON 2023
Co-Convenor, Organizing committee, VIROCON 2023
Co-chairperson Registration, reception, VIP co-ordination & Hospitality committee of VIROCON 2023
Member; Resource mobilization, Web designing, Secretariat& Poster ccommittee of VIROCON 2023
Convenor, Technical session 3, VIROCON 2023
C. Karpagam
National Coordinator of International Workshop held at ICAR-NRCB
External Examiner for Ph.D. Viva Voce at AC&RI, Madurai on January 6, 2023.
Interview Member for the Head Post at KVK, Tenkasi on January 23, 2023.
Chairman, selection committee of YP I for Agriculture Drone Project
Expert member, ‘Agri Expo 2023’ meeting organized by the Tamil Nadu Agriculture Department
Chairman, selection committee of YP I for ITC Bioversity International Project

Panellist, Technical Session on “IoT and AI – Managed Banana Cultivation and Digital Marketing”
External Examiner for Ph.D. (Agricultural Extension) Thesis from Kerala Agriculture University, Kerala
Convenor, National workshop during VIROCON 2023
Convenor, National workshop on “Lumpy Skin Disease Management in Cattle” during VIROCON
Chairperson; Publicity, Exhibition, Extension & Library Advisory Committee of ICAR-NRCB Member Secretary: Publication and Documentation Committee
Member Secretary of Publication and Documentation Committee ICAR-NRCB
Chairperson: Award, Media Publicity Committee of Foundation day 2023
Co-chairperson; Registration, Farmers Coordination Committee of Foundation day 2023
Convenor: Publication Committee of Foundation day 2023
Chairperson; Media Publicity Committee, & Exhibition Committee of VIROCON 2023
Co-chair of Publication Committee of VIROCON 2023
P. Giribabu
Key Speaker at ‘National Conference on Plant Parasitic Nematodes 2023
Fellow of Bose Science Society, Pudukkottai, Tamil Nadu
Chairman / member of advisory committee of PG programs for Dr.Y.S.R.H.U, AP
Convener for three technical sessions in VIROCON 2023
Reviewer – Indian Journal of Nematology
External Examiner for M.Sc. thesis

8. LINKAGES AND COLLABORATIONS

8.1. Collaborations

Project Title	Collaborating Institute(s)
Artificial Intelligence (AI) powered decision support system development for leaf spot disease management in banana (Lead centre: ICAR-NRCB)	BRS, Jalgaon (Maharastra) FRS, NAU, Gandevi (Gujarat) BRS, KAU, Kannara (Kerala) HRS, Kovvur (AP) HRS, Pulivendula (AP) ICAR-IIHR, Bengaluru (Karnataka) College of Hort., Arabhavi (Karnataka) HC &RI, TNAU, Coimbatore (Tamil Nadu) Rajendra Prasad Central Agricultural University, Pusa
Eco-friendly management of banana pseudostem weevil (*Odoiporus longicollis* Olivier) and banana scarring beetle (*Basilepta* spp.)	Assam Agricultural University, Jorhat ICAR RC for Eastern Region, Patna ICAR RC for NE Hilly Region, ICAR-NBAIR, Bengaluru
Effective utilization of different extension methods and mass media for holistic transfer of banana technologies for different stakeholders in banana production system	KVKs, ATARIs, FPOs from different states, ATMA, AIR, Trichy, FM stations, Television Channels, Mass and print media, SAUs.

8.2. Signing of MoUs / MoCs / MoAs

Name of the company / Organization	Purpose	Date
Academic Institutions		
Jamal Mohamed College, Tiruchirappalli	Student exchange & collaborative research	31.01.23
Sathyabama Institute of S&T, Chennai	Student exchange & collaborative research	01.03.23
CARE college of Engineering, Tiruchirappalli	Student exchange & collaborative research	14.03.23
PSG Krishnammal College (W), Coimbatore	Student exchange & collaborative research	15.05.23
Alagappa University, Karaikudi	Student exchange & collaborative research	01.06.23
Lovely Professional University, Punjab	Student exchange & collaborative research	07.07.23
Dr. YSRHU, Andhra Pradesh	Student exchange & collaborative research	03.11.23
Dayal Upadhyaya Gorakhpur University, Uttar Pradesh	Student exchange & collaborative research	03.11.23
SRM Institute of S &T, Chengalpattu	Student exchange & collaborative research	26.12.23

Companies		
Shalom Info Tech Pvt Ltd, Tiruchirappalli	Project specific collaboration	14.03.23
TN Banana Growers Federation/UNIDO/ TESSOL	Project Specific collaboration	21.12.23
Imaya Marketing, Tiruchirappalli	Operation of Common Incubation Centre	21.12.23
Government Agencies		
North East Centre for Technology Application and Reach (NECTAR), Meghalaya	Project Specific collaboration	07.06.23

North East Centre for Technology Application and Reach (NECTAR), Meghalaya

Thermal Energy Solutions Pvt. Ltd, (TESSOL), Mumbai (A UNIDO funded company) and Tamil Nadu Banana Growers Federation, Trichy

9. PUBLICATIONS

9.1 Research Papers

9.1.1 International

Aasha Nandhini, S, Hemalatha, R, Radha, S, Shreya, Gaur and Selvarajan, R. 2023. A smart agriculturing IoT system for banana plants disease detection through inbuilt compressed sensing devices. *Multimedia Tools and Applications*. https://doi.org/10.1007/s11042-023-15442-6.

Anuradha, C, Ramajayam, D, Mayilvaganan, M, Backiyarani, S, Mol, PP, Mailraja, VK, Singh, A, and Uma, S. 2023. Molecular characterization of Red banana and its somaclonal variant: a comprehensive study. *3 Biotech*. 14(1): 19.

Anuradha, C, Chandrasekar, A, Backiyarani, S, Thangavelu, R, Uma, S and Selvarajan, R. 2023. Dataset from transcriptome profiling of *Musa* resistant and susceptible cultivars in response to *Fusarium oxysporum* f.sp. *cubense* race1 and TR4 challenges using Illumina NovaSeq. *Data in Brief*. https://doi.org/10.1016/j.dib.2023.109803.

Anuradha, C, Chandrasekar, A, Backiyarani, S, Thangavelu, R, and Uma, S. 2023. Genome-wide identification, characterization, and evolutionary analysis of NBS genes and their association with disease resistance in *Musa* **spp.** *Functional & Integrative Genomics*. 23 (1), 7.

Anuradha, C, Chandrasekar, A, Prashina Mol, P, Backiyarani, S, Thangavelu, R and Uma, S. 2023. Genome-wide characterization of 2OGD superfamily for mining of susceptibility factors responding to various biotic stresses in *Musa* spp. *Physiology and Molecular Biology of Plants*. 29 (9): 1319-1338.

Babu, N, Tripathi, R, Sampathkumar, M, Caleb, JTD, Prasad, G, Mohanasundaram, A, Mahendiran, G and Sudhikumar, AV. 2023. Two new species of *Afraflacilla* Berland et Millot, 1941 (Araneae: Salticidae: Chrysillini) from India. *Arthropoda Selecta*. 32(4): 459–465.

Goraksha C Wakchaure, Pratapsingh S Khapte, Satish Kumar, Paramasivam Suresh Kumar, Leo Sabatino and Pradeep Kumar. 2023. Exogenous Growth Regulators and Water Stress Enhance Long-Term Storage Quality Characteristics of Onion. *Agronomy*. 13, 297.

Ishwara Bhat, A, Selvarajan, R and Balasubramanian, V. 2023. Emerging and re-emerging diseases caused by badna viruses. *Pathogens*. 12(2): 245.

Jeyabaskaran, KJ, Pitchaimuthu R, Shiva KN, Loganathan M and Uma, S. 2023. Optimising combinations of different nutrient sources of organic banana farming. *Acta Horticulturae* 1367, 151–160.

Muthukumar, S, Sajeev, TV, Thamilarasi, K, Mohanasundaram, A and Lohot, VD. 2023. Trial for the propagation method in *Flemingia spp*., a shrub plant and a lac insect host in Thrissur, Kerala, *International Journal of Zoology and Applied Biosciences.* 8(6): 84-85.

Peng, F, Poorani, J, Booth, R G, Wang, X, Chen, X and Anuradha, C. 2023. *Slipinskiscymnus* gen. nov., a new ladybird genus of Scymnini (Coleoptera, Coccinellidae) and notes on the taxonomic status of *Keiscymnus* Sasaji. *Zootaxa.* 5325 (1): 97–115.

Poorani, J and Jat, BL. 2023. New host plant records for melon ladybird *Chnootri baelaterii* (Rossi) (Coleoptera: Coccinellidae) from India. *Specimen Micropublications*. https://doi.org/10.56222/28166531.2023.19.

Poorani, J and Thanigairaj, R. 2023. A brief review of the tribe Telsimiini (Coleoptera: Coccinellidae) of the Indian subcontinent, including three new species of *Telsimia* Casey from South India. *Zootaxa.* 5352(3): 358–380.

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new species of *Scymnus* Kugelann (Coleoptera: Coccinellidae) predatory on amla aphid, *Schoutedenia emblica* (Patel & Kulkarni) (Hemiptera: Aphididae), from India. *Zootaxa.* 5239 (3): 421–430.

Poorani, J, Booth, RG, Anuradha, C, Gandhi Gracy, R, Thanigairaj, R and Swathi, RS. 2023. Identity of the 'true' *Micraspis discolour* (Fabricius) (Coleoptera, Coccinellidae) with illustrated diagnostic notes on other *Micraspis* spp. in Indian paddy fields. *Zootaxa.* 5271(3): 446–476.

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Sajeev, TV, Muthukumar, S, Krishnan, JK, K, Thamilarasi, Mohanasundaram, A and Lohot VD. 2023. First report of two insects, *Megachile* sp. and *Armadillidium* sp., as new pests on *Flemingia* spp. in Thrissur, Kerala, *International Journal of Zoology and Applied Biosciences*. 8(6): 86-88.

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Selvarajan, R, Renukadevi, P, Balasubramanian, V, Rao, MV, Krishna Reddy, M and Malathi VG. 2023. Association of tomato spotted wilt virus on *Gymnema sylvestre* R.Br. in India. *Journal of Plant Pathology*.1-2. https://doi.org/10.1007/s42161-023-01305-4.

Shuprajhaa, T, Mathav Raj J, Suresh Kumar, P, Sheeba K N and Dhayalini K. 2023. Deep learning based mobile application for varietal identification and ripeness grading of traditional Indian Banana varieties. *Second International Conference on Electrical, Electronics, Information and Communication Technologies (ICEEICT)*. DOI: 10.1109/ICEEICT56924.2023.10157578.

Shuprajhaa, T, Mathav Raj J, Suresh Kumar, P, Sheeba K N and Uma, S. 2023. Deep learning based intelligent identification system for ripening stages of banana. *Postharvest Biology and Technology*. 203. 112410. https://doi.org/10.1016/j.postharvbio.2023.112410.

Suresh Kumar, P, Pushpavalli, S, Shuprajhaa, T, Shiva, KN, Sheeba, N, Pushpa, R, and Uma, S. 2023. Influence of chemical modifications on dynamic rheological behaviour, thermal techno-functionalities, morpho-structural characteristics and prebiotic activity of banana starches. *International Journal of Biological Macromolecules*. 249-126125.

Suresh Kumar, P, Shuprajhaa, T, Pushpavalli, S, Mohanasundaram, A, Shiva, KN, Mayilvaganan M and Uma, S. 2023. Ripening dependent changes in skin color, physicochemical attributes, in-vitro glycemic response and volatile profiling of banana varieties. *Food Bioscience.* 56: 103274. https://doi.org/10.1016/j.fbio.2023.103274.

Suresh Kumar, P, Amelia Keran, D, and Uma, S. 2023. Banana based composite flour blends for the development of low gluten convenience food. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. doi.org/10.1007/s40011-023-01462-7.

Suresh Kumar, P, Thayumanavan, S, Pushpavalli, S, Saraswathi, MS, Backiyarani S, Mohanasundaram, A and Uma, S. 2023. Comparing physico-chemical characteristics, antioxidant properties, glycemic response, and volatile profiles of eleven banana varieties. *International Journal of Food Science and Technology*. 58:2893-2908.

Uma, S, Karthic, R, Kalpana, S, and Backiyarani, S. 2023. A comparative assessment of photosynthetic pigments and defense enzymes in ex vitro and *in vitro* propagated plants of banana (*Musa* spp.). *Biocatalysis and Agricultural*

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Uma, S, Raju Karthic, Sathiamoorthy Kalpana and Suthanthiram Backiyarani. 2023. Evaluation of temporary immersion bioreactors for in vitro micropropagation of banana (*Musa* spp.) and genetic fidelity assessment using flow cytometry and simple-sequence repeat markers. *South African Journal of Botany*. 157: 553-565.

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9.1.2 National

Arun, A, Ambethgar, V, Kalyanasundaram, A, Loganathan, M, Senthil, K and Mohanasundaram, A. 2023. Unleashing the potential of endophytic *Beauveria bassiana* as a biocontrol agent against rice leaf folder (*Cnaphalocrocis medinalis*). *The Pharma Innovation Journal.* **SP-**12(8): 2136–2141.

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Jadhav, MM, Shashank, PR, Rani, AT, Mohanasundaram, A, Rajgopal, NN, Naik, S, Patil, R and Prakash, NR. 2023. DNA Barcoding, Morphological Description and Field Diagnostics of *Eublemma amabilis* (Lepidoptera: Erebidae). *Indian Journal of Entomology.* 85 (Special Issue): 96-100. https://doi.org/10.55446/IJE.2023.1169.

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Mohanasundaram, A, Sharma, KK, Monobrullah, Md, Choudhary, JS, Pramanik, A, Zeeshan, N and Yadav, M. 2023. Weather based forecasting model for emergence of *Aprostocetus purpureus* (Cameron) – a parasitoid of lac insect, *Kerria lacca* (Kerr), *Journal of Agrometeorology.* 25 (4): 589-594. https://doi.org/10.54386/jam.v25i4.2345.

Muthukumar, S, Sajeev, TV, Vandana, B, Mohanasundaram, A, Sharma, KK, Thamilarasi, K, and Lohat VD. 2023. Studies on the pests of the lac insect host plant *Flemingia semialat*a and *Flemingia macrophylla* in Kerala. *International Journal of Zoology and*

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9.2 Popular Articles

Anuradha, C. 2023. Biotechnological approaches for early screening of breeding lines. Eds. Backiyarani S, Uma S, Saraswathi, MS, Ramajayam, D, Anuradha, C, Durai P and Selvarajan, R. 2023. In: Hands-on Training on Banana Breeding Techniques. ICAR-NRCB, Tiruchirappalli. pp. 13-20.

Arjun Singh, Jeyabaskaran, KJ, Pitchaimuthu R, Kumar V and Uma, S. 2023. Kele me sukshma poshak tatvom kaa prabandhan (Management of micronutrient in banana cultivation)" (in Hindi), "Phal – Phool" (Hindi) March-April edition: pp.25-26.

Backiyarani, S, Uma, S, Saraswathi, MS, Anuradha, C, Ramajayam, D, Durai, P and Selvarajan, R. 2023. Training manual on Banana Breeding Techniques, 58 p.

Hiba Rasmin, Amelia Keran D and Suresh Kumar P. 2023. Non-starch polysaccharides: Revolutionizing food and Health. *Food and Beverages processing*. 10 (1): 42-44.

Mayil Vaganan, M and Ravi, I (2023). Anthocyanin Pigments of Banana Flower Bracts as Food and Pharmaceutical Ingredients. *Agri. Tech.* 1(6): 151-153.

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9.3 Monographs

Poorani, J. 2023. An illustrated guide to lady beetles (Coleoptera: Coccinellidae) of the Indian Subcontinent. Part 1. Tribe Coccinellini. *Zootaxa.* 5332(1): 1–307.

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9.4 Books

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10. CONSULTANCY SERVICES AND COMMERCIALIZATIONOF TECHNOLOGIES

I. Consultancy Services / Contract Research

S. No.	Date	Name of the Technology	Address of the Client	Revenue (Rs.)
1.	02.01.23	Evaluation of efficacy of Potassium Schoenite on banana	Gujarat Boron Derivatives Pvt. Ltd, Baroda.	1028191.00
2.	02.11.23	Evaluation of efficacy of Potassium Schoenite on banana as Potassium source	Anglo American Crop Nutrients India Pvt. Ltd, Delhi.	1862370.00
3.	16.03.23	Study on the efficacy of an automated irrigation and fertigation solution using IoT enabled sensors and satellite imaging to optimize yield and quality of Grand Naine banana in Karnataka - Phase II	Digite Infotech Pvt. Ltd, Maharashtra.	808300.00
II. Commercialisation of Technologies				
1.	20–23.06.2023	Variety specific tissue culture protocols for commercial banana varieties	Dr. Ch. Sudhakar, M/s. HBS Agro & Aqua Services Pvt Ltd, H. No. 2 - 214 / 2, Behind SBI, Thammara, Kodad Mandal, Suryapet District - 508206, Telangana, India	50000.00
2.	19–22.09.2023	Low cost tissue culture protocol for commercial banana varieties	Mr. P. Uthamasamy, M/s. Sathya Biotech, Peeppakkarar Thottam, Bhavani Road, Erode district, Anthiyur - 638501, Tamil Nadu	50000.00
3.	12.12.2023	Kaveri Kalki	Mr. M. Sankar, M/s. Sankar Bio-Tech, Hosur - 635109, Krishnagiri, Tamil Nadu	15000.00
4.	10 & 11.01.2023	Technology for handling of banana leaf for domestic and export markets	H. Vijay Raj, Dohrnii Chain Pvt Ltd, Dindigul	15000.00

5.	02.02.2023	Ramkumar Moorthy, 100 Magalir Thozilagam, Chennai	Ramkumar Moorthy, 100 Magalir Thozilagam, Chennai	15000.00
6.	19-22.09.2023	Low cost tissue culture protocol for Banana	Mr.Vikraman, Erode	50,000.00
7.	23.06.2023	Variety specific tissue culture protocols for commercial banana Varieties	M/s. HBS Agro & Aqua Services Pvt Ltd,	50000
8.	19 - 22.09.2023	Low cost tissue culture protocol for commercial banana varieties	M/s. Sathya Biotech, Erode, Tamil Nadu	50000
9.	02.02.2023	Technology for handling of banana leaf for domestic and export markets	Mr. Ramkumar Moorthy, M/s 100 Magalir Thozilagam (Theni), 718/719, 1st Main Road, MG city, Kundrathur, Chennai - 600069.	15000.00
10.	10&17.02.2023	Post-harvest handling, packing, storage and ripening of banana for domestic and export markets	Mr. H. Vijay Raj M/s. Dohrnii Chain Pvt Ltd., 2/397, Kuttiyapatty, Pillayarnatham, Dindigul - 624002	25000.00
11.	22&23.02.2023	Banana Central Core Stem Based Juice / RTS	Mr. Raghu R. S, M/s. Sri Aarogya Food & Beverages Products, Kulambi (Village) & Post, Near Govt hospital, K. K. Main Road, Honnali (Tk), Davangere - 577219, Karnataka	25000.00
12.	02.03.2023	Banana flour based low glycemic prebiotic extruded snacks like noodles, pasta	Mr. S. Vishnu, M/s. Shivani Agri Horti Primary Processing Centre, 26/B, 2nd Sasthri Street, P. N. Pudur, Coimbatore - 641041, Tamil Nadu	21750.00
13.	02.03.2023	Banana Grits / Suji	Mr. S. Vishnu, M/s. Shivani Agri Horti Primary Processing Centre, 26/B, 2nd Sasthri Street, P. N. Pudur, Coimbatore - 641041, Tamil Nadu	21750.00

14.	02.03.2023	Extraction of banana starch & starch modification	Mr. S. Vishnu, M/s. Shivani Agri Horti Primary Processing Centre, 26/B, 2nd Sasthri Street, P. N. Pudur, Coimbatore - 641041, Tamil Nadu	21750.00
15.	02.03.2023	Low fat fortified banana chips	Mr. S. Vishnu, M/s. Shivani Agri Horti Primary Processing Centre, 26/B, 2nd Sasthri Street, P. N. Pudur, Coimbatore - 641041, Tamil Nadu	21750.00
16.	02.03.2023	Cost effective ripe banana powder	Mr. S. Vishnu, M/s. Shivani Agri Horti Primary Processing Centre, 26/B, 2nd Sasthri Street, P. N. Pudur, Coimbatore - 641041, Tamil Nadu	21750.00
17.	17-18.04.2023	Cost effective ripe banana powder	Mr. Kapil Savle, M/s. Kalpana Banana Processing Industries, Dream Land City, Raver Road, Burhanpur - 450331, Madhya Pradesh.	25000.00
18.	14 - 15.06.2022	Banana central core stem based soup-mix	Mrs. D. Mahalakshmi, Avathavadi (Po), 1/11, Pillayar Kovil Street, Krishnagri - 635204, Tamil Nadu.	15000.00
19.	16-17.05.2023	Cost effective ripe banana powder	Mrs. K. P. Uma Maheswari, M/s. MAC & MIC, 88, Police Station Road, Sivakasi - 626123, Tamil Nadu, India	25000.00
20.	12-13.06.2023	Extraction and softening of banana fibre	Mr. M.H.V.S. Krishnan, 187, Agrakaram, Vembathur, Sivaganga - 630559, Tamil Nadu,	25000.00

21.	21-22.06.2023	Dehydrated ripe banana	Andhra Pradesh Food Processing Society (APFPS) D. No. 48 - 11/1-5/8, Gadde Sambasiva Rao Street, Sri Rama Chandra Nagar, Vijayawada - 520008, Andhra Pradesh, India	22500.00
22.	21-22.06.2023	Cost effective ripe banana powder	Andhra Pradesh Food Processing Society (APFPS) D. No. 48 - 11/1-5/8, Gadde Sambasiva Rao Street, Sri Rama Chandra Nagar, Vijayawada - 520008, Andhra Pradesh, India	22500.00
23.	21-22.06.2023	Banana central core stem juice / RTS	Andhra Pradesh Food Processing Society (APFPS) D. No. 48 - 11/1-5/8, Gadde Sambasiva Rao Street, Sri Rama Chandra Nagar, Vijayawada - 520008, Andhra Pradesh, India	21250.00
24.	21-22.06.2023	Extraction of dietary fibre from central core stem and pectin from banana peel	Andhra Pradesh Food Processing Society (APFPS) D. No. 48 - 11/1-5/8, Gadde Sambasiva Rao Street, Sri Rama Chandra Nagar, Vijayawada - 520008, Andhra Pradesh, India	21250.00
25.	21-22.06.2023	Utilization of stem sheath for making of plates and handicrafts	Andhra Pradesh Food Processing Society (APFPS) D. No. 48 - 11/1-5/8, Gadde Sambasiva Rao Street, Sri Rama Chandra Nagar, Vijayawada - 520008, Andhra Pradesh, India	42500.00

26.	14 &16.08.2023	Dehydrated ripe banana	Mr. H. Vijay Raj M/s. Dohrnii Chain Pvt Ltd., 2/397, Kuttiyapatty, Pillayarnatham, Dindigul - 624002	25000.00
27.	11&12.09.2023	Cost effective ripe banana powder	Mrs. H.R. Minumol 1A, Sreya Apartment, 1st Main, 1st Block, Bangalore – 560034, Karnataka	25000.00
28.	12&13.09.2023	Cost effective ripe banana powder	Mr. Indla Chandhra Sekhar M/s. Mahima Sri Food Enterprises, H.No : 9-19/4, Gandhi Nagar, Kothapeta, Dhone, Kurnool - 518222, Andhra Pradesh	22500.00
29.	12-13.09.2023	Banana central core stem juice / RTS	Mr. Indla Chandhra Sekhar M/s. Mahima Sri Food Enterprises, H.No : 9-19/4, Gandhi Nagar, Kothapeta, Dhone, Kurnool - 518222, Andhra Pradesh	22500.00
30.	25 & 27.09.2023	Utilization of stem sheath for making of plates and handicrafts	Mrs.Y.Ganga M/s. Kalpataru Sanijivini Balenarina Mahila Uthpadakara Gumpu, Bukkasagara (PO), Hosadurga (TK), Chitradurga (DT) – 577533, Karnataka	50000.00
31.	16,17 & 18.10.2023	Banana Wine	M/s. Integrated Banana Growers Federation, Chithode, Erode	25000.00
32.	14 & 15.11.2023	Cost effective ripe banana powder	Mr. A. Kirubaharan, M/s. Shri Vaan Food and Snacks, Kuttalam (TK), Mayiladuthurai, Tamil Nadu.	22500.00
33.	14 & 15.11.2023	Banana central core stem Juice / RTS	Mr. A. Kirubaharan, M/s. Shri Vaan Food and Snacks, Kuttalam (TK), Mayiladuthurai, Tamil Nadu.	22500.00

34.	14 & 15.11.2023	Basil Seed Suspended Banana Juice / RTS	Ms. Divya Sathyan, M/s. Jaiva India, Thiruvananthapuram – 695103, Kerala	25000.00
35.	4–8.12.2023	Banana flour based low glycemic prebiotic extruded snacks like noodles, pasta	Mr. Nishanth. S, SVK Layout, Basaveswara Nagar, Bangalore - 560079, Karnataka	18750.00
36.	4–8.12.2023	Cost effective ripe banana powder	Mr. Nishanth. S, SVK Layout, Basaveswara Nagar, Bangalore - 560079, Karnataka	18750.00
37.	4–8.12.2023	Extraction of dietary fibre, pectin and cellulose from banana biomass	Mr. Nishanth. S, SVK Layout, Basaveswara Nagar, Bangalore - 560079, Karnataka	50000.00
38.	27–28.12.2023	Technology for handling of banana leaf for domestic and export markets	Mr. Rajakumar R P, Kulithalai, Karur - 639110, Tamil Nadu	15000.00

Supply of planting materials

- About 1192 batches of tissue culture plants of cvs. Grande Naine, Nendran, Red Banana, Elakki, Bantal, etc. were tested for their genetic fidelity using ISSR markers and reports issued, generating a revenue of **Rs. 34.57 lakhs**.

Patents filed

Patent (No. 447713) obtained for High throughput method for production of banana plantlets using somatic embryo regeneration vessel (SERV), granted on 28.08.2023.

Technology transferred to M/s. Sathya Biotech, Erode district, Tamil Nadu

Technology transferred to M/s. HBS Agro & Aqua Services Pvt Ltd, Suryapet District, Telangana

Technology transferred to M/s. Shivani Agro processing Centre, Trichy, Tamil Nadu

Technology transferred to M/s. Kalpataru Sanijivini Balenarina Mahila Uthpadakara Gumpu (Sponsored by NABARD, Chitradurga (DT), Karnataka)

11. IRC / RAC / IMC MEETS

XXIII Research Advisory Committee (RAC) Meeting

The 23rd RAC meeting of ICAR-NRCB was held on February 14-15, 2023. Dr. R. Selvarajan welcomed the gathering and outlined the achievements since the last meeting in July 2021. Dr. J. Poorani presented the action taken on previous recommendations followed by presentations on salient achievements by the scientists from Crop Improvement, Production, and Protection sections. The RAC made a critical review of the progress and suggested improvements in the ongoing work.

The RAC Chairman and members visited ICAR-NRCB's research farm on February 15, 2023, to review the ongoing field experiments. The Director and scientists provided updates on the field work. The RAC commended the Director and staff for their meticulous care of the experimental fields. A concluding session followed the field visit.

Institute Management Committee (IMC)

The XXVII Institute Management Committee (IMC) meeting of the Centre took place on August 10, 2023 (Thursday). Key research achievements of the Centre in 2022 were highlighted. The Director of ICAR-NRCB provided updates on infrastructural developments and discussed IMC-related issues.

XXVI IRC Meet

The 26th Institute Research Committee (IRC) meeting of the centre was held on April 10-11, 2023. Scientists presented the significant achievements from ongoing projects, followed by detailed discussions and deliberations.

12.1 TRAINING / REFRESHER COURSE/ SUMMER/ WINTER INSTITUTES/ SEMINAR/ CONFERENCE/ SYMPOSIA/ WORKSHOP ATTENDED BY THE SCIENTISTS AND OTHER STAFF

Human Resource Development

12.1. Trainings / Refresher courses attended by staff of ICAR – NRCB

Name of the Staff	Name of the program	Organizers / Venue	Date
R. Selvarajan	Training programme on the conduct of Event Selection Trials of GE banana events	National Agri-Food Biotechnology Institute, Mohali.	17 March, 2023
M. Mayil Vaganan	Training on Omics Data Analyses - Genome to Proteome	ICAR-Indian Agricultural Statistics, Research Institute, New Delhi	09-18 October, 2023
	Training on Metagenomics Data Analyses	ICAR-Indian Agricultural Statistics, Research Institute, New Delhi	11-13 December, 2023
P. Suresh Kumar	Forty-five days ICAR- Lal Bahadur Shastri Outstanding Young Scientist Award (LBSOYSA) sponsored international training programme on "Development of Synbiotic & Designed Foods through Pre & Pro-biotic approaches	Teagasc Food Research Centre, Dublin D15KN3K, Ireland	16.1.2023-1.3.23
P. Suresh Kumar	CPL Institute Enterprise Learning Solutions - Online Manual Handling Training	Teagasc Food Research Centre, Dublin D15KN3K, Ireland	18-24 January 2023
A.Mohanasundaram	ICT in Plant Protection (online)	ICAR-NCIPM, New Delhi, and MANAGE, Hyderabad	6-10 November, 2023
C.Anuradha	Omics Data Analysis: Genome to Proteome	IASRI, New Delhi	09-18 October, 2023

12.2 WORKSHOP / SEMINAR / CONFERENCE / SYMPOSIA / SCIENTIFIC MEET ETC. ATTENDED BY THE STAFF OF ICAR – NRCB

Name of the Staff	Name of the event	Venue	Date
All staff of ICAR-NRCB	30th Foundation Day and Kisan Mela	ICAR-NRCB, Trichy	21.08.2023
All staff of ICAR-NRCB	Banana Stakeholders Interactive Meet	Presided over by Hon'ble Governor of TN, Shri. R.N. Ravi at ICAR-NRCB.	26 August, 2023
All staff of ICAR-NRCB	VIROCON-2023: "Advancements in Global Virus Research Towards One Health" jointly organized by ICAR-NRCB and Indian Virological Society, New Delhi	Hotel Courtyard by Marriott, Tiruchirappalli, Tamil Nadu	1-3 December, 2023
R. Selvarajan A.Mohanasundaram	Workshop on "Sirumalai" a GI tagged banana, organized by ICAR-NRCB with with the Department of Horticulture, Government of Tamil Nadu	Sirumalai	7 December, 2023
R. Selvarajan R. Thangavelu M.S.Saraswathi M. Loganathan	National level consultative meeting on "Revisiting the approaches for rejuvenation of NanjanguduRasabale (NR), a GI Banana variety of Mysore"	College of Horticulture, Mysuru	25 July, 2023
R. Selvarajan K. Jeyabaskaran C. Karpagam M. Loganathan S. Saraswathi P. Sureshkumar	National Workshop on "Paradigm in Production and Utilization of Banana with special reference to management of diseases	JISL, Jalgaon	29 May, 2023
R. Selvarajan K.J.Jeyabaskaran C. Karpagam M. Loganathan M.S.Saraswathi P. Suresh Kumar	Global Conference on Precision Horticulture for Improved livelihood, Nutrition and Environmental Services jointly organized by CHAI, ICAR-NRCB, JISL and ASM Foundation.	JISL, Jalgaon	28-31, May, 2023
R. Selvarajan M.S.Saraswathi P. Suresh Kumar	10th Indian Horticulture Congress -Unleashing Horticultural Potential for Self-Reliant India, organized by the IAHS	College of Veterinary Science Campus, AAU, Guwahati, Assam, India	06-09 November, 2023
R. Selvarajan K. N. Shiva M.S.Saraswathi C.Anuradha	X Group Discussion of AICRP-Fruits Review Meeting	AICRP-F Unit, IIHR, Bengaluru, Karnataka	01.03.2023-02.03.2023

R. Selvarajan R. Thangavelu M. Loganathan	National symposium on "Plant Health Management: Current Trends and Novel Mitigation Strategies" jointly organized by ICAR-CTCRI & IPS	ICAR- CTCRI, Thiruvananthapuram, Kerala	11-12 September, 2023
R. Selvarajan P. Suresh Kumar	XVI Agricultural Science Congress and ASC Expo organized by the National Academy of Agricultural Sciences, New Delhi,	ICAR-Central Marine Fisheries Research Institute, Kochi	10-13, October, 2023.
R. Thangavelu V. Kumar	National Seminar on 'Recent Technological Advancements in Banana Production and Value Addition.	ICAR-IISR, Lucknow	29 September, 2023
K. N. Shiva K.J. Jeyabaskaran	District Mission Committee Meeting (National Horticulture Mission, Micro-irrigation, etc.)	District Collector at Collector's Chamber, Trichy, TN	10.02.2023
R. Selvarajan P. Suresh Kumar	Brainstorming workshop on the Zero Wastage Dream of Perishables" organized by TNAU & IIT	IIT, Chennai	24-25 March, 2023
R. Selvarajan	**Workshop**		
	Workshop on Gender and Plant Health: Sharing insights from case studies was organized by the International Potato Center (CIP), Nairobi, Kenya	Prideinn Azure Hotel in Nairobi, Kenya.	22-23 November, 2023
	Seminar/ Conference/Symposia		
	International		
	2nd Conference of World Society for Virology (WSV) on "ONE HEALTH - ONE WORLD - ONE VIROLOGY	Riga Stradins University, Riga, Latvia	15-17 June, 2023
	International Seminar on Exotic and Underutilized Horticultural Crops: Priorities & Emerging Trends" jointly organized by SPH ICAR-IIHR, Bengaluru	ICAR-IIHR, Bengaluru	17-19 October, 2023
	National		
	Challenges and advances in Platinum Jubilee Conference on Plant and Soil Health Management: Issues and Innovations	Vijnana Bhavan University of Mysore,	2-4 February, 2023
	National Conference on Recent Trends in Genetic Engineering and Biotechnology	SRM Institute of Science and Technology, Chennai	23-24 February, 2023
	Annual Conference of Vice-Chancellors of Agricultural Universities and ICAR Directors	NASC, New Delhi	04-05 March, 2023

R. Selvarajan	ICAR-Industry Stakeholder Consultation meet	Agrinnovate India Ltd., New Delhi	06 March, 2023
	Global Millets (Shree Anna) Conference	NASC, New Delhi	18-19 March, 2023
	One Day National Conference on Law and Agriculture: Prospects and Issues	Tamil Nadu National Law University, Tiruchirappalli.	05 May, 2023
	Meetings		
	Attended the Variety Release meeting	TANSEDA, Chennai	06 January, 2023
	Annual Review Meeting of CRP on Vaccine and Diagnostics project	ICAR-IVRI, Bengaluru	24-25 January, 2023
	Tamil Nadu- Agri Expo 2023- Stakeholders meeting	Directorate of Agriculture, Chennai	28-29 June, 2023
	Agri Marketing Expo 2023	DoA &AB, Chennai	09 July, 2023
	95th ICAR Society Foundation Day	New Delhi	16 July, 2023
	Investors conclave – Business opportunities in Banana	SIPCOT, Manapparai	29 August, 2023
	41st State Sub Seed Committee meeting organized by the DoA, Tamil Nadu,	DoA, Chennai	19 December, 2023
J. Poorani	National Conference on Generative AI in Practice for Empowering Agricultural Research Productivity (Virtual)	Organized by ICAR-NRC for Grapes, Pune	11-12 September, 2023
R. Thangavelu	Workshop on Advances in banana cultivation and IDM of Fusarium wilt in banana in Kushinagar	ICAR-KVK, IIVR, Kushinagar	27 September, 2023
M. Mayil vaganan	Fifth Interaction Meeting on initiation of Event Selection Trials under BIRAC-Banana Biofortification Project	National Agri-Food Biotechnology Institute, Mohali, Chandigarh	17 & 18 March 2023
	Annual Project Review Meeting of BIRAC-Banana Biofortification Project	Biotechnology Industry Research Assistance Council, new Delhi	23 March 2023
	Project Review Meeting of BIRAC-Banana Biofortification Project	Biotechnology Industry Research Assistance Council, new Delhi	26 May 2023
	Sixth Interaction Meeting on initiation of Event Selection Trials under BIRAC-Banana Biofortification Project	Biotechnology Industry Research Assistance Council, new Delhi	7 July 2023
	XIV Institute Biosafety Committee Meeting	ICAR-National Research Centre for Banana, Tiruchirappalli	13 July 2023
	Seventh Interaction Meeting on initiation of Event Selection Trials under BIRAC-Banana Biofortification Project	Biotechnology Industry Research Assistance Council, new Delhi	9 November, 2023

K.N. Shiva	The Second Meeting of TOLIC for the year: 2022-23 convened under the Chairmanship of	Chairman, TOLIC and DRM, Southern Railway, Trichy, TN	17 February, 2023
	Interactive Session on SPS-TBT Issues in Milk and Milk Products and other products.	Export Inspection Agency TN	12 April 2023
	First Meeting of 10th IMC of IISR, Calicut	ICAR-NRCB, Trichy	25 July 2023
	Banana Stakeholders Meet	EDII- PHBIF, HC & RI, Periyakulam, Theni Dt.,	18 August, 2023
	A Conclave for Investors related Food Industry	SIPCOT, Manapparai &	19 August, 2023
	Sensitization Workshop of ICAR-Agri-Business Incubation Centres (ABIs), organized by ADG (IP & TM), ICAR	NASC Complex, New Delhi.	21-22 September, 2023
	26th Scientific Advisory Committee (SAC) Meeting	ICAR-KVK Virudhachalam	06 January, 2023
	20th Scientific Advisory Committee (SAC) Meeting	ICAR-KVK, Sandhiyur, Salem Dt., TN	06 February, 2023
S. Backiyarani	54th State Variety Release Committee & 40th State Seed Sub Committee meeting	Tamil Nadu Secretariat, Chennai	19 December, 2023
M.S. Saraswathi	19th DUS Annual Review meeting	PPV&FRA, New Delhi at ICAR-IIHR, Bengaluru	22-23 May, 2023
	Regional Committee Meeting for NER	ICAR-NER, Umiam, Meghalaya	26 September 2023
P. Suresh Kumar	28th meeting of Scientific Panel of Fruits and Vegetables and their products (SP-12)	FSSAI, HQ, New Delhi.	17 March, 2023
	ICAR-IIHR Industry meet at Bengaluru	IIHR- Bengaluru	31 October, 2023
	9th International food convention	CSIR-CFTRI, Mysuru, India	7-10 December, 2023
	Second International Conference on Electrical, Electronics, Information and Communication Technologies (ICEEICT 2023).	K. Ramakrishnan College of Engineering, Tiruchirappalli	05–07 April, 2023
	Global Millets (Shree Anna) Conference	IARI, new Delhi	18-19 March, 2023
	Scientific Advisory Committee Meeting	KVK, Needamangalam	16 March, 2023
C. Karpagam	National workshop on “Plant Virus disease Management” during VIROCON	Hotel Courtyard Marriott, Trichy	1-3 December, 2023
	National workshop on “Lumpy Skin Disease Management in Cattle” during VIROCON 2023	Hotel Courtyard Marriott, Trichy	1-3 December, 2023

C. Karpagam	International workshop on phenotyping for drought tolerance	ICAR-NRCB	27 Febuary-3 March, 2023
P. Giribabu	National Conference on 'Plant Parasitic Nematodes 2023', organized by Bayer Crop Science Ltd.	Bengaluru	17 January, 2023
	'International Conference on Vegetable Oils 2023 (ICVO 2023)', organized by ICAR-IIOR & (ISOR)	Hyderabad	17-21 January, 2023
	International conference on 'New Generation Horticulture for Prosperity 2023' organized by The Orissa Horticultural Society, Bhubaneswar, Odisha, India	Online	20-21 January, 2023
	12th National Conference on 'Natural Sciences'	Pushkaram College of Agriculture Sciences, Pudukkottai, Tamil Nadu	28 February, 2023
C. Anuradha	International Conference on New Generation Horticulture for Prosperity	Bhubaneswar, Odisha, India	20-21 January 2023
	XLVI Indian Social Science Congress – 2023	BDU, Trichy	27-31 January, 2023
	International workshop on phenotyping for drought tolerances	ICAR-NRCB	27 Febuary-3 March, 2023
	Farmers-Scientists panel on gene-edited crops	The Global Plant Council and WIKIFARMER	8 May, 2023
	An introduction to R and data visualisation	Bioingene	12 May, 2023
	The potential of genome editing for sustainable agriculture	Bioingene	23 May, 2023
	"Philip White - Elements of his life"	Dundee Root Medal Lecture	8 November, 2023
	Online Interaction meeting cum Workshop for the investigators of successful Letters of Intent (LoIs) against the call for proposals	DBT	05 April, 2023
	Women and IP: Accelerating innovation and creativity, World IP day 2023	ICAR-NRCB	26 April, 2023

13. WORKSHOPS, SEMINARS, FARMERS' DAY, ETC. ORGANIZED AT THE CENTRE

National Science Day celebrated as "Open Day" – A new initiative by ICAR-NRCB

ICAR–National Research Centre for Banana, Tiruchirappalli, celebrated 'National Science Day' on February 28, 2023, with an 'Open Day' under the theme "Global Science for Global Well-being," attracting 3000 students and 1000 farmers. The event aimed to raise awareness among students about recent developments in banana science.

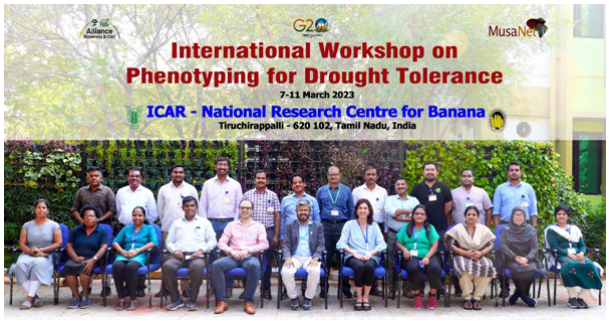
Dr. C. Vanniarajan, Dean of Anbil Dharmalingam Agricultural College and Research Institute (TNAU), Tiruchirappalli, graced the occasion as Chief Guest. Dr. P. Paramaguru, Dean of Horticultural College and Research Institute for Women (TNAU), Tiruchirappalli, and Professor S. Jayasankar from the University of Guelph, Canada, were the Guests of Honor. They inaugurated the National Science Day and Exhibition, respectively. Dr. C. Karpagam, Principal Scientist (Extension) and program convener, highlighted that this outreach would strengthen links among banana production stakeholders and support the "Lab to Land" concept.

The science exhibition featured banana-based and millet-based products, along with stalls displaying agricultural inputs and recent advancements like genome editing, precision farming, AI, and IoT in banana farming. Varietal diversity, including ICAR-NRCB cultivars, popular types, landraces, and wild germplasm, was on display. As many as 28 millets and millet-based products from ICAR-IIMR, Hyderabad, were displayed to highlight the International Year of Millets 2023. The visitors also toured the ICAR-NRCB farm, home to Asia's largest field gene bank for banana with 370 germplasm accessions, and the Common Incubation Centre (CIC) with five production lines for value-added products. Video films on banana-related technologies were screened.

International Workshop on 'Phenotyping for drought tolerance' organized

ICAR–NRCB, Tiruchirappalli, in collaboration with Alliance Bioversity International and CIAT, Italy, a CGIAR institute, organized an International workshop on 'Phenotyping for Drought Tolerance' during March 7–11, 2023. The International workshop was inaugurated by Dr. A.K. Singh, Deputy Director General (Horticulture Sciences) of ICAR, New Delhi, with Dr. Sebastien Carpentier, Senior Scientist at Alliance of Bioversity International and CIAT, as the Guest of Honor.

This training program was designed to teach researchers to identify drought-tolerant crop genotypes under field conditions. Eighteen researchers from France, Belgium, Indonesia, Sri Lanka, Papua New Guinea, the Philippines, and India participated. Dr. I. Ravi, Principal Scientist, was the Course Director.



Workshop on Hi-tech banana cultivation in changing climate scenario

ICAR-National Research Centre for Banana, Tiruchirappalli, and Jain Irrigation System Ltd., Jalgaon, Maharashtra, jointly organized a workshop on "Hi-tech banana cultivation in changing climate scenario" on June 1, 2023, in Barwani, Madhya Pradesh. The workshop aimed to introduce recent cutting-edge technologies to farmers in the region, with a focus on disease management, particularly

the Cucumber Mosaic Virus (CMV), an emerging problem.

Dr. K.J. Jeyabaskaran, Principal Scientist, ICAR-NRCB, elaborated on Nutrient-Soil Management for banana cultivation, while Dr. M. Loganathan, Principal Scientist, ICAR-NRCB, discussed integrated bacterial disease management practices. Around 400 banana farmers from Barwani district attended the workshop.

Student Internship Training Program organized by ICAR-NRCB

In June-July 2023, ICAR-National Research Centre for Banana organized internship programs for 21 M.Sc. students across various disciplines. Ten Food Science and Nutrition students from The Gandhigram Rural Institute were trained in post-harvest handling techniques and value-added product technologies related to bananas. Seven Biochemistry students from Avinashilingam Institute, Coimbatore, and four Biotechnology students from the University of Madras received comprehensive training in molecular techniques, tissue culture, and analytical methods relevant to banana research. The internship culminated on June 30, 2023, with Dr. R. Selvarajan, Director of ICAR-NRCB, awarding certificates to the students.

30th Foundation Day and Kisan Mela held on 21.08.2023

ICAR-National Research Centre for Banana celebrated its 30th Foundation Day with a Kisan Mela on August 21, 2023, in Tiruchirappalli. This year's Kisan Mela focused on the utilization of Artificial Intelligence in banana production and marketing technologies. Dr. V. Palanimuthu, Director of the NIFTEM-T, Thanjavur, was the Chief Guest and Dr. K. Alagusundaram, MD & CEO of the Tamil Nadu Food Processing & Agri Export Promotion Corporation, and Dr. V. Venkatasubramanian, Director of ICAR-Agricultural Technology Application Research Institute, Bengaluru, were the guests of honour at the event. The overall event coordinated by Dr. C. Karpagam, Principal Scientist, ICAR-NRCB

During the function, various stakeholders were recognized, and 14 awards were presented to the Best Banana Farmers, Best Farmer Producer Organizations (FPOs), Best Technology Dissemination, Best Krishi Vigyan Kendras (KVKs), Best Entrepreneurs, and Best Technical Staff. The event attracted around 1000 participants from across the state. An exhibition with 30 stalls was organized as part of the program.

Visit of the Honourable Governor of Tamil Nadu to ICAR-NRCB on 26.08.2023

On August 26, 2023, Shri R.N. Ravi, the Honorable Governor of Tamil Nadu, visited the ICAR-National Research Centre for Banana. The highlight of the day was the "Honorable Governor's interaction with Banana Stakeholders," wherein over 200 stakeholders from various sectors of the banana industry participated. This meeting provided a platform for comprehensive discussions on industry-related topics. Dr. R. Selvarajan, Director of ICAR-NRCB, welcomed the Governor and participants, highlighting the center's progress and achievements over the years.

In his speech, the Governor emphasized the importance of bananas as a staple food and acknowledged the diverse products derived from banana. He stressed the need to improve the lives of farmers by ensuring effective dissemination of technological advancements. The Governor also expressed his commitment to supporting banana farming, drawing parallels with other agricultural crops. He urged scientists to collaborate with institutions like IIM to scale up advanced technologies and integrate them into business ventures.

Internship Training Programme on "Advances in Agricultural Engineering" organized

ICAR-National Research Centre for Banana (NRCB) organized a 10-day Internship Training Programme on "Advances in Agricultural Engineering" during September 11–20, 2023. Ten B.Tech. students from Dhanalakshmi Srinivasan University, Samayapuram, Tiruchirappalli, participated, gaining practical insights into various aspects of agricultural engineering, including banana cultivation, post-harvest handling, waste utilization, and emerging technologies. Dr. R. Selvarajan, Director, distributed certificates to the interns.

Workshop on Advances in Banana cultivation and integrated management on Fusarium wilt for banana farmers of Uttar Pradesh

A workshop on "Advances in Banana Cultivation and Integrated Management of Fusarium Wilt in Kushinagar, Uttar Pradesh" was held on 27.09.2023 at KVK, Kushinagar, organized by ICAR-National Research Centre for Banana (ICAR-NRCB), Tiruchirappalli, and ICAR-KVK, Indian Institute of Vegetable Research, Kushinagar.

Dr. R. Selvarajan, Director of ICAR-NRCB, highlighted the significant increase in UP's banana production from 0.1113 million tons in 2013 to 3.3391 million tons in 2023. He introduced a Panama wilt-resistant Grand Naine variant and discussed ICAR-NRCB's banana export technology, which generated Rs 1188 crores from shipments to the Middle East and Europe as UP primarily grows the Cavendish cultivar Grand Naine, susceptible to Fusarium wilt (Foc TR4), first identified in Faizabad, UP, and Katihar, Bihar, in 2015. ICAR-NRCB has developed integrated management practices, including a biocontrol consortium (NO2Wilt) and resistant Grand Naine variants, to manage Foc wilt and scarring beetles.

Dr. Subhash Singh, Joint Director of Genda Singh Sugarcane Breeding & Research Institute, noted that sugarcane and banana are major crops in local rotations, with sugarcane reducing soil-borne inocula for banana, which is more profitable for local growers.

Scientists Dr. K. Jeyabaskaran, Dr. R. Thangavelu, and Dr. M. Loganathan discussed banana cultivation techniques, soil nutrient management, and integrated disease management for Fusarium wilt. Ms. Anitha Roy of Shree Mythili Enterprises spoke on "Banana Value Addition and Fibre Production," identifying it as an untapped market in UP. An exhibition showcased banana value-added products and handicrafts. Dr. Ashok Rai welcomed the gathering, and Dr. Vikash Singh proposed the vote of thanks. Around 180 farmers benefitted from the workshop.

VIROCON 2023 organized by ICAR–NRC Banana

ICAR-National Research Centre for Banana, Trichy, and the Indian Virological Society (IVCS), New Delhi, jointly organized VIROCON 2023 during December 1-3, 2023, in Tiruchirappalli, Tamil Nadu, focusing on "Advancements in Global Virus Research Towards One Health" under the World Health Organization's One Health concept.

Totally 444 delegates from India and abroad (Germany, France, West Indies, Norway), including scientists, students and research scholars representing 70 institutes such as ICAR, ICMR, AIMS, NIV, PGIMER, DRDO and universities participated in the conference. The largest number of participants were Plant virologists (252) followed by virologists specializing in Medical virology (147), veterinary and aquatic virology (26) and phages (17), with a large representation of women scientists (55%).

There were 19 Technical Sessions in which 3 IVS award lectures, 9 young scientist award lectures, 8 keynote lectures, 69 lead talks, 116 oral presentations and 142 poster presentations were made under various thematic areas. Besides, four workshops (Pre-Conference National Workshop on "Troubleshooting and Quality Control in Molecular Virus Diagnosis: PCR to DNA sequencing"; three workshops on Plant Virus disease management, Disease free Shrimp farming with special reference to WSD and HPM, and Lumpy Skin Disease in Cattle) were organized on the sidelines of VIROCON-2023 in which 146 farmers and other stakeholders participated. The proceedings and recommendations from VIROCON 2023 were communicated to the Ministries and other Departments for consideration and implementation for the benefit of all stakeholders.

Hands-on Training on Banana Breeding Techniques

Improving banana, a polyploid and male and female sterile crop, through conventional breeding is challenging and time-consuming. To address this, a banana breeding network program was initiated based on the 23rd RAC recommendation held on February 14-15, 2023. A "Hands-on Training on Banana Breeding Techniques" was conducted jointly by ICAR-National Research Centre for Banana and ICAR-AICRP(F) on December 28th and 29th, 2023, at ICAR-NRCB, Tiruchirappalli.

The participants were from four AICRP (F) centers in Arabhavi, Coimbatore, Kovvur, and Pusa. Trainees were instructed in banana hybridization techniques. The participants gained both theoretical and practical insights into banana breeding, receiving a manual for reference. Suckers of improved diploid and wild species were distributed to participants for planting in their respective centers, including *Musa acuminata* ssp. *zebrina*, among others.

14. DISTINGUISHED VISITORS

RAC members

S. No.	Name of the official	Date
1.	Dr. N. Kumar, Former Vice Chancellor, TNAU, Coimbatore, Tamil Nadu	14-15 February, 2023
2.	Dr. P.C. Lenka, Former Professor, OUAT, Bhubaneswar, Odisha	
3.	Dr. S.K. Pareek, NIFTEM, Sonepat, Haryana	
4.	Dr. H.B. Singh, Former Professor, BHU, Varanasi, Uttar Pradesh	
5.	Dr. M. Ganapathi, BARC, Mumbai, Maharashtra	
6.	Dr. Jyothi Bhaskar, Professor & Head, Department of Fruit Science, College of Horticulture, Vellanikkara, KAU, Kerala	
9.	Assistant Director General (Hort. Science II), ICAR, New Delhi	

IMC members

S.No	Name of the official	Date
1.	Dr. V.B. Patel, ADG (Fruits & Plantation Crops) Horticulture Science, ICAR, New Delhi	10 August, 2023
2.	Dr. R.H. Laxman, Principal Scientist ICAR–Indian Institute of Horticultural Research Institute, Bengaluru	
3.	Dr. A. Ramesh Sundar, Principal Scientist, ICAR–Sugarcane Breeding Institute, Coimbatore	
4.	Dr. M. Sankaran, Principal Scientist, ICAR–Indian Institute of Horticultural Research Institute, Bengaluru	
5.	Dr. Aundy Kumar, Principal Scientist ICAR–Indian Agricultural Research Institute, New Delhi	
6.	Director (Horticulture and Plantation Crops), 3rd Floor, Agriculture Complex, Ezhilagam, Chepauk, Chennai	
7.	Director of Horticulture, Department of Horticulture, Government of Karnataka, Lalbagh, Bengaluru	
8.	The Dean (Horticulture), Horticultural College & Research Institute, Tamil Nadu Agricultural University, Coimbatore	

S. No	Name of the official
1.	Director General, NECTAR, Meghalaya
2.	Prof. Anupam Varma, Former Dean, IARI, New Delhi
3.	Dr. Bikash Mandal, Assistant Director General (International Relations), New Delhi
4.	Dr. Inkarsal Kalai, General Manager, NABARD, Chennai, Tamil Nadu
5.	Dr.K. Ramasamy, Former Vice-Chancellor, TNAU, Coimbatore, Tamil Nadu

The Honorable Governor of Tamil Nadu, R. N. Ravi visited the ICAR-National Research Centre for Banana on 26th August, 2023.

15. EMPOWERMENT OF WOMEN

Extension-Outreach programmes for women farmers

ICAR-NRCB organized various training programmes for women farmers from various districts of Tamil Nadu and other states. In the reporting year, the total number of women beneficiaries was 3680. Under the ATMA program, training sessions were conducted for women on Integrated Nutrient Management (INM), value addition techniques, and various government schemes such as PM Kisan, KCC, and RKVY.

Sl. No.	Particulars	No. of programme/ Units/ groups	No. of Participants	No. of Women Participants
1	One-day ATMA training on Capacity Development Programme for Farmers (CDPF)	05	152	**20**
2	Two days ATMA training on Capacity Development Programme for Farmers (CDPF)	01	35	**20**
3	Three days ATMA training on Capacity Development Programme for Farmers (CDPF)	01	29	**3**
4	One-day exposure visit by farmers (CDPF)	30	1250	**332**
5	One-day exposure visit by students (CDPS)	93	6565	**3223**
6	Visiting Entrepreneurs/ officials	10	153	**82**
	Total	**140**	**8184**	**3680**

Steps taken to encourage more participation by women in the events/ activities

- Women's participation was encouraged through small-scale training programs.
- School and college students were empowered by raising awareness about NRCB products and technologies.
- Small-scale entrepreneurs were encouraged to venture into cottage industries.
- In collaboration with the Tamil Nadu government's ATMA Scheme, training was provided to women farmers and entrepreneurs.
- Awareness programmes about government schemes aimed at supporting women entrepreneurs were conducted.

Women's participation in different programmes of ICAR-NRCB

16. PERSONNEL

16.1 Staff News

Posting

Name	Event	Date
Dr. Pramod S. Shelake	Joined as Scientist	w.e.f. 20.07.2023 (FN)
Dr. K. Nagendran	Joined on transfer from ICAR-IIVR, Varanasi	w.e.f. 26.12.2023 (FN)

Transfer

Name	Event	Date
Mr. Arjun Singh	Transferred to ICAR–IARI, New Delhi	w.e.f. 29.12.2023 (AN)

Promotion

Name	Event	Date
Mrs. C. Gomathi	Promoted from the post of Finance & Accounts Officer to the post of Senior Finance & Accounts Officer	w.e.f. 15.05.2023 (FN)
Dr. D. Ramajayam	Selected as Head, ICAR–IISWC RS, Koraput	w.e.f. 28.07.2023 (AN)

16.2 Staff position

Scientific Staff

Sl. No.	Name	Designation
1	Dr. R. Selvarajan	Director
2	Dr. J. Poorani	Principal Scientist (Entomology)
3	Dr. S. Uma	Principal Scientist (Horticulture)
4	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
5	Dr. M. Mayil Vaganan	Principal Scientist (Plant Biochemistry)
6	Dr. I. Ravi	Principal Scientist (Crop Physiology)
7	Dr. V. Kumar	Principal Scientist (Horticulture)
8	Dr. K. J. Jeyabaskaran	Principal Scientist (Soil Science)
9	Dr. K. N. Shiva	Principal Scientist (Horticulture)
10	Dr. S. Backiyarani	Principal Scientist (Biotechnology)
11	Dr. Dinesh Kumar Agarwal*	Principal Scientist (Plant Breeding)
12	Dr. M. S. Saraswathi	Principal Scientist (Horticulture)
13	Dr. M. Loganathan	Principal Scientist (Plant Pathology)
14	Dr.D. Ramajayam**	Principal Scientist (Horticulture)

15	Dr. P. Suresh Kumar	Principal Scientist (Horticulture)
16	Dr. C. Karpagam	Principal Scientist (Agricultural Extension)
17	Dr. P. Giribabu	Senior Scientist (Nematology)
18	Dr. C. Anuradha	Senior Scientist (Biotechnology)
19	Dr. A. Mohanasundaram	Senior Scientist (Agricultural Entomology)
20	Dr. Pramod S. Shelake	Scientist (Agricultural Structures and Process Engg.)
21	Dr. K. Nagendran	Scientist (Plant Pathology)
22	Mr. Arjun Singh#	Scientist (Agronomy)

*On deputation as 'Registrar General' in PPV & FRA, New Delhi
**Transferred to ICAR–IISWC RS, Koraput as Head (w.e.f. 28.07.2023)
Transferred to ICAR – IARI, New Delhi (w.e.f. 29.12.2023)

Technical Staff

Sl. No.	Name	Designation
1	Dr. S. Palanichamy	Chief Technical Officer (Lab)
2	Dr. P. Durai	Assistant Chief Technical Officer (Lab)
3	Dr. P. Ravichamy	Assistant Chief Technical Officer (Journalism)
4	Mrs. T. Anithasree	Assistant Chief Technical Officer (Lab)
5	Mrs. C. Sagayam Jacqueline	Senior Technical Officer (Computer Programmer)
6	Mr. D. Ramachandramurthi	Senior Technical Officer (Civil Overseer)
7	Mr. V. Selvaraj	Senior Technical Officer (Field)
8	Mr. T. Sekar	Senior Technical Officer (Lab)
9	Mr. K. Kamaraju	Senior Technical Officer (Lab)
10	Mr. R. Pitchaimuthu	Technical Officer (Field)
11	Mr. N. Marimuthu	Technical Officer (Lab)
12	Mr. M. Bathrinath	Technical Officer (Field)
13	Mr. V. Manoharan	Technical Officer (Driver)

Administrative, Audits & Accounts and Supporting Staff

Sl. No.	Name	Designation
1	Mrs. C. Gomathi	Senior Finance & Accounts Officer
2	Mr. R. Kandamani	Administrative Officer
3	Mr. P. Murugan	Assistant Administrative Officer
4	Mr. R. Sridhar	Assistant Administrative Officer
5	Mrs. S. Durgavathy	Assistant
6	Mr. R. Neela Mega Shyamala Kannan	Personal Assistant
7	Mrs. A. V. Suja	Upper Division Clerk
8	Mr. R. Mohanraj	Lower Division Clerk
9	Mr.V. Thangaraju	Lower Division Clerk
10	Mr. P. Kamaraj	Skilled Supporting Staff
11	Mr.V.Ganesan	Skilled Supporting Staff
12	Mrs. K. Mariammal	Skilled Supporting Staff
13	Mr. A. Kaspar	Skilled Supporting Staff

16. OTHER INFORMATION

ICAR-NRCB signs PPP mode MoU with Thermal Energy Solutions Pvt. Ltd. (TESSOL)

The ICAR-NRCB has signed an MoU with Thermal Energy Solutions Pvt. Ltd. (TESSOL), Mumbai, recognized by UNIDO for innovative energy solutions, and the Tamil Nadu Banana Growers Federation. The collaboration aims to design and assess the effectiveness of temperature control on the shelf life of various banana varieties, particularly for long-distance domestic transport in a low carbon emitting reefer container. The container is currently installed at NRCB for evaluation.

MoU with Thermal Energy Solutions Pvt. Ltd. (TESSOL)

Swachhata Pakhwada activities at ICAR-NRC for Banana

Swachhata Pakhwada activities were held at ICAR-NRC for Banana, Tiruchirappalli, over 15 days in December 2023. The program began with a pledge ceremony and campus cleaning. Various initiatives included digitizing records, campus cleaning, and waste management. 'Kisan Diwas' was celebrated with farmers, emphasizing banana cultivation's benefits. Sanitation campaigns and awareness drives were conducted, including a drawing competition on cleanliness and a plastic waste management campaign. Vermiculture technology demonstrations were provided, promoting composting with biomass and banana pseudostems. The concluding ceremony featured guest speeches, award ceremony, tree planting, and continued cleaning efforts. The programme was coordinated by Dr. V. Kumar and Dr. A. Mohanasundaram.Top of Form

Swachhata Pakhwada activities at ICAR-NRC for Banana

ICAR-NRCB initiative to boost banana cultivation and trade in Uttar Pradesh

The ICAR-NRCB organized a National Seminar on "Recent Technological Advancements in Banana Production and Value Addition" in collaboration with ICAR-IISR and M/s. JISL at ICAR-IISR, Lucknow, on 29th September 2023. The event attracted about 250 farmers from Uttar Pradesh. Shri. Manoj Kumar Singh, IAS, Agriculture Production Commissioner, Govt. of Uttar Pradesh, highlighted the region's favourable conditions for banana cultivation and announced plans for a tissue culture facility in collaboration with ICAR-NRC banana and private firms like M/s. JISL to provide quality planting material at subsidized costs. Dr. V.B. Patel, ADG (Fruits and Plantation Crops), ICAR, encouraged crop diversification with bananas and emphasized post-harvest value addition for entrepreneurial opportunities. Shri K.B. Patil from JISL emphasized drip irrigation automation for

water and fertilizer conservation and advised optimal planting times.

Dr. Selvarajan, Director, ICAR-NRCB, highlighted the center's achievements, climate-resilient varieties, and value-added products. Technical folders on Fusarium wilt disease management were released on the occasion. The technical sessions provided comprehensive coverage of banana cultivation, high density planting systems, nutrient management including fertilizer equation, automation, varietal wealth and Integrated management of fusarium wilt and erwinia rot and value addition. Scientists of NRCB including Drs. V. Kumar, R. Thangavelu, M.S. Saraswathi, K.J. Jeyabaskaran, M. Loganathan and P. Suresh Kumar acted as the resource persons.

Seminar on "Recent Technological Advancements in Banana Production and Value Addition"

77th Independence Day Celebration

India's 77th Independence Day was celebrated on 15th August 2023 at the institute premises with enthusiasm and nationalistic fervour. Dr. R. Selvarajan, Director of ICAR-NRCB, hoisted the national flag and delivered the Independence Day address, followed by the distribution of sweets.

77th Independance Day at ICAR-NRCB

Republic Day Celebration

The 74th Republic Day was celebrated at the Centre on 26th January 2023, with a flag hoisting by Dr. R. Selvarajan, Director, followed by the distribution of sweets. In his Republic Day address, he commended the scientists and staff for the center's achievements in 2022.

International Day of Yoga

The 9th International Day of Yoga was celebrated at ICAR–NRCB, Trichy. Dr. R. Sugumar from Shri Jayarangha Nature Cure Hospital,

Trichy, emphasized yoga's role in establishing harmony between body and mind, promoting a healthy, disease-free life. Dr. Sugumar and his team conducted a live demonstration of nearly 26 asanas, which was enthusiastically followed by the institute's staff.

International Day of Yoga at ICAR-NRCB

ICAR-NRCB Celebrated Pongal Festival

The staff members of ICAR-NRCB celebrated the Pongal festival on January 13, 2023, at the NRCB Research Farm. Games were organized for both staff and their children, and prizes awarded to the winners.

Technology for "Banana leaf production, handling and export" licensed

The ICAR-NRCB Trichy, has transferred the technology for the production, handling, and export of banana leaves to M/s Dohrnii Chain Pvt. Ltd., a Dindigul-based private company, which is involved in the export of fresh fruits and vegetables.

New Year celebrated at ICAR-NRCB, Trichy on 02-01-2023

The staff of ICAR-NRCB celebrated the New Year on January 2, 2023, at the NRCB Conference hall. Dr. R. Selvarajan, Director, addressed the gathering, speaking about New Year resolutions.

New Year celebration at ICAR-NRCB

World Soil day observed on 5.12.2023

ICAR-NRCB celebrated World Soil Day on December 5, 2023, at the NRCB Conference Hall. Dr. R. Selvarajan, Director, emphasized the significance of soil health for our planet and discussed the importance of Soil Health cards. As part of the event, Soil Health cards were distributed to the farmers.

World IP Day-2023

ICAR-NRCB, Trichy, celebrated the World Intellectual Property Day focusing on "Women and IP: Accelerating Innovation and Creativity." Dr. R. Selvarajan, Director, highlighted the role of technology and IP in enhancing agricultural innovation. Ms. Preetham Balakrishnan from Tamil Nadu National Law University demystified patenting and IP protection laws. Drs. S. Backiyarani and M.S Saraswathi shared their experiences on patent filing for banana-based interventions.

Exhibition Stall at Governor's Office

On October 2nd, 2023, the Governor's office arranged a special function to honour freedom fighters and extended an invitation to ICAR–NRCB to host an exhibition stall. In this prestigious event, the NRCB stall featured an impressive display of technologies and products contributed by 13 different banana stakeholders, showcasing the breadth and depth of its contributions to the banana industry. The NRCB stall was inaugurated by the Honorable Governor. Throughout the day, our stall attracted a steady stream of visitors, with the evening tally reaching an impressive total of 2,000 individuals.

Viksit Bharat Sankalp Yatra (VBSY)

The Viksit Bharat Sankalp Yatra (VBSY) is a program launched by the Indian government on November 15, 2023. This nationwide initiative aims to bridge the gap between eligible citizens and various central welfare schemes that they have not yet availed themselves of. The primary objective of VBSY is to enhance awareness and accessibility to essential welfare schemes provided by the central government. These schemes encompass a wide range of sectors, including sanitation facilities, essential financial services, electricity connections, access to LPG cylinders, housing for the poor, food security, proper nutrition, reliable healthcare, and clean drinking water. By reaching out to citizens across various districts of Tamil Nadu and other parts of the country, the initiative strives to ensure that eligible individuals are informed about these schemes and can avail themselves of their benefits. One notable aspect of the VBSY program is the utilization of technology, such as drone technology, to effectively reach remote areas and conduct demonstrations. Moreover, the program emphasizes the enrollment of potential beneficiaries by gathering relevant details during the Yatra. As part of this campaign, NRCB staff covered various districts of Tamil Nadu in collaboration with KVKs and created awareness about the Government's development initiatives.

ICAR-NRCB Staff -VBSY Programme Details

Sl. No.	Name	Designation	Date of Travel	Gram Panchayat Covered	Block	District	No. of Beneficiaries
1	Dr. C. Karpagam	Principal Scientist	19th Dec., 2023 – 20 Jan., 2024	28 nos.	Manapparai, Vaiyampatty Pullambadi	Trichy	4850
2	Dr. K.N. Shiva	Principal Scientist	20-23 Dec., 2023 & 9-13 Jan., 2024	23 nos.	Thiruvarur & Thiruthurai-poondi	Thiruvarur	5000
3	Dr. M. Loganathan	Principal Scientist	11- 13th January, 2024	12 nos.	VIRALIMALAI	Pudukottai	3200
4	Dr. P. Suresh Kumar	Principal Scientist	28th Dec., 2023 – 12th Jan., 2024	12 nos.	Manapparai, Vaiyampatty, Pullambadi	Trichy	2200
5	Dr. P. Giribabu	Senior Scientist	25-31 Dec., 2023& 11-13 Jan., 2024	38 nos.	Tirumangalam, Usilampatti	Madurai	5700
6	Dr A. Mohanasundaram	Senior Scientist	08 -10th Jan., 2024	12 nos.	Viralimalai	Pudukottai	3000
7	Dr.P. Durai	Chief Technical Officer	19 Dec., 2023- 6 Jan., 2024 & 16-24 Jan., 2024	73 nos.	Gandarvakottai and Kunnandrarkoil	Pudukottai	9000
8	Dr. P. Ravichamy	Asst. Chief Technical Officer	18 -23 Dec., 2023 & 1-13, Jan., 2024	49 nos.	Thirukoilur, Rishivandiyam, Thiyagadurgam, Thirunavallur Ulundurpettai	Kallakurichi	4810
9	Mr. K. Kamaraju	Senior Technical Officer	17- 19 Jan., 2024	20 nos.	Pullambadi	Trichy	2500
10	R. Pitchaimuthu	Senior Technical Officer	26 -30 Dec., 2023	10 nos.	Sankarapuram Rishivanthiyam Thiyagadurgam Kalvarayan Hills Thiyagadurgam	Kallakurichi	1080
			01-23 Jan., 2024	37	Kallikudi T. Kallupatti	Madurai	4135
11	N. Marimuthu	Senior Technical Officer	01-18 Jan., 2024	58 nos.	Thiyaga Thuruvam, Rishivandiyam Thirukoviloor	Kallakurichi	2748
12	Mr. M. Bathrinath	Technical Officer	Jan 2-5, 2024	12 nos.	Vaiyampatty	Trichy	1980
			Total	**364**			**50203**

18. SUCCESS STORIES

Release of Provitamin A rich dessert banana for Tamil Nadu State

The 54th State Variety Release Committee and 40th State Seed Sub-Committee of Tamil Nadu have approved the release of progeny NCR 17 as Kaveri Kanchan. It is recommended for cultivation in Trichy, Theni, Pollachi, Coimbatore, Salem, and Tirunelveli districts of Tamil Nadu due to its unique features.

Bunch and fruits of new variety Kaveri Kanchan

Banana Weevil Killer (*Beauveria bassiana*) for the management of weevil borers

Banana Weevil Killer, a bioformulation of *Beauveria bassiana*, was developed to combat banana pseudostem and corm weevils. It effectively controls all stages of the pseudostem and corm weevil, including eggs, larvae, pupae, and adults.

Banana Weevil Killer (*Beauveria bassiana*)

Micronutrient application through Drone Technology – An ICAR–NRCB initiative

An awareness campaign on the use of drone technology for micronutrient application in banana was conducted in collaboration with the Thottiyam Banana Producers Group at Varadarajapuram near Thottiyam, Tiruchirapalli, Tamil Nadu, on 31st January 2023. The event covered 35 acres of banana cultivation and was part of the Agridrone technology project under the Ministry of Agriculture and Farmers Welfare. FPO members and agricultural students participated, and Mr. Subramanian, Coordinator of TNBPCL, gave the vote of thanks.

Micronutrient application through Drone Technology

Drone Technology Demonstration for leaf spot disease management

In response to the sudden outbreak of leaf spot disease in 2400 hectares in Kalakkad block, Tirunelveli district, ICAR-NRCB initiated technological support for fungicide application using drone technology. On January 9th, an awareness meeting was held for farmers at Thirukurungudi, where measures to manage leaf spot disease in bananas were discussed. Following the meeting, a demonstration of

fungicide application via drones was conducted in the village. Approximately 25 acres were covered in the affected area.

Drone Demonstration for leaf spot disease management

ICAR-NRCB bags the Top Stall Award at 2023 State-Level Agri-Expo

ICAR-NRCB actively participated in the prestigious Mega "AGRI EXPO 2023" held during 27–29 July 2023 at CARE Engineering College in Tiruchirappalli. The event, organized by the Ministry of Agriculture and Farmers' Welfare, Tamil Nadu Government, attracted around one lakh farmers over three days.

ICAR-NRCB's stall showcased banana varietal diversity, value-added products, disease-free planting materials, and technology-driven banana farming. The Honorable Chief Minister of Tamil Nadu and other dignitaries visited the stall, showing keen interest in advancements in banana agriculture. Approximately 100,000 farmers visited the stall, where NRCB technologies and management strategies were explained. The stall of ICAR-NRCB team, coordinated by Dr. C. Karpagam, Principal Scientist (Extension), earned the third prize in the Government stall category.

Top Stall Award at 2023 State-Level Agri-Expo

ICAR-NRCB also bagged the Best Stall Award at the 'National Horticulture Fair-2023' and 'Agri Expo-2023', and XVI Agriculture Science Congress Expo-2023.

ANNEXURE – 1

I. Institute Projects

Name of the Project	Principal Investigator
Crop Improvement	
Improvement and management of banana genetic resources in Indian subcontinent	S. Uma
Crop Improvement of banana through conventional breeding	S. Backiyarani
Production of doubled haploids for improvement of bananas (*Musa* spp.)	S. Backiyarani
Improvement of cv. Grande Naine (Cavendish - AAA) for Fusarium wilt resistance through non-conventional breeding	M.S. Saraswathi
Development of trait specific markers for fusarium wilt resistance through association mapping studies in banana (*Musa* spp.)	M.S. Saraswathi
Identification of resistant gene candidate(s) in banana for tropical race 4 of *Fusarium oxysporum* f. sp. *cubense*	C. Anuradha
Crop Production	
Development of clump management technology for enhanced productivity in banana	V. Kumar
Studies on nutrient dynamics in banana	K.J. Jeyabaskaran
Organic banana farming for sustainable soil health and nutritional security	K.J. Jeyabaskaran
Developing agro-techniques for ICAR-NRCB released varieties and selections of banana	K.J. Jeyabaskaran
Mechanism of high temperature tolerance and management of high temperature and soil moisture deficit stresses in banana	I. Ravi
Biochemical dissection of fruit ripening-related phenomena & components and exploring nutraceutical applications of bioactives of banana	M. Mayil Vaganan
Developing integrated package of practices for export of selected commercial and GI tagged varieties of Indian Bananas	K.N. Shiva
Novel nutraceutical smart delivery systems for high-value food and non-food products of banana	P. Suresh Kumar
Effective utilization of different extension methods and mass media for holistic transfer of banana technologies for different stakeholders in banana production system	C. Karpagam
Crop Protection	
Pest mapping in bananas and plantains of India	J. Poorani
Bio-intensive management of major insect pests of banana	J. Poorani
Eco-friendly management of banana pseudostem weevil (*Odoiporus longicollis* Olivier) and banana scarring beetle (*Basilepta* spp.)	A. Mohanasundaram

Investigations on Musa nematode's biology, behaviour, diversity and their interactions	P. Giribabu
Integrated management of Fusarium wilt disease (Foc R1) in banana	R. Thangavelu
Survey, etiology and management of rhizome rot of banana	M. Loganathan
Management of post-harvest diseases of banana	M. Loganathan
Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan

II. ICAR Funded Projects

Name of the Project	Principal and Co-Investigator(s)
Network program on Precision Agriculture (NePPA)	I. Ravi R. Selvarajan K.J. Jeyabaskaran P. Suresh Kumar
All India Coordinated Research Project on Fruits (Banana)	V. Kumar
Intellectual property management and Transfer/Commercialisation of Agricultural technology	P. Suresh Kumar
Agri-Business Incubation (ABI) Centre under ICAR-NAIF (Component-II)	K.N. Shiva P. Suresh Kumar V. Kumar K.J. Jeyabaskaran D. Ramajayam
Development of postharvest handling and smart packaging methods for the export of Traditional banana varieties and digital health monitoring of banana (ICAR-NASF)	P. Suresh Kumar K.N. Shiva V. Kumar R. Thangavelu S. Uma
Development of smart foods, bio-composites, green packaging and bio-energy from agroresidues	P. Suresh Kumar K.N. Shiva M. Mayil Vaganan
Utilization of banana wastes for the development of symbiotic & designer foods through pre-pro-biotic approaches and to enhance the farmer's income (ICAR-LBSOYSA)	P. Suresh Kumar
Development and utilization of diagnostics to viruses of banana under Consortia Research Platform on Vaccines and Diagnostics	R. Selvarajan C. Anuradha

III. Projects Funded by other agencies

Name of the Project	Principal and Co-Investigator(s)
Bioversity International - IITA funded project	
Improvement of Banana for smallholder farmers in the Great Lakes region of Africa: enhancing Banana production by developing Fusarium Wilt-resistant varieties and benefit sharing with African smallholder	S. Uma S. Backiyarani M.S. Saraswathi R. Thangavelu

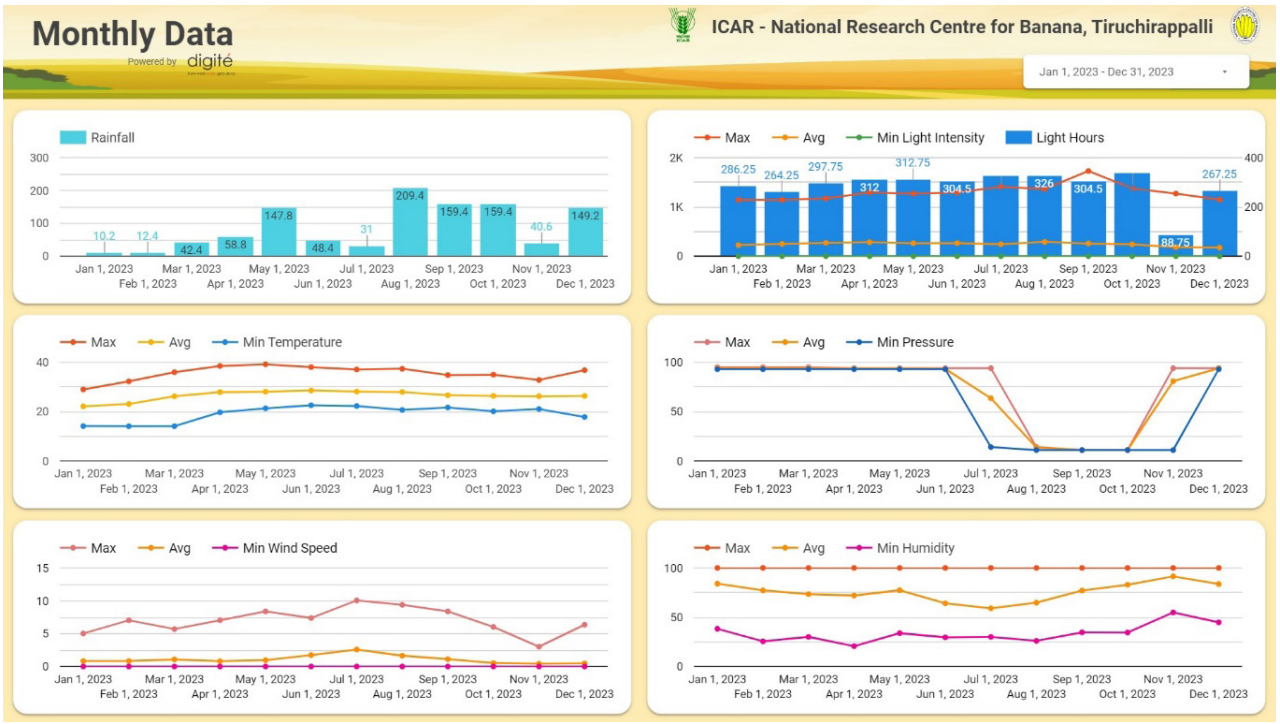
DBT–QUT funded project	
Biofortification and development of disease resistance in banana	
Component-1: Transfer and evaluation of Indian banana with pro Vitamin A (PVA) constructs	S. Backiyarani M. Mayil Vaganan S. Uma
Component-2: Transfer and evaluation of Indian bananas with iron gene constructs	M. Mayil Vaganan I. Ravi K. J. Jeyabaskaran
PPV & FRA funded project	
Framing crop specific DUS guidelines for Banana (Musa spp.)	M.S. Saraswathi S. Backiyarani
BRNS funded project	
High-throughput screening for induced mutations in banana cv. Grand Naine (AAA) with Fusarium wilt (TR4) resistance (Phase III)	M.S. Saraswathi S. Uma R. Thangavelu S. Backiyarani Himanshu Tak
DBT Funded project	
'Banana Sakthi' Nano formulation – Effective delivery systems of the micronutrient mixture for improved banana cultivation	K.J. Jeyabaskaran
CGIAR/Bioversity International Funded projects	
A1553-CGIAR fund INIT-03 - Conservation and use of genetic resource (gene banks) Study–I: Regional workshop on Phenotyping of bananas for drought tolerance	I. Ravi
A1553-CGIAR fund INIT-03 Study–II: Evaluation of ITC genotypes for their reaction to FoC R1 and TR4	R. Thangavelu
A1553-CGIAR fund INIT-03 Study–III: Status of adoption behaviour of ITC accessions in India under the banana production system and the constraint analysis in the dissemination process	C. Karpagam S. Backiyarani
A1555 - INIT-13- Plant health and rapid response to protect food security and livelihoods	R. Thangavelu
DAC & FW, Govt. of India Sponsored Project	
Sub Mission on Agricultural Mechanisation (SMAM) for implementation of its component no.1 under Drone Technology Demonstration	C. Karpagam M. Loganathan I. Ravi K.J. Jeyabaskaran
NABARD Funded projects	
Establishment of banana macropropagation units in Tiruchirappalli district, capacity building and improvement of livelihood opportunities of farmers	S. Uma R. Karthic S. Backiyarani M.S. Saraswathi

Design, Development and Validation of Online Banana Trading platform for farmers of FPOs in Tiruchirappalli District	P. Suresh Kumar R. Selvarajan K.J. Jeyabaskaran
Establishment of common incubation centre (CIC)	P. Suresh Kumar K.N. Shiva
Other externally funded projects	
Gene editing for Fusarium Wilt resistance in banana (Grand Naine, AAA)	C. Anuradha
Induced polyploidy: A tool to improve sterile bananas	S. Kalpana
Efforts towards the development of Fusarium wilt resistance in banana using CRISPR/ Cas9	Jeyabharathy Chandrasekaran

ANNEXURE-II

Meteorological Data

Month	Max. Temp. (°C)	Min. Temp. (°C)	RH (%)	Rainfall (mm)	Wind Speed (m/s)
Jan-23	28.97	14.12	84.03	10.20	0.84
Feb-23	32.27	14.07	77.19	12.40	0.84
Mar-23	35.96	14.09	73.44	42.40	1.08
Apr-23	38.52	19.72	72.06	58.80	0.82
May-23	39.20	21.31	77.35	147.80	0.97
Jun-23	38.04	22.56	64.10	48.40	1.75
Jul-23	37.09	22.25	59.06	31.00	2.59
Aug-23	37.38	20.68	64.79	209.40	1.65
Sep-23	34.81	21.67	77.05	159.40	1.12
Oct-23	34.97	20.12	82.96	159.40	0.53
Nov-23	32.81	21.04	91.46	40.60	0.43
Dec-23	36.78	17.81	83.70	149.20	0.49
Average	**35.57**	**19.12**	**75.60**	**89.08**	**1.09**
				Total Rainfall (mm): **1069.00**	



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भारतीय कृषि अनुसंधान परिषद

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