वार्षिक प्रतिवेदन
Annual Report

2024

இ. வே. ஆ. கு. – தேசிய வாழை ஆராய்ச்சி மையம்
भाकृअनुप – राष्ट्रीय केला अनुसंधान केंद्र
ICAR - National Research Centre for Banana
(An ISO 9001:2015 Certified Institute)
Tiruchirappalli - 620 102, Tamil Nadu, India.
Phone - 0431-2618125, Web: nrcb.gov.in, Email - director.nrcb@icar.gov.in

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Dr. R. Selvarajan
Director
ICAR- National Research Centre for Banana
Thogamalai Road, Thayanur (PO), Tiruchirappalli- 620 102, Tamil Nadu, India

Compiled and Edited

Dr. C. Karpagam
Dr. S. Backiyarani
Dr. K.J. Jeyabaskaran
Dr. A. Mohanasundram
Dr. K. Nagendran
Dr. R. Selvarajan

Technical Assistance

Dr. P. Ravichamy
Dr. R. Arthee
Mr. S. Harishwar

Layout Designed by

Mr. S. Ajith Kumar

Hindi Translation

Shri Anil Kumar Dubey, ICAR, New Delhi

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PREFACE

Although India accounts for 9.6 Percent of the global area under banana cultivation, its contribution to world banana production is significantly higher at 23%. The demand for bananas continues to rise steadily, and by 2050, it is projected that the country may need to produce up to 60 million tons annually.

The ICAR-National Research Centre for Banana (ICAR-NRCB) has made substantial efforts, particularly in ensuring the supply of quality planting materials. However, continuous research and development are still required in several key areas: varietal diversification under changing climatic scenarios, development of cost-effective production technologies, and the protection of banana cultivation from climate-induced stresses. These remain major challenges that demand innovative and sustained solutions.

As the Director of the esteemed ICAR-National Research Centre for Banana, it is with great pride and enthusiasm that I present this Annual Report, which encapsulates the research and developments in banana cultivation and utilization during the year 2024. Our institute's unwavering commitment to advancing agricultural science and fostering innovation has culminated in a wealth of knowledge and achievements poised to revolutionize the banana sector.

This report offers readers a comprehensive overview of banana research across diverse domains, including crop improvement, production, postharvest technology, protection, and outreach initiatives undertaken by ICAR-NRCB to strengthen the banana sector in India. In line with our commitment to public health and inclusive nutrition, ICAR-NRCB evaluated over 15 popular banana cultivars. Among them, Pisang Lilin stood out with a consistently low glycemic response.

In the realm of Crop Improvement, the pro-vitamin-A-rich dessert banana NCR-17 recorded over 20% higher yield than Manjeri Nendran for two consecutive years across various locations. ICAR-NRCB has also pioneered advanced genetic research, including the transformation of CRISPR/Cas9 constructs in Grand Nain to edit genes such as *Ibd20, dmr6, nudix hydrolase, pelota* and *eIF4E*, aimed at enhancing resistance to Fusarium wilt and viruses (BBTV, BBrMV, and CMV). Four farmer varieties-Thottu Chingan, Kuthiraival Chingan, Manoranjitham and Neykadali were successfully registered with the PPV&FRA and Fusarium wilt-resistant mutants were identified in Grand Nain. Furthermore, albino plants were developed in Grand Nain by targeting the phytoene desaturase (PDS) gene using CRISPR-Cas9, providing functional validation of gene editing. An embryogenic cell line was also established in the banana variety cv. Rose, offering a foundation for future genetic transformation studies.

Our Crop Production research has focused on natural farming practices and IoT-enabled precision irrigation to improve yield and efficiency. Development of agro-techniques for ICAR-NRCB-released varieties and selections marked a significant milestone. Emphasis on carbon sequestration, energy budgeting, biodiversity, and productivity under three different banana production ecosystems has significantly strengthened our production research. Physiological studies highlighted varied responses to excess soil moisture among cultivars: Nendran allocates more resources to underground storage, while Karpuravalli and Kaveri Saba prioritize aboveground growth, reflecting their unique genetic traits.

In the Postharvest Technology section, the Centre's work on biofilms as smart packaging is gaining importance in the food industry due to its potential to enhance safety, extend shelf life, and reduce waste. Sustainable packaging solutions, such as smart active films integrating banana bract anthocyanins with modified starch, and exploring banana peel's potential for functional foods, are noteworthy achievements. The banana scutcher a by-product of fibre extraction was evaluated as a sustainable soil amendment, demonstrating better moisture retention and nutrient enrichment than coir pith. Other significant developments include novel nutraceutical smart delivery systems for high-value products, application of banana starch as a wall material for encapsulation, and the design and development of a central core stem juice extractor.

Under Crop Protection, emerging pests, diseases, and nematodes were identified in time and effectively managed through Integrated Pest Management (IPM) strategies. Severe infestations of *Dysmicoccus neobrevipes*, an exotic mealybug species, posed a serious threat to multiple cultivars during 2023–24. This species causes fruit blackening which severely reducing marketability. ICAR-NRCB developed eco-friendly management strategies for pseudostem weevils and banana scarring beetles; employed the Kaveri Microbial Consortium (KMC) as a biopriming agent during tissue culture hardening; and tested entomopathogenic fungi against banana weevils and sucking pests—marking key achievements in pest and disease control.

To enhance dissemination and adoption of banana technologies, multiple Extension and Outreach approaches were deployed. During the reporting period, 255 capacity development programmes reached 8,750 direct beneficiaries. Additionally, 205 print and mass media articles were made reachable to the un-reached. Participation in 20 frontline exhibitions touched an estimated 4,45,680 indirect beneficiaries. Technological demonstration for different technologies are benefited over 9,500 stakeholders. Notable outreach events included National Science Day (celebrated as an Open Day with 6,000 students), Viksit Bharat Sankalp Yatra, NRCB's 31st Foundation Day, Kisan Mela, Banana Festival, and Kisan Diwas.

The dedicated research and development activities detailed in this report stand as a testament to our collective efforts, relentless pursuit of excellence, and steadfast commitment to building a more sustainable and prosperous future for banana cultivation in India.

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.

These accomplishments are the result of the collective efforts of our committed team. I sincerely thank the editorial committee for their meticulous work in preparing the ICAR-NRCB Annual Report 2024 and encourage all readers to explore and make the most of the valuable insights it offers.

(R. Selvarajan)

Director

INTRODUCTION

The ICAR-National Research Centre for Banana is a premier research and development institution dedicated to addressing the needs of banana farmers and other stakeholders. It has significantly contributed to enhancing banana production and productivity in India. The Centre operates a 36.5-hectare research farm and a 3.23-hectare laboratory complex. It also has a residential complex spread across 0.80 hectares within the city. Geographically, the Centre is located at 11.50^{o}N latitude and 74.50^{o}E longitude, 90 meters above mean sea level, and receives an average annual rainfall of 800 mm. The climate is warm and humid, with average minimum and maximum temperatures of 25^{o}C and 35^{o}C, respectively.

ICAR-NRCB focuses on five core research areas: Crop Improvement, Crop Production, Post-Harvest Management, Crop Protection, and Extension. The Institute is equipped with state-of-the-art laboratories for tissue culture, plant virology biotechnology, soil science, water and nutrient management, physiology, biochemistry, entomology, nematology, plant pathology, post-harvest technology, and extension research.

I am pleased to present the milestone research achievements in the banana sector for the year 2024. In the area of banana improvement, the pro-vitamin A-rich dessert banana variety NCR-17 recorded over 20% higher yield than Manjeri Nendran for two consecutive years across multiple locations. ICAR-NRCB has also made significant strides in advanced genetic research.

Research on organic and natural farming has resulted in a comprehensive package of practices, facilitating wider adoption by farmers. The development of agro-techniques for ICAR-NRCB-released varieties and selections marked a major advancement. Noteworthy achievements include sustainable packaging innovations, such as smart active films combining banana bract anthocyanins with modified starch, and the exploration of banana peel for its potential in functional foods. The banana scutcher, a by-product of fibre extraction, was evaluated as a sustainable soil amendment, proving more effective than coir pith in moisture retention and nutrient enrichment.

Emerging pests, diseases, and nematodes were identified and effectively managed using integrated pest management (IPM) strategies. The development of the Kaveri Microbial Consortium (KMC) as a biopriming agent during tissue culture hardening, and the testing of entomopathogenic fungi against banana weevils and sucking pests, were key achievements in pest and disease control.

To promote the dissemination and adoption of banana technologies, a range of extension and outreach initiatives were undertaken. Major events included National Science Day (celebrated as an Open Day with the participation of over 6,000 students), Viksit Bharat Sankalp Yatra, 31st Foundation Day of ICAR-NRCB, Kisan Mela, Banana Festival, and Kisan Diwas. In 2024, the Centre adopted modern cultivation practices such as automation, sensor-based irrigation, IoT-enabled disease detection systems, and drone technology for high-tech value-added product development.

The Centre signed Memoranda of Agreement/Understanding/Collaboration with 10 research institutes, universities, and private companies for research partnerships and student exchange programmes. A total of 255 capacity development programmes were conducted, benefiting 8,750 participants directly. Furthermore, 205 print and mass media articles helped reach wider stakeholders. Participation in 20 frontline exhibitions supported to reach an estimated 445,680 indirect beneficiaries. Technological demonstrations benefited over 9,500 stakeholders. The Centre also regularly

conducts Institute Research Council (IRC) and Research Advisory Council (RAC) meetings to review ongoing projects and monitor progress on RAC and QRT recommendations.

This report reflects the dedicated research and development efforts of our staff, for which I express my sincere appreciation. The credit for these accomplishments goes to every member of the team.

Vision

To be a global leader in banana and plantain production and productivity, thereby meeting India's growing demand.

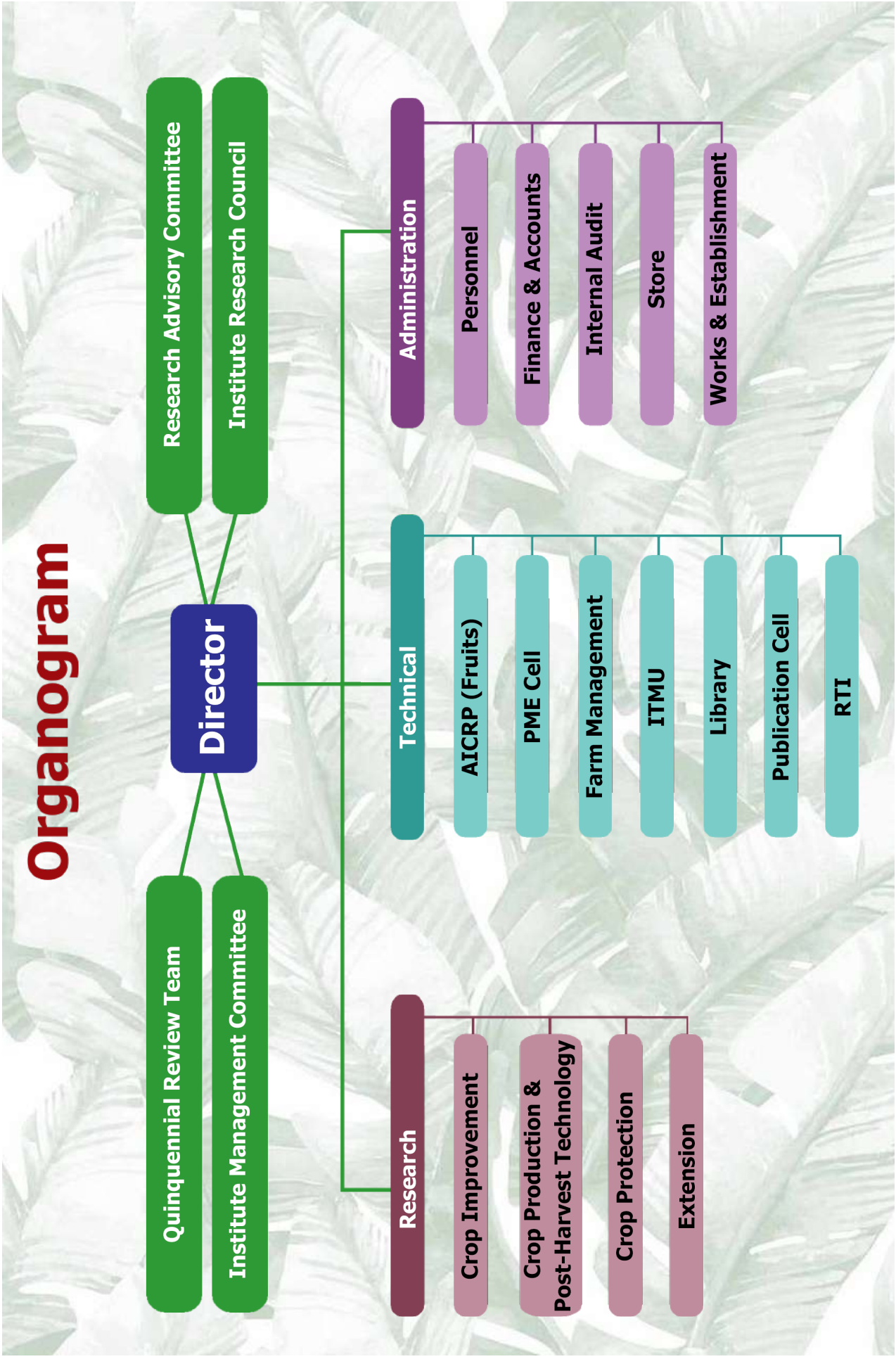
Mandate

- Undertake basic, strategic, and applied research on genetic resource management, crop improvement, and production technologies for sustainable and enhanced banana cultivation.
- Manage the national banana gene bank and coordinate research efforts to enhance and sustain banana productivity.
- Facilitate technology transfer and build stakeholder capacity to support increased and sustained banana production.
- Serve as a referral laboratory for monitoring the quality of micropropagated banana plants.

Budget details for the year 2024

Head	Expenditure (in lakhs)
Equipment	77.10
IT	6.79
Works	44.97
Vehicle	11.13
Establishment	1103.92
Retirement Benefits	170.71
TA	15.52
Research Expenses	53.77
Operational Expenses	161.60
Infrastructure	149.47
Communication	6.58
Repair of equipment, Vehicle	27.85
Other admn. (Other TA)	10.82
HRD	2.67
Publicity & Exhibition	3.00
Miscellaneous	8.73
P Loans & Advances	5.00
Total	1859.63
SCSP-Capital	0
SCSP-General	5.00
Grand Total	**1864.63**

A revenue of Rs. **81.79 lakhs** was generated by the Centre during the year 2024.


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

Executive Summary

Crop Improvement

Improvement & management of genetic resources in India: Among the Grand Nain clones, those from Jalgaon (2020 JLPC 2021 and BRSJ-4) and Mohanpur also displayed variation from their controls. Similarly, Thella Chakkarakeli clones from Kovvur and Kaliethen (2017 7 KAPC) and Swarnamukhi clones (2022 20 KAPC) from BRS, Kannara showed divergence from control. In addition, the 2/5(a) clone from the Arabhavi demonstrated variation from its control.

Rooting efficiency in Grand Nain and Red Banana revealed increased fresh and dry root weights with MS medium concentration, recording dry root weights of 6.7 mg and 7.2 mg per plant, respectively. Secondary hardening survival rates improved significantly (95.0% and 95.6%, respectively) in PG-supplemented media, indicating PG's role in enhancing root development and *ex vitro* acclimatization.

Analysing the stability of Red Banana: Through direct regeneration, shoots were multiplied from immature male flower hands of cv. Red Banana and Pachakappa (somaclonal variant – green). The shoots obtained were morphologically similar to that of respective parental clones. This confirms that the somaclonal variants are not reverting back to red colour which confirms the stability of red banana somaclonal variant for stem colour.

Kaveri Microbial Consortium (KMC) in banana hardening: Micro propagated banana cv. Red Banana was bio-hardened using the Kaveri Microbial Consortium (KMC) at both primary and secondary hardening stages. The treatment was found to stimulate plant growth and recorded higher antioxidant activities.

Improvement of banana through conventional breeding: Kaveri Kanchan, a Tamil Nadu state variety, released for the Tamil Nadu state yielded 20 per cent more than Manjeri Nendran over two consecutive years across India. It has been recommended for cultivation in Bihar, Karnataka, Odisha, Tamil Nadu, Maharashtra, Kerala, and West Bengal by the 11th Group Discussion of the ICAR-AICRP on Fruits held at NAU, Navsari. Four different banana genotypes—Pisang Lilin (AA), Calcutta 4 (AA), Ney Poovan (AB), Bhimkol (BB), and Grand Nain (AAA) were initiated for the development of androgenic haploids using uninucleate and highly vacuolated stages of anthers. The callus induction frequency varied significantly among genotypes, with the highest frequency observed in cv. Bhimkol.

Study on Gene editing for banana improvement: Four *dmr6* genes (Ma04_t20880, Ma04_t23390, Ma02_t12040, and Ma05_t12600) were cloned and characterized from both *Fusarium oxysporum* f. sp. *cubense* (Foc) Race 1 and Tropical Race 4 (TR4)-resistant cultivar 'Rose' and the susceptible cultivar 'Grand Nain'. In addition, the *pelota* gene (Macma4_08_g05970) was cloned and characterized from BBTV-resistant and susceptible banana cultivars.

Six *nudix hydrolase (nh)* genes, Ma05_t05700, Ma01_t15710, Ma10_t17260, Ma11_t18430, Ma08_g26550, and Ma04_g26170 were amplified, cloned, and characterized from both Foc Race 1 and TR4-resistant (cv. Rose) and susceptible (cv. Grand Nain) banana cultivars. Twelve guide RNAs (two per nh gene) were designed, synthesized, and cloned into the pRGEB31 vector. These constructs were transformed into *Escherichia coli* strain DH5α, and sequencing confirmed the integration of the guide RNAs. Subsequently, the constructs were introduced into *Agrobacterium tumefaciens* strain AGL-1 for plant transformation.

Four farmers' varieties, Thottu Chingan, Kudhiraival Chingan, Manoranjitham and Neykadali were registered with the Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi. DUS characterization has been completed for the farmers' variety Chavaniyankal Poovan, along with a reference accession.

Chromosome doubling of Kunnan (AB) and Bhimkol (BB) embryogenic cell suspension

(ECS) resulted in developing tetraploids. These tetraploids were confirmed through morphological traits under field condition and through flow cytometry. ECS has been established in cv. Rose (AA) and treated with antimitotic agent, oryzalin for chromosome doubling.

Crop Production

Organic banana farming: The application of different organic manures significantly influenced key soil physico-chemical properties, including soil pH, EC, organic carbon (OC), cation exchange capacity (CEC), bulk density, porosity, and the availability of nitrogen (N), phosphorus (P), and potassium (K).

The experiment utilized the banana cultivar 'Ney Poovan' due to its known tolerance to saline and sodic conditions. The findings revealed significant salinity stress, leading to poor plant establishment. The study concluded that soils with a pH greater than 8.5 and an ESP exceeding 15 are unsuitable for banana cultivation, even with the application of organic amendments and gypsum.

Nano-formulation of Banana Sakthi: The most effective combination of Nano Banana Shakti (BS) was identified for the cultivation of Ney Poovan. Application of Nano-BS at 0.5% resulted in the highest yield of Ney Poovan banana (37.25 t/ha), followed by Normal-BS at 2% (36.75 t/ha). Compared to the control (30.13 t/ha), the yield increase was 23.6% for Nano-BS (0.5%) and 21.9% for Normal-BS (2%).

Biodiversity analysis from three different production systems: Hill ecosystem demonstrated the greatest plant diversity and richness among the three banana-growing environments. Furthermore, Non-Metric Multi-Dimensional Scaling (NMDS), a distance-based ordination technique, revealed distinctive species distributions ($p < 0.001$) across the production systems. The hill system supported a greater number of species with variable densities compared to the garden and wetland systems.

Banana scutcher as an eco-friendly mulch: Banana plants mulched with scutcher exhibited greater plant girth (7 cm), number of leaves (7), and leaf area (450 cm^2) compared to the control (4 cm, 5.5 leaves, and 350 cm^2, respectively). This study supports that both the physical and chemical properties of scutcher material contribute to plant growth improvement and soil health enhancement in a sustainable manner.

Integrated package of practices for export of bananas: The treatment in Red banana with 100% RDF fertigation, Banana Shakti, bunch cover and potassium sulphate as a bunch spray exhibited the highest plant height (317.08 cm), girth (81.67 cm), number of leaves (21.25), and leaf area (0.93 m^2), whereas yield parameters also followed a similar trend with T1 producing the heaviest bunches (16.97 kg).

Effect of surface coating and packaging: For Grand Nain, a 0.5% chitosan coating at room temperature enhanced visual quality, while a 5% gum arabic coating at 13.5°C effectively reduced physiological weight loss, extending the shelf life up to 52 days. These findings suggest that variety-specific edible coating and storage strategies can significantly improve the shelflife and marketability of bananas.

Green packaging and bio-energy from agro-residues: Ultrasound application enhanced enzymatic activity by disrupting and modifying the starch granule structure, as confirmed through scanning electron microscopy (SEM) analysis. The combined physical-enzymatic treatment (U-AMY-PUL) significantly improved starch solubility by altering its structural configuration, as demonstrated by X-ray diffraction (XRD) and Fourier-transform infrared (FTIR) spectroscopy analyses.

Utilization of banana peel powder: This study evaluated the substitution of refined wheat flour (RWF) with banana peel powder (BPP) at 2–8% levels to develop fortified functional muffins. Overall, 4% BPP substitution improved sensory appeal and nutritional value—lowering fat and gluten while increasing fibre—though higher levels negatively impacted texture and quality.

Under physio-biochemical changes during banana fruit development, immature fruits exhibited high starch content and low total sugar levels. As maturation progressed, starch hydrolysis led to a substantial increase in total

sugars (TS). It increased from 15 to 30 days after flowering (DAF), declined slightly from 30 to 45 DAF, plateaued until 90 DAF, and then peaked at maturity. Reducing sugar levels consistently increased during maturation.

Nutraceutical applications of bioactives of banana: Analysis of the nutritional and nutraceutical properties of 'Monthan' (ABB), a cooking banana variety, revealed high levels of functional bioactive compounds. The peel contained epigallocatechin (182 mg/100 g), a flavonoid known for its strong antioxidant properties. The pulp contained inulin-type fructans (123 µg/g), a dietary fibre with significant immunomodulatory benefits.

Pisang Lilin – a low glycemic banana: Locally known as 'Kaveri' or '*Meluguthiri*' (Candle Banana). 'Pisang Lilin' is cultivated in the Kanyakumari district of Tamil Nadu and in the Thiruvananthapuram, Kozhikode, and Wayanad districts of Kerala. It was identified as a low glycemic banana with a GI of 51.3. This finding is especially valuable for health-conscious consumers and individuals have diabetes mellitus.

Crop Protection

Insect pest management

Pest mapping in bananas and plantains of India: The coexistence of three species of *Spodoptera* (*S. litura*, *S. frugiperda*, and *S. exigua*) on banana foliage was observed for the first time in Trichy, Karur, and Thanjavur districts. *S. exigua* emerged as a serious pest during the vegetative stage of banana (2–3-month-old crops) for the first time.

Outbreaks of banana fruit mealybug: Severe infestations of *D. neobrevipes*, an exotic mealybug species, emerged as a significant concern across several banana cultivars during 2023–24. This mealybug is the most damaging fruit-infesting species as it causes partial or total blackening of fruits, resulting in loss of market value.

Management of major insect pests: Fish oil powder (100%) and Neem + Pongamia soap cake (98%) recorded the highest mortality, followed by Imidacloprid (84%) and Banana Weevil Killer (80%) against banana sucking pest. Among the seven insecticide tested, Indoxacarb, Spinosad, and Chlorpyrifos caused 100% mortality within 12 hours, followed by Fipronil (90%) and Emamectin Benzoate (87%) for emerging banana pests.

Feeding behaviour of banana pseudostem weevil: The larvae fed on both pseudostems and banana leaf sheaths. However, larvae were unable to pupate when fed on pseudostems. Both larvae and adults died on the ninth day after feeding on pseudostems, whereas they survived when fed on leaf sheaths.

Sampling for nematode incidence: Severe infection by root-knot nematodes, *Meloidogyne* sp. (1,264 nematodes per gram of root), was observed on cv. Poovan grown under ratoon cultivation for leaf production in Vadugakudi, Thanjavur district, Tamil Nadu

Disease management

Integrated management of Fusarium wilt *Foc*-TR4 : Secondary metabolites obtained from *Trichoderma asperellum* and *Bacillus flexus* which were added with culture filtrate of *Foc* in varying proportions revealed the presence 25 different compounds which are exhibiting distinct functional activities against *Foc*. Notably, 9-Octadecen-1-ol (E) exhibited the highest peak level at 53.98%, which is responsible for reinforcing the plant cuticle and act as a protective barrier against *Foc* infection.

Management of rhizome rot of banana: Among the eight PGPR isolates evaluated, isolates H6BC3, JP-4, and BCNA 5-3 significantly enhanced plant height, stem girth, leaf length, and leaf breadth compared to the other isolates and the untreated control. Furthermore, three isolates (H6BC3, JP-4, and BCNA 5-3) recorded significant yield increases of 62.50%, 57.95%, and 58.12% per plant, respectively, over the control.

CMV transmission in tissue culture plants: From 165 CMV-infected banana suckers (100 Andhra Pradesh, 65 Maharashtra), meristem culture reduced viral titres significantly. At the S2 stage, the number of high titre plants

dropped from 36 to 5, with most samples shifting to low titre. At S3 and S4 stages, some regenerated shoots showed symptoms while others remained asymptomatic.

Virus indexing of TC mother plant: In the year 2024, a total of 4105 tissue culture banana samples from TCPUs were tested for four viruses under contract services. Additionally, 278 banana germplasm accessions conserved in field gene banks at AICRP (Fruits) centres in Arabhavi, Coimbatore, Gandevi, Jalgaon, and Trichy were screened for viral presence.

Extension & Outreach activities

The outreach and inter-institutional activities as open day and farmers included various initiatives such as celebrating National Science Day with 6000 students on February 28, 2024, on the theme of *"Indigenous Technologies for Viksit Bharat"*. NRCB's 31st Foundation Day and Kisan Mela on 21st August 2024, Banana Festival cum Kisan Diwas on December 23, 2024 and participation in Viksit Bharat Sankalp Yatra are the notable outreach events during the reported period.

During the reporting period, 255 capacity development programmes reached 8,750 direct beneficiaries. Additionally, 205 print and mass media articles were published. Participation in 20 frontline exhibitions reached an estimated 4,45,680 indirect beneficiaries. ICAR-NRCB bagged the "Best Stall Award at "National Horticulture Fair-2024" held at ICAR-IIHR, Bengaluru. Technological demonstration for different technologies are benefited over 9,500 stakeholders.

Other extension initiatives: Farmers participatory technology assessment and refinement for summer management technologies in tissue culture banana cultivation, demonstration on Germplasm diversity block, drone demonstration, value added products demonstration in CIC, Sensor-based automation, research experiment plots. Further, twenty video films and series of publications were developed for extension activities.

Women empowerment: ICAR-NRCB organized various training programs for women farmers and entrepreneur from various districts of Tamil Nadu and other states. In the reporting year, the total number of women beneficiaries was 5117. Under the ATMA program, training sessions were conducted for women on Integrated Nutrient Management (INM), value addition technologies, and disseminating various government schemes such as PM Kisan, KCC, and RKVY.

Publications: A total presentation of 286 publications were contributed by the institute including research papers: 55; Symposia: 30; Book Chapters: 9; Monograph: 1; Popular article: 20; Extension folder: 6; News Stories reported for ICAR NEWS (E- Publications): 12; Technical bulletins: 2; Training manual: 5; Institute Publications: 6; Radio talks: 10; News broadcasts in electronic media (AIR/TV): 32; Press release reported in different mass and print media: 28; News articles published in print media: 53; and Stories shared *via* social media platforms: 29. Thirty nine students belongs to M. Sc and Ph. D were guided by the ICAR-NRCB Scientists.

Commercialization of Technologies: Twenty technologies were licensed during the period and seven copy right's were granted.

कार्यकारी सारांश

फसल सुधार

भारत में आनुवंशिक संसाधनों में सुधार और प्रबंधन: ग्रैंड नैनै क्लोनों में, जलगॉव (2020 जेएलपीसी 2021 और बीआरएसजे–4) और मोहनपुर से प्राप्त क्लोनों ने भी अपने तुलनीयों से भिन्नता प्रदर्शित की। इसी प्रकार, बीआरएस केन्नारा से प्राप्त कोव्वुर और कालीथेन (2017 7 केएपीसी) और स्वर्णमुखी क्लोनों (2022 20 केएपीसी) से थेल्ला चक्करकेली क्लोनों में तुलनीयों से विविधता प्रदर्शित हुई। इसके अतिरिक्त अराभावी से प्राप्त 2/5 (ए) क्लोन ने अपने तुलनीय से विविधता का प्रदर्शन किया।

ग्रैंड नाइन और रेड बनाना में जड़ जमाने की क्षमता ने एमएस माध्यम की सांद्रता के साथ ताजी और सूखी जड़ों के भार में वृद्धि प्रदर्शित की, और प्रति पौधा सूखी जड़ों का भार क्रमशः 6.7 मिलीग्राम और 7.2 मिलीग्राम दर्ज किया गया। पीजी–पूरक माध्यम में द्वितीयक कठोरीकरण उत्तरजीविता दर में उल्लेखनीय सुधार हुआ (क्रमशः 95. 0: और 95.6:), जो जड़ विकास और बाह्य–अनुकूलन (एक्स विट्रो) अनुकूलन को बढ़ाने में पीजी की भूमिका को दर्शाता है।

रेड बनाना की स्थिरता का विश्लेषण: प्रत्यक्ष पुनर्जनन के माध्यम से, रेड बनाना और पचकप्पा (सोमाक्लोनल वैविध्य– हरा) की अपरिपक्व नर पुष्प कलियों से प्ररोहों का गुणन किया गया। प्राप्त प्ररोह आकारिकी की दृष्टि से संबंधित पैतृक क्लोनों के समान थे। इससे यह पुष्टि होती है कि सोमाक्लोनल वैविध्य पुनः लाल रंग में नहीं बदलते, जो तने के रंग के लिए रेड बनाना के सोमाक्लोनल वैविध्य की स्थिरता की पुष्टि करता है ।

केले के कठोरीकरण में कावेरी माइक्रोबियल कंसोर्टियम (केएमसी): प्राथमिक और द्वितीयक कठोरीकरण दोनों चरणों में कावेरी माइक्रोबियल कंसोर्टियम (केएमसी) का उपयोग करके सूक्ष्म प्रवर्धित केले की किस्म रेड बनाना को जैव–कठोरीकृत किया गया। इस उपचार से पौधे की वृद्धि को बढ़ावा मिला और उच्च प्रतिऑक्सीकारक गतिविधियाँ दर्ज की गईं।

पारंपरिक प्रजनन के माध्यम से केले की खेती में सुधार: तमिलनाडु राज्य की किस्म कावेरी कंचन, 17 की उपज मंजेरी से 20 प्रतिशत अधिक है। नेंड्रन को पूरे भारत में लगातार दो वर्षों तक उगाया गया है। एनएयू, नवसारी में आयोजित आईसीएआर–फलों पर एआईसीआरपी की 11वीं समूह चर्चा में बिहार, कर्नाटक, ओडिशा, तमिलनाडु, महाराष्ट्र, केरल और पश्चिम बंगाल में इसकी खेती के लिए अनुशंसा की गई है । चार अलग–अलग केले के जीनप्ररुपों कृ पिसांग लिलिन (एए), कलकत्ता 4 (एए), नेय पूवन (एबी), भीमकोल (बीबी), और ग्रैंड नाइन (एएए) को परागकोषों की एककेन्द्रकीय और अत्यधिक रिक्तिकायुक्त अवस्थाओं का उपयोग करके एंड्रोजेनिक अगुणितों के विकास के लिए आरंभ किया गया था । कैलस प्रेरण आवृत्ति विभिन्न जीनप्ररुपों में महत्वपूर्ण रूप से भिन्न थी, जिसमें सबसे अधिक आवृत्ति किस्म भीमकोल में देखी गई।

केले के सुधार के लिए जीन संपादन पर अध्ययन: चार *कउत6* जीन (*ड॰04ऋज20880, ड॰04ऋज23390, ड॰02ऋज12040,* और *ड॰05ऋज12600*) को पयूजेरियम ऑक्सीस्पोरम एफ.एसपी.क्यूबेंस (फोक) जाति 1 और उष्णकटिबंधीय जाति 4 (टीआर4)–प्रतिरोधी किस्म 'रोज' और संवेदनशील किस्म ग्रैंड नैन' दोनों से सफलतापूर्वक क्लोन करके लक्षणवर्णन किया गया। इसके अलावा, पेलोटा जीन (डंबउंऋ08ऋह05970) को बीबीटीवी–प्रतिरोधी और संवेदनशील केले की किस्मों से क्लोन करके उसका लक्षण–वर्णन किया गया।

छह न्यूडिक्स हाइड्रोलेस (दी) जीन, ड॰05ऋज05700, ड॰01ऋज15710, ड॰10ऋज17260, ड॰11ऋज18430, ड॰08ऋह26550, और ड॰04ऋह 26170, को थ्वब रेस 1 और ज्व4–प्रतिरोधी (किस्म. रोज) और संवेदनशील (किस्म. ग्रैंड नैन) दोनों केले की किस्मों से सफलतापूर्वक प्रवर्धित, क्लोन और लक्षण वर्णित किया गया । बारह गाइड आरएनए (प्रति दी जीन में दो) डिजाइन किए गए, संश्लेषित किए गए, और चत्ळम्ठ31 वाहक में क्लोन किए गए। इन कंस्ट्रक्ट को एस्चेरिचिया कोलाई प्रभेद क्म्5α में रूपांतरित किया गया, और अनुक्रमण ने गाइड आरएनए के सफल एकीकरण की पुष्टि की । इसके बाद, कंस्ट्रक्ट को पादप रूपांतरण के लिए एग्रोबैक्टीरियम ट्यूमेफैसिएन्स प्रभेद ।ळ्ः1 में प्रविष्ट कराया गया।

चार कृषक किस्मों थोट्टू चिंगन, कुधिरैवल चिंगन, मनोरंजितम और नेयकादली को पौधा किस्म एवं कृषक अधिकार संरक्षण प्राधिकरण (पीपीवी और एफआरए), नई दिल्ली में पंजीकृत किया गया है। कृषक किस्म चवनियांकल पूवन का संदर्भ प्रविष्टि के साथ डीयूएस लक्षण–वर्णन पूरा हो चुका है।

कुन्नन (।ठ) और भीमकोल (ठठ) भ्रूणजन्य कोशिका निलंबन (ईसीएस) के गुणसूत्र दोहरीकरण के

परिणामस्वरूप चतुर्गुणित विकसित हुए। इन चतुर्गुणितों की पुष्टि खेत स्थितियों (चित्र 92) में रूपात्मक लक्षणों और प्रवाह कोशिकामिति के माध्यम से की गई। किस्म रोज (।।) में ईसीएस की पुष्टि की गई और गुणसूत्र दोहरीकरण के लिए एंटीमाइटोटिक एजेंट, ओरिजेलिन से उपचारित किया गया।

फसल उत्पादन

गुच्छों के प्रबंधन संबंधी अध्ययन: उर्वरक के प्रयोग के बावजूद, उच्च–घनत्व वाले रोपण (प्रति गड्ढे में तीन मूस्तारी) में उगाए गए पौधों में पुष्पन में देरी हुई, जो 300 दिनों से भी अधिक थी। पुष्पन अवस्था में, सभी उपचारों में मिट्टी का चम मान 6.82 से 7.73 के बीच था, जबकि विद्युत चालकता (ईसी) मान 0.07 कैच्छ और 0. 20 कैच्छ के बीच भिन्न थे।

जैविक केले की खेती: विभिन्न जैविक खादों के उपयोग से मृदा के प्रमुख भौतिक –रासायनिक गुणों को महत्वपूर्ण रूप से प्रभावित हुए, जिसमें मृदा पीएच, ईसी, कार्बनिक कार्बन (ओसी), धनायन विनिमय क्षमता (सीईसी), स्थूल घनत्व, सरंध्रता, तथा नाइट्रोजन (एन), फास्फोरस (पी), और पोटेशियम (के) की उपलब्धता शामिल है।

प्रयोग में केले की किस्म 'नेय पूवन' का उपयोग किया गया क्योंकि यह लवणीय और सोडियम युक्त परिस्थितियों के प्रति सहनशील है। निष्कर्षों से पता चला कि लवणता प्रतिबल का दबाव काफी अधिक था, जिसके कारण पौधों का विकास कम हुआ। अध्ययन से यह निष्कर्ष निकला कि 8.5 से अधिक चम और 15 से अधिक ईएसपी वाली मिट्टी केले की खेती के लिए अनुपयुक्त है और ऐसा जैविक सुधार और जिप्सम के प्रयोग के बावजूद भी होता है।

केला शक्ति नैनो सूत्रीकरण: नेय पूवन की खेती के लिए नैनो केला शक्ति (बीएस) का सबसे प्रभावी संयोजन पहचाना गया। 0.5: पर नैनो–बीएस के प्रयोग से नेय पूवन केले की सबसे अधिक उपज 37.25 टन/हेक्टेयर प्राप्त हुई, इसके बाद 2: सामान्य–बीएस के प्रयोग से 36. 75 टन/हेक्टेयर की उपज प्राप्त हुई। 30.13 टन/हेक्टेयर की उपज दर्ज करने वाले तुलनीय की अपेक्षा में, नैनो–बीएस के लिए उपज में 23.6: (0.5:) और सामान्य–बीएस के लिए 21.9: (2:) की वृद्धि हुई।

तीन विभिन्न उत्पादन प्रणालियों से जैव विविधता विश्लेषण: पहाड़ी पारिस्थितिकी तंत्र में तीनों केला–उत्पादक वातावरणों में सबसे अधिक पादप विविधता और समृद्धि प्रदर्शित हुई। इसके अलावा, दूरी–आधारित समन्वय तकनीक, नॉन–मेट्रिक मल्टी–डायमेंशनल स्केलिंग (एमएमडीएस) से उत्पादन प्रणालियों में विशिष्ट प्रजातियों के वितरण (च ढ 0.001) का खुलासा हुआ। पहाड़ी प्रणाली में उद्यान और आर्द्रभूमि प्रणालियों की तुलना में परिवर्तनशील घनत्व वाली प्रजातियों की संख्या अधिक थी।

पर्यावरण–अनुकूल पलवार के रूप में केले का स्कचर: स्कचर की पलवार लगाए गए केले के पौधों में तुलनीय (क्रमशः 4 सेमी, 5.5 पत्तियाँ और 350 सेमी) की तुलना में अधिक पौध परिधि (7 सेमी), पत्तियों की संख्या (7) और पत्ती क्षेत्र (450 सेमी) प्रदर्शित हुए । यह अध्ययन इस बात का समर्थन करता है कि स्कचर सामग्री के भौतिक और रासायनिक गुण, दोनों ही पौधों की वृद्धि में सुधार और मृदा स्वास्थ्य संवर्धन में स्थायी रूप से योगदान करते हैं।

केले के निर्यात के लिए विधियों का एकीकृत पैकेज: उपचाररू 100: आरडीएफ फर्टिगेशन, केला शक्ति, गुच्छा आवरण और गुच्छा स्प्रे के रूप में पोटेशियम सल्फेट में सबसे अधिक पौधे की ऊंचाई (317.08 सेमी), परिधि (81. 67 सेमी), पत्तियों की संख्या (21.25) और पत्ती क्षेत्र (0. 93 वर्ग मीटर) प्रदर्शित हुए, जबकि उपज मापदंडों के मामले में भी यही प्रवृत्ति देखी गई, जहां टी1 में सबसे भारी गुच्छा उत्पादन (16.97 किलोग्राम) देखा गया।

सतह कोटिंग और पैकेजिंग का प्रभाव: *ग्रैंड नैन* के लिए, कमरे के तापमान पर 0.5: चिटोसन कोटिंग से दृश्य गुणवत्ता में सुधार हुआ, जबकि 13.5ब पर 5: गम अरेबिक कोटिंग से कार्यिकीय भार में कमी प्रभावी ढंग से कम हुई, जिससे निधानी आयु 52 दिनों तक बढ़ गई। इन निष्कर्षों से यह सुझाव मिलता है कि किस्म–विशिष्ट खाद्य कोटिंग और भंडारण कार्यनीतियाँ से केलों की निधानी आय और विपणन क्षमता में उल्लेखनीय सुधार हो सकता है।

कृषि अवशेषों से हरित पैकेजिंग और जैव–ऊर्जा: अल्ट्रासाउंड अनुप्रयोग ने स्टार्च कणिका संरचना को बाधित और संशोधित करके एंजाइमी गतिविधि को बढ़ाया, जैसा कि स्कैनिंग इलेक्ट्रॉन माइक्रोस्कोपी (एसईएम) विश्लेषण द्वारा पुष्ट हुआ। संयुक्त भौतिक–एंजाइमी उपचार (न।डल्व्स) से स्टार्च की संरचनात्मक संरचना में परिवर्तन करके उसकी घुलनशीलता में उल्लेखनीय सुधार किया, जैसा कि एक्स–रे विवर्तन (एक्सआरडी) और फूरियर–ट्रांसफॉर्म इन्फ्रारेड (एफटीआईआर) स्पेक्ट्रोस्कोपी विश्लेषणों द्वारा प्रदर्शित किया गया है।

केले के छिलके के पाउडर का उपयोग: यह अध्ययन फोर्टिफाइड फंक्शनल मफिन विकसित करने के लिए, रिफाइंड गेहूं के आटे (आरडब्ल्यूएफ) की जगह केले के छिलके के पाउडर (बीपीपी) का 2–8: के स्तर पर मूल्यांकन करने के लिए किया गया। कुल मिलाकर, 4: बीपीपी प्रतिस्थापन से संवेदी आकर्षण और पोषण मूल्य में सुधार हुआ; वसा और ग्लूटेन कम हुआ जबकि रेशे में

वृद्धि हुई, हालाँकि उच्च स्तर ने बनावट और गुणवत्ता पर नकारात्मक प्रभाव डाला।

केले के फल विकास के दौरान भौतिक–जैव रासायनिक परिवर्तनों के अंतर्गत अपरिपक्व फलों में स्टार्च की उच्च मात्रा और कुल शर्करा के निम्न स्तर प्रदर्शित हुए। जैसे–जैसे परिपक्वता आगे बढ़ी, स्टार्च के जल–अपघटन के कारण कुल शर्करा (टीएस) में उल्लेखनीय वृद्धि हुई, यह फूल आने के 15 से 30 दिन बाद (डीएएफ) बढ़ी, 30 से 45 डीएएफ तक थोड़ी कम हुई, 90 डीएएफ तक स्थिर रही, और फिर परिपक्वता पर चरम पर पहुँच गई। परिपक्वता के दौरान घटते शर्करा स्तरों में लगातार वृद्धि हुई।

केले के जैवसक्रिय तत्वों के न्यूट्रास्युटिकल अनुप्रयोग: खाना पकाने के लिए इस्तेमाल होने वाली केले की एक किस्म, 'मोंथन' (एबीबी) के पोषण और न्यूट्रास्युटिकल गुणों के विश्लेषण से कार्यात्मक जैवसक्रिय यौगिकों के उच्च स्तर का पता चला। छिलके में एपिगैलोकैटेचिन (182 मिलीग्राम/100 ग्राम) पाया गया, जो एक पलेवोनोइड है जो अपने प्रबल प्रतिऑक्सीकारक गुणों के लिए जाना जाता है। गूदे में इनुलिन–प्रकार के फ्रुक्टेन (123 माइक्रोग्रामध्ग्राम) पाए गए, जो एक आहारीय रेशा है जिसमें महत्वपूर्ण प्रतिरक्षा को बनाए रखने संबंधी लाभ होते हैं।

पिसांग लिलिन – एक कम ग्लाइसेमिक युक्त केला: स्थानीय रूप से इसे 'कावेरी' या 'मेलुगुथिरी' (मोमबत्ती केला), 'पिसांग लिलिन' के नाम से जाना जाता है। लिलिन की खेती तमिलनाडु के कन्याकुमारी जिले और केरल के तिरुवनंतपुरम, कोझिकोड और वायनाड जिलों में की जाती है। इसे 51.3 ग्लाइसेमिक इंडेक्स (जीआई) वाले कम ग्लाइसेमिक युक्त केले के रूप में पहचाना गया है। यह खोज स्वास्थ्य के प्रति जागरूक उपभोक्ताओं और मधुमेह रोगियों के लिए विशेष रूप से महत्वपूर्ण है।

फसल सुरक्षा

कीट प्रबंधन

भारत में केले और हरे केले में कीट मानचित्रण: त्रिची, करूर और तंजावुर जिलों में पहली बार केले के पत्तों पर स्पोडोप्टेरा *(एस. लिटुरा, एस. फ्रुजीपरडा* और *एस. एक्सिगुआ)* की तीन प्रजातियों का सह–अस्तित्व देखा गया। *एस. एक्सिगुआ* पहली बार केले की वानस्पतिक अवस्था (2–3 महीने पुरानी फसल) के दौरान एक गंभीर कीट के रूप में उभरा।

केले के फल में मीलीबग का प्रकोप: वर्ष 2023–24 के दौरान केले की कई किस्मों में एक विदेशी मीलीबग प्रजाति, *डी. नियोब्रेवाइप्स* का गहन संक्रमण एक गंभीर चिंता का विषय बन गया है। यह मीलीबग फलों को सबसे अधिक नुकसान पहुँचाने वाली प्रजाति है क्योंकि यह फलों को आंशिक या पूर्ण रूप से काला कर देती है, जिससे बाजार मूल्य में कमी आती है।

प्रमुख कीट पीड़कों का प्रबंधन: मछली के तेल के पाउडर (100:) और नीम, पोंगामिया साबुन के टुकड़े (98:) से केले के चूषक कीटों के विरुद्ध सबसे अधिक मृत्यु दर दर्ज की, इसके बाद इमिडाक्लोप्रिड (84:) और बनाना वीविल किलर (80:) का स्थान रहा। परीक्षण किए गए सात कीटनाशकों में से, इंडोक्साकार्ब, स्पिनोसैड और क्लोरपाइरीफॉस से 12 घंटों के भीतर 100: मृत्यु दर दर्ज की गई, इसके बाद केले के उभरते हुए कीटों के लिए फिप्रोनिल (90:) और इमामेक्टिन बेंजोएट (87:) का स्थान रहा।

केले के छद्म तने वाले घुन का आहार व्यवहार: लार्वा छद्म तने और केले के पत्ते के आवरण दोनों पर भोजन करते थे। हालाँकि, छद्म तने पर भोजन करने पर लार्वा प्यूपा नहीं बन पाते थे । छद्म तने पर भोजन करने के नौवें दिन लार्वा और वयस्क दोनों मर जाते थे, जबकि पत्ते के आवरण पर भोजन करने पर वे जीवित रहते थे।

सूत्रकृमि प्रकोप के लिए नमूनाकरण: तमिलनाडु के तंजावुर जिले के वडुगाकुडी में पत्ती उत्पादन के लिए पेड़ी खेती के तहत उगाई गई पूवन प्रजाति की जड़–गाँठ सूत्रकृमि, मेलोइडोगाइन प्रजाति (प्रति ग्राम जड़ में 1,264 सूत्रकृमि) द्वारा गंभीर संक्रमण देखा गया।

रोग प्रबंधन

संक्रमित केले के नमूनों के डीएनए अर्क से बनाना बंची टॉप वायरस (बीबीटीवी) के कोट प्रोटीन (सीपी) जीन को सफलतापूर्वक प्रवर्धित किया गया और चळम्ड ज ईजी वेक्टर में क्लोन किया गया, जिसके बाद एस्चेरिचिया कोलाई क्म5α में रूपांतरण किया गया। इसके बाद, सीपी जीन को छकमप और गैवप स्थलों पर चम्28 द्ध अभिव्यक्ति वाहक में उप–क्लोन किया गया ताकि पुनः संयोजक प्लास्मिड चम्28द्ध –बीबीटीवी–सीपी का निर्माण किया जा सके।

फ्यूजेरियम म्लानि का एकीकृत प्रबंधन थ्वब–ज्ज 4: ट्राइकोडर्मा एस्परेलम और बैसिलस फ्लेक्सस से प्राप्त द्वितीयक चयापचयज, जो विभिन्न अनुपातों में थ्वब के कल्चर फिल्ट्रेट के साथ मिलाया गया था, में 25 विभिन्न यौगिकों की उपस्थिति का पता चला, जो थ्वब के विरुद्ध विशिष्ट कार्यात्मक गतिविधियाँ प्रदर्शित कर रहे हैं । उल्लेखनीय रूप से, 9–ऑक्टाडेसेन–1–ओल (1) में 53. 98: पर उच्चतम शिखर स्तर प्रदर्शित हुआ, जो पौधे की वलकुट को सुदृढ़ करने और थ्वब संक्रमण के विरुद्ध एक

सुरक्षात्मक अवरोध के रूप में कार्य करने के लिए उत्तरदायी माना गया है।

केले के प्रकंद सड़न का प्रबंधन: मूल्यांकन किए गए आठ पीजीपीआर (च्छच्त्) विलगकों में से, एच6बीसी3, जेपी–4, और बीसीएनए 5–3 विलगकों ने अन्य विलगकों और अनुपचारित तुलनीयों की अपेक्षा पौधे की ऊँचाई, तने की परिधि, पत्ती की लंबाई और पत्ती की चौड़ाई में उल्लेखनीय वृद्धि दर्ज की। इसके अलावा, तीन विलगकों (एच6बीसी3, जेपी–4, और बीसीएनए 5–3) में तुलनीय की अपेक्षा क्रमशः प्रति पौधा 62.50:, 57.95: और 58.12: की उल्लेखनीय उपज वृद्धि दर्ज की।

ऊतक संवर्धन पौधों में सीएमवी संचरण: 165 सीएमवी–संक्रमित केले के मूस्तारियों (100 आंध्र प्रदेश, 65 महाराष्ट्र) से, विमज्योतक संवर्धन ने विषाणु अनुमापन को उल्लेखनीय रूप से कम हुए। ै2 चरण में, उच्च अनुमापन वाले पौधों की संख्या 36 से घटकर 5 हो गई, और अधिकांश नमूने निम्न अनुमापन वाले पौधों में परिवर्तित हो गए । ै3 और ै4 चरणों में, कुछ पुनर्जीवित प्ररोहों में लक्षण दिखाई दिए, जबकि अन्य लक्षणहीन रहे।

टीसी मातृ पौधे का विषाणु अनुक्रमण: वर्ष 2024 में, विषाणु अनुक्रमण के लिए अनुबंध सेवाओं के अंतर्गत, टीसीपीयू से कुल 4105 ऊतक संवर्धन केले के नमूनों का चार विषाणुओं के लिए परीक्षण किया गया। इसके अतिरिक्त, अरमावी, कोयंबटूर, गणदेवी, जलगाँव और त्रिची स्थित एआईसीआरपी (फल) केंद्रों के प्रक्षेत्र जीन बैंकों में संरक्षित 278 केले के जर्मप्लाज्म अभिगमों की विषाणु उपस्थिति के लिए जाँच की गई।

विस्तार और आउटरीच गतिविधियाँ: आउटरीच और अंतर–संस्थागत गतिविधियों में विभिन्न पहल शामिल थीं जैसे 28 फरवरी, 2024 को 6000 छात्रों के साथ राष्ट्रीय विज्ञान दिवस मनाना, जिसका विषय था 'विकसित भारत के लिए स्वदेशी प्रौद्योगिकियां', राष्ट्रीय केला अनुसंधान केन्द्र का 31वां स्थापना दिवस और किसान मेला, केला महोत्सव सह किसान दिवस 23 दिसंबर 2024 को, विकसित भारत संकल्प यात्रा, रिपोर्ट की गई अवधि के दौरान उल्लेखनीय आउटरीच कार्यक्रम हैं।

कार्यक्रम के अंतर्गत लाभार्थी: समीक्षाधीन अवधि के दौरान, 255 क्षमता विकास कार्यक्रमों के माध्यम से 8,750 प्रत्यक्ष लाभार्थियों तक पहुँच बनाई गई। इसके अतिरिक्त, 205 प्रिंट और मास मीडिया लेख उन लोगों तक पहुँचे जो अभी तक पहुँच नहीं पाए थे। 20 अग्रिम पंक्ति प्रदर्शनियों में भागीदारी से अनुमानित 4,45,680 परोक्ष लाभार्थी जुड़े। भा.कृ.अनु.प.– राष्ट्रीय केला अनुसंधान केन्द्र ने ने भा.कृ.अनु.प.– भारतीय बागवानी अनुसंधान केन्द्र, बेंगलुरु में आयोजित 'राष्ट्रीय बागवानी मेला–2024ः में 'सर्वश्रेष्ठ स्टॉल पुरस्कार' जीता। विभिन्न तकनीकों के तकनीकी प्रदर्शन से 9,500 से अधिक हितधारक लाभान्वित हुए।

अन्य विस्तार पहलें : टिशू कल्चर केले की खेती के लिए ग्रीष्मकालीन प्रबंधन तकनीकों हेतु कृषक सहभागी प्रौद्योगिकी मूल्यांकन और परिशोधन के अतिरिक्त जर्मप्लाज्म विविधता ब्लॉक का प्रदर्शन, ड्रोन प्रदर्शन, सीआईसी में मूल्यवर्धित उत्पादों का प्रदर्शन, सेंसर–आधारित स्वचालन, अनुसंधान प्रयोग प्लॉट आदि का भी पदर्शन किया गया। इसके अतिरिक्त, विस्तार गतिविधियों के लिए बीस वीडियो फिल्में और प्रकाशनों की श्रृंखला विकसित की गई।

महिला सशक्तिकरणरू भा.कृ.अनु.प.– राष्ट्रीय केला अनुसंधान केन्द्र ने तमिलनाडु और अन्य राज्यों के विभिन्न जिलों की महिला किसानों के लिए विभिन्न प्रशिक्षण कार्यक्रम आयोजित किए। समीक्षाधीन वर्ष में, महिला लाभार्थियों की कुल संख्या 5117 थी। 'आत्मा' कार्यक्रम के अंतर्गत, महिलाओं के लिए एकीकृत पोषक तत्व प्रबंधन (आईएनएम), मूल्य संवर्धन तकनीकों और पीएम किसान, केसीसी और आरकेवीवाई जैसी विभिन्न सरकारी योजनाओं पर प्रशिक्षण सत्र आयोजित किए गए।

प्रकाशन: संस्थान द्वारा कुल 286 प्रकाशनों में योगदान दिया गया जिनमें शोध पत्र: 55, संगोष्ठियां:30, पुस्तक अध्यायः 9, मोनोग्राफः 1, लोकप्रिय लेखः 20, विस्तार फोल्डरः 6, न्यूज स्टोरी, आईसीएआर न्यूज (ई–प्रकाशन): 12, तकनीकी बुलेटिनः 2, प्रशिक्षण मैनुअलः 5, संस्थान प्रकाशनः 6, रेडियो वार्ताः 10, इलेक्ट्रॉनिक मीडिया (आकाशवाणी/दूरदर्शन) में समाचार प्रसारणः 32, विभिन्न मास और प्रिंट मीडिया में रिपोर्ट की गई प्रेस विज्ञप्तिः 28, प्रिंट मीडिया में प्रकाशित समाचार लेखः 53, सोशल मीडिया प्लेटफॉर्म के माध्यम से साझा की गई कहानियां: 29 शामिल हैं।

राष्ट्रीय केला अनुसंधान केन्द्र के वैज्ञानिकों द्वारा छात्रों का मार्गदर्शन: भा.कृ.अनु.प.–राष्ट्रीय केला अनुसंधान केन्द्र के वैज्ञानिकों द्वारा एम.एससी. और पीएच.डी. के 39 छात्रों को मार्गदर्शन दिया गया।

प्रौद्योगिकियों का व्यावसायीकरण: इस अवधि के दौरान बीस प्रौद्योगिकियों को लाइसेंस दिया गया। सात को कॉपीराइट प्रदान किया गया।

4.RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

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

(S. Backiyarani, M.S. Saraswathi, R. Selvarajan)

Collection of Banana germplasm

A total of seven accessions were collected from secondary sources. One new seeded type, *Kattu vazhana* (IC631127), was collected from NBPGR, Thrissur, and a variegated banana was collected from Parasala, Kerala. Suckers of five *Musa* species, *M. beccarii* N.W. Simmonds, *M. velutina* H. Wendl. & Drude, *M. cheesmanii* N.W. Simmonds, *M. haekkinenii* N.S. Lý & Haev, and *M. itinerans* Cheesman **(Fig. 1)**, were collected from the Malabar Botanical Garden & Institute for Plant Sciences, Kozhikode, Kerala.

M. beccarii *M. haekkinenii*

Fig. 1. Collection of wild species

GI tagged Nanjangud Rasabale suckers collected from farmer's field, Devarsanahalli, Nanjangud, Mysuru has been established in the field gene bank **(Fig. 2).**

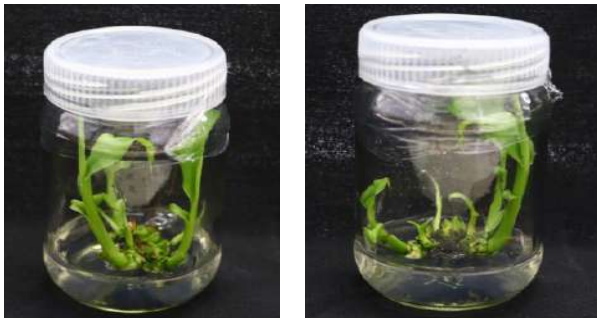


Fig. 2. *In vitro* multiplication & field evaluation of GI banana cv.Nanjangud Rasabale

Establishment of satellite genebank at ICAR-SBI, Agali, Kerala

To study the performance of elite germplasm and ensure safety duplication, a total of 108 accessions were planted in three replications at a slightly elevated location (750 MSL) in Agali, Palakkad District, Kerala.

Molecular characterization

Fingerprinting of Rasthali clones using ISSR and Nematodes Resistance / Susceptible *in-silico* polymorphic markers (NRSIP)

Ten each of SSR and NRSIP markers were used for the genetic differentiation of three Rasthali clones namely Sabri, Bangla Malbhog, and Nanjangud Rasabale (Mysore) along with Rasthali control (Accession No.0297). No polymorphic bands could be observed among the test clones.

Fingerprinting of commercial Cavendish clones using SCoT (Start Codon Targeted) and NRSIP markers

Attempts were made to develop markers for various Cavendish clones so that they could be used in the genetic fidelity testing of tissue culture clones produced by the commercial tissue culture facilities. The results of the various experiments conducted in this regard are briefly described below.

Five each of SCoT and NRSIP markers were used for to develop fingerprints for ten

commercial Cavendish clones (Grand Nain, Williams, Robusta, Jahaji, Borjahaji, Grand Nain Variant, Dwarf Cavendish, TBM-9, TBM-12 and Gandevi Selection). Among these, the NRSIP 2 primer could differentiate TBM-9 and TBM-12 elite mutants from other Cavendish clones **(Fig. 3).** Subsequently, to differentiate TBM-9 and 12, they were amplified using the same NRSIP 2 primer (targeting Serine/threonine-protein phosphatase PP2A catalytic subunit, EC 3.1.3.16), cloned and sequenced. Variation in the repeat region was $(GA)_{16}$ in TBM 9 and it was $(GA)_{15}$ in TBM 12 as against (GA)23 in the reference gene. Based on the sequence information, attempts are being made to develop markers to differentiate the TBM9 and TBM 12.

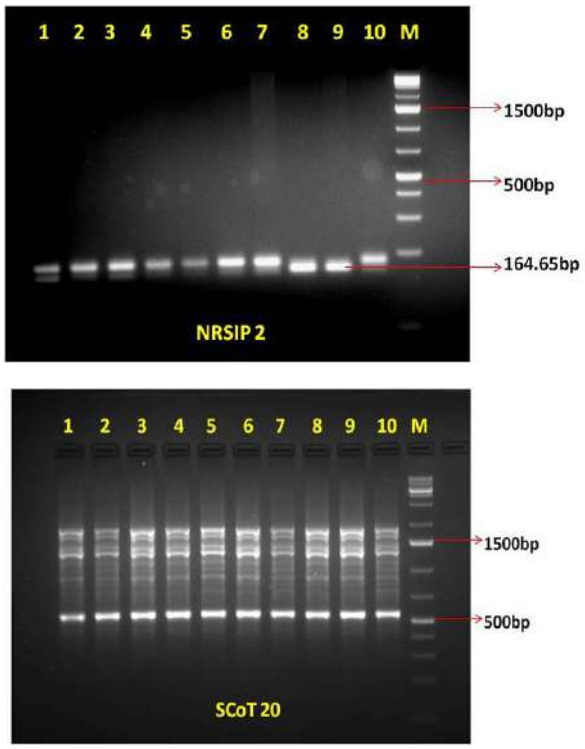


Fig. 3. DNA profiling of commercial Cavendish varieties using NRSIP and SCoT markers

Molecular characterization of clonal selections from AICRP (F) centres

As per the recommendations of AICRP-Fruits (All India Coordinated Research Project on Fruits), molecular characterization of clonal selections was undertaken to assess their genetic distinctiveness using ISSR markers before proceeding with evaluation, which would save time and space.

Out of the 74 clones evaluated across 10 different centres, several clones showed variations when compared to their respective controls. Six Karpuravalli clones from the Pusa centre namely Majhaulia, Nemopore, Simra, Kanthali, Tepri, and Nepali Chinia exhibited clear variations from Karpuravalli control **(Fig. 4-5).** Among the Grande Nain clones, those from Jalgaon (2020 JLPC 2021 and BRSJ-4) and Mohanpur displayed variation from Grande Nain control. Similarly, Thella Chakkarakeli clones from Kovvur and Kaliethen (2017 7 KAPC) and Swarnamukhi clones (2022 20 KAPC) from BRS, Kannara showed variations from Thellachakkarkeli and Nendran respectively. In addition, the 2/5(a) clone from the Arabhavi exhibited variation from respective control. Detailed data on these observations are provided in **Table 1**.

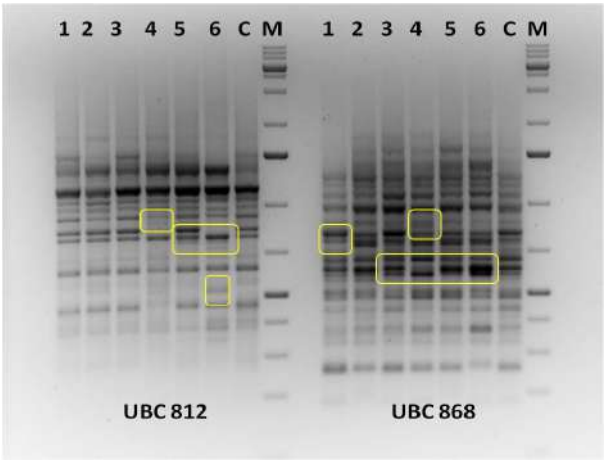


Fig. 4. Molecular characterization of Karpuravalli clones

1- Tepri, 2- Nemopore, 3- Nepali Chinia, 4- Simra, 5- Kanthali, 6- Majhaulia, C- Karpuravalli Control (NRCB), M- 1 Kb plus ladder

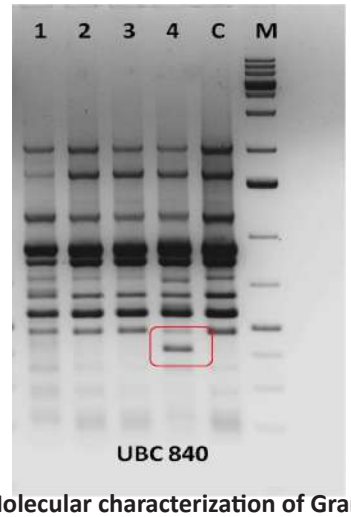


Fig. 5. Molecular characterization of Grande Nain clones from BRS, Jalgaon

1. BRSJ-1, 2. BRSJ-2, 3. BRSJ-3, 4. BRSJ-4, C- Grand Nain Control (NRCB), M- 1 Kb plus Ladder

Table 1: Markers to distinguish the clones conserved in AICRP (F) centres

AICRP (F) Centre	Variety	Marker	Product size (Bp)	Present in control	Present in clone
Pusa	Majhaulia	UBC 810	782	Yes	-
		UBC 808	901	-	Yes
		UBC 812	509	-	Yes
			755	-	Yes
		UBC 868	557	Yes	-
		UBC 834	970	Yes	-
		UBC 840	1163	Yes	-
			1686	-	Yes
	Nemopore	UBC 810	501	-	Yes
			849	-	Yes
		UBC 834	1102	-	Yes
	Simra	UBC 810	483	Yes	-
		UBC 812	872	-	Yes
		UBC 868	851	-	Yes
			557	Yes	-
		UBC 834	1102	-	Yes
	Kanthali	UBC 812	755	-	Yes
		UBC 868	557	Yes	-
		UBC 834	1102	-	Yes
	Tepri	UBC 868	733	Yes	-
	Nepali chinia	UBC 868	557	Yes	-
Mohanpur	Grand Nain	UBC 834	949	Yes	-
Jalgaon	Grand Nain (2020 JLPC 2021)	UBC 807	797	-	Yes
Kovvur	Thella chakarakeli	UBC 834	1591	-	Yes
		UBC 840	1657	-	Yes

Kannara	Kaliethen (2017 7 KAPC)	UBC 808	1277	-	Yes
		UBC 810	1360	-	Yes
			786	Yes	-
			511	Yes	-
			352	Yes	-
		UBC 834	1718	-	Yes
			967	-	Yes
			784	-	Yes
			309	-	Yes
		UBC 840	786	Yes	-
			711	-	Yes
			556	-	Yes
			468	-	Yes
			218	-	Yes
			127	-	Yes
	Swarnamukhi (2022 20 KAPC)	UBC 834	632	Yes	-
Jalgaon	Grand Nain (BRSJ-4)	UBC 808	725	-	Yes
			963	Yes	-
			997	Yes	-
		UBC 810	508	Yes	-
			573	Yes	-
			1470	-	Yes
			1549	Yes	-
			1709	-	Yes
		UBC 818	440	-	Yes
			1218	Yes	-
			1272	-	Yes
		UBC 840	416	-	Yes
		UBC 868	855	-	Yes
			892	Yes	-
Arabhavi	2/5(a)	UBC 807	1953	-	Yes

Evaluation of elite clones at farmers' fields

NRCB 16 and NRCB 19 were planted across five farmers' fields: Karamadai (1), Sirumalai (2), and Thadiyankudisai (2). NRCB 19 yielded an average of 30 kg at Karamadai and 28 kg at Thadiyankudisai. **(Fig. 6)**

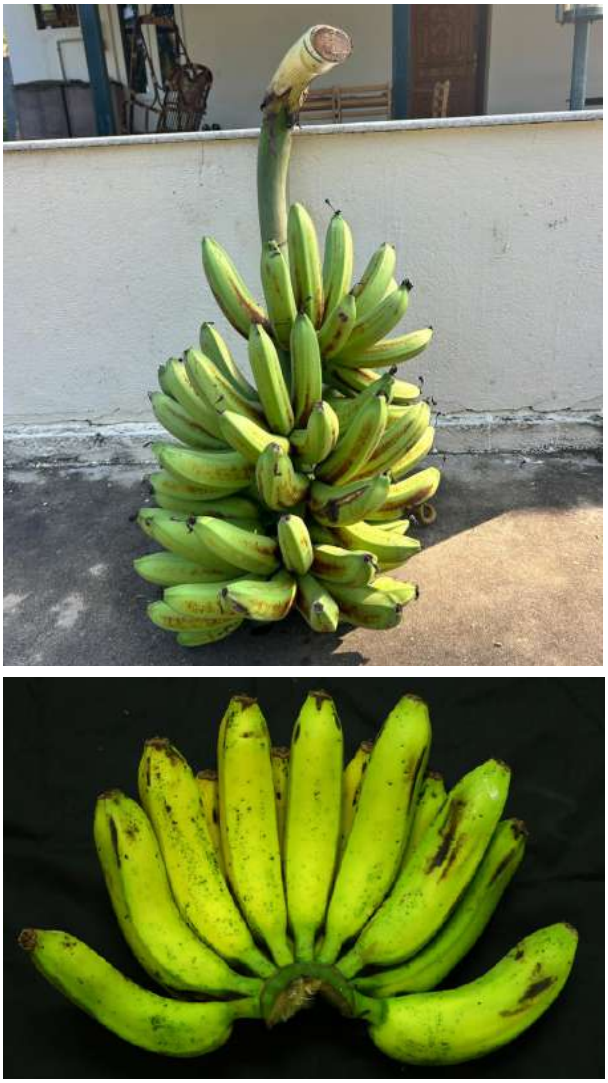


Fig. 6. Bunch harvested at Karamadai

Enhancing rooting efficiency of somatic embryo-derived shoots under *in vitro* conditions

Rooting efficiency in Grand Nain and *Red Banana* cultivars was assessed by supplementing MS medium with various concentrations of phloroglucinol (PG). The concentration of 118.5 µM resulted in superior root diameter (1.49 mm) and longer secondary roots, particularly in Grand Nain. Both cultivars exhibited increased fresh and dry root weights at this concentration, with Grand Nain and Red Banana recording dry root weights of 6.7 mg and 7.2 mg per plant, respectively. Secondary hardening survival rates improved significantly (95.0% and 95.6%, respectively) in PG-supplemented media, indicating PG's role in enhancing root development and *ex vitro* acclimatization **(Fig. 7)**.

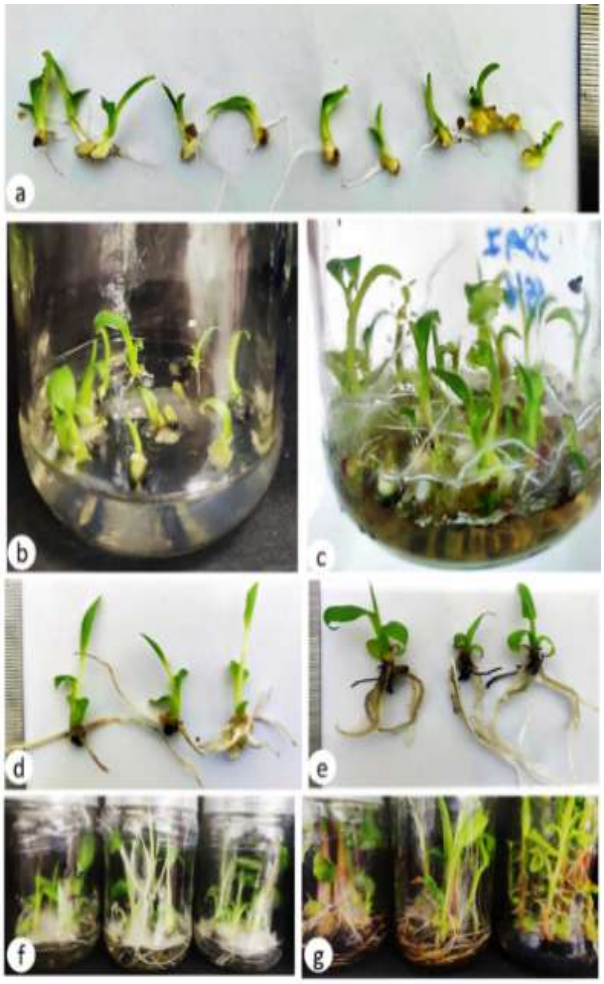


Fig. 7. Effects of PG on morphogenic development (a) Somatic embryo-derived shoots used as explants. (b and c) Growth of somatic embryo-derived shoots in IBA & PG (d) Plantlets in IBA, (e) Plantlets in IBA & PG (f and g) Plantlets after 35 days in IBA &PG of Grand Nain and Red Banana

Anthocyanin Pigment Efficiency in SE-Derived Red Banana Plants

Approximately 40% of virescent variants from shoot-tip-derived TC plants of Red Banana are discarded, increasing plant costs. However, plants derived via somatic embryogenesis (SE) using embryogenic cell suspension (ECS) in Temporary Immersion Bioreactor (TIB) systems consistently exhibited red pseudostems. This confirms that ECS-based propagation minimizes somaclonal variation especially for pigmentation and ensures stable anthocyanin expression.

Direct regeneration of banana cv. Red banana and Pachakappa using immature male flower bud explants

Male flower bud of banana cv. Red banana and Pachakappa (somaclonal variant – green) were collected from farmers' field at Theni, Tamil Nadu. Immature male floral hands (ranging from 12-20) were inoculated in MS medium with BAP + IAA for meristematic clump formation. Furthermore, the floral meristem was converted into shoot meristem and produced more number of shootlets on BAP + IAA **(Fig. 8)**. Single shoots obtained were morphologically similar to the parental clone i.e., red and green pigments in Red banana and Pachakappa respectively. The well developed plantlets with shoots and roots were successfully hardened and acclimatized. This will be tested for their colour stability using anthocyanin specific markers.

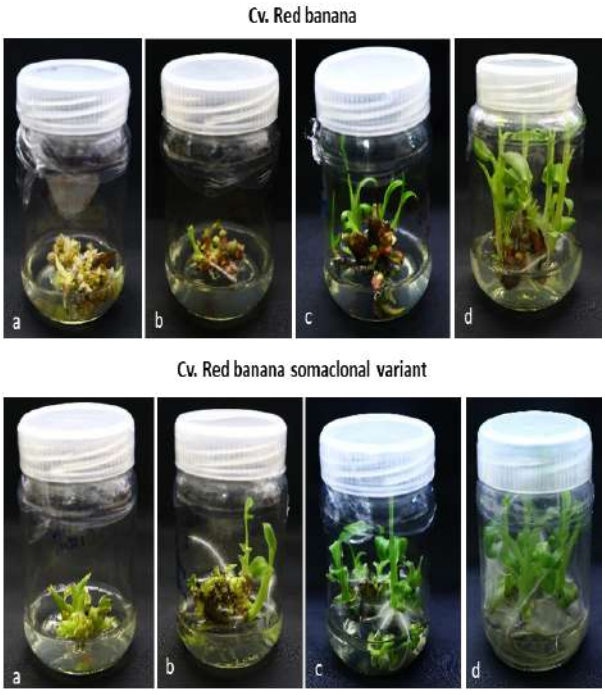


Fig. 8. Direct regeneration of banana cv. Red banana and its somaclonal variant using immature male flower bud explant. a. Meristematic clump formation; b. Shoot induction; c. Shoot multiplication; d. Rooting

In vitro mass production of variegated Banana from Trivandrum

Direct regeneration of immature male flower buds of variegated banana from Trivandrum resulted in developing 210 plantlets. Of which 9.52% showed variegated plants, 3.33% showed albino plants, and the remaining 87.14% were green plants **(Fig. 9).** Variegated and albino plantlets could not be established at the primary hardening stage while green plants could be successfully hardened with 90% survival rate. The well acclimatized plants (20 no's) were planted at ICAR – NRCB farm for the evaluation of growth and yield parameters and the crop is in vegetative stage. They will be morpho-taxonomically characterized once after it comes to shooting to identify the taxonomic status.

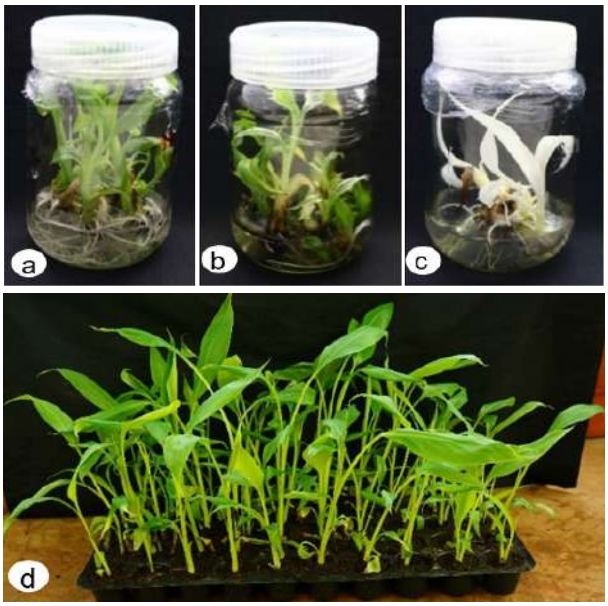


Fig. 9. *In vitro* propagation of Trivandrum variegated banana. a. Green shoots b. variegated shoots c. Albino shoots d. primary hardening.

Production of embryogenic cells through scalp method

Scalp is an effective and alternative explant for production of somatic embryos in banana. Scalp has been established using shoot tip explants of banana cv. Grand Nain (AAA). Thin slices were made using the base of the meristematic clump and placed in MA1 medium for embyogenic calli production. The embryogenic calli were transferred to suspension medium (MA2) for the establishment of embryogenic cell suspension **(Fig. 10).**

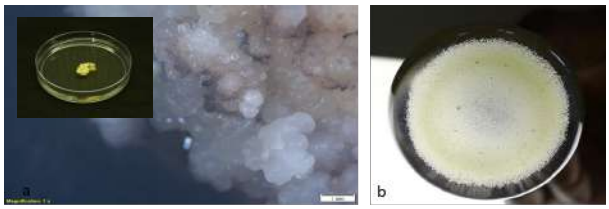


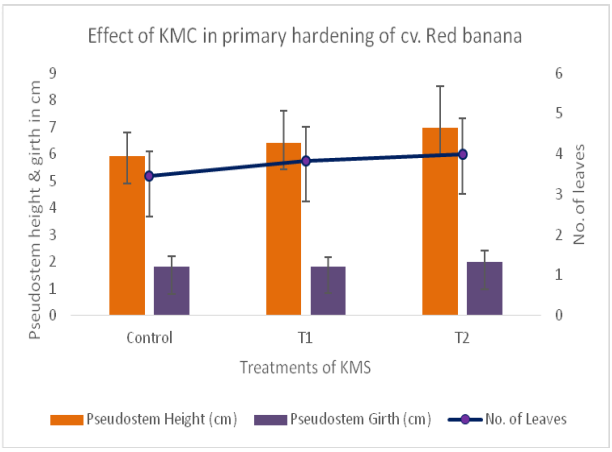
Fig 10. Induction of embryogenic cells using scalp. a. Pro-embryogenic cell mass developed using scalp; b. Proliferation of embryogenic cells

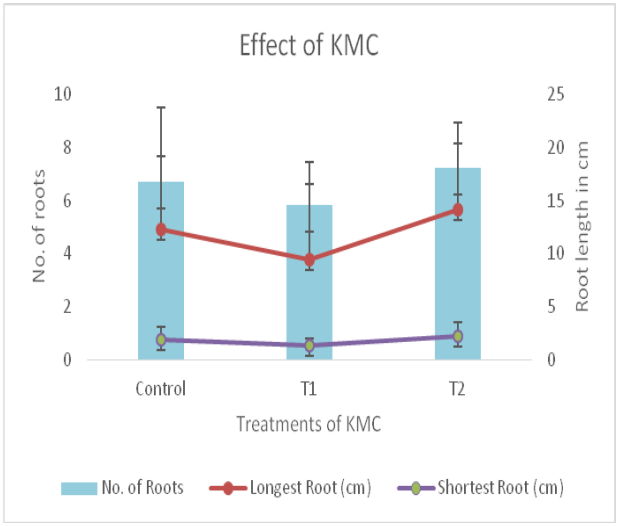
Development of embryogenic cell lines in ICAR-NRCB released & ruling commercial cultivars

Embryogenic calli were induced in MA1 medium using immature male floral hands of ICAR–NRCB varieties, namely Kaveri Sugantham and Kaveri Vaaman, and the GI-tagged banana cv. Nanjangud Rasabale and commercial cultivars Grand Nain, Red Banana, and Ney Poovan Embryogenic cell suspensions (ECS) have been established in all varieties/ cultivars for mass production of planting materials and/or to induce variability through induced mutagenesis using both physical and chemical mutagens.

Effect of Kaveri Microbial Consortium (KMC) in banana hardening

Micro propagated banana cv. Red Banana was bio-hardened using the Kaveri Microbial Consortium (KMC) at both primary and secondary hardening stages. The treatment was found to stimulate plant growth **(Fig. 11-12).** In primary hardening, application of cocopeat with KMC @ at 25 g (T1) of showed higher growth rate than the cocopeat with KMC @ at 50 g/kg (T2) and control. In secondary hardening, T1 and T2 were further divided into two sub-treatments each, with applications of 10 g and 50 g of KMC per kg of cocopeat (T1S1, T1S2, T2S3, and T2S4). Among these, T1S2 showed better growth compared to the other treatments. This implies that application of KMC @ at 25 g/kg in primary hardening and application of KMC @ at 50 g/kg in secondary hardening is the best for hardening.





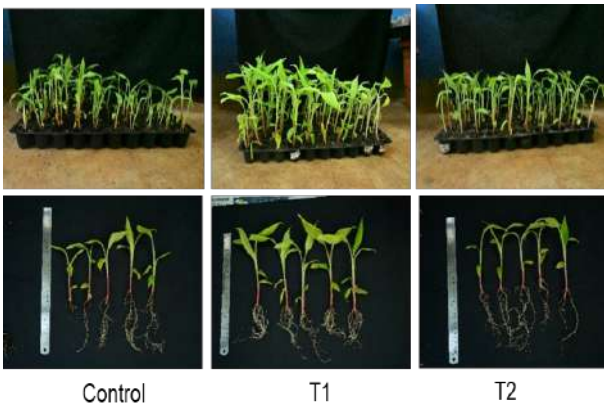


Fig. 11. Effect of KMC during primary hardening stage

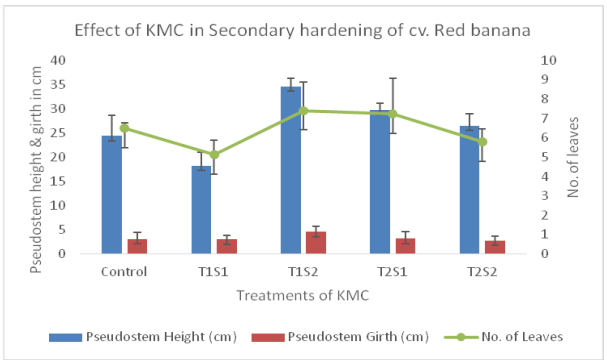


Fig. 12. Secondary hardened plants bio-hardened red banana ready for field planting

4.1.2 Crop Improvement of banana through conventional breeding

(S. Backiyarani, M.S. Saraswathi, R. Thangavelu, G. Prabhu, P. Giribabu, A. Mohanasundaram)

Kaveri Kanchan (NCR 17) - A pro-vitamin A rich dessert Banana

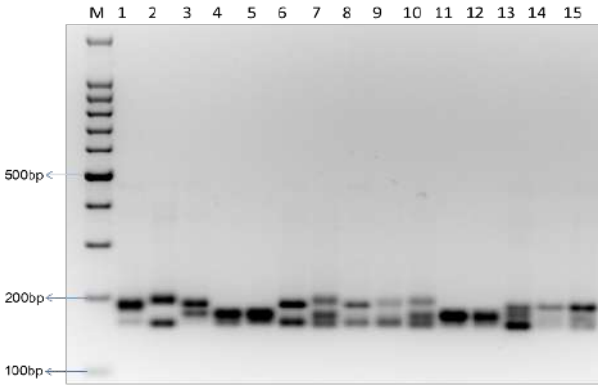
Kaveri Kanchan, released for culitvation in Tamil Nadu yielded 20 per cent more than Manjeri Nendran over two consecutive years across India. It has been recommended for cultivation in Bihar, Karnataka, Odisha, Tamil Nadu, Maharashtra, Kerala, and West Bengal in the 11th Group Discussion of the ICAR-AICRP on Fruits held at NAU, Navsari.

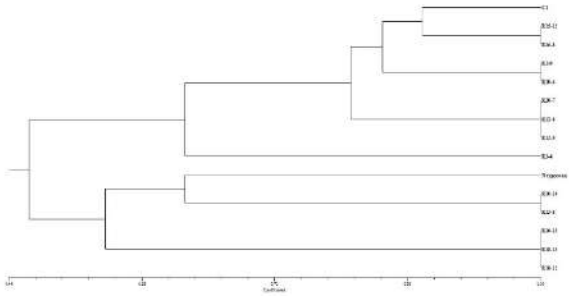
Newly developed progenies under evaluation

To broaden the genetic base of diploids, thirty-one progenies from diploid × diploid crosses were established in the field. These include combinations such as: cv. Rose × Pisang Lilin (13); *M. acuminata* ssp. *microcarpa* × Pisang Lilin (5); Calcutta 4 × cv. Rose (1); Calcutta 4 × Pisang Lilin (4); *M. acuminata* × cv. Rose (8). Additionally, six, three-way crosses and five open-pollinated (OP) progenies were also established to develop disease resistance varieties.

Molecular characterization of Calcutta 4 × Ney Poovan tetraploid progenies

Based on the morphological characters, the Calcutta 4 x tetraploid Neypoovan progenies were grouped into five. SSR-based molecular characterization placed the progenies into six groups. Except for R1-4, all progenies corresponded with their morphological groupings—four aligned with the female parent (Calcutta 4) and two with the male parent (tetraploid Ney Poovan) **(Fig. 13).**





M-100bp ladder; 1-C4; 2-Neypoovan tetraploid;3 to 15 – progenies of C4 x 2-Neypoovan tetraploid (R1-4,R1-9,R10-4,R10-7,R10-10,R12-6,R13-5,R13-8,R15-12,R16-8,R16-13,R18-12 & R18-13)

Fig. 13. construction of dendrogram for progenies of Calcutta 4 x tetraploid NeyPoovan based on SSR markers

Superior performance of open-pollinated Kothia-based progenies

Among 52 progenies of four Kothia-based crosses, most traits showed negative heterobeltiosis, except for fruit number per hand. OP progenies Pro.932 and Pro.933 exhibited positive heterobeltiosis for this trait, surpassing the better parent, Kothia. Flow cytometry confirmed 48 progenies as diploids, while four were not: Pro.542, Pro.515 and were triploid, and Pro.480 and Pro.432 were aneuploid.

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

To develop homozygous AA and BB genotypes, as a first step, uninucleate and highly vacuolated stage anthers of Pisang Lilin (AA), Calcutta 4 (AA), Ney Poovan (AB), Bhimkol (BB), and Grand Nain (AAA) were initiated for the development of haploids. The callus induction frequency varied significantly among genotypes, with the highest frequency observed in cv. Bhimkol. The embryogenic calli obtained from the anthers were transferred into germination medium (MA4) containing BAP and IAA. Germinated embryos with 2–3 leaves were placed on multiplication medium containing MS salts with the same BAP and IAA at different concentrations. More than 50 plantlets were produced and hardened successfully. Initial screening of the regenerated plants (three plants) developed at ICAR–NRCB using flow cytometry revealed differences in chromosome content between

diploid Bhimkol and the anther-derived plants, suggesting the latter are aneuploids **(Fig. 14).**

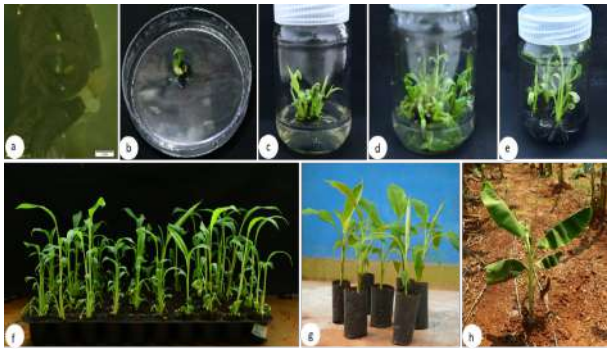
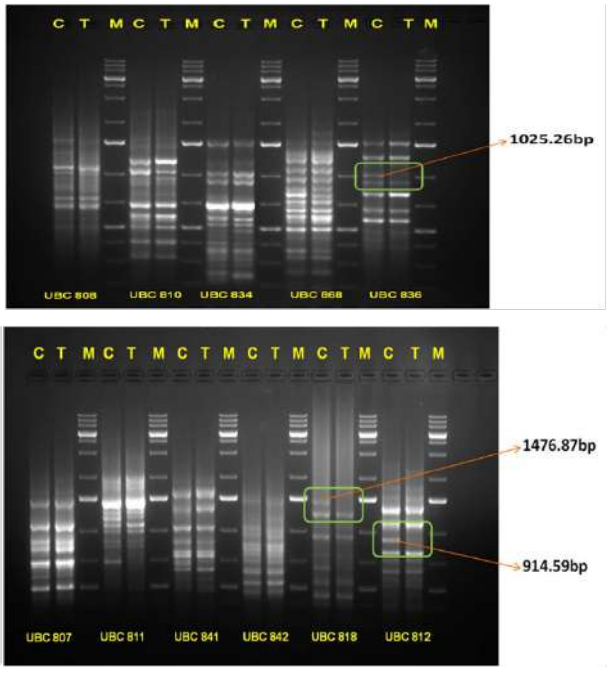


Fig. 14. Development of androgenic haploids of banana cv. Bhimkol. a. Callus induction; b. Shoot induction; c & d. Shoot multiplication; e. Rooting of shoots; f. Primary hardening; g. Secondary hardening; h. Field establishment.

Genotyping of anther-derived Bhimkol using AGMI and ISSR Markers

Eight SSR (AGMI) and 11 ISSR primers were used to assess genetic variation between anther-derived Bhimkol and Bhimkol control. SSR primers did not distinguish while three ISSR primers (UBC 836, 818, and 812) distinguished the Bhimkol and anther-derived Bhimkol producing polymorphic bands **(Fig. 15).** The aneuploid status obtained in the Flow cytometry could be the reason for the polymorphism obtained in the marker studies.



C- Bhimkol Mother Plant; T- Bhimkol from Anther Culture; M- 1Kb plus ladder

Fig. 15. Genotyping of Bhimkol derived from anther culture using ISSR markers

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

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

Plantlets of cv. Grand Nain derived through *in vitro* immunisation using various concentrations of gallic acid were hardened and subsequently challenge-inoculated with spores of *Fusarium oxysporum* f. sp. *cubense* (Foc) Race 1 and TR4, individually (Table 2), but none of the treatments gave resistant reaction for Foc race 1 and TR 4 **(Fig. 16)**.

Table 2: Effect of gallic acid-treated in vitro plantlets

Treatment	Disease Score for Cavendish infecting Foc Race 1	Disease Score for TR4
GN + *Foc* Control	3.5	3.6
T1 (0.025%)	2.6	3.8
T2 (0.05%)	2.0	4.0
T3 (0.075%)	2.5	4.3

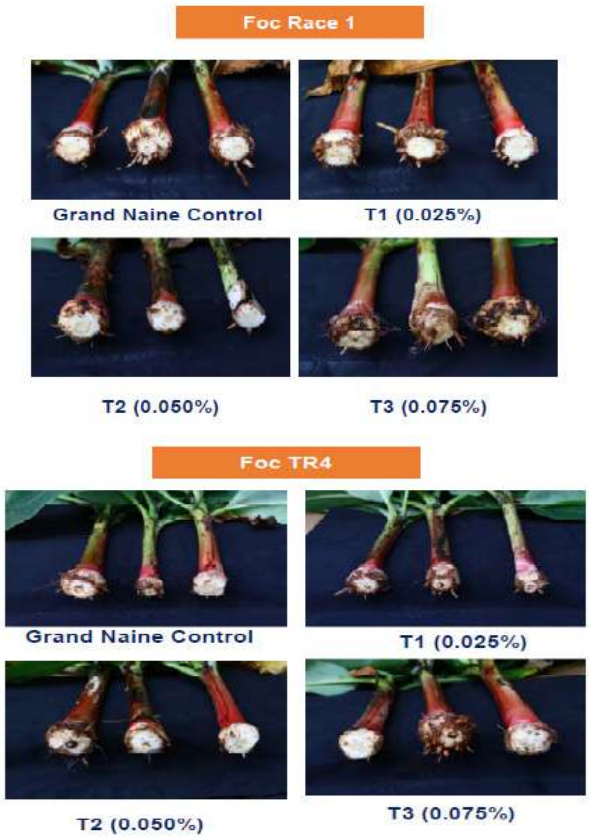


Fig. 16. Effect of Gallic Acid-treated *In Vitro* plantlets

Field evaluation of NRCBGNM 1 (NRCB Sel.14) in wilt infested fields of Karjan, Kamrej of Surat, Gujarat

Large scale evaluation of NRCBGNM 1 (NRCB Sel.14), a Fusarium wilt resistant Grand Nain mutant, under wilt infested field at Karjan, Kamrej of Surat, Gujarat indicated that the per cent incidence was 17.33 as against 80% in control Grand Nain **(Fig. 17).**

Fig. 17. Performance of NRCBGNM 1 (NRCB Sel.14) at Surat, Gujarat

Field Evaluation of Grand Nain Mutants

Mutant lines of cv. Grand Nain namely R1L2, R4L3, and R4L15 developed through various physical and chemical mutagenesis were evaluated for Fusarium wilt resistance under sick plot conditions of Surat. Nearly 80% of the mutant plants survived and they were harvested **(Fig. 18).**

Fig. 18. Field performance of Grand Nain Mutants at Surat, Gujarat

Field Performance of Foc resistant banana cvs. Red Banana and Williams in Surat, Gujarat

Tissue cultured bananas of cvs. Red Banana and Williams were field planted in the sick plot for FoC TR4 at Amboli. None of the plants showed wilt symptoms and the yield was normal **(Fig. 19).**

Fig. 19. Banana Cultivars Red Banana and Williams

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

(M. S. Saraswathi, S. Uma [up to 31.5.2024], R. Thangavelu, S. Backiyarani)

Phenotyping of Banana Mini-Core Collection

Out of the 379 accessions maintained in the field genebank, phenotyping has been completed for 306 accessions and the remaining 73 accessions are yet to be phenotyped. Out of 73 accessions, 50 accessions have been established in pots for screening against fusarium wilt resistance. Phenotyping was attempted for a new set of 50 core collection accessions during the reporting period **(Table 3).**

Table 3: Status of phenotyping of banana core collection accessions

S. No.	Genome	Accessions to be phenotyped for fusarium wilt resistance	Accessions established in pots for phenotyping against fusarium wilt resistance
1	BB	11	11
2	AA	6	1
3	AAA	12	10

4	AB	3	3
5	AAB	19	12
6	ABB	17	11
7	ABBB	2	2
8	Rhodo	3	0
Total		**73**	**50**

Genotyping of Banana Mini-core collection

Genotyping of 153 mini-core accessions was conducted using resistance pathway-related SSR markers. Among the 13 standardized primers, two primers—Cytochrome P450 84A1 and Caffeic acid 3-O-methyltransferase 1—did not produce reliable amplification. The remaining 11 SSR primers were successfully used for genotyping but, none of the marker differentiated the resistant and susceptible cultivars.

4.1.5 Identification of resistant gene candidate(s) in banana for race 1 and tropical race 4 of *Fusarium oxysporum* f. sp. *cubense*

(C. Anuradha, R. Thangavelu, S. Backiyarani, M. S. Saraswathi)

The *rga2* gene from Nendran (AAB) and Red Banana (AAA) was successfully cloned and characterized. Additionally, the *rga2* gene (3.7 kb) from cv. Rose was amplified, cloned into the pCAMBIA1302 vector, and transformed into the *Agrobacterium* strain AGL1. The transformed strain was subsequently co-cultivated with the ECS of Grand Nain to over-express the gene, aiming to develop resistance against Foc. Currently, the embryos are in the maturation stage. Guide RNAs (gRNAs) have been specifically designed to target and knock out the *rga2* gene in the resistant cultivar Rose and the Ma10_g00550 gene in Grand Nain. This approach aims to functionally validate the roles of these genes in resistance mechanisms against Foc TR4 and Race 1, respectively. The co-cultivated embryogenic cells are currently in the maturation medium.Eight *dmr6* and one *dlo1* genes (Ma00_t04490, Ma04_t20880, Ma04_t36640, Ma02_t12040, Ma05_t12600, Ma08_t12090, Ma11_t02650, Ma05_t09980, Ma04_t23390) were amplified cloned and sequenced and their expression was studied in resistant and susceptible cultivars upon Foc, *P.eumusae* and *P. coffeae* infection.

Nudix hydrolase (NUDX) gene family in *Musa* spp., was comprehensively investigated covering their classification, genome organization, phylogenetic relationships (**Fig. 20**), gene structure, motif composition, evolutionary patterns, and expression profiles in response to Foc and P. eumusae (**Fig.21**). A total of 30 and 31 putative *Nudix hydrolases* were identified from A and B genomes of *Musa* spp., respectively and these genes were classified into eight subfamilies based on substrate preference.TGA transcription factors (Ma02_t08720, Ma09_t14970, Ma09_t18630), Enhanced Disease Susceptibility 1 (EDS1- Ma08_t26030, Ma02_t22600, Ma06_t14360), and Non-expressor of Pathogenesis-Related genes 1 (Ma07_t09020, Ma06_t02690), which showed significant differential expression during Foc infection, were cloned and characterized from both resistant and susceptible cultivars.Genic SSR markers associated with Foc resistance and parthenocarpy were further validated across the Kothia x Calcutta 4 progenies. Genic SSR markers associated with dwarfness were validated in dwarf Grand Nain selections and mutants.

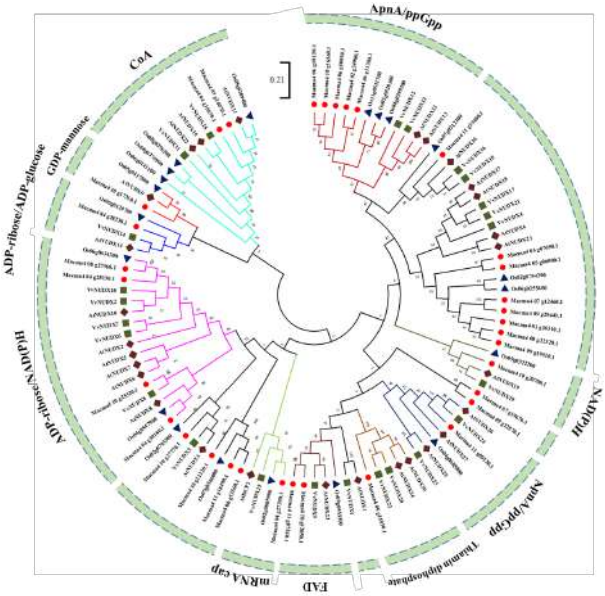


Fig. 20. Phylogenetic analysis of *Nudix hydrolase* (NUDX) genes from *Musa* A genome, *A. thaliana*, *O. sativa* and grapes

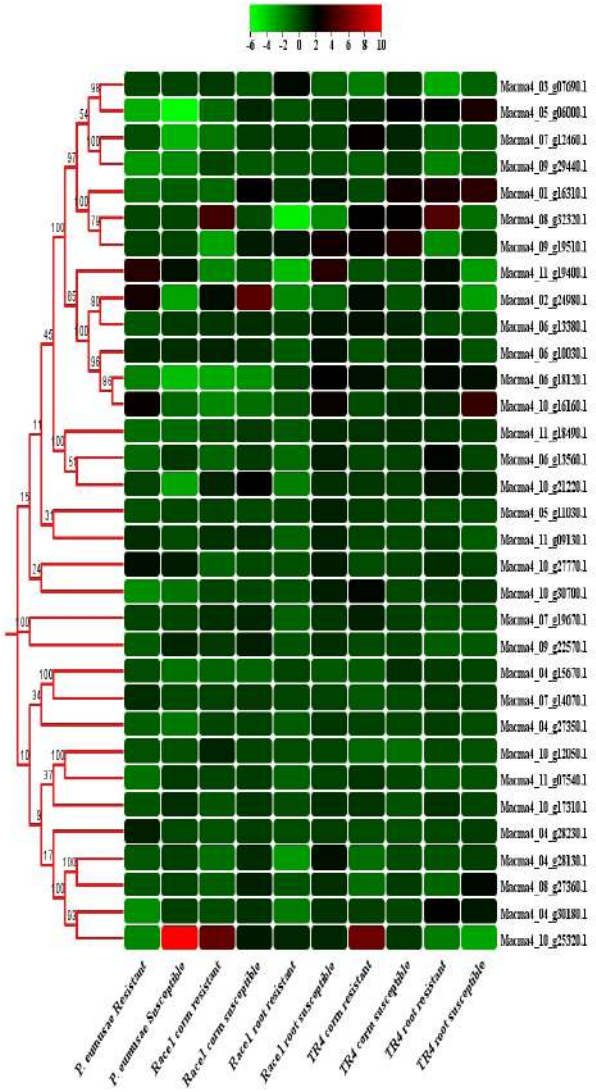


Fig. 21. A graphical representation of expression details of *nudix hydrolase* (NUDX) genes under biotic stresses (Eumusae leaf spot and *Foc* race 1 and TR4) in *Musa* cultivars

4.2 CROP PRODUCTION, POST HARVEST TECHNOLOGY & EXTENSION

4.2.1 Development of clump management technology for enhanced productivity in banana

(V. Kumar, K. J. Jeyabaskaran, I. Ravi, R. Thangavelu, P. Giribabu, G. Prabhu)

A confirmative trial was initiated in banana cv. Kaveri Saba (ABB) with seven treatments

The trial was laid out in a Randomized Block Design (RBD) with four replications. A spacing of 3.0 m × 3.0 m was adopted for treatments T1 to T6, whereas a spacing of 2.0 m × 2.0 m was maintained under the control treatment (T7). The tallest plants (182.2 cm) greatest plant girth (59.3 cm) were recorded under treatment T2, whereas the shortest plants (157.6 cm) and smallest girth (48.1 cm) were observed under T5. Treatment T2 also exhibited the highest values for mean leaf area (0.84 m²), total leaf area (12.19 m²), and leaf area index (1.36).

Phyllochron (time interval for the production of successive leaves) values varied throughout the observation period, ranging from 6.01 days (T2) to 6.86 days (T5). The number of days to flowering ranged from 257.8 to 303.2 days, with treatments T1 and T2 promoting earlier flowering compared to the other treatments. Irrespective of fertilizer application, plants grown under high-density planting (three suckers per pit) exhibited delayed flowering, exceeding 300 days. At the flowering stage, soil pH across treatments ranged from 6.82 to 7.73, while electrical conductivity (EC) values varied between 0.07 dS/m and 0.20 dS/m. The organic carbon content of rhizosphere soil ranged from 0.29% to 0.73%. Furthermore, leaf tissue analysis revealed nitrogen concentrations ranging from 1.55% (T7 – Control) to 2.40% (T1), phosphorus from 0.14% (T2) to 0.20% (T6), calcium between 0.66% and 0.84%, and magnesium ranging from 0.25% to 0.40% **(Fig.22)**.

Treatment details

- T1- Mother Plant + two suckers (6 & 8 MAP) with 150% RDF @ first year & 75% RDF @ 2nd year
- T2 - Mother Plant + 2 suckers (6 & 8 MAP) with 175% RDF @ first year & 87.5% RDF @ 2nd year
- T3 - Mother Plant + 3 suckers (6, 8 &10 MAP) with 150% RDF @ 1st year & 75% RDF @ 2nd year
- T4 - Mother Plant + 3 suckers (6, 8 &10 MAP) with 175% RDF @ 1st first year & 87.5% @ 2nd year.
- T5 - HDP with 3 suckers/ pit with 150% RDF/ per pit in 7 splits at 45-day intervals
- T6 - HDP with 3 suckers/pit with 175% RDF/pit in 7 splits at 45-day intervals
- T7 - Conventional planting with 2.1 m × 2.1 m with 1 sucker after flowering of the MP with 100% RDF/pit in five splits

Fig. 22. Clump management technology experimental field view

4.2.2 Organic banana farming for sustainable soil health and nutritional security

(K. J. Jeyabaskaran, V. Kumar, K.N. Shiva, M. Loganathan, A. Mohanasundaram, G. Prabhu)

In 8-month-old Karpurvalli banana, inorganic fertilizers (100%) treatment (M4) produced the tallest plants (239.58 cm), although this was statistically comparable to the poultry manure-based treatment (M2, 232.32 cm). Conversely, the control treatment (M5), which did not receive any fertilizers, resulted in the shortest plants (177.54 cm). The maximum pseudostem girth was recorded in M2 and M4 treatments (78.75 cm and 78.54 cm, respectively). Treatments with FYM (M1) and pressmud (M3) recorded pseudostem girth of 70.98 cm and 67.41 cm, respectively, whereas M5 registered the lowest girth (63.21 cm).

The number of leaves was not significantly affected by any of the treatments, ranging from 12.18 to 15.26 leaves per plant. The phyllochron (time taken to produce a leaf) varied from 6.9 to 9.1 days per leaf, with the longest duration observed in M5 (9.1 days/leaf) and the shortest in M2 (6.9 days/leaf). The highest petiole length was recorded in M4 (42.57 cm), which was statistically on par with the organic treatments (M1, M2, and M3). The total leaf area ranged from 11.73 m^2 to 15.41 m^2, with the highest value recorded in M2 (15.41 m^2), followed by M1 (13.8 m^2), M3 (14.03 m^2), and M4 (14.26 m^2). The control treatment (M5) had the lowest total leaf area (11.73 m^2) are presented in the following **Fig.23.**

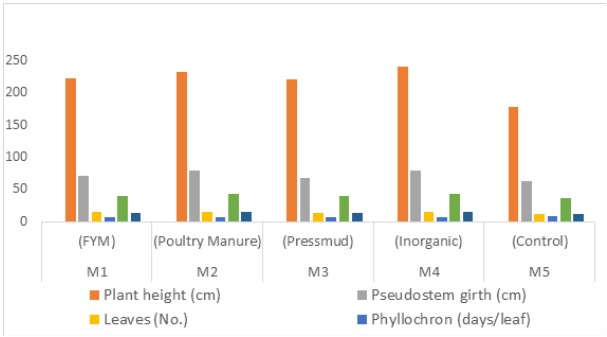


Fig.23. Effect of organic and inorganic treatments on Karpuravalli banana

Effect of organic manure treatments on soil physico-chemical properties

The application of different organic manures significantly influenced key soil physico-chemical properties, including soil pH, EC, organic carbon (OC), Cation Exchange Capacity (CEC), bulk density, porosity, and the availability of nitrogen (N), phosphorus (P), and potassium (K) (Fig. 25). The M4 treatment maintained a relatively high soil pH (~8.9), whereas M2 reduced the pH from 8.9 to 7.5 over three cropping seasons. The decline in pH followed the order: M2 > M1>M3. Soil EC increased under the M4 treatment (from 0.21 to 0.29 dS/m), while the organic treatments led to a reduction in EC, reaching a minimum of 0.11 dS/m. The order of EC reduction was: M2 > M3 > M1. Regarding organic carbon content, organic treatments significantly improved OC, with M2 recording the highest value (0.65%), followed by M1 (0.38%) and M3 (0.31%).

CEC under the M4 treatment remained stable (~9.1 cmol/kg), the magnitude of increase followed the order: M2 > M3 > M1. Soil bulk density remained stable under M4 (~1.38 g/cc), while organic treatments led to a decrease, with M2 recording the lowest value (1.25 g/cc), followed by M1 and M3. Soil porosity under M4 ranged between 39.2% and 40.3%, while M3 recording the highest value (46.4%), followed by M1 (43.2%) and M2 (42.5%). Available soil moisture content declined gradually under M4 whereas organic treatments improved soil moisture retention (**Fig. 24**).

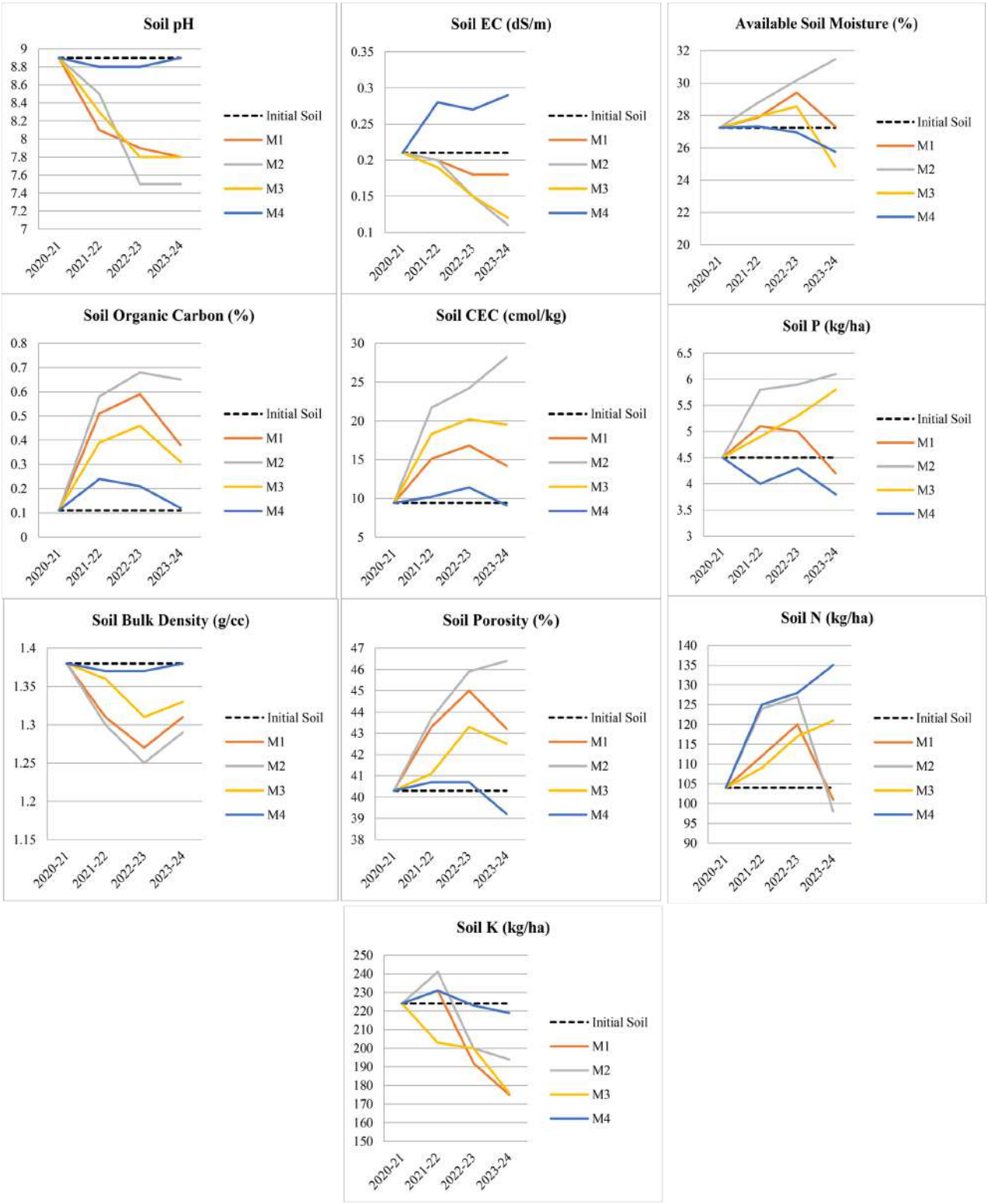


Fig. 24. Effect of organic banana farming on soil physico-chemical properties

Studies on natural farming

A natural farming experiment in banana was initiated in 2024. The varieties such as Ney Poovan, Karpuravalli, Kaveri Saba, and Muppattai have been tested, using *Neem Astra*, *Agni Astra*, and *Brahmastra*. Furthermore, the use of natural and locally available inputs, such as Jeevamruth and Panchakavya, were encouraged.

In this study, the selected banana varieties under natural farming were compared with plants grown under 100% inorganic and 100% organic fertilization with respect to plant growth parameters at the 5-month growth stage. The observed values are presented in **Table 4**.

Table 4: Percent increase or decrease in plant growth parameters

Plant Growth Parameters	Ney Poovan	Karpuravalli	Kaveri Saba	Muppattai
Plant height (cm)	-27.3	-26.5	-31.4	-31.5
Pseudostem girth (cm)	-28.6	-21.9	-21.4	-27.6
Number of leaves	-16.7	-7.7	-7.7	-21.4
Leaf area (m^2)	-20.0	-25.0	-30.8	-27.3
Phyllochron (days/leaf)	14.3	25.0	25.0	42.9

Observational trial on reclamation of saline and sodic soils

An observational trial was conducted on a soil characterized by a pH range of 8.5 to 8.7, electrical conductivity (EC) values between 0.66 and 1.28 dS/m, and an Exchangeable Sodium Percentage (ESP) exceeding 15 at the research farm of ICAR–NRCB. The experiment utilized the banana cultivar 'Ney Poovan' due to its known tolerance to saline and sodic conditions. Organic amendments, including rice husk ash (5 kg/plant), poultry manure (2 kg/plant), and farmyard manure (2 kg/plant), were applied as the main treatments. Gypsum was applied at 50 g per plant, with or without the aforementioned organic amendments, as sub-treatments. The findings revealed significant salinity stress, leading to poor plant establishment. Sodicity injury symptoms were observed in more than 50% of the plants, and no plants produced bunches. The study concluded that soils with a pH greater than 8.5 and an ESP exceeding 15 are unsuitable for banana cultivation, even with the application of organic amendments and gypsum.

4.2.4 Assessment of carbon sequestration, energy budgeting, biodiversity and production potential of three different banana production ecosystems

(G. Prabhu , K. J. Jeyabaskaran, V. Kumar, M. Loganathan, A. Mohanasundaram, P. Giribabu, K. Nagendran)

Biodiversity analysis from three different production systems

A comparative study of three different banana production systems, garden, hill, and wetland revealed that the hill production system had a higher initial soil organic carbon content (4.7%) compared to the garden and wetland systems. The garden system exhibited a lower soil pH (5.76) than the hill and wetland systems. Additionally, the garden system recorded a higher available potassium content (1838 kg ha^{-1}) than the hill and wetland systems.

The plant diversity profile indicated that the hill system supported more weed species (21) and exhibited a higher Shannon-Wiener diversity index (2.2), followed by the wetland system (15 species and 1.9, respectively). The plant diversity profiling across three different banana ecosystems (garden, hill, and wetland)

revealed notable variations in species richness and diversity indices. The hill ecosystem exhibited the highest number of taxa, with an average of 21 (±1.1), which was significantly greater than that in the garden ecosystem, which had 11 (±1.8) taxa. The wetland system showed an intermediate value of 15 (±2.8) taxa, not significantly different from either of the other two.

Shannon's diversity index (Shannon) was also highest in the hill ecosystem at 2.2 (±0.09), followed by the wetland at 1.9 (±0.37), and lowest in the garden at 1.1 (±0.02), with a significant p-value of 0.03. Simpson's index (Simpson D) showed less variation among the ecosystems, ranging from 0.2 to 0.4, and was not significantly different (p = 0.09). Evenness values ranged from 0.3 (±0.05) in the garden to 0.5 (±0.08) in the wetland, but these differences were not statistically significant (p = 0.22).

Overall, the hill ecosystem demonstrated the greatest plant diversity and richness among the three banana-growing environments. Furthermore, Non-Metric Multi-Dimensional Scaling (NMDS), a distance-based ordination technique, revealed distinctive species distributions ($p < 0.001$) across the production systems **(Fig. 25).** The hill system supported a greater number of species with variable densities compared to the garden and wetland systems.

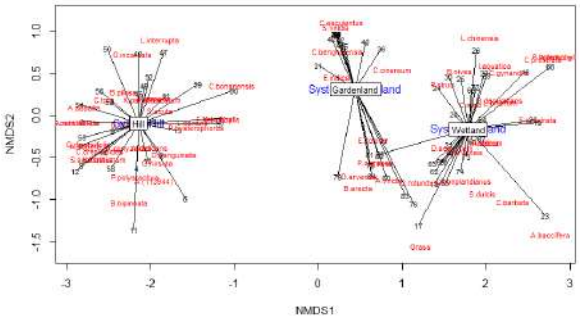


Fig. 25. Plant diversity status in three different Banana ecosystems

Table 5: Biometric parameters of banana plants across three distinct production systems

System	Plant Height (cm)	Girth (cm)	Leaves (No.)
Garden	162.5 (±14) a	51.2 (±3.0) a	10.8 (±0.74) b
Hill	136.3 (±13) a	32.5 (±3.2) b	8.5 (±0.63) c
Wetland	130.0 (±18) a	37.9 (±3.0) b	12.7 (±0.52) a
P value	0.28	0.003	0.03

Overall, based on preliminary data on soil characteristics and plant diversity, the hill production system appears to be more sustainable than the other systems.

Insect diversity analysis from three different production systems

Five insect pests were identified: Grasshopper, Tingid, Whitefly, Thrips, and *Spodoptera*, along with two natural enemies: *Stethorus* sp. and Spiders. The highest percentage of damage caused by Grasshoppers (15.4%) and *Spodoptera* (6.2%), as well as the highest number of Spiders (0.88 per plant), were observed in the hill ecosystem. The garden ecosystem recorded the highest number of Tingids (3.64 per plant) and Thrips (0.24 per plant), along with the predator *Stethorus* sp. (1.00 per plant). Meanwhile, the highest number of Whiteflies (0.80 per plant) was recorded in the wetland ecosystem.

The highest insect diversity was recorded in the hill ecosystem (208 individuals), followed by the wetland (84) and garden (59) ecosystems. Insects from eight different orders were recorded in the hill ecosystem, in contrast, only six insect orders were recorded in the garden ecosystem and four orders in the wetland ecosystem. Economically important insect pests and natural enemies were more abundant in the hill ecosystem compared to the other two ecosystems.

Banana scutcher as an eco-friendly mulch

The physical property analysis revealed that scutcher material could retain three times more water than coir pith ($p < 0.01$), attributable to its higher bulk density. Chemical analysis of scutcher and coir pith further indicated that scutcher contained higher concentrations of nitrogen (70% more), phosphorus (77%), potassium (52%), calcium

(62%), and magnesium (84%), while having 59% less sodium than coir pith.

Additionally, even when watered only once at the time of planting, both scutcher alone and scutcher mixed with coir pith resulted in higher and long-lasting soil moisture retention than the control **(Fig. 26).** Furthermore, banana plants mulched with scutcher exhibited greater plant girth (7 cm), number of leaves (7), and leaf area (450 cm^2) compared to the control (4 cm, 5.5 leaves, and 350 cm^2, respectively) **(Fig. 27).** This study supports that both the physical and chemical properties of scutcher material contribute to plant growth improvement and soil health enhancement in a sustainable manner.

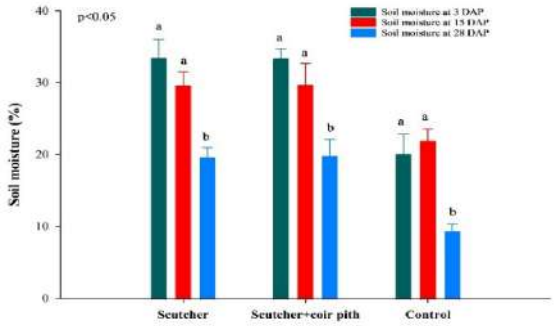


Fig. 26. Effect of banana scutcher mulch on soil moisture retention at 3, 15, and 28 days after planting (DAP)

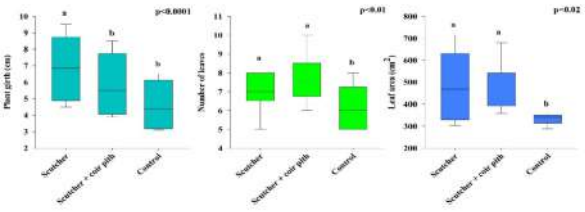


Fig. 27. Plant girth, number of leaves and leaf area influenced by banana scutcher mulch

Post Harvest Technology

4.2.5 Developing integrated package of practices for export of selected commercial and GI tagged varieties of Indian Bananas

(K.N. Shiva, P. Suresh Kumar, V. Kumar, R. Thangavelu, K.J. Jeyabaskaran, G. Prabhu, C. Karpagam, Alka Joshi, Anamika Thakur, Dinesh Kumar)

A field trial was conducted at Mullukuruchi village, Namakkal District, with the objective of developing an integrated package of practices for improving the export potential of Red Banana**.** The experiment consisted of four treatments: T1 – 100% RDF fertigation with Banana Shakti, Banana Bunch Cover (non-woven fabric), and potassium sulphate (K_2SO_4); T2 – 100% RDF fertigation without Banana Shakti; T3 – 100% RDF soil application with Banana Shakti, Banana bunch cover, and K_2SO_4; and T4 – 100% RDF soil application without Banana Shakti**.**

The results revealed that significant variations among treatments in growth and yield parameters (**Tables 6-8**)**.** Growth parameters recorded after seven months indicated that T1 exhibited the highest plant height (317.08 cm), girth (81.67 cm), number of leaves (21.25), and leaf area (0.93 m^2), whereas T4 recorded the lowest values (302.92 cm height, 77.92 cm girth, 20.50 leaves, and 0.86 m^2 leaf area). Yield parameters also followed a similar trend with T1 producing the heaviest bunches (16.97 kg), while T4 recorded the lowest bunch weight (15.43 kg) **(Fig. 28).**

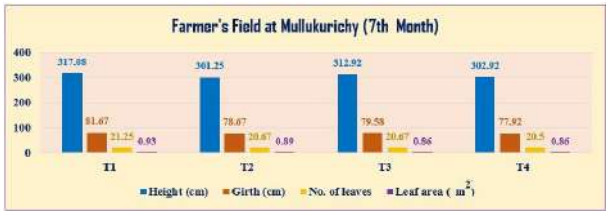


Fig. 28. Growth parameters of red banana-TC plants

T3, which involved the soil application of Banana Shakti along with bunch covering and potassium sulphate, exhibited notable improvement in bunch weight (17.12 kg), number of hands (6.78), and overall fruit yield compared to other soil-applied treatments. The superior performance of T3 highlights the positive influence of Banana Shakti in enhancing nutrient uptake, bunch filling, and fruit development even under soil-based application. In comparison, T1 (fertigation with Banana Shakti) recorded maximum vegetative growth, while T3 demonstrated better yield efficiency under soil nutrition management.

The study thus emphasizes that the integration of Banana Shakti with appropriate nutrient application mode and bunch management practices can significantly enhance growth, yield, and fruit quality of

Red Banana, thereby contributing to improved export potential and economic returns for farmers.

Effect of surface coating and packaging on extending shelf-life & quality of banana

The study evaluated the effects of various edible coatings (chitosan, gum arabic, and carrageenan) at different concentrations (0.5%, 1.0%, and 5.0%) and storage temperatures (room temperature and 13.5°C) on the shelf life and quality of bananas, integrated with appropriate packaging solutions. Grand Nain bananas exhibited superior physical attributes, in fruit weight (157.76 ± 6.92 g), length (23.30 ± 0.26 cm), and girth (13.53 ± 0.61 cm), while Ney Poovan showed a higher pulp-to-peel ratio (3.52 ± 0.74) and total soluble solids (TSS) content (27.89 ± 1.22). In Ney Poovan, a 1% chitosan coating at room temperature yielded the highest lightness (L* value: 82.76 ± 4.8), whereas a 1% carrageenan coating at 13.5°C extended shelf life and improved overall acceptability (8.00 ± 1.00). For Grand Nain, a 0.5% chitosan coating at room temperature enhanced visual quality, while a 5% gum arabic coating at 13.5°C effectively reduced physiological weight loss, extending shelf life up to 52 days. These findings suggest that variety-specific edible coating and storage strategies can significantly improve the shelf life and marketability of bananas **(Fig. 29).**

Table 6: Red banana yield parameters at farmer field during the year 2024

Treatment	Bunch weight (kg)	No. of hands	No. of fingers
T1	16.97	6.75	80.41
T2	15.52	6.75	78.58
T3	17.12	6.78	77.66
T4	15.43	6.66	78.41
CD 1%	1.31	1.52	2.56
CD 5%	0.98	1.02	1.92

Table 7: Red banana physico-chemical parameters at harvest

Treatment	Fruit length (cm)	Fruit Girth (cm)	Fruit weight (g)	Pulp peel ratio	L	a*	b*	TSS (°Brix)	Acidity (%)
T1	20.5	16	157.9	1.96	25.12	3.35	9.18	4.05	0.19
T2	18.76	15.73	155.167	1.91	23.82	4.78	9.42	4.18	0.19
T3	19.03	15.23	164.2	1.94	25.03	3.91	8.66	4.33	0.18
T4	18.76	15.5	154.3	1.84	21.4	4.26	8.73	3.8	0.16
CD 1%	0.59	0.55	6.55	0.01	1.55	0.11	0.01	0.59	0.01
CD 5%	0.41	0.46	6.02	0.03	1.27	0.03	0.13	0.41	0.05

Table 8: Red banana physico-chemical parameters after ripe

Treatment	Pulp peel ratio	Hardness (N)	L	a*	b*	TSS (°Brix)	Acidity (%)
T1	2.35	16.73	22.64	4.23	8.1	24.53	0.34
T2	2.17	13.02	26.48	6.3	8.98	23.83	0.34
T3	2.26	16.97	28.42	8.35	12.11	24.03	0.35
T4	2.27	16.24	24.38	7.4	12.09	23.43	0.35
CD 1%	2.35	1.56	2.77	2.39	3.39	2.77	0.01
CD 5%	2.17	2.79	1.9	1.64	2.33	1.9	0.05

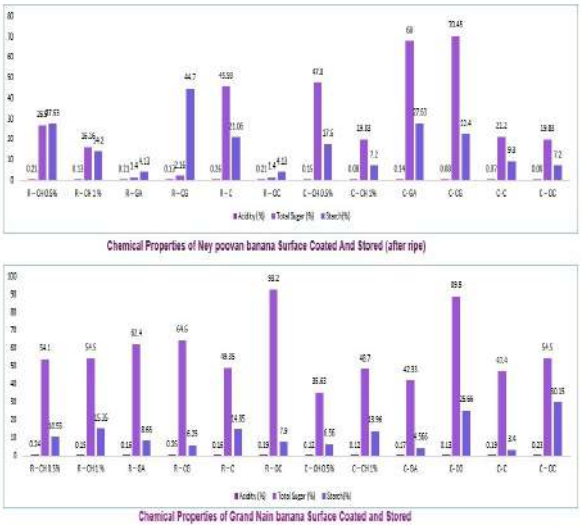


Fig. 29. Effect of surface coating and packaging on extending shelf-life & quality

Standardization of banana central core stem juice blends with tropical fruit juices

The study aimed to develop and evaluate banana central core stem juice blends enriched with tropical fruit juices (papaya and custard apple) and nutraceuticals, with a focus on value addition and waste reutilization. the study utilized three banana varieties—Poovan, Karpuravalli, and Grand Nain **(Table 8a)**.

Juice yield ranged from 32.84% in Poovan to 37.39% in Grand Nain. Among the varieties, Karpuravalli exhibited the highest total soluble solids (TSS) at 2.19°Brix; Grand Nain recorded the highest total sugar (0.63%) and phenoic content (1665.29 mg/100g); while Poovan had the highest carbohydrate content (2.57%) and vitamin C concentration. Among the tropical fruit juices, custard apple showed higher TSS (21.87°Brix), sugar (22.75%), carbohydrate (20.08%), acidity (0.61%), and phenol content (3829 mg/100g), whereas papaya was richer in vitamin C (48.33%). In blended juice formulations:

- Poovan + Papaya (PP) recorded the highest TSS (10.86°Brix)
- Poovan + Custard Apple (PC) showed the highest phenol content (1100.95 mg/100g)
- Karpuravalli + Custard Apple (KC) had the highest carbohydrate level (16.0%)
- Karpuravalli + Papaya (KP) showed the highest protein content (0.31%)
- Grand Nain + Papaya (GP) exhibited the highest vitamin C content (24.26%)

Sensory evaluation indicated that papaya and custard apple blends received the highest scores (7.63–7.96), while turmeric-infused (KJ) blends scored the lowest (4.33). Overall, papaya-blended banana stem juices—particularly those prepared from Poovan and Grand Nain—demonstrated superior nutritional quality, high consumer acceptability, and strong potential for commercialization.

Table 8a: Physico-chemical parameters of blended juices of banana central core stem juice, tropical fruit juices and nutraceuticals

Name of the juice	Total sugar (%)	Phenol (mg/100g)	Total Carbohydrate (%)	Protein (%)	Vitamin C (mg/100g)
Poovan central core stem juice	0.60 ± 0.06^{c}	1139.69 ± 40.34	2.57 ± 0.18^{b}	6.15 ± 2.00^{a}	0.00^{c}
Karpooravalli central core stem juice	0.35 ± 0.08^{c}	1420.54 ± 169.25	3.59 ± 0.69^{b}	7.24 ± 1.96^{a}	0.00^{c}
Grand Nain central core stem juice	0.63 ± 0.05^{c}	1665.29 ± 71.91	1.88 ± 1.22^{b}	7.17 ± 2.08^{a}	0.00^{c}
Papaya juice with central core stem juice	6.25 ± 0.66^{b}	1932.06 ± 41.28	7.58 ± 7.17^{b}	0.64 ± 0.18^{c}	48.33 ± 2.88^{a}
Custard apple juice with central core stem juice	22.75 ± 1.56^{a}	3829.34 ± 196.87	20.08 ± 1.04^{a}	2.73 ± 0.74^{b}	17 ± 2.01^{b}

4.2.6 Novel nutraceutical smart delivery systems for high-value food and non-food products of banana

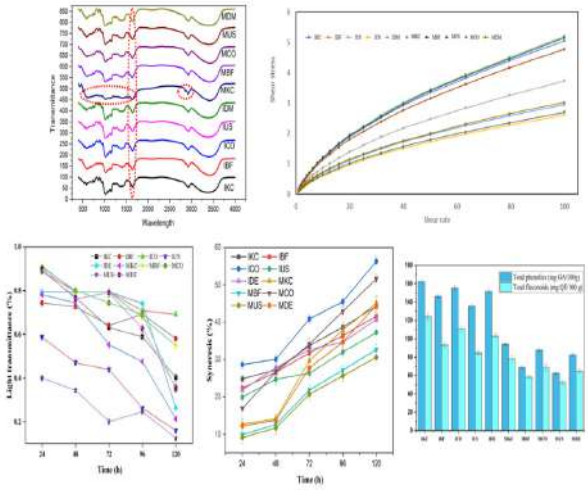
(P. Suresh Kumar, K.N. Shiva, M. Mayil Vaganan, I. Ravi, Pramod Shelake, D. Ramya Devi, Veda Hari

Modification methods in green banana flour and glycaemic response

This study investigated the effects of ultrasound (US), Blast freezing (BF), clove oil infusion, and their combinations on green banana flour derived from banana var. Grand Nain at two different maturity stages: immature (70% maturity) and fully mature (100% maturity). Morphological analysis revealed that Blast Freezing (BF) and Ultrasound (US) treatments significantly modified starch granule structures, reducing particle size and potentially enhancing hydration and textural characteristics. Fourier Transform Infrared Spectroscopy (FTIR) confirmed O-H stretching vibrations near 3400 cm^{-1}, indicating starch presence and revealing structural changes between immature and mature samples due to processing. X-ray diffraction (XRD) analysis identified a B-type crystalline pattern across all samples, with clove oil treatments effectively preserving crystallinity at both maturity levels.

Water solubility index (WSI) varied by treatment, ranging from 6.66 g/g (clove oil) to 7.9 g/g (US) in immature fruit flour, and from 9.31 g/g to 11.74 g/g in mature fruit flour, with US treatment exhibiting the highest solubility. Textural evaluations showed clove oil-treated samples had the highest hardness values (251.61 and 245.34), whereas US-modified samples had the lowest (168.91 and 179.53), indicating a softer texture.

Immature samples exhibited a slower hydrolysis rate, with a gradual increase in hydrolysis percentage over time and lower glycaemic index (42-44) than the matured fruits (52-54%). In contrast, flour from mature fruits showed a steeper increase, with hydrolysis percentages reaching 60-70% for treatments like MBF. These findings highlight the potential of using immature and export-rejected green bananas in developing value-added functional food products to meet growing consumer demand for health-focused alternatives **(Fig. 30).**



(IKC – Immature KMS + Citric Acid, IBF – Immature Blast Freezing, ICO – Immature Clove Oil, IUS – Immature Ultrasound, IDM – Immature Dual Modification, MKC – Mature KMS + Citric Acid, MBF – Mature Blast Freezing, MCO – Mature Clove Oil, MUS – Mature Ultrasound, MDM – Mature Dual Modification)

Fig. 30. FTIR, rheological, syneresis, and antioxidant activity of green banana flour at different maturity stages and modification methods

Banana starch-based films with varying starch concentrations

Banana starch-based biofilms were formulated using solution casting with varying starch concentrations (2%, 4%, and 6%) and plasticizers (glycerol, sorbitol, and a combination of both). Sorbitol-plasticized films exhibited improved tensile strength, water absorption, contact angle, surface smoothness, and structural integrity due to enhanced compatibility with starch. In contrast, glycerol increased flexibility, solubility, biodegradability, and water vapor transmission rate, though it resulted in rougher film surfaces and disrupted crystallinity. The glycerol-sorbitol combination provided balanced mechanical and physical properties.

Higher starch concentration (6%) resulted in increased crystallinity, rigidity, water absorption, and contact angle, but reduced solubility, moisture content, water vapor permeability, and biodegradability. The 4% starch concentration yielded optimal mechanical performance, with the highest tensile strength and elongation values **(Fig. 31).**

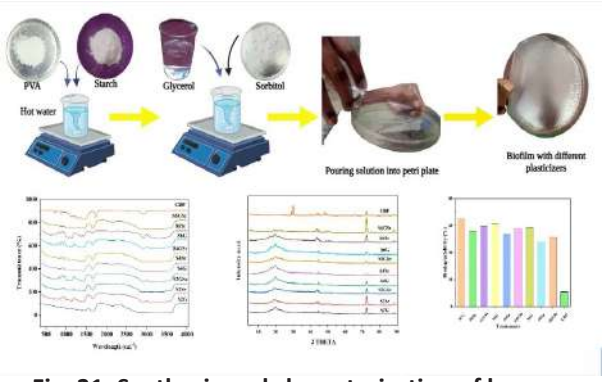


Fig. 31. Synthesis and characterization of banana starch-based films with varying starch concentrations and plasticizers

Banana starch as a wall material for encapsulation of *Lactiplantibacillus plantarum* in synbiotic fermented milk

Microencapsulation significantly increased survival rates of the probiotic under simulated gastric [sodium chloride solution (5 g/L) was adjusted to pH 2 by using 6 M HCl and 0.3% pepsin] and intestinal conditions [0.6% bile salt was added 0.05 M KH_2PO_4 solution]. The highest survival and yield were observed with single Encapsulation [SE] using hydroxy propylated [HYP] + oxidized [OXY]-modified starch (encapsulation yield: 60.03%, viability: 95.56%). SE OXY samples exhibited the highest bulk (0.67 g/cm³) and tapped densities (0.72 g/cm³). SE HYP + OXY also showed superior flowability with a Carr index of 18.75. Heat resistance was lowest in double encapsulation DE- OXY only samples, which retained 60% viability post-heat exposure. Total sugar content was highest in the 1:1 ratio formulation with diluted SE HYP + OXY **(Fig. 32)**

Fig. 32. Preparation of fermented milk using microencapsulated *Lactiplantibacillus plantarum*

Phase change material (PCM)-based reefer container for Ney Poovan for storage and quality

This study revealed that to achieve better outcomes, it is essential to maintain more stable temperatures and ensure RH levels are sufficiently high to prevent dehydration and maintain the fruit's quality **(Table 9).**

Table 9. Variation in Green life (in days) with wrapping methods and storage conditions

Materials	Foam sheet			Pulp based paper			Foam+Vacuum		
Storage	R	P	C	R	P	C	R	P	C
Green life (in days)	8	16	24	6	16	24	20	28	32

R-Room Temperature, P-PCM, C-Cold storage

Testing of PCM-based reefer container for Karpuravalli for shelf life and quality

The study showed that room temperature led to faster weight loss as the fruits transitioned from unripe to ripe stages. A weight loss of 18% occurred within 7 days of storage at room temperature, whereas the loss in weight was gradual in cold storage and took 16 days in the reefer container to loose the same amount of weight. Cold storage maintained fruit integrity even after 25 days of storage. The same trend was observed with the Total Soluble Solids (TSS) of the stored products. The fruits stored at room temperature exhibited a steeper and faster reduction in firmness, whereas the cold storage and reefer container maintained the firmness of the fruits for up to 16 days **(Fig. 33).** The peel turned black and lost turgidity and weight more quickly at room temperature, which resulted in higher Peel-to-Pulp Ratio

(PPR), while the peel firmness in the reefer container and cold storage was lesser due to better peel firmness and probably lesser moisture removal from the peel **(Table 10).**

Table 10: Changes in Firmness (N) under different storage conditions over the period (days)

Day	1	3	6	7	8	9	13	14	15	16	17	20	21	22	23	25
RT	28.76	22.4	8.69	7.76	-	-	-	-	-	-	-	-	-	-	-	-
PCM-RCo-18 °C	27.42	26.63	20.83	20.97	18.17	13.25	11.97	10.50	7.30	8.73	5.36	4.66	-	-	-	-
CS-13.5°C	33.6	32.0	30.6	30.4	29.36	25.47	18.0	16.7	14.3	11.54	8.96	6.58	5.78	5.22	5.01	4.08
CS- RC	33.6	32.0	30.6	30.4	29.36	19.3	16.24	13.25	10.41	11.28	6.25	5.18	-	-	-	-

RT - Room Temperature, **RCo** - Reefer Container, **CS** - Cold Storage, **CS - RC** - Cold Storage Ripening Chamber

Fig. 33. Testing PCM-based reefer container for var. Karpuravalli for shelf life & quality

Response surface methodology-based process optimization of banana flour

This study examined the effects of key parameters such as steaming (blanching) time (10-30 min (citric acid concentration (0.501.0%), and drying time (6-8 hours) on the production of banana flour. In the Response Surface Methodology, regression polynomial models were employed to describe the relationships between process variables and the responses, resulting in R^2 values of 0.96 for yield, 0.99 for moisture content, 0.99 for water activity, 0.99 for amylose content, 0.73 for starch content, 0.79 for solubility index, 0.89 for swelling power, and 0.97 for resistant starch. The optimized conditions for producing banana powder from green bananas (var. Poovan) was as follows; a steaming time of 10 min, citric acid concentration of 0.5%, and drying time of 7 hours. Under these optimal conditions, the predicted values for the responses were: yield 19.09% (**Fig. 34)**, moisture content 4.74%, water activity 0.33 aw, amylose content 22.99 g/100g, starch content 86.95 g/100g, solubility index 3.47%, swelling power 19.44 g/g, resistant starch 39.40 g/100g **(Fig. 35)**, and colour parameters L 50.24, a* 7.60 and b 16.53 In conclusion, this study demonstrates the potential of converting green banana into a value-added powder that minimizes waste and provides both nutritional and economic benefits.

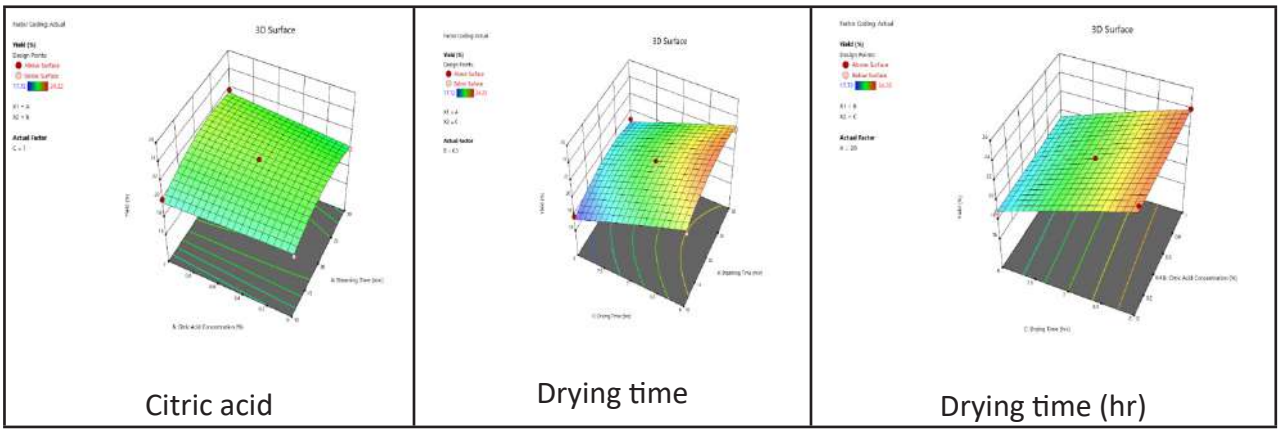


Fig. 34. Effect of process variables on yield of the Banana flour

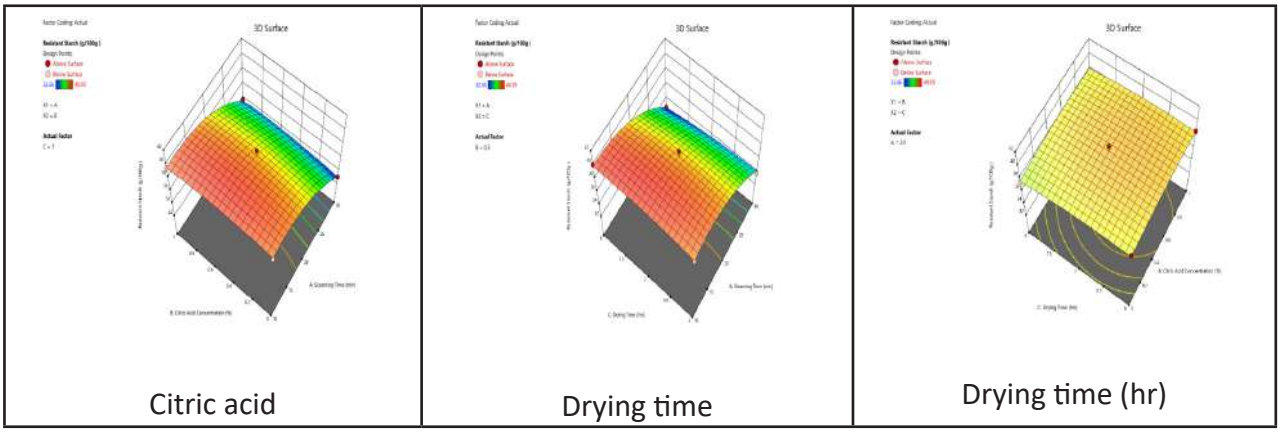


Fig. 35. Effect of process variables on the resistant starch (%) of the Banana powder

4.2.8 Design and development of banana central core stem juice extractor

(Pramod Shelake, R. Selvarajan, P. Suresh Kumar, K. N. Shiva, M. Mayil Vaganan)

The mechanical properties, including compression force, hardness, cutting force, and shearing force of the central core stem from different banana varieties were evaluated. These findings provide valuable insights into the mechanical characteristics essential for designing an efficient extraction unit. Based on the study, the conceptualization of a suitable extraction machine was undertaken to define and incorporate the required mechanical parameters.

Nanocellulose-induced banana fibre epoxy composites

Epoxy polymer was utilized as the matrix phase, while banana fibre served as the primary reinforcing agent. To further improve the composite's structural performance, nanocellulose was introduced as a secondary reinforcement or filler material. The addition of nanocellulose significantly enhanced the interfacial bonding between the fibre and the polymer matrix, thereby promoting more efficient stress transfer throughout the composite structure. As a result, the fabricated composite exhibits improved mechanical performance and showed strong potential for deployment in high-strength, load-bearing industrial applications **(Fig. 36).**

Fig. 36. Nanocellulose-induced banana fibre epoxy composites

Extension- Outreach programmes

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

(C. Karpagam, A. Mohanasundaram, R. Selvarajan, V. Kumar, K.N. Shiva, K. J. Jeyabaskaran)

To enhance the dissemination and adoption of banana technologies, various extension methods and mass media channels were effectively utilized during the reporting period. Several capacity development programmes (CDPs) were organized to benefit diverse stakeholders involved in the banana production system (**Table 11**). Technology demonstration, technology assessment and refinement were undertaken as research part.

Table 11: Outreach modality - Capacity development programmes (CDPs)

Particulars	No. of programme
Training	
One Day Training for farmers	02
Two Days Training for farmers	01
Three Days Training programme for farmers	05
Five days training programme for farmers	01
Entrepreneurs/ officials visit	05
Total	**14**
One day Exposure visit	
One Day Farmers Exposure Visit	102
One Day Students Exposure Visit	139
Total	**241**
Total (including Famers Day/ Kisan Diwas and Science Day)	**255**

Fig. 37 Capasity Development Programme at ICAR-NRCB

Outreach modality - Mass media and print media

To further expand the outreach of banana technologies, mass media platforms were strategically employed. The details are summarized in the below **(Table 12)**

Table 12. Mass media and print media

S. No.	Activity Description	No. of Instances
1.	News/Stories reported in media	28
2.	Press meets and phone-based communications related to NRCB activities	56
3.	News articles published in print media	53
4.	News broadcasts in electronic media (AIR/TV)	32
5.	Stories shared via social media platforms	29
6.	News stories featured in ICAR–NEWS (Online)	7
	Total	**205**

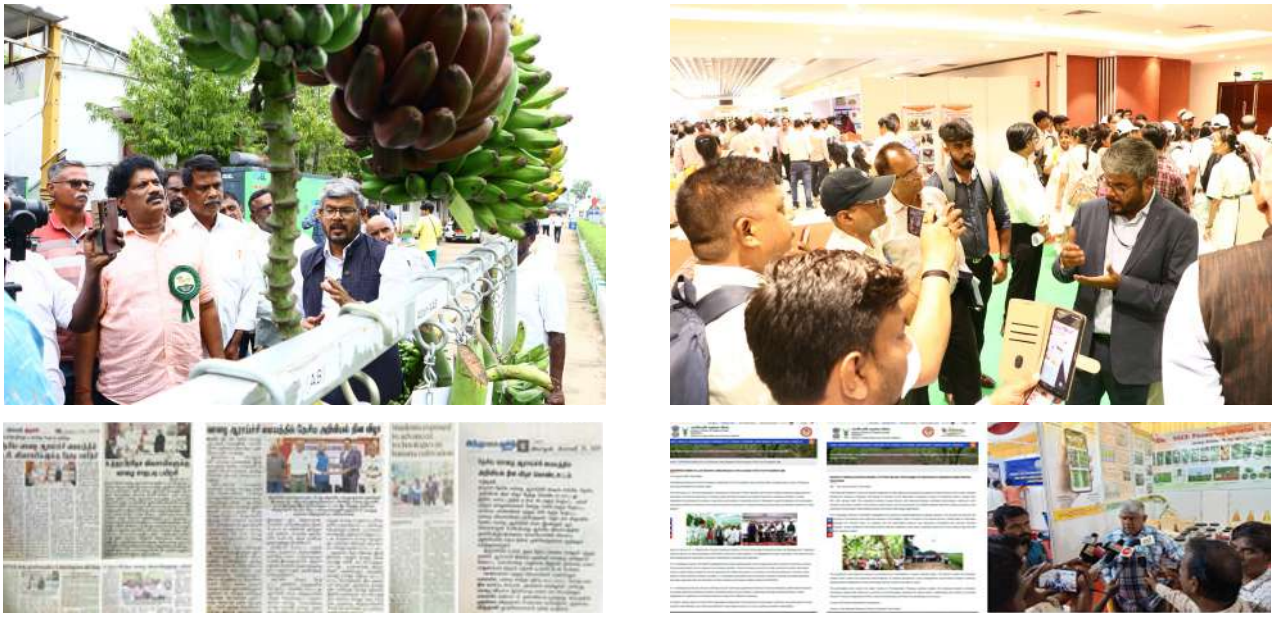


Fig.38 News Published in Mass media and Print Media

Outreach modality – Inter institutional activities

National Science Day 2024 was celebrated on February 28, 2024, with the theme *"Indigenous Technologies for Viksit Bharat."* The event witnessed participation from nearly 6,000 students from various schools and colleges in and around Tiruchirappalli. Additionally, more than 600 farmers and general public members attended the event.

NRCB's 31st Foundation Day and Kisan Mela were observed on August 21, 2024. An exhibition stall was arranged, and over 700 farmers took part in the celebrations.

Banana Festival cum Kisan Diwas was organized on December 23, 2024, attracting around 300 farmers.

National Science Day | 31st Foundation Day | Kisan Diwas

Fig.39 ICAR-NRCB Inter Institutional Activities

Outreach modality – Farmers – Scientist interface

Banana farmers from Uttar Pradesh were trained on Hi-Tech banana cultivation at ICAR- NRCB from Feb 17 – 21, 2024, in collaboration with the State Department of Agriculture, Uttar Pradesh **(Fig. 40)**

Fig.40 Training of banana farmers from Uttar Pradesh

ICAR – NRCB vs ISHA FPOs

A series of training programs were organized for Manneeswarar and Chenni Andavar FPOs of Annur block on 14th May 2024. On 15th May, the training program was extended to FPO members of Karamadai FPO in Karamadai block.

Outreach modality - Frontline exhibition activities

A total of 4,45,680 beneficiaries were impacted through ICAR-NRCB's participation in various frontline exhibition activities across different locations during 2024.

Outreach modality- To develop a series of Institute publications

Around Ten institutional publications were brought out during the year 2024

Outreach modality- To develop a series of video films

Around Ten institutional video files were developed during the year 2024

Outreach modality – Farmer participatory technology assessment and refinement

Technology assessment

A field survey conducted in Raver Taluk, Jalgaon district, documented several effective summer stress management practices adopted by farmers to protect tissue culture (TC) banana plants. These practices not only enhance plant survival during extreme heat but also ensure optimal growth, showcasing the importance of adopting summer management strategies. Implementing such approaches is essential to fully realize the potential of TC technology in banana cultivation and to ensure long-term sustainability and profitability for growers.

Farmers practice for high temperature stress for tissue culture banana plants

1. Better root zone microclimate

- Dig pits of 1.5 ft × 1.5 ft × 1 ft
- Fill with well-decomposed FYM and vermicompost/coir pith (1:1) mixture
- Irrigate pits one day before planting for moisture buffering
- Apply coir pith or rice husk ash (1.5–2 kg/ plant)
- Sow sunhemp seeds around each plant for partial shade

2. Sunhemp as a shade crop

- Sow Sunhemp 20 days prior to transplanting. Use 8–10 kg of Sunhemp seed per acre
- Maintain 20–30 Sunhemp plants
- Always plant Sunhemp on the western side of the banana
- The Sunhemp should be approximately ½ foot lower than banana
- After 2.5 months plough the Sunhemp

Fig. 41. Sunhemp as a shade crop

3. Grow cover – The protective shield for banana plants

- For one acre with 1,000 plants, the total cost is ₹3,000.
- Widely adopted in Maharashtra's Jalgaon district, over 80% of banana farmers use either Grow Covers, Sunhemp, or a combination of both.
- In areas where Sunhemp doesn't germinate well, Grow Covers are used exclusively.

Fig. 42. Grow cover protection for TC plants

Outreach modality – Technology demonstration

During 2024, ICAR-NRCB conducted a series of technology demonstrations benefiting approximately 9,500 stakeholders. These activities aimed to promote awareness and adoption of advanced technologies in banana cultivation **(Fig. 43).**

Key Technology Demonstrations:

- **Germplasm Diversity Block**: Display of traditional, wild, and improved banana varieties to highlight the importance of conserving genetic resources.
- **Drone Demonstration**: Live operation of agricultural drones for micronutrient and fungicide spraying, promoting precision farming.
- **Value added products demonstration in CIC**: Introduction to value-added banana products, post-harvest processing, and entrepreneurship opportunities.
- **Sensor-Based Automation:** Demonstration of smart irrigation systems using soil moisture sensors for efficient water management.
- **Research Experiment Plots**: Overview of ongoing trials in varietal evaluation, nutrient management, and sustainable farming practices.

These outreach efforts underscore ICAR-NRCB's role **in** technology transfer**,** capacity building**,** and **farmer empowerment** for sustainable banana cultivation.

Fig. 43. ICAR- NRCB Technology demonstrations

Outreach modality - Vazhayum Valamum – Farmers' Field School

Vazhayum Valamum – Farmers' Field School, a collaborative initiative by ICAR-NRCB and All India Radio, Tiruchirappalli, was successfully organized to enhance outreach among banana farmers. Dr. C. Karpagam, Principal Scientist and Nodal Officer, Media & Publicity Committee, coordinated the programme. A total of 16 modules were presented during the programme.

4.3 PHYSIOLOGY AND BIOCHEMISTRY

4.3.1 High temperature and soil moisture deficit stresses in banana: Mechanism of high temperature tolerance and management of high temperature and soil moisture deficit stresses in banana

(I.Ravi, M. Mayilvaganan, S. Backiyarani)

Total Soluble Solids (TSS) as a maturity and sweetness indicator

TSS (˚Brix) is a standard measure for fruit maturity and sweetness. As fruit ripens, enzymes hydrolyze complex carbohydrates (e.g., starch) into simple sugars (fructose, glucose, sucrose), thereby increasing the TSS.

Genotypic Variation in TSS: Significant variation in TSS exists among different banana genotypes, indicating a natural difference in sweetness/sugar content **(Fig.44).**

- **Higher TSS** (>25°Brix): Malbhoh, Udhyam, and Desihadali.
- **Lowest TSS** (18°Brix): Borchamba and Bangrier.

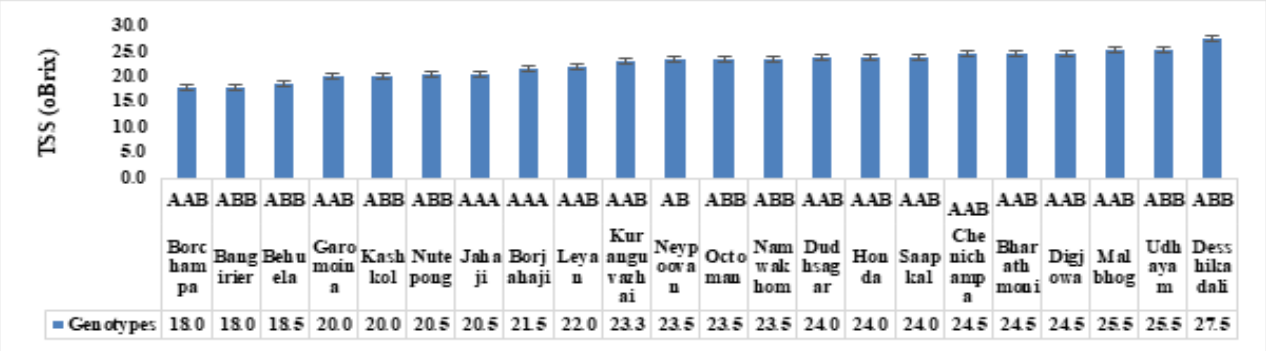


Fig. 44. Total Soluble Solids (TSS) among different banana genotypes

Physio-Biochemical changes during banana fruit development

This study examined the physiological and biochemical changes in 'Grand Nain' banana fruit during development (15 DAF to 105 DAF), focusing on starch, total sugars (TS), TSS, fruit girth (FG) and fruit length (FL).

Fruit Growth: Fruit weight, FL, and FG significantly increased throughout development. FL and FG increased from approximately 15 cm and 7.8 cm at 15 DAF to 24 cm and 13 cm at 105 DAF, respectively.

Starch and Sugar Metabolism: Immature fruit had high starch content and low total sugar (TS). Starch content increased from 15 to 90 DAF, then plateaued until 105 DAF, indicating the onset of the starch-to-sugar conversion process. Starch hydrolysis led to a substantial increase in TS (conversion of starch to sucrose, fructose, and glucose) as maturation progressed. TS increased from 15 to 30 DAF, followed by a dip from 30 to 45 DAF, plateaued until 90 DAF, and then peaked at maturity. The reducing sugar levels consistently increased during maturation. However, the non-reducing sugar content increased from 0.9 mg/g at 15 DAF to 2.4 mg/g at 105 DAF. The TSS increased significantly from 2.6°Brix at 15 DAF to 4.5°Brix at 105 DAF. The amylose activity was highest in unripe fruit and decreased sharply upon ripening. The decline in amylopectin (which is about 80% of starch) paralleled the decrease in starch content.

Dry Matter Partitioning of Commercial Cultivars of Banana at harvest

At harvest, most of the dry matter accumulates in the economic yield parts of the bunch, followed by the pseudostem, corms, leaves, peduncle, and roots. Harvest Index (HI): Genotypic variation in HI is significant, ranging from over 40.25% in 'Grand Nain' (AAA) and 'Kaveri Saba' (ABB) to less than 30.75% in 'Ney Poovan' (AB) and 'Poovan' (AAB). These findings confirm the critical role of genetic factors in dry matter partitioning.

Pattern of dry matter partitioning of banana genotypes under different water regimes at early vegetative stage under controlled pot studies

A pot culture study on 'Nendran' (AAB), 'Karpuravalli' (ABB), and 'Kaveri Saba' (ABB) investigated dry matter allocation under optimum soil moisture (OSM), saturated soil moisture (SSM), and waterlogged conditions (WL). Dry matter partitioning refers to the distribution of organic material produced by photosynthesis to different plant parts.

Genotypic Response to Stress:

- 'Nendran': Allocated more dry matter to the corm under SSM and WL than under OSM, suggesting a strategy for underground storage and stress survival.
- 'Karpuravalli' and 'Kaveri Saba': Partitioned more dry matter to the leaf and pseudostem under SSM and WL, potentially indicating a strategy to increase photosynthetic area or promote aboveground growth to escape the waterlogged environment.
- All Genotypes: Dry matter allocation was significantly lower in roots under SSM and WL conditions, a typical response to oxygen deprivation (hypoxia) from excess water.

• The study highlights that different cultivars ('Nendran' prioritizing storage, 'Karpuravalli' and 'Kaveri Saba' prioritizing aboveground growth) have distinct strategies for dealing with excess soil moisture **(Fig.45-47).**

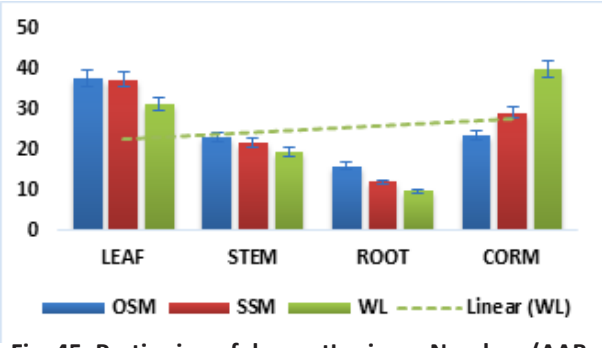


Fig. 45. Partioning of dry matter in cv. Nendran (AAB

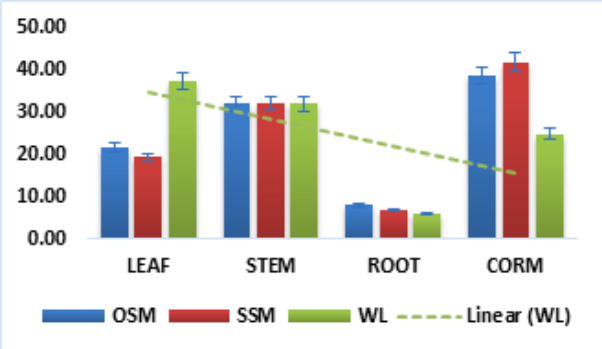


Fig.46. Partioning of dry matter in cv. Karpuravalli

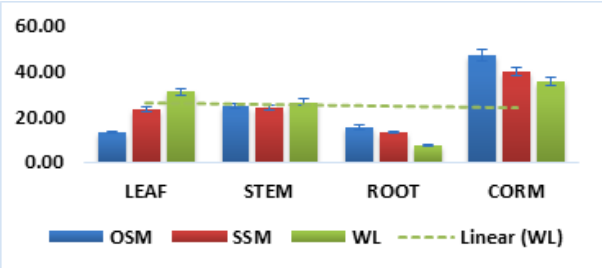


Fig. 47. Partition (%) of DM in Kaveri Saba (ABB)

Biochemical dissection of fruit ripening-related phenomena & components and exploring nutraceutical applications of bioactives of banana

(M. Mayil Vaganan, I. Ravi, C. Anuradha)

Studies on peel senescent spots initiation and development

Grand Nain bananas in full physiological maturity were ripened with fumigation of ethylene at 500 ppm concentration at 21 ^{O}C and 94% RH in a ripening chamber. 'Poovan' and 'Ney Poovan' bananas at physiological maturity were ripened naturally at ambient temperatures. At ripening stage 6 (fully yellow), the fruits were stored under ambient conditions for the observation.

Senescent spot initiation began on day 1 or 2 in 'Grand Nain' and 'Poovan' bananas **(Figs. 48 - 49)**, whereas in 'Ney Poovan', spotting initiation was observed only on day 4 or 5 **(Fig. 50).** A score of 3 was reached by day 5 or 6 in 'Grand Nain' and 'Poovan', while the same was observed on day 9 or 10 in 'Ney Poovan'. Key cell wall-depolymerizing enzymes, polygalacturonase and pectin methyl esterase (PME), along with biochemical parameters such as total sugars, reducing sugars, starch, total phenols, and flavonoids were analysed in the peels of the three cultivars during the initiation and development of senescent spots.

Polygalacturonase activity increased during spot initiation and development **(Fig. 51a),** while PME activity initially increased and subsequently declined **(Fig. 51b)** in all three cultivars. Total and reducing sugars increased, while starch content decreased, consistent with typical ripening trends. Total phenol and flavonoid contents continuously increased during the development of senescent spots. Notably, 'Grand Nain' and 'Poovan' peels exhibited higher phenol and flavonoid levels compared to 'Ney Poovan'.

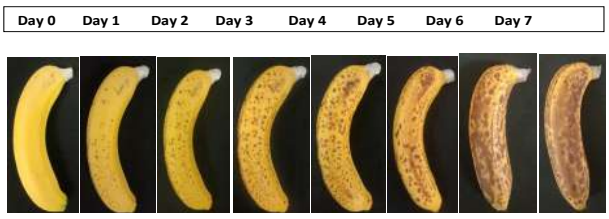


Fig. 48. Senescent spots initiation in Grand Nain bananas

Fig. 49. Senescent spots initiation in Poovan

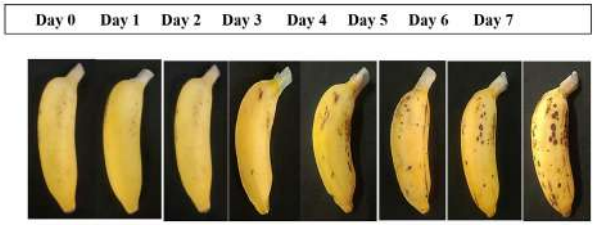


Fig. 50. Senescent spots initiation in Ney Poovan

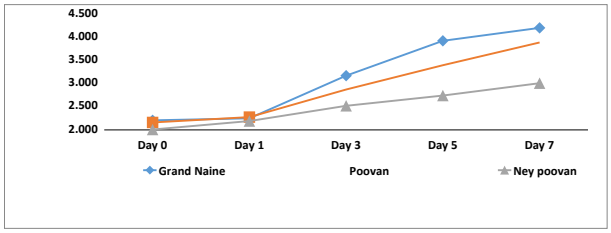


Fig. 51a. Level of polygalactronase activity (units/g)

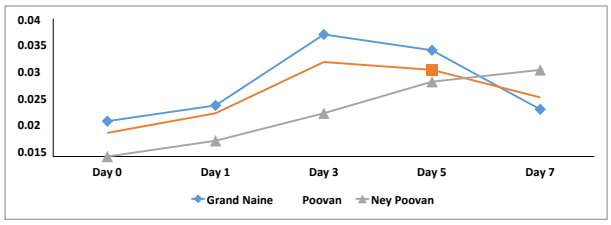
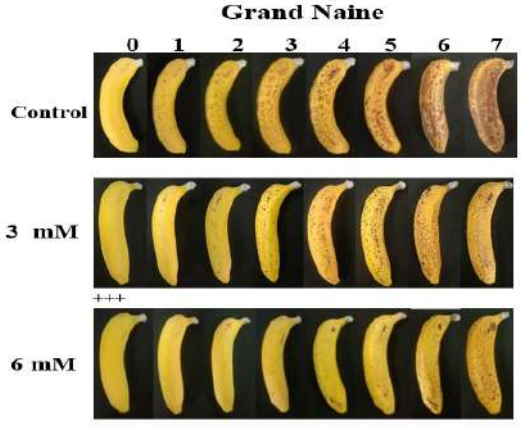


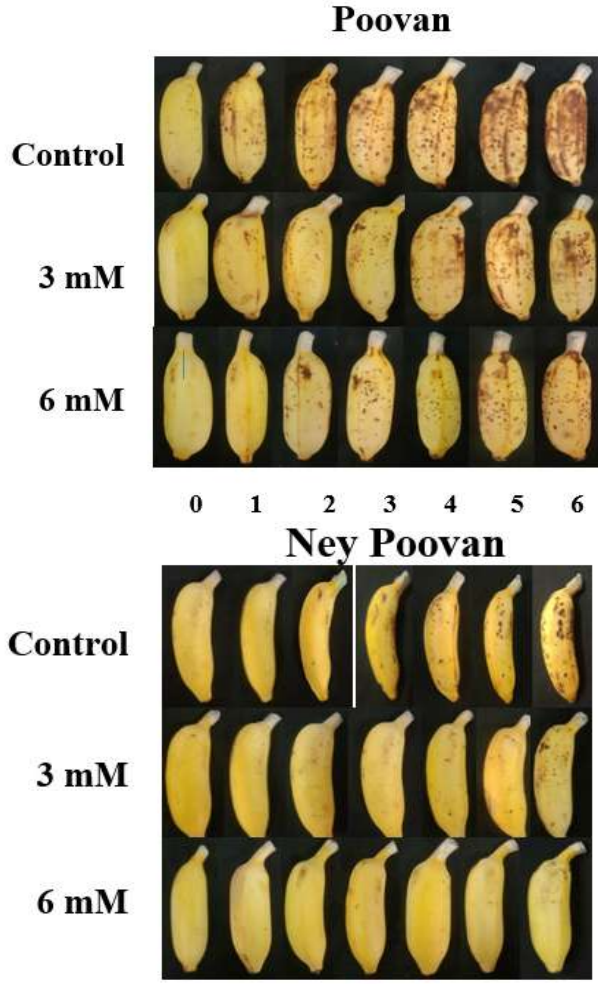
Fig. 51b. Level of pectin methyl esterase activity (units/g)

Retardation of senescent spot development using methyl salicylate

To delay the onset and progression of senescent spots during the late yellow stage of ripening (stage 6), ripe fruits of 'Grand Nain', 'Poovan', and 'Ney Poovan' were treated with exogenous methyl salicylate (MeSA) at concentrations of 3 mM and 6 mM, and stored at 21 °C or ambient temperatures. MeSA treatment successfully delayed the onset of senescent spot formation.

Generally, the 6 mM concentration was more effective than 3 mM, with the greatest delay observed in 'Ney Poovan', followed by 'Poovan' and 'Grand Nain'. In 'Grand Nain', the delay in spot formation was 1 and 3 days for 3 mM and 6 mM MeSA, respectively **(Fig. 52).** In 'Poovan', spotting was delayed by 2 days, with no significant difference between concentrations **(Fig. 53).** For 'Ney Poovan', the delay was 5 days with 3 mM and 7 days with 6 mM MeSA **(Fig. 54).**





Figs. 52, 53 & 54 Methyl salicylate (MeSA)-treated Grand Nain, Poovan and Ney Poovan fruits

Monthan – a bioactives rich banana

Analysis of the nutritional and nutraceutical properties of 'Monthan' (ABB), a cooking banana variety, revealed high levels of functional bioactive compounds. The peel contained epigallocatechin (182 mg/100 g), a flavonoid known for its strong antioxidant properties. The pulp contained inulin-type fructans (123 µg/g), a dietary fibre with significant immunomodulatory benefits. 'Monthan' peel exhibited the highest antioxidant activity (90 µmol TE) among commercial banana varieties. Starch analysis of the pulp indicated a high total starch content of 83.5%, with amylose content at 36.78%, making it one of the richest starch sources among bananas.

Pisang Lilin – a low glycemic banana suitable for diabetic patients

'Pisang Lilin', a parthenocarpic diploid cultivar, was identified as a low glycemic banana

with a GI of 51.3. This finding is especially valuable for health-conscious consumers and diabetic individuals.

Locally known as 'Kaveri' or '*Meluguthiri*' (Candle Banana), 'Pisang Lilin' is cultivated in the Kanyakumari, Tamil Nadu and in Thiruvananthapuram, Kozhikode, and Wayanad districts of Kerala. The banana produces a medium-sized bunch (11–13 kg) with 7–10 hands. The fruits are 12–17 cm long and weigh 50–70 g each **(Fig. 55).** The physiological weight loss is around 14%, and the total soluble solids (TSS) are 24.2 °Brix. The unripe fruit contains 75.51% starch, with 44.04% amylopectin.

Fig. 55. 'Pisang Lilin' – Bunch, ripe hand, and ripe fingers

4.4 CROP PROTECTION

4.4.1 Pest mapping in bananas and plantains of India

(J. Poorani, A. Mohanasundaram and C. Anuradha)

Studies on parasitoids of banana flower thrips

Ceranisus menes and two mymarid egg parasitoids were observed parasitizing the banana flower thrips, *Thrips hawaiiensis*, on all major cultivars such as Grand Nain, Ney Poovan, Poovan, Karpooravalli, Udhayam, Rasthali, Virupakshi, Ash Monthan, Popoulu, and recently released varieties including Kaveri Kalki, Kaveri Saba, Kaveri Sugantham, and Kaveri Kanchan. The activity of *C. menes* started at the end of January 2024 and continued until the first week of April 2024, reaching a peak of 63 individuals per plant during the fourth week of February. A barcode sequence was generated for the rapid identification of *C. menes* (GenBank accession number PQ498732.1). White cardboard traps (20 cm × 15 cm), smeared with coconut oil and castor oil in a 1:1 ratio, were used for sampling and assessing the populations of thrips and their natural enemies in the banana ecosystem. Both egg parasitoids and *Ceranisus* spp. were recovered from thrips-infested fields using the white cardboard traps.

New and emerging pests of banana

Spodoptera exigua, an emerging pest of banana

The coexistence of three species of *Spodoptera* (*S. litura*, *S. frugiperda*, and *S. exigua*) on banana foliage was observed for the first time in Trichy, Karur, and Thanjavur districts. *S. exigua* emerged as a serious pest during the vegetative stage of banana (2–3-month-old crops) for the first time. Population levels of *S. exigua* **(Fig. 56)** were 10-fold greater than those of *S. litura*, a common foliage feeder on banana. Negligible levels of infestation by *S. frugiperda* were also recorded in bananas. Sudden and short-lived outbreaks of *S. exigua*, previously considered a minor pest of banana, were observed in many parts of Trichy and Karur districts of Tamil Nadu, starting from the second week of June 2024 and continuing for three weeks up to the first week of July 2024. Heavy parasitization of all stages of *S. exigua* by various parasitoids, including *Trichogramma* sp. **(Fig. 57),** rapidly reduced the pest population; however, no parasitoids were observed on *S. litura* and *S. frugiperda*.

Fig. 56. *Spodoptera exigua* feeding on banana foliage

Fig. 57. *Trichogramma* sp. parasitizing the egg mass of *S. exigua*

Spodoptera exigua incidence on cv. Grand Nain

Extended observations on the incidence of *S. exigua* on the cultivar Grand Nain at the ICAR-NRCB research farm revealed that larval activity began in the second week of June 2024 and continued until the first week of December 2024. Larval populations peaked during October 2024, with a maximum of 89 larvae per leaf and 134 larvae per plant. The population subsequently declined to zero by the second week of December 2024.

Outbreaks of banana fruit mealybug (*Dysmicoccus neobrevipes*)

Severe infestations of *D. neobrevipes*, an exotic mealybug species, emerged as a significant concern across several banana cultivars during 2023–24. This mealybug is the most damaging fruit-infesting species as it causes partial or total blackening of fruits, resulting in loss of market value.

In April 2024, infestations on the leaf sheath and bunches were observed in parts of Trichy district, Tamil Nadu. *Nephus* sp., a known predator of mealybugs, was found feeding on the pest. Infestation levels were notably higher in shaded areas and in fields bordered by *Sesbania* plants. Additionally, three ant species, *Camponotus compressus*, *Crematogaster* sp., and *Anoplolepis gracilipes* were consistently associated with mealybug colonies, suggesting a potential mutualistic relationship.

Survey, awareness, and advisory services for managing emerging banana pests

The ICAR–NRCB has taken proactive steps to manage mealybug infestations, which have become a major threat to banana cultivation in the Karur and Trichy districts, particularly along the banks of the Cauvery river. Severe fruit infestations were observed on the cultivars Ney Poovan and Karpooravalli in several canal-irrigated banana belts within the Cauvery river basin in Trichy and Karur districts **(Fig. 58).** In addition to fruits **(Fig. 59a),** other plant parts such as the foliage and leaf sheath in Nendran, Red Banana, Grand Nain, Ney Poovan, Poovan, and Karpooravalli were affected. Infestation was also observed in the corms of Grand Nain **(Fig. 59b).**

Fig. 58. Mealybug affected banana at Kandiyur, Naduvathiyam Panchayat, Karur district

Fig. 69 a & b. *Dysmicoccus neobrevipes* infestation on (a) fruits; (b) corm

4.4.2 Bio-intensive management of major insect pests of banana

(J. Poorani, A. Mohanasundaram)

Soap-based and powder-based formulations of Pongamia oil, fish oil, and neem oil were developed and evaluated through laboratory bioassays against sucking pests of banana. Among the treatments [neem oil (10 ml/L), Pongamia oil (10 ml/L), fish oil (10 ml/L), neem + Pongamia soap (10 g/L), fish oil powder (10 g/L), Banana Weevil Killer® (10 ml/L), and thiamethoxam (0.4 g/L)], fish oil powder and neem + Pongamia soap were the most effective, causing 92–100% mortality of mealybugs within 24 hours. This was followed by Banana Weevil Killer®, which caused 88% mortality within the same time frame. Neem oil and Pongamia oil, when used individually, were less effective than their respective soap-based formulations against *D. neobrevipes*.

Probit analysis of fish oil formulation against *D. neobrevipes*

Fish oil formulations at different concentrations were evaluated against *D. neobrevipes* in laboratory bioassays. The fish oil powder was found to be the most effective, with an LC_{50} value of 2.58 grams and an LC_{90} value of 6.42 grams, along with an R^2 value of 0.921 on the fourth day after treatment **(Fig. 60).**

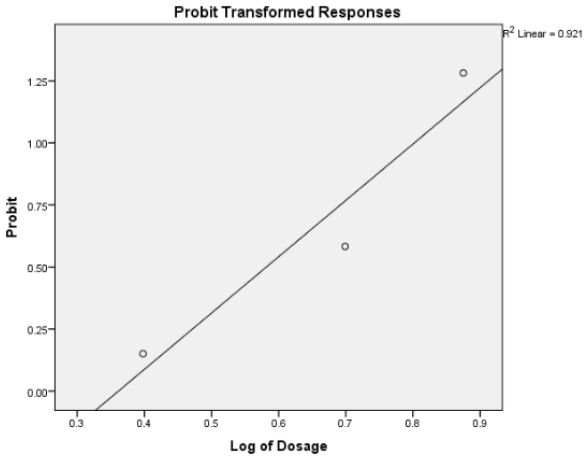


Fig. 60. Probit analysis of fish oil powder formulation against banana mealybug

Evaluation of eco-friendly and commercial formulations against *D. neobrevipes*

Neem + Pongamia soap cake, Neem + Pongamia soap powder, fish oil powder, imidacloprid 17.8% SL, Banana Weevil Killer®, and two commercial formulations (CLEANZA® and NS 100®) were evaluated against the aphid (*Aphis gossypii*) under laboratory conditions over a period ranging from 2 hours to 4 days. Fish oil powder (100%) and Neem + Pongamia soap cake (98%) recorded the highest mortality, followed by imidacloprid (84%) and Banana Weevil Killer® (80%) two days after treatment **(Fig. 61).**

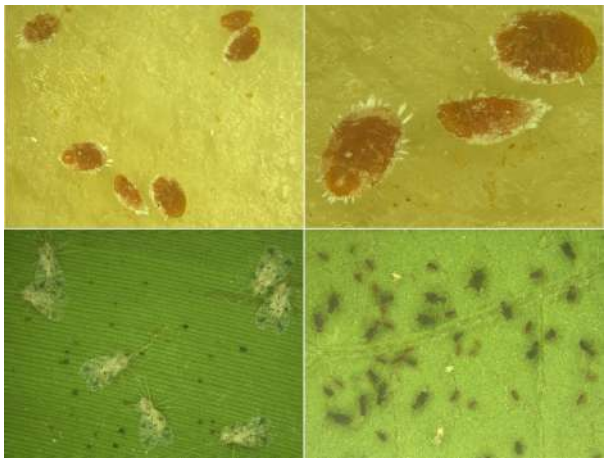


Fig. 61. Mortality caused by neem+pongamia soap in *D. neobrevipes, Stephanitis typica,* and *A. gossypii*

Similarly, Neem + Pongamia soap cake, Neem + Pongamia soap powder, fish oil powder, and the two commercial formulations (CLEANZA® and NS 100®) were evaluated against the solenopsis mealybug (*Phenacoccus solenopsis*) under the same laboratory conditions. Fish oil powder recorded the highest mortality (100%), followed by Neem + Pongamia soap cake (96%) and Neem + Pongamia soap powder (88%) on the third day after treatment.

Insecticide bioassays against emerging banana pests

Seven insecticides (fipronil 5% SC, indoxacarb 14.5% SC, emamectin benzoate 5% SG, spinosad 45% SC, chlorpyrifos 20% EC, Lambda-cyhalothrin 5% EC, flubendiamide 39.35% SC), two entomopathogenic fungi (Banana Weevil Killer® *[Beauveria bassiana]* and NRCB EPF Ma 50 *[Metarhizium anisopliae]*), and one botanical (Vijayneem® [Azadirachtin]) were tested against *Spodoptera exigua* under laboratory conditions (2 hours to 2 days). Indoxacarb, spinosad, and chlorpyrifos caused 100% mortality within 12 hours, followed by fipronil (90%) and emamectin benzoate (87%).

The same insecticides and *Beauveria bassiana* (Banana Weevil Killer® and Beverilin®) were also evaluated against *Olepa ricini,* an occasional pest of banana. Lambda-cyhalothrin, chlorantraniliprole, and chlorpyrifos caused 100% mortality within 12 hours. Banana Weevil Killer®, Bannari Pest Hunter®, Pest Repellent (Neem Oil) TNAU®, Beauverilin®, Vijayneem®, Fish oil, imidacloprid 17.80% SL, and thiamethoxam 25% WG were tested against banana fruit mealybug (*D. neobrevipes*). Fish oil and thiamethoxam 25% WG resulted in 100% mortality within a day. Imidacloprid and Banana Weevil Killer® also caused 100% mortality by day 4.

4.4.3 Eco-friendly management of banana pseudostem weevil (*Odoiporus longicollis* Olivier) and banana scarring beetle (*Basilepta subcostata* (Jacoby).)

(A. Mohanasundaram, J. Poorani, P. Giribabu, M. Loganathan, Collaborators : Kesavan Subaharan (ICAR-NBAIR), MS Sai Reddy (RPCAU, PUSA)

Comparison of ICAR-NRCB *Beauveria bassiana* with commercial formulation

Banana Weevil Killer® (*B. bassiana* ICAR-NRCB Bb EPF 22) and the commercial

formulation Beauverilin® (*B. bassiana*, AGRIYA Agro Tech, Madurai) were evaluated at six different dosages against the banana pseudostem weevil. Banana Weevil Killer® achieved 100% mortality at all dosages by the 7th day, while Beauverilin® showed 24–76% mortality over the same period **(Fig. 62).**

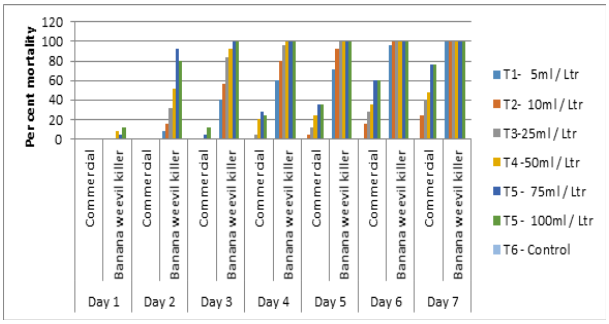


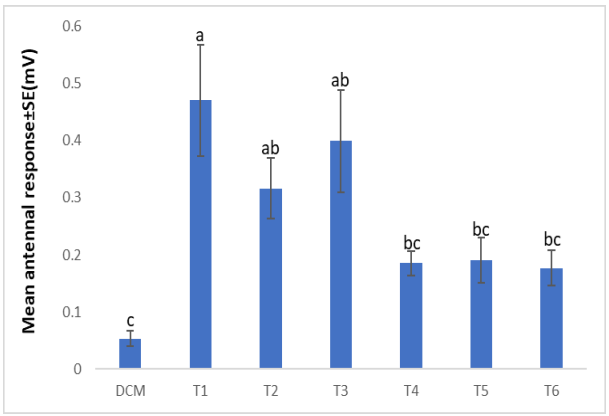
Fig. 62. Comparison of ICAR-NRCB *Beauveria bassiana* with commercial formulation against the banana pseudostem weevil

NRCB microbial consortia and its activity against banana insect pests

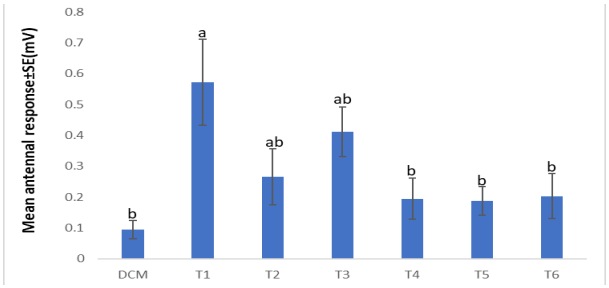
The NRCB EPF consortia comprising *B. bassiana* (Bb EPF 22), *M. anisopliae* (Ma EPF 50), and *B. brongniartii* (Bb EPF 28) was prepared in liquid and powder formulations and tested against the banana pseudostem weevil under laboratory conditions (2 hours to 4 days). The consortia powder and Banana Weevil Killer® achieved 100% mortality, followed by the liquid formulation on the 5th day. The same EPF isolates, their consortia powder, and Banana Weevil Killer® were also tested against the banana mealybug (*D. neobrevipes*), recording 100% mortality by the 2nd day after treatment.

Electroantennography studies of banana weevils

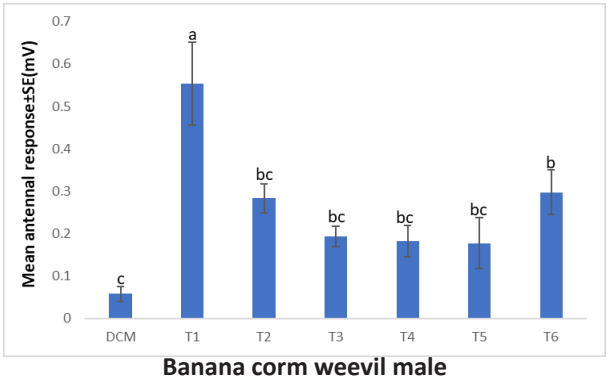
Male and female banana pseudostem and corm weevils showed the strongest antennal responses to tetradecanoic acid (0.572 mV and 0.471 mV for pseudostem weevils; 0.952 mV and 0.553 mV for corm weevils) compared to the control (dichloromethane) and other compounds, including hexadecanoic acid, 9-octadecenal, whole body extracts (male and female BSW), and Nendran pseudostem extract **(Fig. 63).** This study was conducted at NBAIR, Bengaluru.



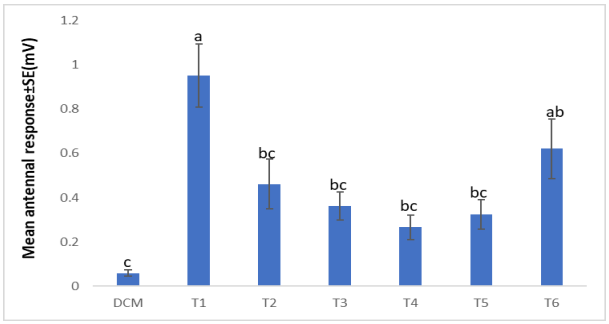
Banana pseudostem weevil male



Banana pseudostem weevil female



Banana corm weevil male



Banana corm weevil female

Fig. 63. Electroantennography studies of banana weevils

Orientation response of banana pseudostem weevil

The orientation response of banana pseudostem weevil populations to the identified

semiochemical compound, tetradecenoic acid (10%), was studied over a 15-minute period using a "Y"-tube olfactometer. It was observed that 53% of female and 33% of male banana pseudostem weevils moved towards the tetradecenoic acid, while 17% of females and 20% of males moved towards the solvent (methanol). Additionally, 30% of females and 47% of males did not exhibit any movement **(Fig. 64).**

The orientation response of banana pseudostem weevil populations to the identified semiochemical compound mixtures (Blend 1 to Blend 9) and host plant extract (HPE) alone was studied over a 15-minute period using a "Y"-tube olfactometer. Results showed that 70% of males and 63% of females moved towards Blend 1 and Blend 4, respectively. This was followed by 67% of males and 60% of females responding to HPE alone, and 53% of females moving towards Blend 4 **(Fig. 65).**

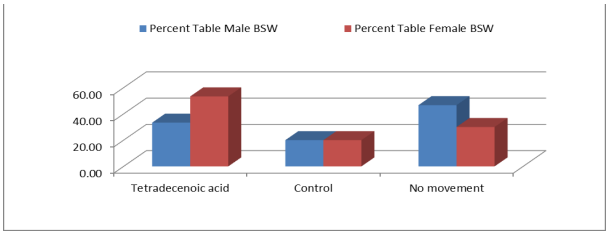


Fig. 64. Orientation response of banana pseudostem weevil

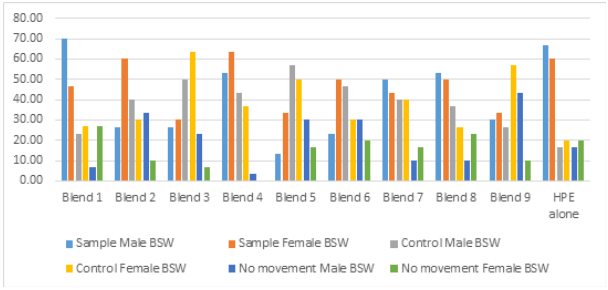


Fig. 65. Orientation response of banana pseudostem weevil towards semiochemical mixtures

Feeding behaviour of banana pseudostem weevil

The feeding behaviour of the banana pseudostem weevil was studied, revealing that the larvae fed on both pseudostems and banana leaf sheaths. However, larvae were unable to pupate when fed on pseudostems. Both larvae and adults died on the ninth day after feeding on pseudostems, whereas they survived when fed on leaf sheaths **(Table 13).**

Table 13: Feeding behaviour of banana pseudostem weevil

Treatment	Weight Reduction (g)
T1 – Pseudostem with larva	12.2^{a} (3.44)
T2 – Pseudostem with adult male	9.8^{abc} (3.12)
T3 – Pseudostem with adult female	10.6^{ab} (3.25)
T4 – Pseudostem alone	8.0^{bc} (2.82)
T5 – Leaf sheath with larva	12.4^{a} (3.50)
T6 – Leaf sheath with adult male	12.6^{a} (3.53)
T7 – Leaf sheath with adult female	10.6^{ab} (3.25)
T8 – Leaf sheath alone	7.2^{c} (2.68)
CD	**0.455**

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

In vitro bioassays of botanicals and newer insecticide molecules against *Basilepta* spp.

Banana scarring beetles were collected from the Banana Research Centre under RPCAU at Goraul, Vaishali district, and laboratory bioassays were conducted at RPCAU, Pusa, Samastipur **(Fig. 66).** Fourteen treatments, including insecticides and botanicals, were evaluated using the leaf-dipping method against the banana scarring beetle. Mortality data were recorded from 2 hours up to 4 days after treatment.

Thiamethoxam 25% WG, Fipronil 5% SC, Emamectin Benzoate 5% SG, Spinosad 45% SC, Chlorpyrifos 20% EC, Imidacloprid 17.80% SL, and Fipronil 0.3% G all recorded 100% mortality within 12 hours after treatment **(Fig. 67).**

Fig. 66. Bio-assay against new insecticides against banana scarring beetle at RPCAU, PUSA, Samastipur

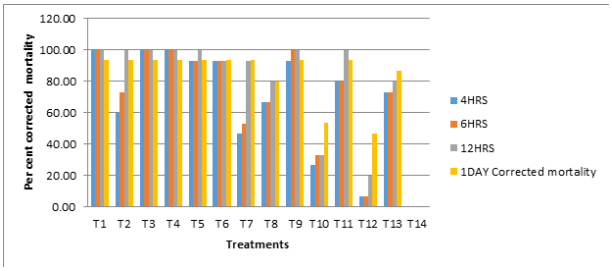


Fig. 67. Effect of new insecticides on fruit scarring beetle

Probit analysis of newer insecticides against *Basilepta* spp.

Thiamethoxam 25% WG, Fipronil 5% SC, Imidacloprid 17.80% SL, and Fipronil 0.3% G were evaluated at different concentrations using the leaf-dipping method against the banana scarring beetle (*Basilepta* spp.) in laboratory bioassays. These insecticides were found to be the most effective, with LC_{50} and LC_{90} values calculated, along with R^2 values, 4 hours after treatment **(Table 14, Fig. 68).**

Table 14: Probit analysis of concentration mortality response at 4 hours post-treatment against *Basilepta* spp.

Insecticide	LC_{50} (ppm)	LC_{90} (ppm)	R^2 Value
Thiamethoxam 25% WG	0.103	2.764	0.773
Fipronil 5% SC	0.545	19.727	0.966
Imidacloprid 17.80% SL	0.609	3.920	0.818
Fipronil 0.3% G	0.757	4.035	0.961

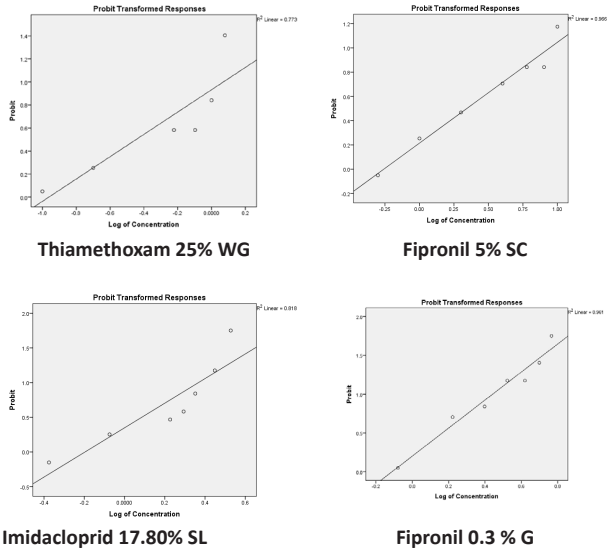


Fig. 68. Probit analysis of insecticides against banana scarring beetle

Entomopathogenic fungi tested against banana weevils and sucking pests

Entomopathogenic fungi were isolated from naturally infected insects such as aphids, corm weevils, mealybugs, and pseudostem weevils collected from various locations, including Pothavur, Ettrai, Mullikarumbur, Adavathur, and Ezhumalai in Tiruchirappalli district, and Thadiyangudisai in Dindigul district **(Fig. 69a & 69b).** In addition, endophytic fungi were isolated from both susceptible banana cultivars (Poovan [AAB], Nendran [AAB], and Karpuravali [ABB]) and resistant cultivars (Pisang Lilin [AA], Bhimkol [BB], and Athiakol [BB]) **(Fig. 70a & 70b).** Fungal isolates were also obtained from wetland soils at ICAR–NRCB, Tiruchirappalli, and hill banana soils from Thadiyangudisai, Dindigul. All isolates were identified and evaluated for their efficacy against major banana pests.

Volatile profiling was conducted for fungal isolates derived from soil samples. The fungi were identified as *Beauveria* spp. and *Metarhizium* spp., and were tested for effectiveness against banana pests, including pseudostem and corm weevils, and sucking pests such as aphids, thrips, and lacewing bugs. Several isolates exhibited excellent performance, with 100% mortality observed in *in-vitro* assays.

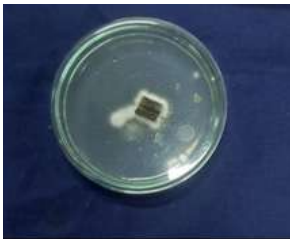


Fig. 69a. Endophytic fungi growing from banana midrib *(Beauveria* sp.*)*

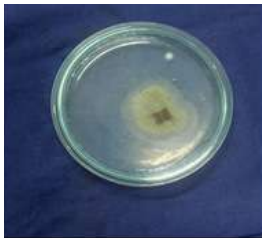


Fig. 69b. Endophytic fungi growing from banana midrib (*Metarhizium* sp.)

Fig. 70a. Entomopathogenic fungi identified from naturally infected insects (*Metarhizium* sp.)

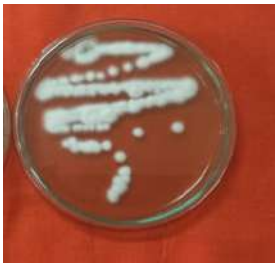


Fig. 70b. Entomopathogenic fungi identified from naturally infected insects (*Beauveria* sp.)

4.4.4 Investigations on Musa nematode's biology, behaviour, diversity and their interactions

(P. Giribabu, R. Thangavelu, C. Anuradha, K.J. Jeyabaskaran)

Survey and sampling for nematode incidence

Severe infection by root-knot nematodes, *Meloidogyne* sp. (1,264 nematodes per gram of root), was observed on cv. Poovan grown under ratoon cultivation for leaf production in Vadugakudi, Thanjavur district, Tamil Nadu **(Fig. 71).** An abundant soil population of spiral nematodes, *Helicotylenchus* sp. (1–13.5 nematodes per ml of soil), was recorded on cv. Grand Nain grown under ratoon cultivation in Erasakkanaickanur, Theni district, Tamil Nadu. Incidence of root galls and root-knot nematode (*Meloidogyne* sp.) infection was observed on several *Musa* genotypes, including Bhatmanohar, Nendra Kunnan, Mysorebale, Athiakol, Poovilla Chundan, Safed Velchi, Agniswar, Somai, and Valliya Kunnan **(Table 15, Fig. 72).**

Fig. 71. Root galls on cv. Poovan

Table 15: Incidence of root knot nematode in *Musa* field gene bank at ICAR-NRCB

Genome	Accession no.	Genotype	Nematodes / g root
AAB	0075	Bhatmanohar	195.7
AB	0107	Nendra Kunnan	167.3
AAB	0619	Mysorebale	161.8
BB	0011	Athiakol	150
AB	0699	Poovilla Chundan	145.8
AB	0458	Safed Velchi	32.9
AB	0153	Agniswar	32.4
AB	0511	Somai	20.0
AB	0234	Valliya Kunnan	10.5

Athiakol **Bhatmanohar** **Mysorebale**

Fig. 72. Incidence of root galls and root knot nematodes (*Meloidogyne* sp.) in three different Musa accessions

Sampling of *Musa* germplasm at NRCB farm showed root lesion nematodes (*Pratylenchus coffeae*) infection on *Musa* genotypes *viz*., Karibontha, Sanna Chenkadali, Pidimonthan, Tongat, Pagalapahad wild I, Manjeri Nendran, Karibale, Kanai Bansi and Borchampa **(Table. 16 and Fig. 73).**

Table16: Incidence of root lesion nematode in *Musa* field gene bank at ICAR-NRCB

Genome	Accession no.	Genotype	Nematodes / g root
ABB	0121	Karibontha	81.1
AA	0201	Sanna chenkadali	47.1
ABB	0115	Pidimonthan	40.0
AA	0380	Tongat	34.3
BB	1182	Pagalapahad wild I	29.2
AAB	2455	Manjeri Nendran	27.1
ABB	0129	Karibale	22.2
AA	0064	Kanai bansi	17.1
AAB	0045	Borchampa	17
ABB	0246	Batheesa Ash	13.0
ABB	2254	Ashmonthan	8.3
AAB	0390	Sawai	2.2
AAB	0254	Neyvannan	0.9

Karibontha Pidimonthan

Fig. 73. Root lesion nematodes (Pratylenchus coffeae) infection on Musa genotypes

Response of traditional banana cultivars to root lesion nematode

In vitro-derived popular banana cultivars, namely Red Banana (AAA), Grand Nain (AAA), Ney Poovan (AB), Hill Banana (AAB), Poovan (AAB), Nendran (AAB), Karpuravalli (ABB), and Kaveri Kalki (ABB) were evaluated under pot conditions for their response to root lesion nematode (*Pratylenchus coffeae*) through challenge inoculation. The cultivars Ney Poovan and Hill Banana were found to be moderately resistant (moderately susceptible) to both nematodes, whereas the other cultivars showed susceptible to highly susceptible reactions **(Table 17, Fig. 74).**

Table 17: *P. coffeae* reproduction on eight popular banana cultivars measured 10 weeks after inoculation

Cultivar	Total Root Population ($log_{10}(x+1)$)	Reproduction Factor
Ney Poovan	1422 (3.2)^{f}	1.4
Red Banana	4538 (3.7)^{c}	4.5
Karpuravalli	3517 (3.5)^{d}	3.5
Nendran	8656 (3.9)^{a}	8.7
Grand Nain	6501 (3.8)^{b}	6.5
Hill Banana	1422 (3.2)^{f}	1.4
Poovan	3823 (3.6)^{d}	3.8
Kaveri Kalki	2095 (3.3)^{e}	2.1

Coefficient of Variation (CV): 0.992

Figures in parentheses are log_{10} (x + 1) transformed values. Means in the same column followed by the same letter do not differ significantly according to Tukey's method (P < 0.05).

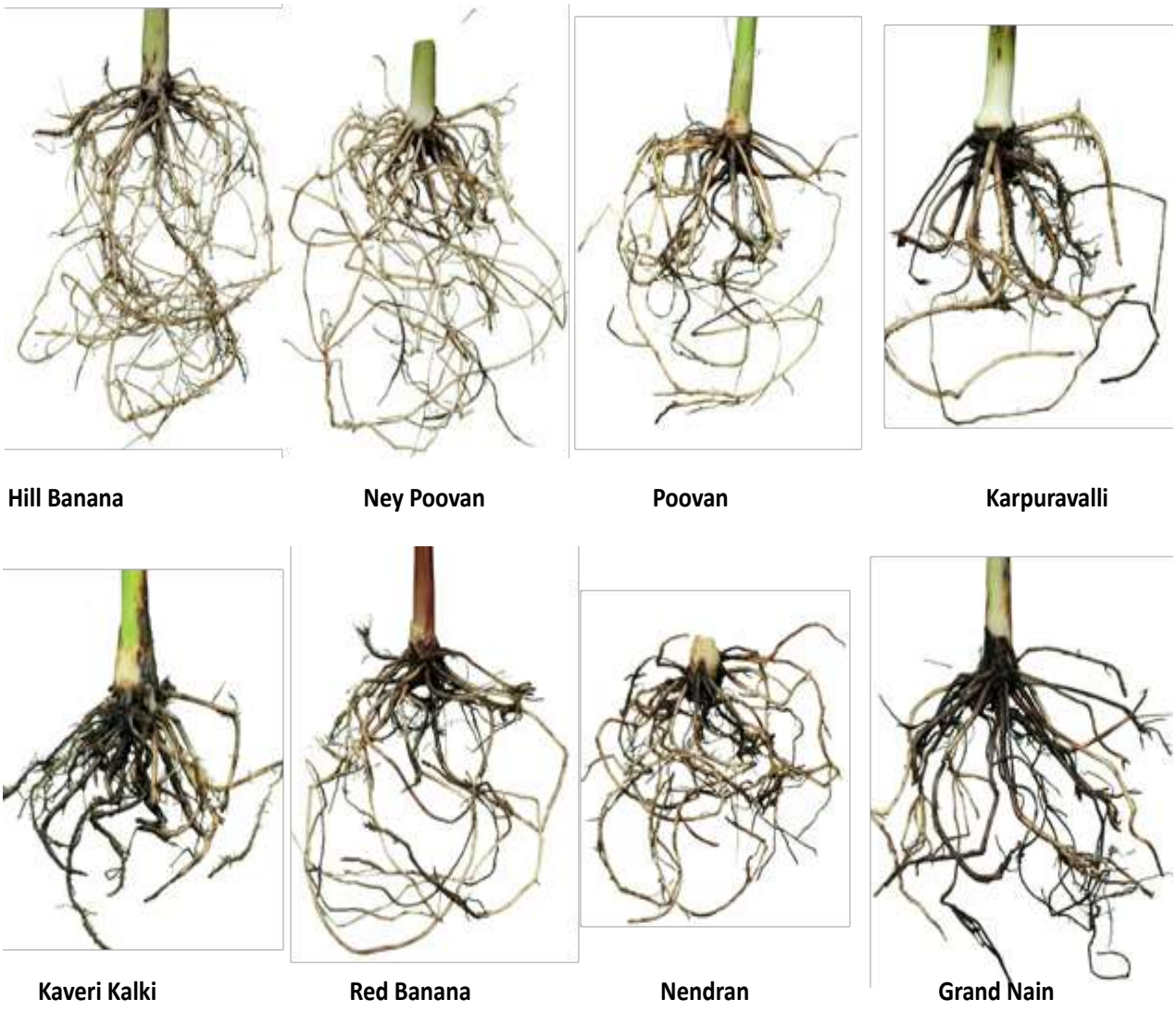


Fig. 74. *P. coffeae* on eight popular banana cultivars

4.4.5 Integrated management of Fusarium wilt disease (*Foc* R1) in banana

(R. Thangavelu, M. Loganathan, M.S. Saraswathi, R. Selvarajan)

Impact of organic amendments on *Foc*-R1 and plant growth

The effect of eight organic amendments such as neem cake, groundnut cake, castor cake, gingelly cake, mustard cake, vermicompost, rice husk ash, and farmyard manure were evaluated against Fusarium wilt disease (FWD) in banana cv. Grand Nain. Applied at 100, 200, and 300 g per plant, the amendments significantly reduced FWD, with 300 g of neem cake showing the highest suppression (disease score 0.30) compared to the Foc-R1-inoculated control (score 4.50) **(Fig. 75).** All treatments also enhanced plant growth parameters.

Fig. 75. Effect of Neem cake on Fusarium wilt disease caused by Foc-TR4

Impact of soil organic amendments on *Foc*-DNA (R1) in soil through qRT-PCR analysis

qRT-PCR analysis showed that all amendments lowered Foc-R1 DNA levels in soil. Comparative analyses of the *Foc*R1 DNA quantification from 25ng of extracted soil DNA showed that both groundnut cake (98.13pg)

and mustard cake (98.8pg), when applied at 300g per plant, significantly reduced the *Foc*R1 DNA compared to the *Foc*-alone control (524.3pg). Highest reduction in *Foc*-R1 DNA was observed neem cake (300g/plant) treatment which was confirmed in the PCA analysis also.

GC-MS analysis of *Foc*-TR4 and BCA interaction in plants

GC-MS analysis was performed to investigate the biological interactions between various bio-consortia and the *Foc*-TR4 pathogen in banana cv. Grand Nain with 11 treatments with different bioagents combinations. After 14 days of treatment, stem, root, and corm samples were collected from each treatment, grinded and pooled. Upon quantifying the VOCs through GC-MS analysis, Fusaric acid production was higher (48.7%) in *Foc*-infected plants **(Fig. 76)** compared to those treated with biocontrol (15.1%). However, in the bioagents and *Foc* applied plants, the production of antifungal compounds such as butanoic acid, 2-methylpropyl ester, 11-(2-Cyclopenten-1-yl) undecanoic acid, (+)-1-Iodo-2-methylundecane, benzene, 1,2-dimethoxy-4-(1-propenyl)-, 7-dimethyl (trimethylsilyl) silyloxytetradecane, acrylic acid (4-cyclopropylidenebutyl ester), cyclopentaneundecanoic acid, didodecyl phthalate, and 1-tridecene were present in varying quantity. In case of *Foc* alone inoculated plants, these compounds were absent.

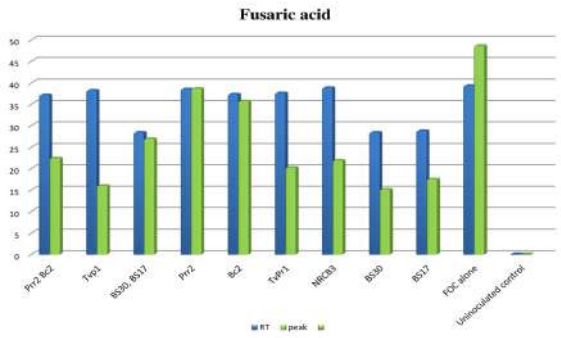


Fig. 76. GC-MS analysis of Fusaric acid in banana samples treated with different bioagents

GC-MS analysis of *Trichoderma asperellum* and *Bacillus flexus* against *Foc*-TR4 under in *in vitro* condition

The GC-MS analysis of secondary metabolites obtained from *Trichoderma asperellum* and *Bacillus flexus* which were added with culture filtrate of *Foc* in varying proportions revealed the presence 25 different compounds which are exhibiting distinct functional activities against *Foc*. Notably, 9-Octadecen-1-ol (E) exhibited the highest peak level at 53.98%**,** which is responsible for reinforcing the plant cuticle and act as a protective barrier against *Foc* infection. Additionally, docosanoic acid had a peak level of 41.49% and function as a primary antifungal agent. Several other antifungal compounds are dimethyl sulfoxide (12.21%), Phenol (5.33%), 2-pyrrolidinone, 1-methyl (14.44%), amphetamine (0.98%), 1H-Indene, 1-methylene (19.77%) and chidanthine, 1,2-dihydro (27.82%). Furthermore, diisooctyl adipate (34.82%) specifically involved in triggering the activation of defense-related genes against *Foc* was also observed.

Evaluation of Elite Banana cultivars Poovan (AAB), Red Banana (AAA), and Nendran (AAB) under *Foc* TR4 infected areas

Fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (*Foc* TR4) poses a serious threat to banana cultivation in India, particularly in the major banana-growing states of Uttar Pradesh (UP), Gujarat and Madhya Pradesh (MP). The widely cultivated Cavendish group, especially the popular cultivar Grand Nain (AAA), has been severely affected by this virulent strain of the pathogen.

In an effort to identify potential alternative cultivars with resistance or tolerance to *Foc* TR4, three *Foc* Race 1-resistant banana varieties Elite Poovan (AAB), Red Banana (AAA), and Nendran (AAB) were selected for evaluation under TR4 problematic areas. Field trials were conducted in *Foc* TR4-affected regions of Uttar Pradesh (Lakhimpur Kheri and Maharajganj) and Madhya Pradesh (Burhanpur). Up to the flowering stage (8 months after planting), none of the three varieties exhibited any external symptoms of Fusarium wilt. However the internal symptoms are to be assessed at the time of harvest to determine the disease resistance. In addition, 1,000 Red Banana (AAA) plants were evaluated in a known *Foc* TR4-infected field at Karjan village, Surat district, Gujarat.

Remarkably, during the 2023–24 cropping season, these plants remained free of visible *Foc* TR4 symptoms and recorded an average yield of 14–16 kg per plant. This performance suggests that Red Banana (AAA) may possess a degree of resistance or tolerance to *Foc* TR4 under field conditions **(Fig. 77 a & b).**

Fig. 77. Performance of Red Banana in Karjan, Surat a. Field view; b. Plant with bunch

4.4.6 Survey, etiology and management of rhizome rot of banana

(M. Loganathan, R. Thangavelu, R.Selvarajan)

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

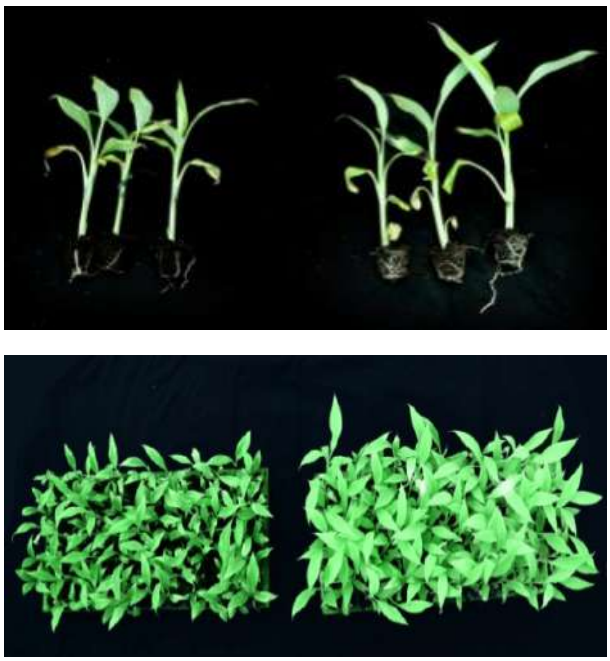
Among the eight PGPR isolates evaluated, four BCNA 5-3, H6BC2, H6BC3, and JP-4 exhibited complete suppression of rhizome rot disease incidence (0.00%), significantly lower than the control (58.30%). In terms of plant growth parameters, isolates H6BC3, JP-4, and BCNA 5-3 significantly enhanced plant height, stem girth, leaf length, and leaf breadth compared to the other isolates and the untreated control. Furthermore, three isolates (H6BC3, JP-4, and BCNA 5-3) recorded significant yield increases of 62.50%, 57.95%, and 58.12% per plant, respectively, over the control.

Demonstration and registration of Kaveri Microbial Consortium (KMC)

Application of a microbial formulation (KMC), containing PGPR strains (*Bacillus aryabhattai*, *Priestia megaterium*, *B. pumilus*, *B. altitudinis*, *B. subtilis*, and *B. flexus*), significantly enhanced growth and yield in tissue culture-derived Elite Poovan banana. Following planting, 10 kg of KMC was mixed with 500 kg of decomposed FYM and applied at a rate of 500 g per plant at 3, 5, and 7 months after planting. KMC-treated plants showed improved performance compared to controls, with higher plant height (308 vs. 294 cm), pseudostem girth (76 vs. 74 cm), number of hands (11.73 vs. 11.1), total fruits (210 vs. 193.6), reduced flowering-to-maturity duration (84.8 vs. 100 days), and increased bunch weight (27.07 vs. 24.34 kg/plant). The formulation is licensed for production by the Tamil Nadu Government (License No: CR. No:40/BF/TRY/AND/WS/2024-29) for a five-year period (2024–2029).

Effect of KMC treatment on promotion of growth in bioreactor derived TC banana plants

Biopriming of bioreactor-derived tissue culture banana plants with the microbial consortium KMC, comprising *Bacillus aryabhattai*, *Priestia megaterium*, *B. pumilus*, *B. altitudinis*, *B. subtilis*, and *B. flexus*, at both primary and secondary hardening stages, resulted in a significant enhancement of plant growth parameters compared to untreated controls **(Fig. 78).**



Control Treated

Fig. 78. Growth promotion effect of KMC on bioreactor derived TC banana plants

4.4.7 Management of post harvest diseases of banana

(M. Loganathan, R. Thangavelu, J. Poorani, K.N. Shiva, R. Selvarajan)

Effect of bacterial isolates from home made curd on post harvest pathogens of banana

A total of eight bacterial isolates were obtained from home made curds. Among these, two isolates, designated C0-2 (i.e., 4-1) and C2-2, exhibited significant *in vitro* antagonistic activity against postharvest fungal pathogens *Colletotrichum musae* and *Lasiodiplodia theobromae*. Molecular identification revealed these isolates as gram-positive *Bacillus velezensis* (PQ901993) and *B. subtilis* (PV324961), respectively.

Effect of CIBRC approved fungicides on post harvest diseases

CIBRC-approved fungicide formulation Metiram 55% + Pyraclostrobin 5% WG was evaluated *in vitro* at concentrations of 0.025%, 0.05%, 0.10%, 0.15%, 0.20%, 0.25%, and 0.30% against postharvest pathogens *Colletotrichum musae* and *Lasiodiplodia theobromae*. All tested concentrations exhibited >95% inhibition of both pathogens. Complete (100%) inhibition of *C. musae* was observed at all concentrations except the lowest (0.025%).

Four CIBRC-approved fungicides for banana such as Metiram 55% + Pyraclostrobin 5% WG, Fluxapyroxad 167 g/L + Pyraclostrobin 333 g/L SC, Mancozeb 75% WP, and Copper oxychloride 50% WP were evaluated under field conditions in cv. Grand Nain. Treatments were applied as bud injection, bunch spray, or a combination of both. Their efficacy on control of post harvest diseases, residues and fruit qualities are to be tested at and after harvest.

4.4.8 Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses

(R. Selvarajan, K. Nagendran, M. Loganathan, J. Poorani, S. Uma (up to 31-5-2024), C. Karpagam, A. Mohanasundaram)

Diagnostics and host-virus-vector interaction of Cucumber mosaic virus (CMV) infecting Banana

Disease survey

A field survey conducted in 2024 revealed CMV incidence ranging from 30% to 70% in Jalgaon, Maharashtra, with characteristic symptoms including mosaic patterns, stunting, spindle-shaped spots, and heart leaf rot. Aphid infestations were observed on nearby weeds. In Annamayya district (Andhra Pradesh), CMV incidence was 60% to 70%. Among affected banana plants, 83.3%–87.5% recovered and produced bunches, while 12.5%–16.66% failed to yield.

Impact of host species on CMV evolution

Mechanical inoculation of CMV onto 17 host plants showed variable symptom severity. Isolates from severely symptomatic hosts (*Nicotiana* spp. and *Phaseolus vulgaris*) caused severe symptoms in banana upon back-inoculation. Symptom expression ranged from 20%–60%, while 40%–80% of plants were latently infected. CMV presence was confirmed by TAS-ELISA and RT-PCR.

Validation of TAS-ELISA CMV kit

The ICAR-NRCB-developed TAS-ELISA kit was validated across 60 host species. Infected samples showed clear OD separation from healthy and buffer controls at 405 nm. 25 ELISA-positive samples were also confirmed CMV-positive by RT-PCR. Sequencing of the coat protein gene from multiple hosts placed them in subgroup IB, confirming the kit's reliability and broad applicability.

Role of weeds and vectors in CMV spread

Of 20 weed species tested from CMV-infected banana ecosystems, eight were CMV-positive by TAS-ELISA and RT-PCR. *Solanum nigrum* and *Cyathillium cinereum* showed visible symptoms upon inoculation, while *Acalypha indica* had latent infection. Among aphid vectors, CMV transmission efficiency was highest in *Pentalonia nigronervosa* (66.66%), followed by *Aphis gossypii* (60%) and

A. craccivora (40%). RT-PCR confirmed latent infections, with *A. craccivora* showing the highest infection rate (60%).

CMV transmission in tissue culture plants

From 165 CMV-infected banana suckers (100 Andhra Pradesh, 65 Maharashtra), meristem culture reduced viral titres significantly. At the S2 stage, the number of high titre plants dropped from 36 to 5, with most samples shifting to low titre. At S3 and S4 stages, some regenerated shoots showed symptoms while others remained asymptomatic. Virus titre assessment is under progress, indicating the effectiveness of meristem culture in reducing CMV infection.

Documentation of BBrMV in banana cv. Korangi of Andaman and Nicobar Is.

Banana bract mosaic virus (BBrMV) has been documented and characterized for the first time from Andaman and Nicobar Is. on the banana cv. Korangi. Based on the characterization of coat protein, HC-Pro and VPg region, isolate is found to be distinct compared to the previously documented BBrMV genome from India **(Fig. 79).**

Fig. 79. Symptoms of BBrMV infection on cv. Korangi banana

Characterization of full-length genome of banana mild mosaic virus

Banana plants exhibiting mild mosaic symptoms were collected from the ICAR-NRCB Research Farm, Trichy. Total RNA was successfully extracted using the CTAB-$LiCl_2$ method and converted to cDNA using the RevertAid First Strand cDNA Synthesis Kit. Five newly designed primer pairs targeting overlapping regions of the BanMMV genome (GenBank accession no. OL874429) successfully amplified the complete viral genome through RT-PCR. Cloning of the amplified genome is currently in progress.

Development of RT-LAMP assay for the detection of major banana viruses

LAMP primers specific to BBTV, BBrMV, CMV, and BSMYV were successfully designed and standardized. The coat protein genes of all four viruses were individually cloned, and plasmid DNA was extracted. Standardization of the LAMP assay using varying concentrations of plasmid DNA is currently in progress to evaluate its sensitivity in comparison to the conventional PCR assay.

In vitro synthesis of double stranded RNA targeting various genes of CMV & testing of its efficacy

In order to synthesize, dsRNAs for coat protein (CP), movement protein (MP) and 2b genes of CMV *in vivo* and *in vitro*, coding regions were amplified using previously reported respective primer pairs. The amplified fragments were cloned in the pGEM-T Easy vector. Clones were confirmed through RFLP analysis and sent for sequencing. Further, subcloning in the pL440 vector for *in vivo* synthesis by transformed into *E. coli* HT115 (DE3) cells is under progress.

Transmission study of Banana Bract Mosaic virus (BBrMV)

Mechanical inoculation of banana bract mosaic virus (BBrMV) onto 7-day-old cowpea plants (cv. C154) using 0.1 M phosphate buffer (pH 7) resulted in visible symptom development. Chlorotic lesions appeared on new leaves by 5 days post-inoculation (DPI). By 10 DPI, minute necrotic spots developed systemically and progressed into a distinct mosaic with vein clearing. Severe systemic mosaic symptoms with pronounced vein clearing were evident by 15–16 DPI. RT-PCR analysis of symptomatic leaves collected at 8, 12, and 15 DPI using HC-Pro and CP gene-

specific primers confirmed the presence of BBrMV.

Establishment of BBTV free mother block for the Hill banana varieties

To establish BBTV-free mother blocks of Sirumalai and Virupakshi hill banana cultivars, suckers of Virupakshi were collected from the Thadiankudisai area of the Lower Pulney Hills. Indexing of mother plants categorized them into non-symptomatic PCR-negative and non-symptomatic PCR-positive groups. These plants were planted separately in the K5 block of the research farm. To monitor BBTV infection status, all plants were subjected to PCR assays at three-month intervals.

Virus indexing of TC mother plants

In 2024, a total of 4105 tissue culture banana samples from TCPUs were tested for four viruses under contract services for virus indexing. Additionally, 278 banana germplasm accessions conserved in field gene banks at AICRP (Fruits) centres in Arabhavi, Coimbatore, Gandevi, Jalgaon, and Trichy were screened for viral presence.

4.4.9 Development of agro-infectious clones for the DNA viruses infecting banana

(K. Nagendran, R. Selvarajan, C. Anuradha)

Cloning of individual components of BBTV genome through PCR

BBTV-infected symptomatic banana samples were collected from Sirumalai, Thadiyankudisai, and the ICAR-NRCB research farm. For molecular cloning and characterization, the isolate from the research farm was selected, and all six genomic components of BBTV (DNA-R, -U, -S, -C, -M, and -N) were successfully PCR-amplified using reported primer pairs. Each component yielded the expected amplicon size of approximately 1.1 kb. The amplified fragments were gel-purified, cloned into the pJet1.2/blunt vector, and samples were sent for sequencing. PCR amplification of the six components from Sirumalai and Thadiyankudisai samples is currently in progress.

Cloning of full length genomic fragment of BSMYV based on RCA

In order to characterize the Banana streak Mysore virus (BSMYV), symptomatic samples from the cv. Motta Poovan from the Research Farm of NRCB and subjected to DNA isolation. Isolated DNA was subsequently subjected rolling circle amplification (RCA) followed by RFLP analysis using the *Kpn*I restriction endonuclease. As expected, RFLP analysis yielded an expected fragment size of ~7 kb (presumed to be the complete genome of BSMYV). Fragment has PCR purified and the cloning in pUC18 vector is under progress. An agroinfectious dimeric construct of Banana streak MY virus (BSMYV) was obtained from the Advanced Centre for Plant Virology, ICAR-IARI, New Delhi. The plasmid construct was successfully transformed into *Escherichia coli* strain DH5α, propagated in large quantities, and stored. Confirmation of the plasmid was achieved through PCR using BSMYV-specific primers targeting the RNaseH region, which yielded the expected amplicon size of approximately 500 bp.

4.5 EXTERNALLY FUNDED PROJECTS

ICAR funded projects

4.5.1 Network programe on Precision agriculture (NePPA)

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

An experiment conducted on the banana cultivar 'Grand Nain' evaluated the effects of controlled soil moisture and nutrient management using an IoT-based automated irrigation system integrated with soil moisture sensors. Irrigation was initiated at soil moisture tension thresholds of -33 kPa (M1), -50 kPa (M2), and -75 kPa (M3), and continued until field capacity was reached.

A split-split plot design was employed to study the interaction between moisture regimes and nitrogen and potassium applications at 0%, 50%, 75%, and 100% of the recommended dose of fertilizers (RDF). At the M2 level (-50 kPa), the IoT-based system reduced irrigation water use by 25–30% compared to conventional drip irrigation,

without compromising yield or fruit quality. This demonstrates its potential for sustainable banana cultivation and broader applicability in horticultural crops.

The total water applied per plant (excluding annual rainfall of 960 mm) was 6480 L (M1), 5760 L (M2), and 5560 L (M3). Corresponding water use efficiency (WUE) values were 4.16 kg/m³ (M1), 4.40 kg/m³ (M2), and 4.25 kg/m³ (M3), underscoring the significance of optimizing soil moisture levels for efficient resource utilization **(Fig. 80).**

Fig. 80. IoT enabled soil moisture sensor based automated irrigation

Nutrient use efficiency was also assessed during the study. Leaf nitrogen content ranged from 1.66% to 1.73%, with the highest concentration observed at M2. Phosphorus content varied between 0.27% and 0.31%, again peaking at M2 and lowest at M3. Potassium content increased under moisture stress, ranging from 3.21% at M1 to 3.36% at M3.

The combination of M2 with 50% RDF of nitrogen and 75% RDF of potassium resulted in the highest nutrient use efficiency, with yields comparable to those recorded under M1. At M3, the application of 100% RDF of both nitrogen and potassium enhanced nutrient efficiency, although yields remained lower than those under M1 and M2. Overall, sensor-based irrigation demonstrated the potential to reduce water usage by 10–15% and improve nutrient use efficiency by up to 25%.

Disease monitoring and prediction

Leaf spot symptoms emerged in late October 2023, with severity (LSS %) ranging from 7.18% to 44.73%. A regression model linked severity to mean relative humidity and plant age, explaining 90% of the variation:
LSS% = -73.316 + (0.481 × RH) + (0.285 × Age)
This highlights the key roles of humidity and plant age in disease development.

Deep learning for disease detection

Using MATLAB's Deep Network Designer, a pre-trained AlexNet CNN was fine-tuned to classify leaves as healthy and Sigatoka-infected. Image Data store managed dataset labelling, and a user-friendly GUI was developed for interactive disease diagnosis.

Maturity prediction for Red Banana

A mobile application incorporating a ridge regression model was developed to predict the maturity index of red bananas based on physical attributes. This tool facilitates timely harvesting and enhances market preparedness.

Ethylene-based ripeness indicator

An intelligent ripeness label, composed of palladium sulphate embedded in a starch matrix, exhibits a visible colour change—from yellowish-green to dark blue or black—in response to ethylene exposure. This provides a more reliable indication of ripeness compared to traditional methods.

IoT-based cold storage monitoring

A cost-effective cold storage monitoring system was developed using Arduino UNO and ESP8266 Wi-Fi modules. It delivers real-time data on temperature and humidity, with integrated alarms and remote access features to reduce post-harvest losses and preserve fruit quality.

Ripening colour charts

Ripening stages were documented for four banana varieties, highlighting variations in firmness, sugar–acid ratio, weight loss, and glycemic index. GC-MS and PCA analyses revealed distinct, variety-specific aroma profiles, aiding in post-harvest quality assessment.

Smartphone app for variety and ripeness classification

A mobile application employing a CNN-XGBoost model was developed to non-invasively classify banana varieties and ripeness stages. Achieving 95% accuracy with real-time feedback, the app supports informed decision-making, reduces post-harvest losses, and promotes AI-driven precision horticulture.

4.5.2 Agri-Business Incubation (ABI) Centre under ICAR-NAIF (Component-II)

(K.N. Shiva, P. Suresh Kumar, K. Nagendran, R. Selvarajan)

The Agri-Business Incubation (ABI) Centre continued to promote innovation, entrepreneurship, and value addition in the agricultural sector. In 2024, the centre incubated 15 new agri-startups focusing on banana-based value-added products, fibre processing, and waste management. Key innovations such as variety specific TC protocol banana chips, flour, beverages, and fibre processing techniques were successfully transferred to startups, MSMEs, and agripreneurs. In 2024, over 500 participants were trained through capacity-building programs, enhancing market linkages and export readiness.

The centre received ₹16,58,100 from ICAR. Several training and awareness programmes were conducted to empower entrepreneurs, artisans, and stakeholders in agriculture and allied sectors. Key initiatives included: Awareness programme for fibre artisans under Gramodyog Vikas Yojana and Strengthening Tamil Nadu connectivity – Trichy International Hub for Agricultural Exports.

Fig. 81. Dr. K. Alagusundaram, MD & CEO TNAPEx, delivering chief guest address

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

(P. Suresh Kumar, K.N. Shiva, M. Mayilvaganan, I. Ravi)

Native banana starch (NS) possesses certain limitations, such as poor solubility, low resistance to shear and temperature, and a propensity for retrogradation. This study evaluated the effects of mono-enzymatic (α-amylase and pullulanase) and sequential enzymatic modifications of NS, in combination with ultrasound treatment, to improve its functional characteristics.

Ultrasound application enhanced enzymatic activity by disrupting and modifying the starch granule structure, as confirmed through scanning electron microscopy (SEM) analysis. Starch treated with α-amylase (AMY) and ultrasonic α-amylase (U-AMY) exhibited the lowest amylose and resistant starch contents, along with increased levels of rapidly digestible starch. This was due to the extensive hydrolysis of amylose into smaller dextrins by α-amylase.

In contrast, pullulanase (PUL) and ultrasonic pullulanase (U-PUL) selectively hydrolyzed the amorphous regions of amylopectin, resulting in increased amylose and resistant starch contents, as well as enhanced swelling power and water-holding capacity.

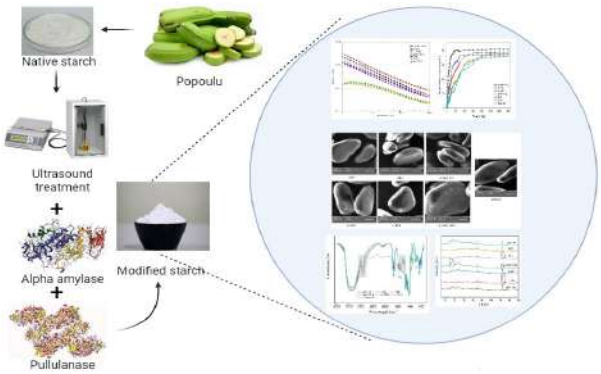


Fig. 82. Native banana starch extracted from rejected unripe bananas

The combined physical-enzymatic treatment (U-AMY-PUL) significantly improved starch solubility by altering its structural configuration, as demonstrated by X-ray diffraction (XRD) and Fourier-transform

infrared (FTIR) spectroscopy analyses. Overall, ultrasound-assisted enzymolysis offers a greener and more effective approach for enhancing enzymatic modifications of starches **(Fig. 85).**

Utilization of banana peel powder in dietary fibre-enriched muffins

This study evaluated the substitution of refined wheat flour (RWF) with banana peel powder (BPP) at 2–8% levels to develop fortified functional muffins. At 8% substitution, compressibility and flowability of the premix decreased due to higher fibre content. Optical and SEM analyses showed that BPP altered the muffin crumb's cell structure, making it coarser and more irregular. Substituting RWF with 4–8% BPP reduced gluten and increased dietary fibre without compromising the gluten–polysaccharide matrix essential for texture. A 4% BPP addition enhanced total phenolics and flavonoids by 20–30%, boosting antioxidant activity.

Storage studies showed that BPP extended muffin shelf life from five to nine days, maintaining textural qualities and acting as a natural preservative. Sensory analysis indicated that consumers prioritised appearance, colour, and texture over aftertaste. Overall, 4% BPP substitution improved sensory appeal and nutritional value—lowering fat and gluten while increasing fibre—though higher levels negatively impacted texture and quality **(Fig. 83).**

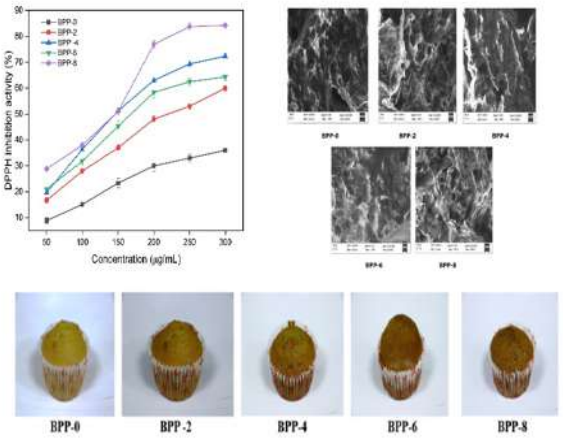


Fig. 83. Muffins prepared using banana peel powder

Influence of additives on the development of banana starch-based bioplastic films

This study examined the effects of different concentrations of polyvinyl alcohol (PVA) and carboxymethyl cellulose (CMC) on banana starch-based bioplastic films, using glycerol as a plasticizer. Films with 1.5% CMC showed the highest tensile strength (24.73 MPa) and greater hydrophilicity. FTIR and XRD analyses indicated that films without PVA, unlike those with CMC, had reduced carbonyl peak intensity—resulting in lower polarity and crystallinity, which affect adhesion. SEM images confirmed a uniform surface morphology across all formulations, regardless of the additive used **(Fig. 84).**

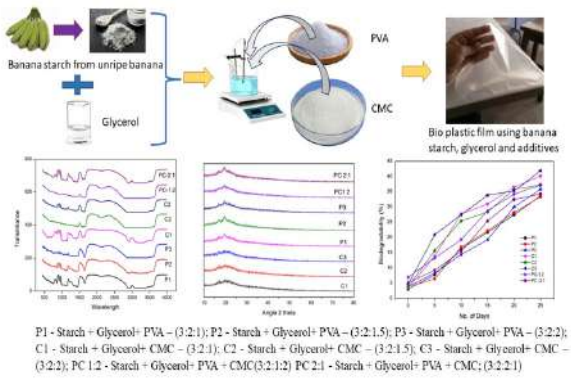


Fig. 84. Development of banana starch-based bioplastic film

Banana starch-based microencapsulation for synbiotic jelly pudding

A synbiotic jelly pudding was developed by blending banana juice with probiotic-enriched encapsulated starch powder. The highest encapsulation viability of *Lactiplantibacillus plantarum* was observed in the DE HYP + OXY treatment, followed by DE NS, SE HYP, and DE HYP. Bulk density was highest in FC and lowest in DE HYP + OXY, while SE HYP had the highest particle density. DE HYP + OXY also showed the lowest tap density **(Table 18; Fig. 85).**

Carr index and Hausner ratio values indicated improved flowability in DE HYP + OXY and reduced flowability in DE NS. Microencapsulation significantly enhanced the survivability of *L. plantarum* in simulated gastric and intestinal fluids compared to free cells. Physicochemical analysis of the jelly showed a pH of 4.32, moisture content of

76.22%, ash content of 0.9958%, water activity (aw) of 0.98, and a °Brix of 23.02. Probiotic viability at a 10^{-6} dilution was approximately 7.75 log CFU g^{-1}.

Fig. 85. Synbiotic jelly pudding

Table 18. Physiochemical analysis of synbiotic jelly pudding

Parameters	Content
Moisture content (%)	73.22±0.02
Water activity (aw)	0.98±0.003
TSS °Brix	28.02±0.56
pH	4.32±0.01
Titratable acidity (%)	0.16±0.03
Carbohydrate (%)	7.58±1.58
Total sugar (%)	25.61±6.31
Total Protein (%)	0.79±0.27
Fat (%)	0.89±2.26
Ash content (%)	1.13±0.03

4.5.4 Development and utilization of diagnostics to viruses of banana under Consortia Research Platform on Vaccines and Diagnostics

(R. Selvarajan, K. Nagendran, C. Anuradha)

Development and optimization of TAS-ELISA for Banana Bunchy Top Virus Diagnosis

The coat protein (CP) gene of Banana Bunchy Top Virus (BBTV) was successfully amplified from DNA extracts of infected banana samples and cloned into the pGEM-T Easy vector, followed by transformation into *Escherichia coli* DH5α. The CP gene was then sub-cloned into the pET28a(+) expression vector at *NdeI* and *XhoI* sites to construct the recombinant plasmid pET28a(+)-BBTV-CP. Expression in *E. coli* BL21(DE3) cells produced a ~20 kDa 6×His-tagged BBTV-CP protein, which was purified under denaturing conditions using Ni–NTA affinity chromatography. SDS-PAGE confirmed the presence of the purified protein.

The recombinant CP was used to generate monoclonal (MAbs) and polyclonal antibodies (PAbs). Six hybridoma lines producing MAbs were screened via DAC-ELISA for reactivity to both recombinant BBTV-CP and BBTV-infected sap. Hybridoma clone 4, showing strong and specific reactivity without cross-reaction to healthy or other virus-infected banana samples, was selected for large-scale MAb production.

A triple antibody sandwich ELISA (TAS-ELISA) was developed using the generated MAb and PAb. The assay successfully detected BBTV in fresh, dried, and meristem tissues. Validation with 114 field samples showed 97% relative sensitivity and 100% specificity compared to PCR, confirming TAS-ELISA as a reliable, high-throughput, and cost-effective method for BBTV detection in banana.

Developed ready to use DAC-ELISA kit for detection of banana bunchy top virus (BBTV) in banana sample

The coat protein gene of BBTV was cloned and expressed in a bacterial system to produce polyclonal antibodies for developing a DAC-ELISA kit. It includes high-quality recombinant antiserum, ELISA plates and buffers, positive and negative controls, and a user protocol. It is now routinely used in the laboratory for screening tissue culture banana plantlets for BBTV.

4.5.5 ICAR-Enabling climate resilience and ensuring food and Nutritional security through gene editing in horticultural crops: sub-scheme – Application of genome editing to develop trait specific varieties / hybrids in banana crop - Gene editing to develop resistance against Foc TR4/ race1 and multiple viruses in Grand Nain banana

(C. Anuradha, K. Nagendran, S. Backiyarani, R. Thangavelu)

Four *dmr6* genes (Ma04_t20880, Ma04_t23390, Ma02_t12040, and Ma05_t12600) were successfully cloned and

characterized from both *Fusarium oxysporum* f. sp. *cubense* (Foc) Race 1 and Tropical Race 4 (TR4)-resistant cultivar 'Rose' and the susceptible cultivar 'Grand Nain'. In addition, the *pelota* gene (Macma4_08_g05970) was cloned and characterized from BBTV-resistant and susceptible banana cultivars.

A total of four guide RNAs (gRNAs) were designed for the *dmr6* genes and two for the *pelota* gene. These gRNAs were synthesized and cloned into the pRGEB31 CRISPR/Cas9 expression vector. The resulting constructs were first transformed into *Escherichia coli* strain DH5α, where sequencing confirmed successful integration. These validated constructs were subsequently introduced into *Agrobacterium tumefaciens* strain AGL-1 for plant transformation. Two independent batches of embryogenic banana cells were co-cultivated with the transformed *Agrobacterium*. Additionally, the protocol for protoplast isolation in the 'Grand Nain' cultivar has been successfully standardized.

CRISPR/Cas9 gRNA design and cloning for banana eIF4E gene editing

Target sequences for the banana *eIF4E* gene and its isoforms (4E1–4E6) were retrieved from the Plant Ensembl database. After sequence annotation, three guide RNAs (gRNAs) targeting conserved regions were designed using CRISPOR, CRISPR-R, and CRISPR-P v2 tools. The specificity of these gRNAs was validated using CAS-OFFinder and CRISPR-PLANT.

The gRNA oligonucleotides were synthesized, annealed (duplexed), and ligated into the BsaI-digested pRGEB-31 CRISPR/Cas9 expression vector. Kanamycin-resistant colonies were screened via colony PCR using gRNA bottom and M13 reverse primers. Sequencing of positive clones confirmed successful gRNA insertion.

Cloning of CMV Coding Genes for Yeast Two-Hybrid Analysis with eIF4E

Specific primers were designed to amplify the full-length coding sequences of five CMV genes: 1a (2.9 kb), 2a (2.5 kb), 2b (360 bp), 3a (860 bp), and coat protein (657 bp). The 2b, 3a, and CP genes were cloned into the pGEM-T vector, and sequencing is in progress. Cloning of 1a and 2a genes is currently in progress to facilitate further yeast two-hybrid interaction studies with banana *eIF4E* proteins.

DBT-QUT funded project

4.5.6 Biofortification and development of disease resistance in banana

Component 1: Transfer & Evaluation of Indian Bananas with PVA Constructs

(S. Backiyarani, M. Mayil Vaganan, S. Uma up to 31.05.24)

Estimation of provitamin A (PVA) content and proximate analysis of 20 PVA-enriched transgenic Grand Nain events under the Event Selection Trial (EST) have been completed. The Central Compliance Committee (CCC) of the RCGM, DBT, visited the EST site for genetically engineered (GE) banana lines (PVA and Iron) under confined field conditions at ICAR-NRCB **(Fig.86)**. The fruit samples of 20 PVA transgenic Grand Nain events collected from the Event Selection trial (EST) conducted at ICAR- NRCB, Trichy and Nausari Agricultural University, Gujarat trial sites were analysed for Pro Vitamin A (PVA) content. Of which three events namely NABI-GN 346, NRQP34-'19/03, NRQP34-'19/08 and NRQP34-'19/13 recorded more than 40µg/g of DW in both the centers. There is no variation in the proximate analysis of the fruit samples collected at ICAR-NRCB had no significant variation between the control and transgenic events.

CCC visiting EST trial sites at ICAR-NRCB trial sites

Fig. 86. EST trials are terminated at ICAR-NRCB in front of RCGM Member (30.08.24)

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

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

Five elite transgenic iron events, along with untransformed 'Grand Naine' controls, were planted at the Event Selection Trial (EST). The EST concluded on 30.08.2024. Unripe and ripe pulp samples from these plants were lyophilized and sent to the National Agri-Food Bioengineering Institute (NABI), Mohali, for trait and proximate analysis. In turn, lyophilized fruit pulp samples from parallel ESTs at NABI and the Fruit Research Station, Gandevi (Gujarat), were received for similar analyses.

For Biosafety Research Level-1 (BRL-1) trials, shoot tip culture-based multiplication of elite iron events was conducted in three batches, with plants currently at various growth stages **(Fig. 87).** Molecular characterization of the transgene flanking regions was carried out using TAIL-PCR followed by sequencing. Genes were integrated were inserted in Chr. 8 & 11 in iron transgenic event 1; in Chr. 6 in event 2; in Chr. 2 & 4 in event 3; in Chr. 3 & 6 in event 4 and 5, 6 & 9 in iron event 5 (**Fig. 88)**.

Fig. 87. Event selection trial of iron transgenic events in the flowering and fruit development stages

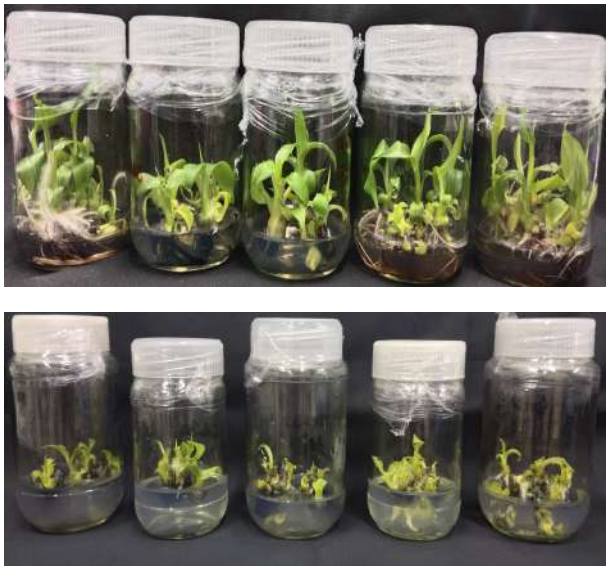


Fig. 88. Elite iron events in different stages of multiplication

PPV&FRA funded project

4.5.7 Framing crop specific DUS guidelines for Banana (Musa spp.)

(M. S. Saraswathi and S . Backiyarani)

Four farmers' varieties, Thottu Chingan, Kudhiraival Chingan, Manoranjitham, and Neykadali were registered with the Protection of Plant Varieties and Farmers' Rights Authority (PPV&FRA), New Delhi. DUS characterization has been completed for the farmers' variety Chavaniyankal Poovan, along with a reference accession Rasthali.

BRNS funded project

4.5.8 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)

The four mutant lines (two each resistant to *Foc* race 1 and TR4) which were found to be resistant during the previous year pot screening were mass multiplied and hardened plants will be carried forward for sick plot screening in Tamil Nadu and Bihar & Gujarat for race 1 and TR4 respectively (**Fig. 89)**.

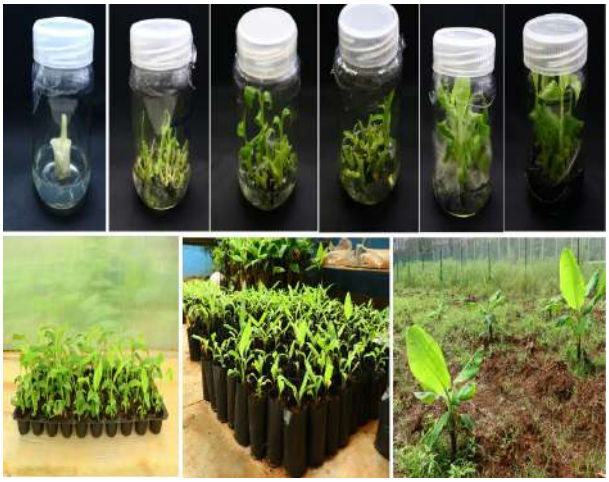


Fig. 89. Mass multiplication of putative resistant mutant lines of cv. Grand Naine using cormlet explant a. Initiation; b & d. Shoot multiplication; e. Shoot elongation; f. Rooting; g. Primary hardening; h. Secondary hardening; i. Planting at ICAR – NRCB farm

Fig. 90. Hardened plants of putative fusarium wilt resistant mutant lines of cv. Grand Naine ready for sick plot evaluation

Ten plants each of putative Fusarium wilt-resistant mutant lines of cv. Grand Naine—including two lines resistant to *Foc* Race 1 and two lines resistant to TR4—were planted at ICAR–NRCB for preliminary field evaluation, prior to testing under sick plot conditions. In the second round of pot culture screening, nine plants were identified as resistant to *Foc* Race 1 and two plants as resistant to TR4. These selected plants have been initiated for *in vitro* multiplication **(Fig. 90).**

The details of the treatments found to be resistant to *Fusarium oxysporum* f. sp. *cubense* (Foc) are summarized below **(Table 23):**

Table 19: Treatments

Sl. No.	Mutagen Treatment	Resistance to	No. of Resistant Plants
1	40 Gy	TR4	1
2	0.2% EMS + 20 Gy	TR4	1
3	40 Gy	Foc Race 1	3
4	45 Gy	Foc Race 1	2
5	0.2% EMS	Foc Race 1	1
6	0.2% EMS + 20 Gy	Foc Race 1	3
	Total		**11**

Fig. 91. Identified resistant lines of cv. Grand Naine against Foc race 1 and TR4

Two sets of plants were challenge-inoculated with Foc Race 1 and TR4. The first set of plants, currently under multiplication, will be hardened and subsequently used for sick plot evaluation. This set includes irradiated plants, EMS- and DES-treated plants, as well as combined treatments (EMS + Gamma irradiation) (**Fig. 91)**.

Mutated population of cv. Grand Nain ready for pot screening against Foc race 1 and Foc TR4

Field Evaluation

About 500 mutated plants were field-planted during May 2024, and approximately 75% have reached the shooting stage. Side suckers from around 208 mutated plants (M1V2 population) were collected and planted in pots for screening against Foc Race 1 and TR4 **(Fig. 92a -b).**

Fig. 92a. Field Evaluation of mutated population for desirable agronomic traits

Fig. 92b. Morphological variations observed among the mutated population

DBT funded projects

4.5.9 Banana Sakthi Nano formulation – Effective delivery systems of the micronutrient mixture for improved banana cultivation

(K.J. Jeyabaskaran)

The most effective combination of Nano Banana Shakti (BS) was identified for the cultivation of Ney Poovan. Three main treatment groups were tested: M1 – Nano Banana Shakti, M2 – Normal Banana Shakti, and M3 – Control (no treatment). Each main treatment was applied at four concentrations: S1 – 0.25%, S2 – 0.50%, S3 – 1.00%, and S4 – 2.00%.

The experiment followed a split-plot design with four replications per treatment, and a spacing of 2 m × 2 m between plants. Among the treatments, application of Nano-BS at 0.5% (M1S2) resulted in the highest yield of Ney Poovan banana at 37.25 t/ha, followed by Normal-BS at 2% (M2S4) with a yield of 36.75 t/ha. Compared to the control (M3), which recorded a yield of 30.13 t/ha, the yield increase was 23.6% for Nano-BS (0.5%) and 21.9% for Normal-BS (2%) **(Fig. 95).**

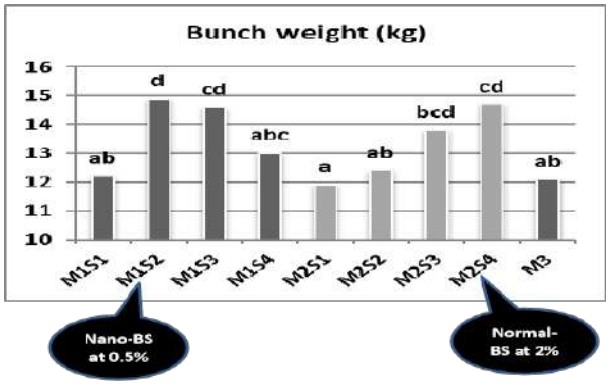


Fig. 93. Neypoovan banana bunches obtained with Nano-BS and Normal-BS treatments

DBT – UNESCO -TWAS Project

4.5.10 Eco-friendly Management of postharvest diseases and enhancing shelf life of banana through yeast based bioformulation and its green chemistry derivatives for ensuring extended availability of the quality fruits to consumers

(M. Loganathan and N. Chibuzor [Post-Doctoral Fellow])

Isolation and identification of effective antagonistic yeast species against postharvest pathogens

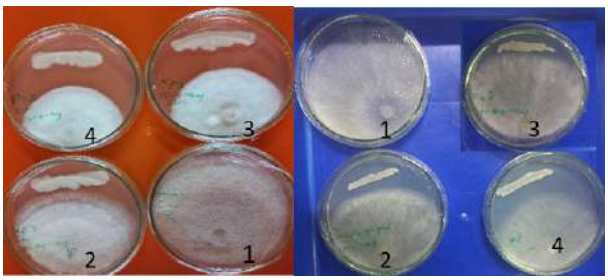
A total of 37 yeast isolates were obtained from healthy banana fruits and screened *in vitro* for antagonistic activity against the postharvest pathogens *Colletotrichum musae* (PQ289237) and *Lasiodiplodia theobromae* (PQ312878). Among these, 22 isolates showed inhibitory activity against both the pathogens. Based on the extent of inhibition, seven isolates—Ra-1, Ra-2, Ra-3, Po-4, Np-3, GN-2, and SC—were selected for molecular identification and *in vivo* evaluation **(Fig. 94).**

Molecular characterization identified the isolates as follows:

- Ra-1: *Hanseniaspora opuntiae* (PQ289240)

- Ra-2 and Ra-3: *Kodamaea ohmeri* (PV355116 and PQ151698)
- Po-4: *Meyerozyma caribbica* (PQ151710)
- Np-3 and GN-2: *Pichia bruneiensis* (PQ151709 and PV355128)
- SC: *Saccharomyces cerevisiae*

Based on literature and safety assessments, *H. opuntiae* and *K. ohmeri* strains were excluded from further use due to their human pathogenic nature. In contrast, *S. cerevisiae*, *M. caribbica* (Po-4), and *P. bruneiensis* (Np-3) tested negative for gelatinase and hemolytic activity, confirming their safety for human use and suitability for further application.



A B

Fig. 94. Effect of some Yeast Species on the Mycelial Growth of *C. musae* and *L. theobromae.*

A= Effect of yeast on *C. musae;* B = Effect of yeast isolates on *L. theobromae;* 1 = Control; 2 = *M. caribbica;* 3 = *P. bruneiensis;*4 = *S. cerevisiae*

In vivo evaluation of antagonistic yeasts

Application of antagonistic yeasts—*Saccharomyces cerevisiae* (strain SC), *Meyerozyma caribbica* (strain Po4), and *Pichia bruneiensis* (strain Np3)—to pathogen-inoculated banana fruits resulted in a significant reduction of crown rot and anthracnose. Crown rot severity caused by *Colletotrichum musae* (strain CM1) and *Lasiodiplodia theobromae* (strain Lt1) was reduced by 25% to 50%, while anthracnose incidence decreased by up to 75% in treated fruits.

Field Evaluation of Antagonistic Yeast Bio-formulations

Based on their proven *in vitro* and *in vivo* efficacy, bioformulations of *S. cerevisiae* (SC), *M. caribbica* (Po4), and *P. bruneiensis* (Np3) were developed and evaluated under field conditions. Banana bunches were treated using three application methods: (i) bud injection, (ii) bud injection followed by bunch spray, and (iii) bunch spray alone. Both individual and consortium yeast formulations were tested, alongside chemical treatment and untreated control groups.

DST funded projects

4.5.11 DST - Gene editing for Fusarium Wilt resistance in banana (Grand Naine, AAA)

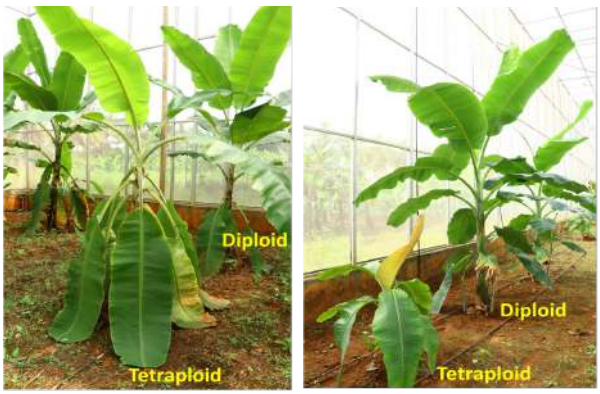
(C. Anuradha)

Six nudix hydrolase (nh) genes, Ma05_t05700, Ma01_t15710, Ma10_t17260, Ma11_t18430, Ma08_g26550, and Ma04_g26170 were successfully amplified, cloned, and characterized from both Foc Race 1 and TR4-resistant (cv. Rose) and susceptible (cv. Grand Nain) banana cultivars. Twelve guide RNAs (two per nh gene) were designed, synthesized, and cloned into the pRGEB31 vector. These constructs were transformed into Escherichia coli strain DH5α, and sequencing confirmed successful integration of the guide RNAs. Subsequently, the constructs were introduced into Agrobacterium tumefaciens strain AGL-1 for plant transformation. Two batches of embryogenic cells were co-cultivated with the transformed Agrobacterium. One batch is currently progressing through the germination medium, while the second batch remains in the maturation medium.

4.5.12 DST - Induced polyploidy: A tool to improve sterile bananas

(S. Kalpana, S. Backiyarani)

Chromosome doubling of Kunnan (AB) and Bhimkol (BB) embryogenic cell suspension (ECS) resulted in developing tetraploids. These tetraploids were confirmed through morphological traits under field condition **(Fig. 95)** and through flow cytometry. ECS has been established in cv Rose (AA) and treated with antimitotic agent, oryzalin for chromosome doubling.



Kunnan Bhimkol

Fig. 95. Comparison of tetraploid with diploid

4.5.13 DST - Efforts towards the development of Fusarium wilt resistance in banana using CRISPR/ Cas9

(C. Jeyabharathy, S. Backiyarani)

To validate the efficiency of the pRGEB32 vector and the gene editing protocol, the *phytoene desaturase* (PDS) gene in banana cv. Grand Naine was targeted using the construct pRGEB32-PDS. Phenotypic analysis of the gene-edited plants revealed that out of 139 regenerated plants, 112 exhibited an albino phenotype, 24 were variegated, and only 3 remained green **(Fig. 96).** These results confirm a high editing efficiency of 98% for the guide RNA and pRGEB32 vector in targeting the endogenous *PDS* gene in Grand Naine.

To develop resistance against *Fusarium oxysporum* f. sp. *cubense* Tropical Race 4 (Foc TR4) in cv. Grand Naine, CRISPR/Cas9 constructs—pRGEB32-LBD20 and pRGEB32-ATAF2—were developed. These constructs were introduced into embryogenic cell suspensions (ECS) of cv. Grand Naine via *Agrobacterium tumefaciens*-mediated transformation. The aim is to edit two transcription factor genes, *LBD20* (Lateral Organ Boundaries Domain 20) and *ATAF2* (*Arabidopsis thaliana* Activating Factor 2), which are identified as susceptibility factors to the root-infecting fungal pathogen *Foc* TR4.

Fig. 96. PDS edited cv. Grand Nain plants shows albino and variegated phenotype

CGIAR / Bioversity International funded projects

4.5.14 A1555 - INIT-13- Plant health and rapid response to protect food security and livelihoods

(R. Thangavelu, M. Loganathan)

Integrated management of Fusarium wilt Tropical race 4 in banana

Survey on Fusarium wilt incidence in Gujarat

A survey conducted in Gujarat identified 18 *Fusarium oxysporum* f. sp. *cubense* (*Foc*) isolates from major banana-growing districts, including Surat, Bharuch, and Vadodara, where disease incidence ranged from 2.5% to 70%. Vegetative compatibility group (VCG) analysis revealed that 7 isolates belonged to Foc Race 1 (VCG 01220), while 11 were classified as *Foc* Tropical Race 4 (TR4, VCG 01213/16). All isolates from Bharuch were identified as TR4, whereas those from Vadodara were Race 1.

Phylogenetic analysis based on EF-1α gene sequences grouped the isolates into two major clusters: Cluster A (*Foc* R1) and Cluster B (*Foc* TR4), each further divided into 4–5 sub-clusters, indicating substantial genetic diversity among the isolates. SIX gene profiling supported these results—*Foc* R1 isolates amplified *SIX4* and *SIX6*, while TR4 isolates amplified *SIX2*, *SIX8*, and *SIX9*.

Transcriptomic responses of banana cv. Grand Nain to bio-consortia & Foc TR4 interaction

A transcriptomic study was conducted to investigate the molecular interactions between *Fusarium oxysporum* f. sp. *cubense* TR4 (Foc TR4) and microbial bio-consortia in banana cv. Grand Naine. The experiment included six treatments: T1 – Foc TR4 alone, T2 – Consortia 1 (*Bacillus flexus* Tvpr-1 + *Trichoderma asperellum* NRCB-3), T3 – Consortia 2 (*Bacillus subtilis* sp. *inaquosorum* BS30 + *Bacillus haynesii* BS17), T4 – Foc TR4 + Consortia 1, T5 – Foc TR4 + Consortia 2, and T6 – untreated control.

Results revealed significant upregulation of defense-related genes in consortia-treated plants, particularly those involved in pathogen recognition, signaling,

cell wall re-modeling, and detoxification. In contrast, growth-related genes were downregulated in plants treated with Foc TR4 alone.

Validation with 30 defense-related genes identified 8 with consistent expression patterns. In T5 (Foc TR4 + *B. subtilis* + *B. haynesii*), five key defense genes, including peroxidase and jasmonyl signaling genes, were highly upregulated (up to 46-fold). In T4 (Foc TR4 + *T. asperellum* + *B. flexus*), strong induction of genes such as chitinase and zinc finger transcription factors was observed. These findings suggest that specific bio-consortia can effectively prime banana plants against Foc TR4 by activating key defense pathways.

Impact of organic amendments on *Foc* TR4 and plant growth

Eight organic amendments *viz.*, neem cake (NC), groundnut cake (GNC), castor cake (CC), gingelly cake (GC), mustard cake (MC), vermicomposting (VER), rice husk ash (ASH), and farmyard manure (FYM) were evaluated at three application rates (100 g, 200 g, and 300 g per plant) for their effectiveness in managing Fusarium wilt (*Foc* TR4). Applications at 200 g and 300 g per plant significantly reduced internal corm disease severity, with suppression ranging from 16.28% to 100%. Complete suppression (disease score = 0) was recorded with 300 g of GC and GNC, in contrast to an average disease score of 4.30 (**Fig. 97**) in untreated, *Foc* inoculated controls.

In terms of plant growth, all eight amendments significantly improved height, girth, leaf number, and leaf area compared to *Foc*-infected plants. The most notable improvements were observed with 300 g of GNC, which resulted in increases of 158.87% in height, 147.78% in girth, 41.25% in leaf number, and 315.52% in leaf area, demonstrating its strong potential to both suppress disease and promote plant vigor.

Fig. 97. Effect of Groundnut cake on Fusarium wilt disease caused by *Foc* TR4

Mechanism of Fusarium wilt suppression by oil cake amendments

Application of groundnut cake (GNC) and gingelly cake (GC) at 300 g/plant resulted in the highest microbial populations. GNC-treated soil recorded 33 × 10^{10} CFU/g bacteria, 4 × 10^{10} CFU/g fungi, and 1 × 10^{10} CFU/g actinomycetes. GC-treated soil had 28 × 10^{10}, 5 × 10^{10}, and 1 × 10^{10} CFU/g, respectively. In comparison, the control showed lower counts: 11 × 10^{10}, 2 × 10^{10}, and 1 × 10^{10} CFU/g. These findings suggest that oil cakes, especially GNC and GC, significantly enhance beneficial microbial populations, potentially contributing to Fusarium wilt suppression

Effect of organic amendments on *Foc* TR4 DNA in soil quantified by qRT-PCR

Quantitative real-time PCR analysis showed that all organic amendments significantly reduced *Foc*-TR4 DNA concentration in soil. Groundnut cake (300 g/plant) was the most effective, reducing DNA levels from 537.7 pg in the *Foc* inoculated control to 50.3 pg—a 90.6% reduction. Mustard cake (300 g/plant) reduced the DNA to 70.3 pg (86.9% reduction), followed by gingelly cake. Principal Component Analysis (PCA) further confirmed that groundnut, mustard, and gingelly cakes at 300 g/plant were the most effective in lowering soil inoculum levels, highlighting their potential for sustainable Fusarium wilt management

Isolation & screening of soil microbes from organic cake-amended soil against *Foc* TR4

A total of 49 bacterial and 14 fungal isolates were obtained from soils amended with various organic cakes and screened *in vitro* against *Foc* TR4. Among the fungal isolates, F13 showed the highest mycelial growth inhibition (82.9%) in dual culture and the largest inhibition zone (3.0 cm) in agar well diffusion assays **(Fig. 98).** Isolate F6 exhibited the greatest spore germination inhibition (26.6%).

Enzyme assays revealed that bacterial isolates B2, B17, and B22, along with fungal isolates F5, F6, and F10, produced hydrolytic protease, while only six isolates exhibited

cellulase activity. Indole-3-acetic acid (IAA) production was observed in four bacterial (B2, B12, B22, B23) and three fungal (F5, F6, F13) isolates.

These results indicate that selected microbial isolates from organically amended soils possess antifungal, enzymatic, and plant growth-promoting properties, potentially contributing to *Foc*-TR4 suppression and enhanced plant health.

Fig. 98. Inhibition of mycelial growth of *Foc* TR4 by Trichoderma isolates under *in vitro* condition

Effect of flooding & paddy cultivation on *Foc* TR4 inoculum and Fusarium wilt incidence

Mini-plot trials demonstrated a significant reduction in Foc-TR4 inoculum and disease incidence following flooding and paddy cultivation. Quantitative real-time PCR analysis showed a decline in *Foc* DNA from 7995 pg to 174.2 pg per 25 ng of soil DNA post-paddy cultivation, representing a 97.8% reduction. Correspondingly, the internal corm disease score decreased from 3.5 to 1.13 (67.7% reduction). At three months post-planting, water stagnation alone led to a decline in disease score from 3.4 to 2.2. *Foc* DNA concentration dropped from 5630 pg to 104.5 pg, indicating a 98.14% reduction due to flooding **(Fig. 99).**

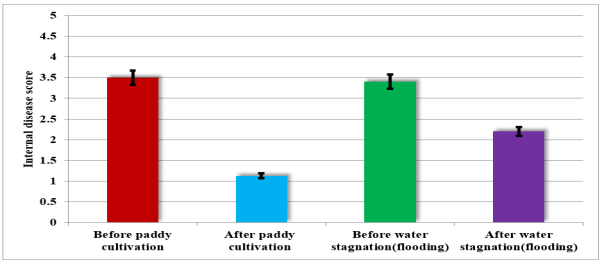


Fig. 99. Effect of water stagnation and paddy rice cultivation on *Foc* TR4

SEM analysis of biocontrol agent–Foc-TR4 interactions in banana cv. Grand Naine

Scanning Electron Microscopy (SEM) analysis revealed distinct structural interactions between bio-control agents and *Foc* TR4 in the corm tissues of banana cv. Grand Nain. The treatments included:

T1 – *Foc* TR4 alone

T2 – *Trichoderma asperellum* (NRCB-3) + *Bacillus flexus* (Tvpr-1)

T3 – *Trichoderma* sp. (UP4) + *T. asperellum* (Assam)

T4 – *Bacillus subtilis* (cv. Matti, strain 16) + *B. subtilis* (cv. Safed Velchi, strain 32)

T5 – *B. subtilis* subsp. *inaquosorum* (BS30) + *T. asperellum* (Prr2)

T6–T9 – Combinations of T2–T5 with *Foc*

T10 – Uninoculated control

In *Foc*-inoculated treatments (T6–T9), extensive colonization by biocontrol agents was evident in the corm tissues. SEM imaging showed visible degradation of *Foc* mycelia in the presence of *Trichoderma* and *Bacillus* spp., likely due to enzymatic breakdown by extracellular cellulases.

Antagonistic effects included mycelial coiling, distortion, and surface shrinkage of *Foc* hyphae **(Fig. 100).** *Trichoderma* hyphae measured 3.5–5 µm in diameter, while *Foc* hyphae ranged from 5–8 µm, aiding morphological distinction. In contrast, untreated controls (T1 and T10) showed dense *Foc* colonization with intact hyphae, clearly differing from the disrupted mycelia in bioagent-treated tissues **(Fig. 101).**

These findings underscore the antagonistic potential of the tested biocontrol consortia against *Foc* TR4, primarily through direct mycoparasitism and enzymatic degradation.

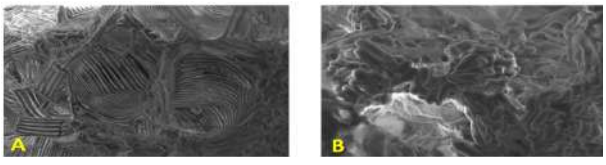


Fig. 100. A) 0th day B) Interaction of Endo. B. *subtilis* (16), Rhi. B. subtilis (32) and *Foc* TR4 after 25 days of inoculation (Profuse growth of *Bacillus subtilis*)

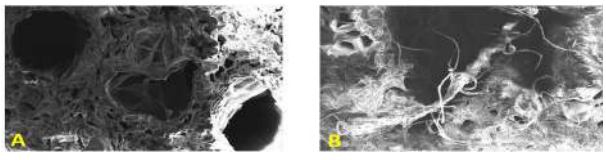


Fig. 101. A. Control plants B. *Foc* TR4 25 days of inoculation (coiling of Trichoderma over the *Foc* TR4 mycelium

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Radio talks

Name of the Staff	Topic/ Venue	Date of broadcast/ recording	Media
R. Selvarajan	Research and development at National Research Centre for Banana	09.03.2024	*AIR News Chennai*
	ICAR-NRCB 31st Foundation Day and Kisan Mela	21.08.2024	*AIR News, Trichy*
	Live Programme on ABI Activities	02.12.2024	*AIR News, Trichy*
C. Karpagam	About ICAR-NRCB Kisan Diwas Live Programme	24.12.2024	*AIR News, Trichy*
A. Mohanasundaram	Integrated Pest Management in Banana Cultivation	02.07.2024	*AIR, Tirichy*
	Integrated Pest Management in Banana Cultivation	27.08.2024	*AIR, Tirichy*
	Sucking pest problem in banana and its management	15.10.2024	*AIR, Tirichy*
	Mealybug problem in banana and its management	12.11.2024	*AIR, Tirichy*

5.2 Television talks

Name of the Staff	Topic / Venue	Date of Telecast	*Channel*
R. Selvarajan	NRCB technologies for stakeholders	09.03.2024	*DD-Tamil News TV*
	ICAR-NRCB 31st Foundation Day and Kisan Mela	21.08.2024	*TV Channels of Puthiyathalaimurai, Makkal, Jeya, Thanthi, Sathiyam, Tamilan, DD Tamil News, News-7and Dinamalar*
	Kisan Diwas and its Importance	24.12.2024	*Puthiyathalaimurai TV, Makkal TV and News-7 TV*
C. Karpagam	About Farmer's Day Exhibition	21.08.2024	*Dinamalar TV, Puthiyathalaimurai TV, Makkal TV, Jeya TV, Thanthi TV, Sathiyam TV, Tamilan TV and Dinamalar TV*
	Farmers mela at Thanjavur	04.10.2024	*Kumudham News 24X7*
	Display of Banana varieties	04.10.2024	*Raj News-TV*
P. Suresh kumar	Services provided at the National Research Center for Banana	13.07.2024	*News -18 & Srikali-TV*
A. Mohanasundaram	Field visit at Vadugakudi during UP farmers training programme	21.02.2024	*Sun News, Mali Murasu and Puthiyathalaimurai*

5.3 Frontline Exhibitions conducted / participated

Name of the event	Organizer & Venue	Date	Number of Visitors	Name of the staff participated
Agriculture Exhibition 2024	NIFTEM-T, Thanjavur, TN	23 January, 2024	1,000	C. Karpagam A.Mohanasundaram P. Ravichamy
Regional Agriculture Fair 2024 (North Zone)	ICAR-IIVR, Varanasi, UP	3-5 February, 2024	50,000	R. Selvarajan K.N. Shiva C. Sivananth S. Harishwar
ICAR - Regional Committee No. VIII Meeting	ICAR-CIBA, Chennai	16 February, 2024	1,000	J. Poorani C. Sivananth S. Harishwar
Mega Festival of Banana & Turmeric	Burhanpur, MP	20-21 February, 2024	2,000	K.N. Shiva P. Suresh Kumar
National Science Day – Open Day	ICAR-NRCB, Trichy, TN	28 February, 2024	4,000	All Staff of NRCB
National Horticulture Fair 2024	ICAR-IIHR, Bengaluru	5-7 March, 2024	1,20,000	R. Selvarajan C. Karpagam R. Pitchaimuthu S. Harishwar S. Ajith Kumar
Workshop on "Hi-Tech Banana Cultivation"	ISHA, Erode, TN	12 May, 2024	400	C. Karpagam A. Mohanasundram K.J. Jeyabaskaran K.N. Shiva M. Loganathan
Workshop on "Hi-Tech Banana Cultivation"	ISHA, Annur, Coimbatore, TN	14 May, 2024	400	C. Karpagam A. Mohanasundram K.J. Jeyabaskaran K.N. Shiva M. Loganathan
Workshop on "Hi-Tech Banana Cultivation"	ISHA, Karamadai, Coimbatore, TN	15 May, 2024	350	C. Karpagam A. Mohanasundram K.J. Jeyabaskaran K.N. Shiva M. Loganathan

Triphal Diversity Show 2024 (Mango, Jackfruit, Banana)	ICAR-IIHR, Bengaluru	31 May to 2 June, 2024	20,000	R. Selvarajan C. Karpagam K.N. Shiva Pramod Shelake P. Durai K. Kamaraju R. Pitchaimuthu S. Harishwar S. Ajith Kumar
Cultivation of Food Forest and Triphal Diversity Show 2024	Pudukkottai, TN	23 June, 2024	10,000	A.Mohanasundaram P. Durai P. Ravichamy K. Kamaraju R. Pitchaimuthu S. Harishwar S. Ajith Kumar
AGRI INTEX 2024	CODISSIA, Coimbatore, TN	11-15 July, 2024	2,00,000	C. Karpagam A.Mohanasundaram P. Ravichamy P. Durai R. Pitchaimuthu M. Bathrinath
96th ICAR Foundation & Technology Day (Fruit Diversity Show)	NASC Complex, New Delhi	15 -16 July, 2024	10,000	R. Selvarajan K.N. Shiva S. Backiyarani Pramod Shelake C. Sivananth S. Harishwar S. Ajith Kumar
AGRI TECH EXPO 2024	CII & Rasi Seeds Pvt. Ltd, Attur, TN	3-5 August, 2024	12,000	C. Karpagam P. Ravichamy R. Pitchaimuthu M. Loganathan S. Harishwar S. Ajith Kumar
ICAR-NRCB FD & Farmers Day 2024	ICAR-NRCB, Trichy, TN	21 August, 2024	1,000	All Staff of NRCB
CCI-Delta Agri & Food Expo 2024	CCI at Thanjavur, TN	4-6 October, 2024	10,000	R. Selvarajan C. Karpagam P. Ravichamy K. Kamaraju R. Pitchaimuthu M. Bathrinath S. Harishwar

Gramodyog Vikas Yojana	NRCB	10 October, 2024	130	C. Karpagam P. Suresh Kumar K.N. Shiva P. Ravichamy K. Kamaraju
2nd ICAR-IIHR-Industry Meet 2024	ICAR-IIHR, Bangalore	24 October, 2024	300	P. Suresh Kumar C. Sivananth
Banana Festival 2024	ISHA, Save soil Movement at Tirunelveli, TN	24 November, 2024	2,500	R. Selvarajan C. Karpagam K.J. Jeyabaskaran P. Suresh Kumar R. Pitchaimuthu
Banana Festival and Kisan Diwas	ICAR-NRCB, Trichy	23 December, 2024	600	All Staff of NRCB
Total (Indirect Beneficiaries from frontline exhibition activities)			4,45,680*	

***The number of visitors is an estimate provided by the organizer.**

Frontline Exhibition

6. EDUCATION AND TRAINING

6.1. Education – Students guided by NRCB Scientists

Chairperson	Degree	Project title	Student Name
R. Thangavelu	Ph.D. (Plant Pathology)	Eco-friendly approaches for the management of fusarium wilt tropical race 4 (*Fusarium oxysporum* f.sp. *cubense*) in banana (cv. Grand nain)	Amaresh Hadimani
	M. Sc. (Microbiology)	Antimicrobial effect of native endophytic bacterial and fungal isolates for the control of fusarium wilt causing banana pathogen *Fusarium oxysporum* f. sp. *cubense* – tropical race 4	B. Kanagasri
	M. Sc. (Microbiology)	Isolation and evaluation of bacteria and fungi from bioaltered soil treated with different organic cakes against *Fusarium oxysporum* f. sp. *cubense* – tropical race 4	T. Abinaya
	M. Sc. (Microbiology)	Effects of indigenous rhizospheric bacterial and fungal isolates against fusarium wilt of banana pathogen *Fusarium oxysporum* f. sp. *cubense* – tropical race 4 under in vitro condition	V. Vijayarahini
M. S. Saraswathi	B. Tech. (Biotechnology)	Effect of Kaveri microbial consortium (KMC, product of ICAR-NRCB) on growth and development of micro propagated banana (*Musa* spp.) cv. red banana (AAA, unique)	Dhanusha A
	M.Sc. (Biotechnology)	Fingerprinting on commercial Cavendish clones using SCoT markers	Kowshika G
	M.Sc. (Biotechnology)	Virus eradication through chemotherapy technique for Musa spp.	Maria Gladiya T
	M.Sc. (Biotechnology)	Fingerprinting of commercial Cavendish clones using NRSIP markers	Swetha S
I. Ravi	M.Sc. (Botany)	Genome impact on biomass partitioning at flowering and harvest in banana	G. Subhashini
	M.Sc. (Botany)	Influence of nitrogen levels on fruit development in banana cv. Grand Nain (AAA)	I. Subaragavi
	M.Sc. (Fruit Science)	Field evaluation of banana under sodic soil for growth and yield	Kalaivani J

P. Suresh Kumar	Ph.D. (Fruit Science) Co-Chairperson	Development of green nanopackages and smart foods using banana fruits	Yellapu Rammohan
	M.Sc. (Food Processing)	Exploring the potential of banana starch as a versatile wall material for *Lactiplantibacillus plantarum* and development of symbiotic fermented milk	T. Gowsika
	M.Sc. (Food Processing)	Banana starch based microencapsulation of *Lactiplantibacillus plantarum* for synbiotic jelly pudding development	D. Nivetha
	M.Sc. (Nutrition and Dietetics)	Development of complementary food products using custard apple fruit powder mixes based food products for toddlers	C. Prathyangara
K. Nagendran	M.Sc. (Botany)	Cloning and characterization of DNA-N component of banana bunchy top virus infecting banana	S. Maathangi
	M.Sc. (Botany)	Cloning and characterization of DNA-M component of banana bunchy top virus infecting banana	S. Suvaethalakshmi
	M.Sc. (Botany)	Cloning and characterization of DNA-S component of banana bunchy top virus infecting banana	K. Abinaya
	M.Sc. (Plant Pathology)	Unravelling begomovirus diversity infecting weed plants of vegetable ecosystem	Ajit Kumar Patel
K.N. Shiva	M.Sc. (Food Processing)	Standardization of banana central core stem juice blends with tropical fruit juices and nutraceuticals	S. Selvapriya
	M.Sc. (Food Processing)	Effect of surface coating and packaging on extending shelf-life and quality of banana	A. Keerthiya
M. Loganathan	M.Sc. (Microbiology)	Studies on efficacy of microbes on decomposition ability of banana waste for sustaining environment and soil health	A. Anusuya
	M.Sc. (Microbiology)	Studies on consortium of microbes on the growth of banana plants	B. Bathmasri

C. Anuradha	M.Sc. (Biotechnology)	Cloning and characterization of nudix hydrolase gene from banana	Abitha G
	M.Sc. (Bioinformatics)	Genome-wide analysis of PR family from Musa spp.	Swetha Menon V
S. Backiyarani	B. Tech. (Biotechnology)	A study on expression analysis of Lbd20 (transcriptional factor) and Ataf2 (a NAC transcriptional factor), a fusarium wilt susceptibility factor in banana tissues	Akshaya T
	B. Tech. (Biotechnology)	A study on expression analysis of Lbd20 (transcriptional factor) and Ataf2 (a NAC transcriptional factor), a fusarium wilt susceptibility factor in banana tissues	Arsheya Begam
	B. Tech. (Biotechnology)	Molecular confirmation of transgene integration in banana cv. Grand Nain through PCR screening	Sneka N
A. Mohana sundaram	M.Sc. (Microbiology)	Identification of fungal endophytes isolated from banana plants and assessment of their entomopathogenic abilities against banana insect pests	M.S. Ghayathri
	M.Sc. (Microbiology)	Studies on the identification and bio-efficacy of different entomopathogenic fungi against major banana insect pests	S. Keerthana
	M.Sc. (Microbiology)	Characterization and volatiles profiling of soil borne microbes and investigation of their entomopathogenic properties against banana insect pest	S. Sineka
M. Mayilvaganan	M.Sc. (Biochemistry)	Studies to elucidate the biochemical and molecular mechanisms of senescent spots initiation and development during ripening of banana fruit	D. Logavarthini
	M.Sc. (Biochemistry)	*In vitro* screening of some commercial banana varieties for low temperature tolerance and its preliminary biochemical and molecular characterisation	S. Shruthi
	M.Sc. (Biochemistry)	Recent advances in biochemistry and biotechnological techniques in banana	M. Lakshimi Priya
	M.Sc. (Biochemistry)	Recent advances in biochemistry and biotechnological techniques in banana	P. G. Yazhini
C. Karpagam	B.Sc. (ABM)	Impact Study of ICAR-NRCB Technologies - Banana Shakti	S. Rohan
	B.Sc. (ABM)	Bananapreneurship through ICAR-NRCB Technologies - Documentation of Success stories in Bananapreneurship	R. Gokul Prakash

6.2. Training for Capacity Development for farmers, Students & other Stakeholders

6.2.1. On-Campus Trainings

Title of the Training Program/ State	Course Co-ordinator(s)	No. of participants	Date
Two days NHM training programme on Cultivation practices, integrated nutrient and pest & disease management in banana for farmers from Erode, Tamil Nadu	C. Karpagam A. Mohanasundaram P. Ravichamy R. Selvarajan	79	7– 8 February 2024
Two days ATMA training programme on Good practices in banana cultivation for farmers from Cuddalore, Tamil Nadu	C. Karpagam A. Mohanasundaram P. Ravichamy R. Selvarajan	45	13– 14 February 2024
Five days training programme on Improved production technologies for hi-tech banana cultivation for farmers from Basti District, Uttar Pradesh	C. Karpagam V. Kumar I. Ravi K.J. Jeyabaskaran K.N. Shiva	21	17– 21 February 2024
Two days ATMA training programme on Integrated banana cultivation for farmers from Coimbatore, Tamil Nadu	C. Karpagam A. Mohanasundaram P. Ravichamy R. Selvarajan	42	4 – 5 March 2024
Two days awareness cum demonstration programme for farmers from Raver District, Maharashtra	C. Karpagam A. Mohanasundaram P. Ravichamy R. Selvarajan	25	6– 7 March 2024
Two days training programme on Good agricultural practices in banana cultivation for farmers from Kalakurchi block, Cuddalore district	C. Karpagam A. Mohanasundaram P. Ravichamy R. Selvarajan	50	13– 14 June 2024
Two days training programme on Good agricultural practices in banana cultivation for farmers from Kalakkad, Tirunelveli district	C. Karpagam A. Mohanasundaram P. Ravichamy R. Selvarajan	50	4– 5 July 2024
Ten days training programme on Cutting-edge techniques in banana tissue culture and its applications	S. Backiyarani R. Selvarajan M.S. Saraswathi C. Anuradha K. Nagendran	9	11– 20 December 2024
Technical know-how of triple antibody sandwich ELISA (TAS-ELISA) kit for detection of banana bract mosaic virus (BBrMV)	R. Selvarajan K. Nagendran	2	12– 13 August 2024
Recent advances in biochemical and biotechnological techniques in banana	G. Prabhu K. Nagendran	35	20 June 2024 – 19 July 2024

SC/SP - sponsored training programme on Utilization of banana sheath and its by-products for women empowerment for women	R. Selvarajan P. Suresh Kumar K.N. Shiva C. Karpagam Pramod Shelake	100	8 – 12 January 2024
Awareness programme for fiber artisans under Gramodyog Vikas Yojana on transforming waste to wealth: unlocking the value of banana fiber	P. Suresh Kumar Pramod Shelake K.N. Shiva C. Karpagam	75	23 October 2024
Hands-on training on banana breeding techniques imparted for three days	S. Backiyarani M.S. Saraswathi R. Selvarajan C. Anuradha	10	7– 9 January 2024
Banana processing technologies and by-products utilisation: advancements and applications	Pramod Shelake	05	1– 19 July 2024
Twenty-one days internship training programme on Entomological, nematological, and pathological techniques in banana	A. Mohanasundaram M. Mayilvaganan	2	13– 27 May 2024
Five days internship training programme on comprehensive banana cultivation, improvement, production, protection, post-harvest technology and extension	C. Karpagam A. Mohanasundaram M. Mayilvaganan	16	24– 28 June 2024
Five days internship training programme titled Techniques in biochemistry and biotechnology	M. Mayil Vaganan A. Mohanasundaram	8	11– 15 November 2024
Internship training programme on recent advances in biochemistry and biotechnological techniques in banana	G. Prabhu M. Mayilvaganan	13	21 May 2024 – 19 June 2024
Internship training programme on recent advances in biotechnological techniques in banana	K. Nagendran M. Mayilvaganan	18	24 May 2024 – 24 June 2024
Internship training programme on microbes in pest management	M. Loganathan M. Mayilvaganan	6	5-19 June 2024
Internship training programme on recent advances in IoT and its applications	I. Ravi M. Mayilvaganan	2	1-31 July 2024
Internship training programme on recent biotechnological innovations in banana cultivation	S. Backiyarani C. Anuradha M. Mayilvaganan	14	22– 30 August 2024
Internship training programme on techniques in biological and chemical sciences	M. Mayilvaganan K. J. Jeyabaskaran	11	16 - 30 September 2024
IP and the SDGs: Building our common future with innovation and creativity	P. Suresh Kumar	150	30 April 2024

Different On-Campus Trainings

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Workshop cum training on integrated (Hi-tech) cultivation in banana organized by Isha Outreach and ICAR-NRCB at Sathyamangalam.	R. Selvarajan C. Karpagam A. Mohanasundram K.J. Jeyabaskaran K.N. Shiva M. Loganathan	250	12 March 2024
Workshop cum training on integrated (Hi-tech) cultivation in banana organized by Isha Outreach and ICAR-NRCB for Manneswarar FPO at Annur.	C. Karpagam A. Mohanasundram K.J. Jeyabaskaran K.N. Shiva M. Loganathan	200	14 May 2024
Workshop cum training on integrated (Hi-tech) cultivation in banana organized by Isha Outreach and ICAR-NRCB for Karamadai FPO.	C. Karpagam A. Mohanasundram K.J. Jeyabaskaran K.N. Shiva M. Loganathan	200	15 May 2024
Drone application demonstration of input materials (pesticides and micronutrients) in agriculture crops in Pudukkottai district.	M. Loganathan	2060	10-12 January 2024

Different Off-Campus Trainings

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
Best Stall Award for Extension Exhibition	At National Horticulture Fair-2024 held at ICAR-IIHR, Hessaraghatta organised by ICAR-IIHR, Bengaluru, Karnataka
R. Selvarajan	Ariviyal Kalanjiyam Award from Mylai Thiruvalluvar Tamizh Sangam at Alagappa University, Karaikudi
	Enduring Impact in Plant Pathology award in the International Conference on Precision Horticulture-ICPM-2024
	Honoured as Guest of Honor in the "International Conference on Plant Protection in Horticulture–Advance and Challenges" (ICPPH-2024).
P.S. Waghrulkar K. Nagendran V. Balasubramanian R. Selvarajan	Best Poster Presentation at VIROCON 2024, organized by DRDE Gwalior and Indian Virological Society, held at DRDE, Gwalior.
R. Thangavelu	Fellow of National Academy of Agricultural Sciences (NAAS), New Delhi
K. Nagendran	Young Plant Pathologists Award – 2024 by Dr. B. Vasanthraj David Foundation
	Best oral presentation in International Conference on Plant Protection in Horticulture: Advances and challenges (ICPPH-2024) held at ICAR-IIHR, Bengaluru
	Best oral presentation in International conference on Emerging Viruses: Pandemic & Biosecurity Perspectives (VIROCON-2024) held at DRDO, Gwalior
K.N. Shiva	Best oral presentation in the International Conference on Precision Horticulture, held at HC&RI, Periyakulam, TN
P. Suresh Kumar	Dr JS Pruthi Award-Fruits and vegetable in the 30th ICFoST 2024 at Navi Mumbai.
	Fellow of the Institute of Food Science and Technology, United Kingdom, 24th September 2024 Membership No. 182428
	Fellow of National Academy of Agricultural Sciences (NAAS), New Delhi
	Best oral presentation in NC-ISTAH 2024, Nehru Institute of Engineering & Technology, Coimbatore.
C. Anuradha R. Selvarajan	Springer Natures-IVS Best Paper Award for the article Evidence of viral genome linked protein of banana bract mosaic virus interaction with translational eukaryotic initiation factor 4E of plantain cv. Nendran based on yeast two hybrid system study. Virus Disease 32 (1), 123-130C. Anuradha, R Selvarajan, T Jebasingh, PS Naynar. 2021.

Pramod Shelake	Best oral presentation in the International Symposium on Agricultural Engineering Education for Aspiring Youth in Transforming Agriculture.
A. Mohanasundaram	Best oral presentation during National Conference on Agro Ecological Farming System to promote sustainable Agriculture held at Pushkaram college of Agrl. Sciences- Pudukottai
P. Ravichamy	Best Technical Staff Award during ICAR-NRCB Foundation Day cum Farmer Day-2024

7.2. Important and Special Recognitions Received by the Scientists

R. Selvarajan
Chief Guest, International Conference on Microbiological Research, BU, Tiruchirappalli
Chief Guest, ICAR-sponsored short course on Volatilomics, TNAU, Coimbatore on
Chief Guest, Workshop on Hi-tech Banana Cultivation, ICAR-NRCB & ISHA Outreach
Chief Guest, 10th National Conference on Agro-Ecological Farming Systems
Chief Guest, National Level Quiz Competition 2024, organized by Union Bank of India
Chief Guest, CCI-Delta Agri & Food Expo 2024, organized by CII, Thanjavur
Chief Guest, Banana Festival, organized by ICAR-NRCB & ISHA at Tirunelveli
Co-Patron, National Conference on Plant Health for Food Security: Threats and Promises, IISR
Co-Chairman, Triphal Diversity Show-2024 organized by ICAR-IIHR & ICAR-NRCB, Bengaluru
Co-Chairman, Crop Protection, 11th Group Discussion of ICAR-AICRP on Fruits, NAU, Gujarat
Co-Chairman, Success Stories of ABI/BESST-HORT Incubates, 2nd ICAR-IIHR Industry Meet
Guest of Honour, Inaugural function of ICPPH-2024, ICAR-IIHR, Bengaluru
Guest of Honour, Workshop cum Training for Agri Engineers of KVKs in MP & Chhattisgarh.
Guest of Honour, International Conference on Precision Horticulture, HC&RI, TNAU, Periyakulam
Guest of Honour, State-Level Workshop at Shri Shivaji Agriculture College, Amravati
Chairman, Technical Session on Detection, Diagnosis, Pathogen Diversity, ICAR-IISR, Lucknow
Chairman, Technical Session-II, Global Conference on Nano Connect 2024, TNAU, Coimbatore
Chairman, Technical Session-II on Emerging Pest Management Approaches, ICPPH-2024, IIHR
Chairman, Session on Diagnostics, Biosurveillance, & Biosecurity, VIROCON 2024, DRDE, Gwalior
Chairman, Selection Committee for Administrative Officer, NIFTEM, Thanjavur
Coordinator, INDO-ISRAEL Workshop at Sri Sivasubramaniya Nadar College of Engineering
Keynote Lecturer at National Conference, ICAR-IISR, Lucknow
Keynote Lecturer on Digital Technologies in Banana Precision Farming, JAU, Junagadh, Gujarat
Keynote Lecturer on Banana Protection Technologies, AGSC-2024, TNAU, Coimbatore
Keynote Lecturer on Plant Viral Diagnostics–Advances & Challenges, VIROCON 2024, Gwalior
Keynote Lecturer on Advanced Detection of Plant Pathogens, RAPPID, PJTSAU, Hyderabad
Lead Speaker at Technical Session III, Nano Connect 2024, TNAU, Coimbatore
Invited Speaker at INDO-ISRAEL Workshop, SSN College of Engineering, Chennai
Invited talk at Workshop on Quarantine for Invasive Pathogen Prevention, ICAR-CIARI, Port Blair
External Examiner, M.Sc. and Ph.D. Thesis – TNAU, AU, SRM, University of Delhi (South Campus).
Doctoral Committee Member – VIT, Kerala Agricultural University, SRM University.

Nominated Member, State Variety Release Committee, Government of Tamil Nadu.
Nominated Vice President (Plant Virology), Indian Virological Society, New Delhi.
Nominated Member, Editorial Board of Virus Disease Journal (Springer), Indian Virological Society
Nominated Member (DBT), Institute Biosafety Committee, ICAR-CTCRI, Thiruvananthapuram.
Nominated Member, National Advisory Committee, ICPPH-2024, ICAR-IIHR, Bengaluru.
Nominated Member, Assessment Committee for Scientist (Plant Pathology), ICAR-DFR, Pune
J. Poorani
Peer reviewer for international journals (*Zootaxa*, *Phytoparasitica*, *Journal of the Lepidopterists' Society*).
Contributed an invited research article for a special issue of the journal *Insects*.
External examiner for the Ph.D. thesis submitted to Kerala Agricultural University (KAU), Vellayani.
R. Thangavelu
Senior Editor (Fungal Pathology, Nematology, Mycology) of the journal *Indian Phytopathology*
Panelist for the session on Disease Management during the XI Group Discussion of ICAR-AICRP
Keynote lecture during National Dialogue on Management of Banana Wilt at JISL, Jalgaon
Lead paper presentation at the National Conference at ICAR-IISR, Lucknow
Co-Chair for a session during the National Conference at ICAR-IISR, Lucknow
Ph.D. examiner and conducted viva voce for the student at, TNAU
M. Loganathan
Reviewer of DBT project proposal on Plant Pathology
Expert for assessment of ARS scientist (Plant Pathology), ICAR-CICR, Nagpur
Invited talk for faculty, PG, and Ph.D. students of AC & RI, TNAU, Madurai
Panelist for the workshop on Hi-Tech Banana Cultivation at Sathyamangalam
Invited talk in the Faculty Development Programme at Jamal Mohamed College, Tiruchirappalli
External examiner for four Ph.D. scholars from TNAU Annamalai University
Panelist for a technical session during Kisan Diwas and Banana Festival at ICAR-NRCB
Serving as Supervisor of a DBT–UNESCO–TWAS Post Doctoral Fellow.
Reviewer for peer-reviewed international and national journals
S. Backiyarani
Organizing committee member of Triphal Diversity Show held at ICAR-IIHR
External expert for the Research Advisory Committee by Madurai Kamaraj University.
External expert for the Scientific Writing Workshop held at ADAC&RI, Trichy.
External expert for the award of Ph.D. degree of Bharathiyar University
External examiner for the Ph.D. viva-voce at HC&RI, Coimbatore
Evaluated the M.Sc. (Ag.) thesis from AC&RI, Madurai.
External expert for the Sixth IBSC meeting of ABLEST, SASTRA University
Guest lecture on "Banana Breeding is No More Recalcitrant: An Overview" at CPBG, TNAU
External examiner for the award of Ph.D. degree at Mangalore University & KU, Madurai

V. Kumar
External expert for the CAS Evaluation Committee at Gandhigram Rural Institute, Dindigul
External Examiner for the Viva-voce for M.Sc. (Hort.) students at Annamalai University
External Member for the Selection Committee (TSP) for Field Assistants in Salem/Trichy districts
Nominee of Chairman, ASRB, in the Assessment Committee at ICAR-Directorate of Cashew Research
Invited lecture at the District Level Horticultural Seminar in Pudukkottai
Invited lecture during a Training Programme for Indian Potash Limited Field Officers at Trichy
M.S. Saraswathi
Reviewer for the eight National and international journals
Evaluated M.Sc. thesis for HC&RI, TNAU, Periyakulam & Dr. YSRHU, Andhra Pradesh
External Examiner for Ph.D. final Viva-Voce at Dr. YSRHU, Andhra Pradesh.
Panel Member for selection of SRF under ABI project
Co-chairperson, PMEC, ICAR-NRCB
Member Secretary of IRC, ICAR--NRCB
Nodal Officer, ARMS, ICAR-NRCB
Convenor, technical session on Banana Biodiversity during 31st Foundation Day and Kisan Mela
Four Guest lectures on Banana Systematics to Ph.D. students of ICAR-IIHR, Bengaluru
Two expert talks at Scientific Writing Workshop at HC&RI, TNAU, Periyakulam
Lecture at RUSA-sponsored Workshop by BDU, Trichy
Chairperson of Programme Committee for 31st FD & KM & Banana Festival and Kisan Mela
P. Suresh Kumar
Member of the Expert Group for implementing the PM-DevINE project
Member of the Board of Studies in PSGR Krishnammal College for Women, Coimbatore
Member of the Scientific Panel on Fruits & Vegetables and their Products (SP-12), FSSAI
Member of the Assessment Committee Meeting of faculty at NIFTEM-T, Thanjavur
Member of the Cost Fixation Committee, NIFTEM-T, Thanjavur
Panelist in the Technical Session during the 31st Foundation Day & Kisan Mela, ICAR-NRC Banana
Reviewer for the twenty National and international journals related to food science & technology
Keynote lecture at Dhanalakshmi Srinivasan University, Trichy during DSU HR Conclave 2024
Keynote lecture at Uzhavae Thalai 6.0, AGRI INTEX 2024, ICCI
Keynote lecture at International Conference at PSGR Krishnammal College for Women
Lecture at one-day workshop, NIFTEM, Thanjavur.
Lead presentation during Save Soil event, ISHA Foundation, Tirunelveli
Lead presentation at Futuristic Horticulture ICFH'24, HC&RI, TNAU, Coimbatore
External examiner for Ph.D. thesis and viva voce at KAU-CoA, Vellayani.
Management Representative for ISO 9001:2015 certification
Editor and Editorial board member in five leading National and International journal
Chairperson for VIP Coordination, Awards & Mementos Committee during 31st FD& KM.
Member of organizing committee for Triphal Diversity Show held at ICAR-IIHR, Bengaluru.

Nodal Officer of ITMU, ICAR-NRCB
Technical Consultant for AP Food Processing Society, for establishment of Banana Food Park.
Invited speaker at Scientific Writing Workshop at TNAU, Coimbatore and HC&RI Periyakulam
Lecture at Lovely University.
Invited speaker at DSU HR Conclave Meet at Dhanalakshmi Sreenivasan University, Tiruchirappalli.
K.N. Shiva
Invited lead talk in the International Conference held at TNAU, Coimbatore
Keynote address at Dr. Nalla G. Palaniswami Arts & Science College
Member of Advisory Committee for Ph.D. student from Kerala Agricultural University, Thrissur
Coordinator, Organizing & Exhibition Committee of Tri Phal Diversity Show-2024
Evaluated Ph.D. thesis for Dr. YSRHU, Tadapalligudem, West Godavari District, Andhra Pradesh.
IMC member of ICAR, participated in the 2nd meeting of 10th IMC of IISR, Calicut, Kerala
Member (ABI nominee), ITMC (reconstituted committee) of ICAR-NRCB, Tiruchirappalli
Selection committee member for the recruitment of SMS at ICAR-KVK, BSS, Idukki
Convener, panel discussion during the 31st Foundation Day and Kisan Mela
External Examiner for Ph.D. thesis from to Dr. YSRHU, Tadapalligudem, Andhra Pradesh
Special invitee for XXVIII Institute Management Committee (IMC) meeting of ICAR-NRCB
Organizing Secretary, Interactive Meet organized jointly by ICAR-NRCB and TNAPEx, Chennai
Coordinator, Awareness Programme for Fiber Artisans organized jointly by ICAR-NRCB & KVIC
Evaluated M.Sc. thesis for TNAU, Coimbatore & Dr. YSRHU, Andhra Pradesh
Co-Chairman, Farmers - Scientists Interface during Kisan Diwas, ICAR-NRCB
C. Karpagam
Organizing Secretary for Tri Phal Diversity Show 2024, organized by ICAR-IIHR & ICAR-NRCB
Chief Guest & a guest lecture at the Thottiyam Banana Farmers Producers Company function
Member Secretary for the selection of awardees on 31st Foundation Day and Kisan Mela
Nodal Officer of ICAR-NRCB for VBSY Programme
Chairperson, Award Mementoes Certificate and Media Publicity Committee during FD&FM
Chairperson-Press & Media Committee for awareness programme: “Transforming Waste to Wealth”
Chairperson- Farmers & FPO Coordination & Media Publicity Committee for Kisan Diwas – 2024
Convener, Publication Committee & Mass Media/Social Media Committee during 31st FD & FM
Convener -National Science Day – 2024: Chairperson- Visitors Mobilization
Convener for Programme on Interactive Meeting on Strengthening Tamil Nadu Connectivity
Chairman- Publication, Publicity, Media, Exhibition and Extension Committee, ICAR-NRCB
Chairman- Library Advisory Committee, ICAR-NRCB
Coordinator for the ICAR-NRCB Exhibition at Agri Index by CODDISIA, Coimbatore
Nodal officer for VBSY Programme at ICAR-NRCB
Coordinator for ICAR-NRCB exhibition at Agri Tech Expo – 2024 at Attur, Salem
Nodal Officer for training programme Organised by ICAR-NAARM, Hyderabad
Co-Chairperson, Programme and Farmers FPO Coordination Committee for 31st FD &FM
Co-Nodal Officer, Intellectual Technology Management Unit (ITMU), ICAR-NRCB

Co-Chairperson for Programme Committee & Exhibition Stall Committee during Kisan Diwas – 2024
Member- Variety, Germplasm and Technology Identification Committee; HRD and PG Cell
Advisory Committee Member for M.Sc. student from Annamalai University.
ICAR nominee for the Assessment of Technical Personnel at ICAR-IISR, Kozhikode, Kerala
Invited lecture on "Precision Farming in Banana" for MANAGE training programme
Lead presentation during Save Soil event, ISHA Foundation, Tirunelveli
Lead presentation during CII. Agri Expo, Attur
Five guest lectures at off campus training programmes
External Expert for the SMS Selection Committee Meeting at KVK, Ariyalur
External Examiner for the viva voce of ten students at KAU, Kerala
Evaluated three M.Sc. (Agricultural Extension Education) thesis from TNAU, Coimbatore.
Moderator for the panel discussion during Banana Festival & Kisan Diwas 2024
G. Prabhu
Top cited article (2022–2023) by WILEY for the publication in Grass and Forage Science journal.
"Excellence in Reviewing" recognition by Indian Journal of Agricultural Sciences, ICAR, New Delhi.
K.J. Jeyabaskaran
Soil Science expert in the committee meeting for the assessment of ARS Scientist of ICAR-SBI
Resource person for a one day training programme at KVK, Sirugamani, Tiruchirappalli.
Lecture at Banana Farmers' Meet organized by Tamil Nadu State Rural Livelihoods Mission, Tuticorin
Lecture during World Soil Day at Mother Teresa College of Agriculture, Iluppur, Pudukkottai
K. Nagendran
Jury for Poster Evaluation in ICPPH 2024
Rapporteur for one technical session in VIROCON 2024
Guest lecture at the Department of Plant Pathology, TNAU, Coimbatore
Expert for the Scientific Writing Workshop for Ph.D. and M.Sc. students at Coimbatore
Evaluated one M.Sc. (Plant Pathology) thesis of TNAU, Coimbatore.
Served as External Examiner for one Ph.D. candidate at TNAU.
Reviewer for ten National & International journals.
C. Anuradha
Expert member in five committee for the selection of various posts at ICAR-NRCB
Lecture at Bishop Heber College during International Day of Women and Girls in Science
Resource person for two Internship Training Programme for M.Sc. & B.Sc students
Nodal Officer – SC-SP Cell, Co-Nodal Officer – Swachh Bharat Mission,
Member – Library Committee, HRD Cell, PMEC, Institute Biosafety Committee
Convener - Registration and Member- Hospitality & Refreshment Committee during 31st FD
Convener - Registration Committee for the National Science Day 2024
Pramod Shelake
Best Performer during the ICAR Short Course conducted by ICAR-CIRCOT, Mumbai

A. Mohanasundaram
Editor – Agriculture and Food (e-newsletter)
Reviewer for PLOS ONE, Indian Journal of Entomology & Journal of Non-Timber Forest Products
External expert for reviewing scientific papers by PG/Ph.D. students at ADAC and RI & HC & RI
Lecture at the workshop organised by ICAR-NRCB & Isha at Sathyamangalam, Annur & Karamadai
Co-developer - patent for an invention entitled Natural Resin based Novel Non-Drying Adhesive
Member, selection committee of research personnel for DST-SERB, Virus testing
External member (Two times) in the Board of Studies of Zoology at Bishop Heber College
Member, selection committee for YP I - Virology Lab & CRP on Vaccines and Diagnostics project
Evaluated M.Sc. thesis (Entomology) for AC and RI, Madurai, TNAU, Coimbatore
M. Mayilvaganan
DG nominee for DPC under CAS for a biochemistry scientist at ICAR-IISR, Kozhikode
Convener & Panelist at Panel Discussion during the 31st Foundation Day-cum-Kisan Mela
P. Giribabu
Lead lecture at International conference organized TNAU & Shastri Indo-Canadian Institute, New Delhi
Reviewer, Indian Journal of Nematology
Represented ICAR-NRCB at ICAR-Inter Zonal Sports Meet at ICAR-CAZRI, Jodhpur
Member - Photography, Media, Publicity &Press Co-Ordination Committee of NSD 2024
Co-Chairperson – Registration, Publication Committee during 31st Foundation Day & Kisan Mela
Member – Hospitality, Exhibition, & Field Visit committee during 31st FD & KM
Co-Chairperson - Registration / Reception Committee of Kisan Diwas held at ICAR-NRCB
'Day Nodal Officer' and covered 18 villages of Usilampatti Block under VBSY
Chairman, Sports Committee; Co-Nodal Officer, SC-SP Cell; Member, HRD and PG Cell

8. LINKAGES AND COLLABORATIONS

International collaborations
Alliance of Bioversity International, France
Institute of Food Science and Technology, United Kingdom
DBT–UNESCO–TWAS
Linkage through MoU with ICAR-NRCB
SSN College of Engineering, Chennai
Dhanalakshmi Srinivasan University
SRM Institute of Science and Technology
Uka Tarsadia University, Kishorbhai Institute of Agriculture Sciences and Research Centre, Surat, Gujarat
Linkage with industries
M/s. Mahadhan Agritech Ltd, Pune, Maharastra
M/s. Jayasree Biotech, Hosur, Krishnagiri
M/s. Impensus Electronics Pvt. Ltd, Chennai
M/s. Oleevia Foundation, Palakkad, Kerala
M/s. JISL, Jalgaon, Maharashtra
M/s. Indian Potash Limited
M/s. Mahadhan Agritech Ltd, Pune, Maharastra
M/s. Jayasree Bio-Tech, Hosur, Krishnagiri
M/s. U.M. Agritech, Chinsurah, Hooghly, West Bengal
M/s. Pratyaksha Agrotech Private Ltd., Cachar, Assam
Linkage with other state & Central Government agencies
Madhya Pradesh State Government, Burhanpur, Madhya Pradesh
Satpura Nature Fresh Producer Company Limited, MP.
ICAR-ATARI, Jabalpur, Hyderabad, Bengaluru
NAU, Gujarat and Department of Horticulture,
DBT funded project Transgene free gene editing in high value vegetatively propagated crops - Sugarcane and Banana
Linkage for collaborative Research & Development (R&D) activities
NIFTEM, Thanjavur, TN
ICAR-IIVR, Varanasi, UP
ICAR-CIBA, Chennai
ICAR-IIHR, Bengaluru
ICAR- DRDE Gwalior

Dr. B. Vasanthraj David Foundation
HC&RI, Periyakulam, TN
Nehru Institute of Engineering & Technology, Coimbatore.
Pushkaram college of Agrl. Sciences- Pudukottai
BU, Tiruchirappalli
TNAU, Coimbatore
ICAR-IISR
NAU, Navsari, Gujarat
Shri Shivaji Agriculture College, Amravati
Sri Sivasubramaniya Nadar College of Engineering, Chennai
JAU, Junagadh, Gujarat
PJTSAU, Hyderabad
ICAR-CIARI, Port Blair
University of Delhi (South Campus)
ICAR-CTCRI, Thiruvananthapuram
ICAR-DFR, Pune
Kerala Agricultural University (KAU), Vellayani
ICAR-CICR, Nagpur
Madurai Kamaraj University
SASTRA University
Gandhigram Rural Institute, Dindigul
Annamalai University
ICAR-Directorate of Cashew Research
Dr. YSRHU, Andhra Pradesh
PSG Krishnammal College for Women, Coimbatore.
Mother Teresa College of Agriculture, Iluppur, Pudukkottai

Project based linkage

Project	**Collaborating Institute(s)**
Artificial intelligence (AI) powered decision support system development for leaf spot disease management in banana (lead centre: ICAR-NRCB)	BRS, Jalgoan (Maharastra), FRS, NAU, Gandevi (Gujarat), BRS, KAU, Kannara (Kerala), HRS, Kovuur (AP), HRS, Pulivendula (AP), ICAR-IIHR, Bengaluru (Karnataka), College of Hort., Arabhavi (Karnataka), HC &RI, TNAU, Coimbatore (Tamil Nadu), Dr. Rajendra Prasad Central AU, Pusa (Bihar) OUAT, Bhubaneswar and BCKV, Mohanpur

Extension & Outreach based Linkages	
Effective utilization of different extension methods and mass media for holistic transfer of banana technologies for different stakeholders in banana production system (Lead centre: ICAR-NRCB and in charge of the programme: Dr. C. Karpagam)	KVKs, ATARIs, FPOs from different states ATMA
TV Chennels: Kumudham News 24x7, Raj News-TV, Dinamalar, Puthiyathalaimurai TV, Makkal TV, Jeya TV, Thanthi TV, Dinamalar TV, Puthiyathalaimurai TV, Makkal TV, Jeya TV, Thanthi TV, Sathiyam TV, Tamilan TV, Dinamalar-TV	
Print Media The Hindu, The New Indian Express, Now India, Dinamalar, Dinamani, Daily Thanthi, Dinakaran, Hindu Tamil Thisai, The Times of India, Malai Murasu, Malai Malar, Pasumai vikadan, Muthal Oosai, Malai murasu news TV, Makkal TV, Jeya TV, Thanthi TV, Sathiyam TV, Tamilan TV, Dinamalar TV, DD Tamil TV, News Tamil TV, AIR News Trichy & Chennai, PTI and Social media etc.	
All India radio , Tiruchirappalli	
ISHA Outreach programme, Coimbatore	
CODISSIA, Coimbatore, TN	
CII & Rasi Seeds Pvt. Ltd, Attur, TN	
CCI at Thanjavur, TN	
ISHA, Save soil Movement at Tirunelveli, TN	
National Horticultural Mission	
Department of Agriculture, Basti District, Uttar Pradesh	
Department of Agriculture, Raver District, Maharashtra	
Department of Agriculture, Kalakurchi block, Cuddalore district	
Department of Agriculture, Kalakkad, Tirunelveli district	
Dept. of Agriculture, Govt. of Puducherry, Puducherry	
Dept. of MSME, By DIC, Trichy	
Gramodyog Vikas Yojana	
Manneswarar FPO from Annur, Mettupalayam TK, Coimbatore Dt., TN	
Karamadai FPO from Karamadai, Mettupalayam TK, Coimbatore Dt., TN.	
Thottiyam Banana Farmers Producers Company, Tiruchirappalli	
Avinashappar FPO Ltd., Tiruppur	
KVKs in MP & Chhattisgarh, and in Tamil Nadu	
ASSOCHAM, NIFTEM- T & TNAPEX at NIFTEM, Thanjavur, Tamil Nau	
ICAR-NAARM, Hyderabad	
MANAGE, Hyderabad	
NR IAS Academy, Tiruchirappalli	

Dhanalakshmi Srinivasan University, Tiruchirappalli

Uka Tarsadia University, Kishorbhai Institute of Agriculture Sciences and Research Centre, Maliba Campus, Gopal Vidyanagar, Bardoli - Mahuva Road, Ta. Mahuva, Dist - Surat, Gujarat

SRM Institute of Science and Technology, Tiruchirappalli

Jayasree Biotech, Hosur, Krishnagiri

9. PUBLICATIONS

9.1 Research Papers

9.1.1 International

Ali, M, Hazra, DK, Naiya, H, Sharma, KK, Mohanasundaram, A. 2024. Microwave-assisted extraction and purification of aleuritic acid from seed lac: A fast, eco-friendly and cost-effective single process for enhanced yield and purity. *Chemical Engineering & Processing: Process Intensification.* 197:1-10. DOI:https://doi.org/10.1016/j.cep.2024.109716.

Anuradha, C, Chandrasekar, A, Backiyarani, S, Thangavelu, R, Uma, S and Selvarajan R. 2024. 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.* 52:109803.

Anuradha, C, Mol PP, Chandrasekar, A, Backiyarani, S, Thangavelu R and Selvarajan R. 2024. Unveiling the dynamic expression of PR-1 during Musa spp. infection by *Fusarium oxysporum* fsp. *cubense*: a cloning and characterization study. *Molecular Biology Reports*. 51 (1): 362.

Borthakur, P, Chinnasamy, K, Suresh Kumar, P, Venkatachalam, S, Alagarswamy, S, Iruthayasamy, J, Thiyagarajan, E and Muthusamy, S. 2024. Exogenous Melatonin as Pre- and Postharvest Application on Quality Attributes, Antioxidant Capacity, and Extension of Shelf Life of Papaya. *Horticulturae.* 10:1099. https:// doi.org/10.3390/horticulturae10101099.

Czerwiński, T, Poorani, J, Thanigairaj, R and Szawaryn, K. 2024. Revision of an Enigmatic Ladybird Genus *Empia* Weise, 1901 (Coleoptera: Coccinellidae) with Description of a New Species from India. *Annales Zoologici*. 74(2): 325–336.

Dev, R, Patidar, A, Sureshkumar, M, Kumar, S, Venkatesan, K, Saranya, R, Singh, T and Dayal D. 2024.Genetic diversity assessment of *Cordia gharaf* (Forsk.) germplasm for morpho-physiological and fodder traits in hot-arid Kachchh region of India. *Indian Journal of Plant Genetic Resource.* 37(2):283-293.

Halli, HM, Govindasamy, P, Wasnik, VK, Shivakumar, BG, Swami, S, Choudhary, M, Yadav, VK, Singh, AK, Raghavendra, N, Govindasamy, V and Chandra, A. 2024. Climate-smart deficit irrigation and nutrient management strategies to conserve energy, greenhouse gas emissions, and the profitability of fodder maize seed production. *Journal of Cleaner Production*. 442: 140950.

Hrishikesh, P, Naik, R and Suresh Kumar, P. 2024. Utilization of banana crop ligno-cellulosic waste for sustainable development of biomaterials and nanocomposites. *International Journal of Biological Macromolecules.* 282:137065.

Iyarin, TME, Aravind Kumar, BN, Babu, R, Nirmalnath, PJ, Hebsur, NS, Halli, HM, Govindasamy P, Senthamil, E, Sannagoudar, MS and Palsaniya, DR. 2024. Nanocomposite based slow release atrazine effectively controlled Striga asiatica incidence, and enhanced sugarcane yield. *Scientific Reports*. 14(1): 30821.

Kalaivani, J, Jedadeeswari, V, Vijayalatha, KR, Arulmozhiyan, R, Meena, S, Selvarajan, R, Ravi, I and Jeyabaskaran, KJ. 2024. Impact of Salinity in Tropical Fruit Crops – A Review. *Communications in Soil Science and Plant Analysis.* 55: doi.org/10.1080/00103624.2024.2390478.

Kaur, R, Bana, RS, Singh, T, Meena, SL, Raj, R, Dass, A, Govindasamy, P, Gill, JS, Kumar, S, Sen, S and Kumar S. 2024. Sequential herbicide application coupled with mulch enhances the productivity and quality of winter onion (*Allium cepa* L.) while effectively controlling the mixed weed flora. *Frontiers in Sustainable Food Systems.* 7:1271340.

Kumaravel, M, Uma, S, Backiyarani, S, Saraswathi, MS, Mayilvaganan, M and Anuradha, A. 2024. Endogenous phytohormone analysis during sequential stages of somatic embryogenesis in Musa AAA cv. Grand Nain (subgroup Cavendish). *Israel Journal of Plant Sciences.* DOI:https://doi.org/10.1163/22238980-bja10099.

Mahesh, S, Nirmal, K, Varun, P, Ravi, I and Jeyabaskaran, KJ. 2024. IoT and sensor technologies: Increased water and nutrient savings and profit in Banana cv. Grand Nain (AAA) production. *Scientia Horticulturae.* 341: doi.org/10.1016/j.scienta.2025.113982.

Majumder, S, Mishra, P, Pandey, J, Nagendran, K, Sharma, S, Maurya, S, Singh, AK, Pandey, KK and Behera, TK. 2024. Optimisation and application of the multi-residue analysis method for detection of 50 pesticides in cabbage by using LC-MS/MS-QuEChERS. *International Journal of Environmental Analytical Chemistry*. 1-18. https://doi.org/10.1080/03067319.2024.2313004.

Muthulakshmi, C, Priya, J, Mayilvaganan, M and Purushothaman, M. 2024. Proximate Analysis and Estimation of flavan-3-ol compounds in Grape Seed Extract. *International Journal for Scientific Research and Development.* 9(4): 1473-1478.

Nagargade, M, Singh, MK, Tyagi, V, Govindasamy, P, Choudhary, AK, Rajpoot, K, Kumar, A, Singh, P and Sarangi, D. 2024. Ecological weed management and square planting influenced the weed management, and crop productivity in direct-seeded rice. *Scientific Reports.* 14(1): 10356.

Nagendran, K, Kumari, S, Vignesh, S, Pradeep, RM, Reddy, YS, Bahadur, A and Behera, TK, 2024. Molecular characterization of emerging distinct watermelon bud necrosis virus (Orthotospovirus citrullonecrosis) variant causing necrosis disease on tomato in India. *Physiological and Molecular Plant Pathology*. 131:102276.

Nalawade, RD, Singh, KP, Roul, AK, Agrawal, KN, Sonawane, S, Mahore, A, Patel, A, Kumar, M, Shelake, P, Salem, A and Elbeltagi, A. 2024. Study on the effect of geometrical and operational parameters on performance dynamics of modified rotary blades using DEM. *Scientific Reports*, 14(1):19239.

Nargund, R, Verma, RK, Ramesh, A, Sharma, MP, Halli, HM and Govindasamy P. 2024. Short-term benefits of tillage and agronomic biofortification strategies on soil properties, carbon sustainability, and seed quality under the soybean–wheat cropping sequence in Central India. *CLEAN- Soil, Air, Water*. 52 (11): e202300300.

Palsaniya, DR, Kumar, TK, Chaudhary, M, Choudhary, M, Govindasamy, P, Prasad, M and Srinivasan R. 2024. Tillage and mulching influence weed community dynamics and crop productivity of Sesbania alley–based food–fodder systems in rainfed agro-ecosystems. *Field Crop Research*. 314: 109411.

Poorani, J, Anuradha, C, Thanigairaj, R and Prashina Mol, P. 2024. Coccinellid predators of mealybugs infesting banana in South India, including a new species and a new record of *Scymnus* Kugelann (Coleoptera: Coccinellidae), with notes on other natural enemies. *Zootaxa*. 5419 (4): 525-544.

Poorani, J. 2024. A Brief Review of the Microweiseinae (Coleoptera: Coccinellidae) of the Indian Region, Including Description of a New Species. *Insects*. 15(11): 874. https://doi.org/10.3390/insects15110874.

Poorani, J. 2024. A new host association for *Euryischia indica* Mani & Kurian (Hymenoptera: Pirenidae) from India. *Specimen*. 21: 1–2. https://doi.org/10.56222/28166531.2024.21.

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10. CONSULTANCY SERVICES AND COMMERCIALIZATIONOF TECHNOLOGIES

Consultancy Services / Contract Research / Commercialization of Technology

I. Contract Research				
S. No.	**Date**	**Name of the Technology**	**Address of the Client**	**Revenue (Rs. in Lakhs)**
1.	24.06.2024	Assessing the efficiency of customized water-soluble fertilizer grades on improvement of banana growth, yield and quality	M/s. Mahadhan Agritech Ltd, Pune, Maharastra	2747087.00
2.	21.09.2024	Variety specific tissue culture protocols for commercial banana varieties	Mr. Rama Vijayraja, 283, Old Street, Kurinjipadi (TK), Cuddalore - 607301, Tamil Nadu	50000.00

II. Commercialization of Technologies				
Crop Improvement				
S. No	**Date**	**Technology**	**Address**	**Revenue**
1.	20.03.2024	Kaveri Kalki	M/s. Jayasree Bio-Tech, Hosur - 635109, Krishnagiri	15000.00
2.	17-21.09.2024	Variety specific tissue culture protocols	Mr. Rama Vijayraja, Kurinjipadi (TK), Cuddalore.	50000.00
Crop protection				
1.	06-09.02.2024	Bio-stimulant for enhanced growth and yield in banana	M/s. U.M. Agritech, Chinsurah, Hooghly – 712 103, West Bengal	200000.00
2.	12-13.08.2024	Triple Antibody Sandwich ELISA (TAS-ELISA) kit	The Professor & Head, Banana Research Station, Thrissur, Kerala - 680 652.	90000.00
Post-harvest technology				
1.	01.03.2024	Low fat fortified banana chips	M/s. Kisan Kairali Producer Company Ltd., Karshika Vikasana Bank Building, Kannur, Talap - 670002, Kerala	25000.00
2.	16.04.2024	Dehydrated / fortified / flavored ripe banana fig	M/s. Puthuvazhvu Banana Famers Producer Company Limited, Kanjiracode P.O, Kanyakumari - 629155, Tamil Nadu	25000.00

3.	11.06.2024	Fortified basil seed suspended banana juice	Mr. Yash Vyas, Ratlam - 457001, Madhya Pradesh.	25000.00
4.	09-10.07.2024	Process for making banana Grits/Suji and flakes	Ms. J. Jeevika Shree, Palladam, Tiruppur - 641664	25000.00
5.	06-07.08.2024	Banana flour-based weaning (Baby) food	Mr. Anish John, Mavila Villa, Nallila (Po), Nedumpana, Kollam - 691515, Kerala	25000.00
6.	28-29.08.2024	Dehydrated / fortified / flavoured ripe banana fig	Mr. Satish Viswanathan, M/s. Parvat Premium Agro Products, Bangalore - 560076, Karnataka	25000.00
7.	10-11.09.2024	Central core stem juice	Mr. Neelesh Gharmalkar, M/s. Mahaorganic FPC, Ltd., - 411004, Maharashtra.	25000.00
8.	18-19.09.2024	Post-harvest handling, packing, storage and ripening of banana	Mr. I. Mohammed Rafeek, M/s. Happy Morning Export / Import, Coimbatore	25000.00
9.	23-27.09.2024	Banana flour-based low glycemic prebiotic extruded snacks. Rhizome based hot extruded puffed snack Low fat fortified & flavoured chips Cost effective ripe banana powder & products	Mr. Tushar Kolhe, M/s. Amrutaya Processing (India) Private Ltd., Pune - 412115, Maharashtra	87500.00
10.	18-20.11.2024	Banana flour-based weaning (Baby) food Banana flour-based low glycemic prebiotic extruded snacks like noodles, pasta & prebiotic cookies. Ready to serve clarified banana juice / Fortified basil seed suspended banana juice. Low sodium banana flower, central core stem & peel pickle Central core stem Juice (Low Calorie / Fortified) Rhizome based hot extruded puffed snack Extraction and softening of banana fibre for handicrafts, making plates and bagasse products	M/s. Pratyaksha Agrotech Private Ltd., Cachar - 788113, Assam	189497.00

11.	18-19.11.2024	Central core stem Juice [Low Calorie / Fortified]	Mr. P. Varun, Ambattur, Chennai -600053	25000.00
12.	12-13.12.2024	Banana flour-based weaning (Baby) food	Mr. V. Rajesh, Allur, Trichy - 620102	25000.00
			Total	**881997.00**

M/s. Jayasree Bio-Tech, Hosur, Krishnagiri

Mr. Rama Vijayraja, Kurinjipadi, Cuddalore

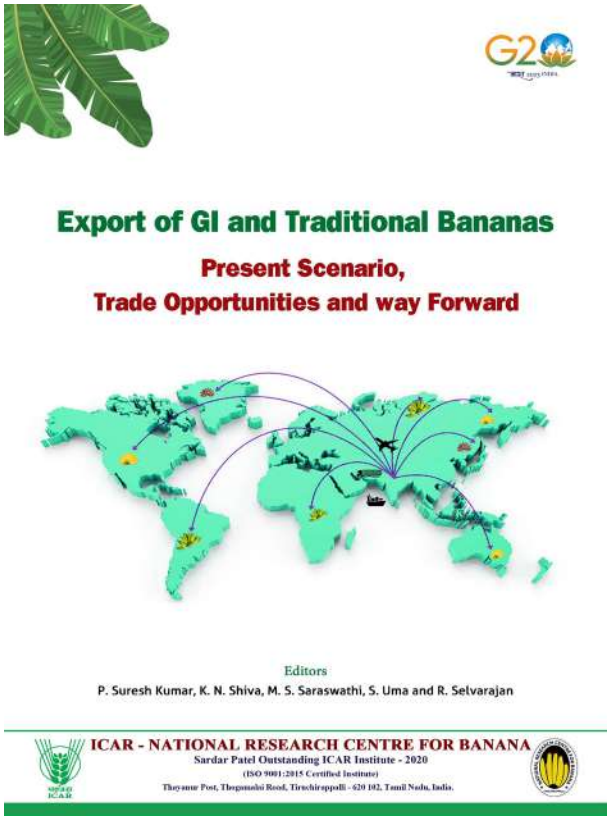
The Professor & Head, Banana Research Station, Thrissur, Kerala

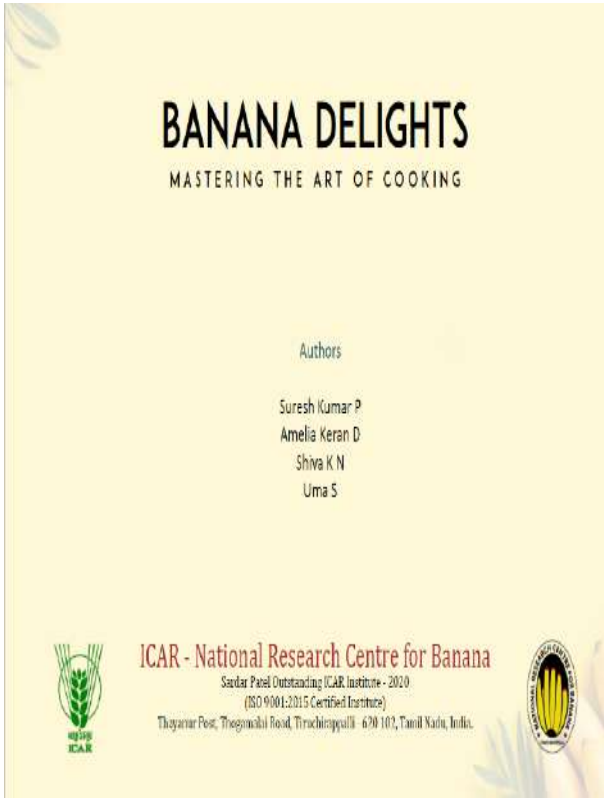
INTELLECTUAL PROPERTY RIGHTS

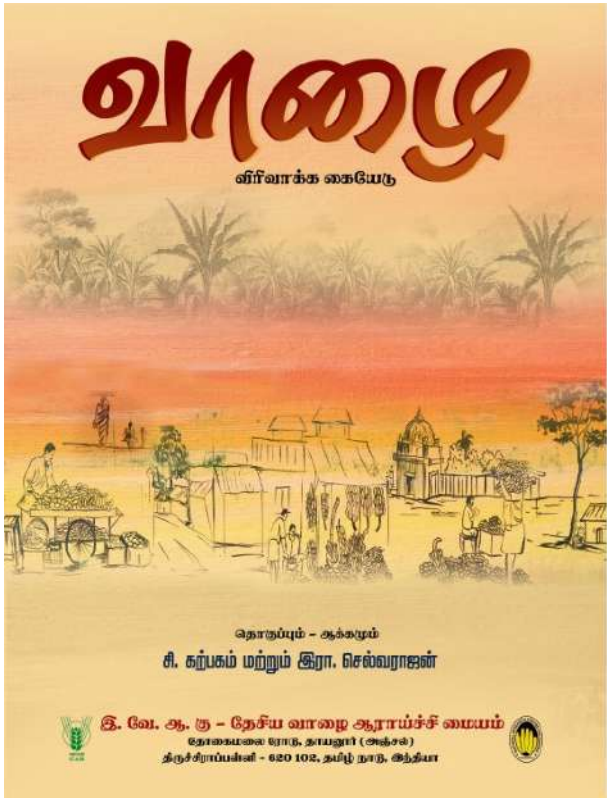
Patents / Trademarks / Copyrights

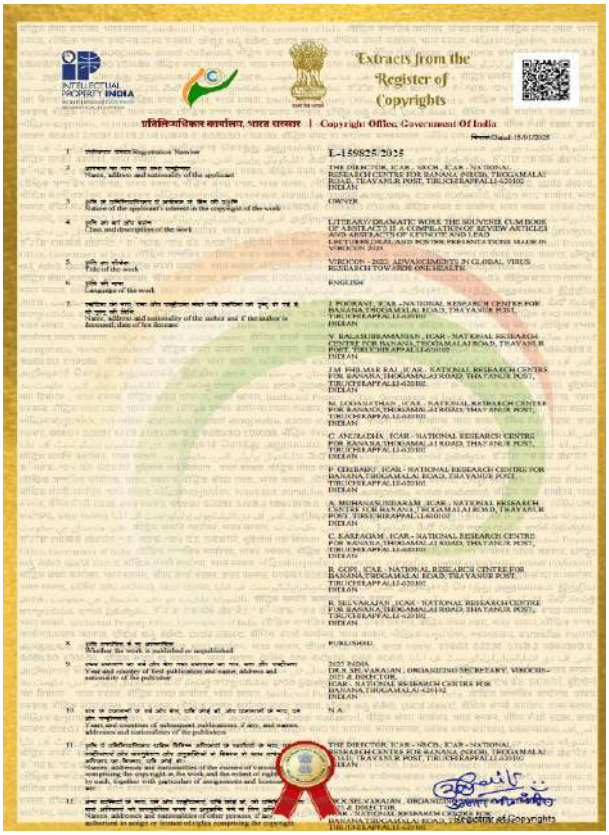
IPRs	Application/ Registration No.	Name of Innovation/ Technology/ Product/ Variety	Date of Filing/ Registration	Application Granted/ Registered
Patent				
Copyrights				
1.	L-159825/2025	VIROCON - 2023: Advancements in Global Virus Research Towards One Health	17/05/2024	Granted
2.	L-159496/2025	Vazhai Virivakka Kaiyaedu	20/05/2024	Granted
3.	L-159870/2025	Export of GI and Traditional Bananas: Present Scenario, Trade Opportunities and Way Forward	17/05/2024	Granted
4.	L-156799/2024	Banana Delights: Mastering the art of cooking	20/05/2024	Granted
5.	15936/2024-CO/SW	R-package (AgroSoilIndices) to calculate soil physical, chemical and root parameters	17/05/2024	Granted

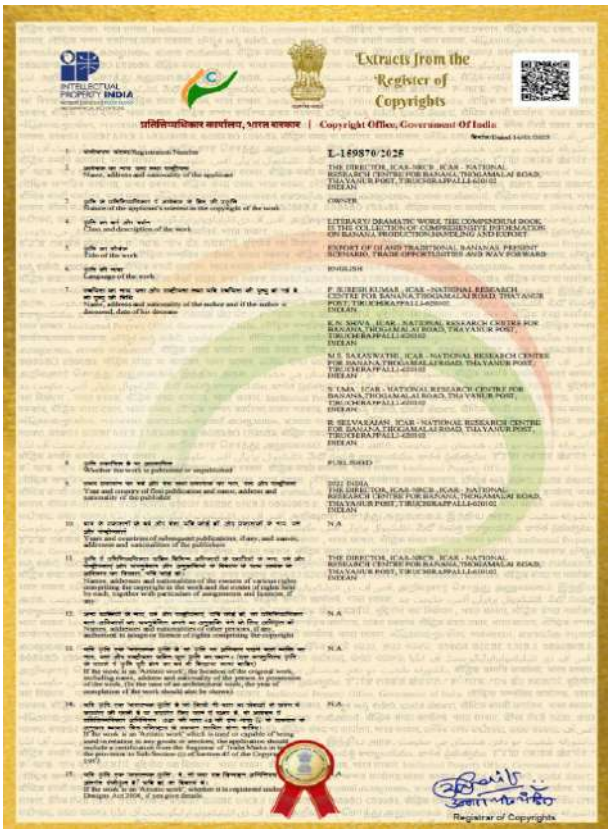
6.	15930/2024-CO/SW	Banana ripening stage classifier using CNN-XgBoost	17/05/2024	Granted
7.	28524/2024-CO/SW	Program for mass modeling of fruits / vegetables based on physical properties	12/09/2024	Registered








Extracts from the Register of Copyrights
L-159825/2025


Extracts from the Register of Copyrights
L-149870/2025


Extracts from the Register of Copyrights
L-149496/2025


Extracts from the Register of Copyrights
L-186799/2024

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11. IRC / RAC / IMC MEETS

RAC Meeting

The 24th Research Advisory Committee meeting was held on 3-4 January 2024 to review the work done in all research projects. All the scientists presented their research achievements and action taken on the previous RAC recommendations.

Mid-IRC 2024

The mid-IRC 2024 meeting was held on 19 and 29 January 2024 to review the work done in all research projects. All the scientists presented their research achievements and action taken on the previous XXVI-IRC recommendations.

IRC Meeting

The Twenty Seventh Institute Research Council (XXVII-IRC) meeting was held from 8-7-2024 to 10-7-2024 and 28-8-2024 in the ABI hall of the Centre with all the members. The Chairman of IRC appreciated the good work of Scientists and emphasized that the major recommendations of the RAC, if feasible, should be taken into consideration and included in the technical programme. The Director also suggested that both ongoing and new projects should end up in a technology/publication/ patent. The salient achievements made under various institute and externally funded projects were presented by the scientists in two phases for four days.

IMC

The XXVIII Institute Management Committee (IMC) meeting of the Centre was held at the centre on 09.09.2024 (Monday). Key research achievements of the Centre were highlighted. The Director of ICAR-NRCB provided updates on infrastructural developments and discussed IMC-related issues.

12. TRAINING / REFRESHER COURSE

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	Executive Development Programme (EDP) on Leadership Excellence	ICAR-NAARM, Hyderabad.	12-17 February 2024
K. Nagendran	Short course on Volatilomics	TNAU, Coimbatore	1–10 February 2024
	Laboratory Quality Management System and Internal Audit	BIS, Southern Regional Office, Chennai	14 – 17 May 2024
	Application of CRISPR-Cas mediated genome editing for vaccines and diagnostics	ICAR-IVRI, Hebbal, Bengaluru	2 – 6 December 2024
P. Suresh Kumar	Building a Successful Incubation Ecosystem	ICAR-NAARM, Hyderabad	3 – 5 July 2024
	Empowering ZTMC and ITMU	IP&TM Unit, ICAR, New Delhi	13 – 15 February 2024
Pramod Shelake	Professional Attachment Training (Three months)	ICAR-CIRCOT, Mumbai	11 January – 19 April 2024
	Advances in Applications of Nanotechnology in Agriculture	ICAR-CIRCOT, Mumbai	29 January – 08 February 2024
	Value Chain Management in Natural Fibres	ICAR-NINFET, Kolkata	25 – 29 November 2024
A. Mohanasundaram	Winter school on Recent Advances in Molecular Diagnostics of Insect Species including Invasive and their Natural Enemies	ICAR-NBAIR, Bengaluru	18 January – 07 February 2024
I. Ravi	Statistical training programme on "'R' for Biological Data Analysis	ICAR–CTCRI, Thiruvananthapuram	08 – 12 January 2024
P. Giribabu	Developing Winning Research Proposals	ICAR-NAARM, Hyderabad	15 – 19 July 2024
T. Shuprajhaa	Faculty Development Programme on Machine Learning Techniques and its Real-Time Applications	K. Ramakrishnan College of Engineering, Tiruchirappalli	14 – 19 October 2024

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 August 2024
All staff of ICAR-NRCB	National Science Day – 2024	ICAR-NRCB, Trichy	28 February 2024
All staff of ICAR-NRCB	Banana festival and Kisan Diwas 2024	ICAR-NRCB, Trichy	23 December 2024
R. Selvarajan M. Mayil Vaganan S. Backiyarani M.S. Saraswathi C. Anuradha K. Nagendran	16th IBSC meeting	ICAR-NRCB, Trichy	12 April 2024
R. Selvarajan M. Mayil Vaganan	CCC visit meeting on EST trial	ICAR-NRCB, Trichy	4 May 2024
R. Selvarajan K.N. Shiva S. Backiyarani Pramod Shelake C. Sivananth S. Harishwar S. Ajith Kumar	96th ICAR foundation day and technology day	NASC, New Delhi	15 July 2024
R. Selvarajan R. Thangavelu V. Kumar M.S. Saraswathi M. Loganathan	XI group discussion of ICAR-AICRP on fruits	NAU, Navsari, Gujarat	16 July 2024
R. Selvarajan R. Thangavelu	National Conference on Plant Health for Food Security: Threats and Promises	ICAR-IISR, Lucknow	1–3 February 2024
R. Selvarajan Pramod Shelake Shelake	State-level banana workshop at Shri Shivaji Agriculture College, Amravati	Amravati	27 August – 2 September 2024
R. Selvarajan C. Karpagam P. Suresh Kumar K.J. Jeyabaskaran	ISHA Save Soil Movement Workshop & Expo 2024	ISHA at Tirunelveli	24 November 2024
R. Selvarajan C. Karpagam K.N. Shiva V. Kumar	CCI-Delta Agri & Food Expo 2024	CCI, Thanjavur	4–6 October 2024
K. Nagendran P. Giribabu	International conference on Plant Protection in Horticulture: Advances and challenges	ICAR-IIHR, Bengaluru	25–27 September 2024

R. Selvarajan	Indo-Israel workshop on network reliability in WSN for agricultural applications	Sri Sivasubramaniya Nadar College of Engineering, Chennai	04–05 January 2024
	Meeting on Sustainable plant protection strategies for Andaman and Nicobar Islands	ICAR-CIAR, Port Blair	21–22 March 2024
	National and international patent filing on the occasion of World IP Day – 2024	ICAR-NRCB, Tiruchirappalli	30 April 2024
	Global conference on Nano Connect 2024	Directorate of NRM, TNAU, Coimbatore	05 September 2024
	International conference on plant protection in horticulture – advance and challenges (ICPPH-2024)	ICAR-IIHR, Bengaluru	24–25 September 2024
	VIROCON 2024: International conference on "Emerging viruses: Pandemic & biosecurity perspectives	DRDE, Gwalior & IVS, New Delhi	11–13 November 2024
	Annual conference of Vice-Chancellors of agricultural universities and ICAR directors	NASC, New Delhi	26–27 February 2024
	National conference on the paradigm and dynamics of digital horticulture for food, nutrition, and entrepreneurship	JAU, Junagadh, Gujarat	28–31 May 2024
	National symposium on Transforming IARI into a global leader in agricultural research and education	ICAR-IARI, New Delhi	22 June 2024
	9th Agricultural Graduate Students Conference (AGSC) 2024	School of Post Graduate Studies, TNAU, Coimbatore	12 August 2024
	National conference on recent advances in plant pathology and innovative approaches in plant disease management (RAPPID)	PJTSAU, Hyderabad	12 December 2024
	Valedictory function of the ICAR-sponsored 10 days short course on "Volatilomics	Dept. of Agricultural Microbiology, TNAU	01 March 2024
	CRPVD annual review meeting	ICAR at IVRI, Bengaluru	06 March 2024
	National Hrticulture Fair-2024	ICAR-IIHR, Bengaluru	07 March 2024
	Board of Studies (BoS) meeting of Bengaluru Academic Hub	Virtual mode	11 March 2024
	MIDH-NHM state level executive committee meeting	Secretariat, Chennai, Tamil Nadu	01 June 2024

R. Selvarajan	Indo-Israel workshop on network reliability in WSN for agricultural applications	Sri Sivasubramaniya Nadar College of Engineering, Chennai	04–05 January 2024
	Meeting on Sustainable plant protection strategies for Andaman and Nicobar Islands	ICAR-CIAR, Port Blair	21–22 March 2024
	National and international patent filing on the occasion of World IP Day – 2024	ICAR-NRCB, Tiruchirappalli	30 April 2024
	Global conference on Nano Connect 2024	Directorate of NRM, TNAU, Coimbatore	05 September 2024
	International conference on plant protection in horticulture – advance and challenges (ICPPH-2024)	ICAR-IIHR, Bengaluru	24–25 September 2024
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	Board of Studies (BoS) meeting of Bengaluru Academic Hub	Virtual mode	11 March 2024
	MIDH-NHM state level executive committee meeting	Secretariat, Chennai, Tamil Nadu	01 June 2024

R. Selvarajan	Signed an MoU with Government of Madhya Pradesh, Bhopal	Secretariat, Govt. of MP	01 July 2024
	ICAR-AUs interaction meeting	Virtual mode	08–10 July 2024
	62nd annual function and tri-festival – Mupperum Vizha	Alagappa University, Karaikudi	17 August 2024
	Working group on post-harvest engineering & technology for horticulture	NASC, New Delhi	31 August 2024
	Interactive meeting on strengthening Tamil Nadu connectivity: Trichy – international hub for agricultural exports,	ICAR-NRCB & TNAPEx	24 September 2024
	Transforming waste to wealth: Unlocking the value of banana fibre (Gramodyog Vikas Yojana),	ICAR-NRCB & KVIC,	10 October 2024
	Second ICAR–IIHR industry meet of South Zone horticultural institutes	ICAR-IIHR, Bengaluru	24 October 2024
	Second review meeting of the advisory committee for the project	ICAR-CTCRI, Thiruvananthapuram	09 December 2024
J. Poorani	Regional Committee Meeting of Zone VIII	CIBA, Chennai	16 February 2024
R. Thangavelu	Board of Studies meeting	Srimad Andavan Arts & Science College, Trichy	30 April 2024
M.S. Saraswathi	Banana breeder's interactive meeting	Alliance of Bioversity International, France	16–20 April 2024
	District executive council meeting	Trichy Collectorate	7 August 2024
	Interactive meet on strengthening Tamil Nadu connectivity: Trichy – international hub for agricultural exports	TNApex, Chennai & ICAR-NRCB	27 September 2024
	Scientific writing workshop	HC&RI, Periyakulam	28 May 2024
	Scientific writing workshop	HC&RI(W), Trichy	24–26 June 2024
K. Nagendran	Annual review meeting of ICAR-Consortium Research Platform on vaccines and diagnostics for the year 2023	ICAR-IVRI, Bengaluru	4–5 March 2024
	International conference on "Emerging viruses: Pandemic & biosecurity perspectives (VIROCON-2024)"	DRDO, Gwalior	11–13 November 2024
	International conference on plant protection in horticulture (ICPPH 2024)	ICAR-IIHR,Bengaluru	25-27, September 2024

M.Mayil Vaganan	7th internal review meeting on EST	BIRAC, New Delhi	2 January 2024
	45th SAC meeting of KVK	KVK, Sirugamani,	20 Feb 2024
	Annual project review meeting	BIRAC, New Delhi	11 March 2024
	Board of studies meeting of ICAR Mega University, IARI-IIHR Hub	ICAR-IIHR, Bengaluru	21 March 2024
	Stakeholder meeting on transforming agriculture research - enhancing the role of the private sector	ICAR, New Delhi	3 September 2024
	National conference on managing agro-biodiversity in NE India	ICAR Research Complex for NE Hill Region, Meghalaya	23–25 October 2024
K. N. Shiva	Review meeting of Centre of Excellence for Millets	Thiruvannamalai	20 August 2024
	International Conference on Precision Horticulture – 2024	HC&RI, Periyakulam	22–24 August 2024
	58th foundation day of ICAR-IIHR	ICAR-IIHR, Bengaluru	5 Sep 2024
	One day workshop on Online digital marketing and branding in banana	ICAR-NRCB, Trichy	9 February 2024
	International conference on Translational research towards attaining good health and well-being for sustainable development	Dr. Nalla G. Palaniswami Arts & Science College	9 March 2024
	Workshop on Agricultural and processed food products export promotion	Organized by Tamil Nadu Food Processing and Agri Export Promotion	11 March 2024
K. J. Jeyabaskaran	Training Programme on Advances in fertilizer management with respect to soil fertility in banana cultivation	Indian Potash Limited	19 July 2024
	Training Programme on Innovations in soil and nutrient management for sustainable banana production	Avinashappar FPO Ltd., Tiruppur	6 October 2024
P. Suresh Kumar	International conference on "Futuristic Horticulture ICFH'24"	TNAU, Coimbatore	14–15 Nov 2024
	International conference on exploring the new horizons in nutrition security through sustainable development in food technology	PSGR Krishnammal college for Women, Coimbatore.	21–22 March 2024
	One-day workshop on agri-business opportunities in banana and coconut crops using improved production and value addition technologies	NIFTEM, Thanjavur	23 January 2024
	Inaugural meeting of juice production facility by FPO	Thottiyam	25 January 2024
	31st FSSAI scientific panel meeting	FDA Bhavan, New Delhi	29 July 2024

Pramod Shelake	58th annual convention of the ISAE*	VNMKV, Parbhani	12–14 Nov 2024
A. Mohanasundram	One-day workshop & training on Biomolecular characterization: GC-MS technique	ADAC&RI, TNAU, Trichy	11 December 2024
I. Ravi	National conference on Digital agriculture: Empowering Indian farming	NAAS, New Delhi	17–18 December 2024
V. Kumar	21st SAC meeting	ICAR-SKVK, Karur	21 Feb 2024
	21st SAC meeting	ICAR-KVK, Salem	12 March 2024
	District Mission Committee meeting	Trichy	27 Nov 2024
	Seminar on Emerging trends in plant nutrition – Role of fertilizer policy	Fertilizer Association of India, Madurai	21 March 2024
	Workshop on Sustainable banana farming practices	Kongu Nadu College, Thottiyam	24 October 2024
	Banana cluster meeting & training	TNSRLM: Mahalir Thittam Tuticorin	29 November 2024
	International conference on Unleashing the power of seed and crop health innovations for a food secure world	TNAU, Coimbatore	21–22 November 2024
C. Karpagam	Workshop on agri-business opportunities in banana and coconut crops using improved production and value addition technologies	NIFTEM, Thanjavur	23 January 2024
	Inaugural meeting of juice production facility by FPO	Thottiyam	25 January 2024
	SAC meeting	KVK, Perambalur	1 March 2024
	National conference on emerging opportunities for economic resilience.	Vivekandha Arts & Science College for Women, Salem	16 March 2024
	KVK SAC meeting	KVK, Cuddalore	2 February 2024
	Workshop on “Hi-tech banana cultivation”	Sathyamangalam, Erode	12 March 2024
	Workshop on “Hi-tech banana cultivation”	Annur, Coimbatore	14 May 2024
	Workshop on “Hi-tech banana cultivation”	Karamadai, Coimbatore	15 May 2024
	Print Expo 2024	Chennai Trade Centre	22–24 August 2024
	Workshop during CCI–Delta Agri & Food Expo	Thanjavur	4–6 October 2024
R. Saranya	International Conference on Plant Protection in Horticulture (ICPPH - 2024)	ICAR-IIHR, Bengaluru	25-27 Sep 2024
	Workshop on Biomolecular Characterization: GC-MS Techniques	ADAC & RI, Trichy	11 – 12 December 2024

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

UP banana farmers trained on Hi-Tech banana cultivation at ICAR-NRCB

Farmers from Basti district in Uttar Pradesh underwent comprehensive training on "Improved Production Technologies for Hi-Tech Banana Cultivation" at the ICAR-NRCB during from February 17–21, 2024, sponsored by the State Department of Agriculture, Uttar Pradesh.

National Science Day observed as 'Open Day' by ICAR-NRCB

The ICAR-NRCB hosted the second edition of an "Open Day" on National Science Day, February 28, 2024, to promote science and technology with the theme "Indigenous Technologies for Viksit Bharat." Over 3,500 students from 40 schools and colleges, and more than 500 banana farmers and stakeholders, attended.

Sries of training programme on Integrated banana cultivation for FPO farmers

The ICAR-NRCB and ISHA Outreach jointly organized training programs on "Integrated Cultivation of Banana" for FPO farmers of ISHA Outreach on March 12.

One day workshop on "Online digital marketing and branding in banana"

On February 9, 2024, a one-day workshop on "Online Digital Marketing and Branding in Banana" was organized. Dr. Pragati Gokhale presented insights on "Online Trade and Marketing of Bananas - Marketmirchi

Perspectives," demonstrating the Marketmirchi platform connecting FPOs, farmers, producers, traders/sellers, and buyers.

Training for economic empowerment of women farmers

ICAR-NRCB organized a transformative five-day hands-on training initiative from January 8-12, 2024, centered on "Utilization of Banana Sheath and Its By-products for Women Empowerment" under the SCSP program in Tamil Nadu.

Hands-on Training on Banana Breeding Techniques

The "Hands-on Training on Banana Breeding Techniques" training, conducted jointly by ICAR-NRCB and ICAR-AICRP(F), took place during February 7–9, 2024, at ICAR-NRCB in Tiruchirappalli.

Series of training programmes for FPO farmers of ISHA

ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, and ISHA Outreach jointly organized a series of training programs on "Integrated Cultivation of Banana" for the FPO farmers of ISHA Outreach. A training program was held for Manneeswarar and Chenni Andavar FPOs of Annur block on 14th May 2024. On 15th May, the training was extended to FPO members of Karamadai FPO in Karamadai block. Approximately 550 FPO members were trained with the two programs.

ICAR-NRCB co-organized the Triphal Diversity Show

ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, and ICAR-IIHR, Bengaluru, jointly organized the Triphal Diversity Show 2024. The event, held at ICAR-IIHR, Hesaraghatta, Bengaluru, from May 31 to June 2, 2024, showcased the diversity of mango, jackfruit, and banana varieties. The show attracted over 15,000 visitors and reached more than 20,000 enthusiasts through social media. ICAR-NRCB showcased around 120 distinct banana varieties including GI-tagged bananas with unique traits such as high carotenoids, minerals, iron, resistant starch, medicinal properties, and distinct flavors.

ICAR-NRCB and ISHA outreach (Kaveri Calling) jointly organized "Cultivation of Food Forest and Triphal Diversity Show"

ICAR institutes, including the National Research Centre for Banana (NRCB), IIHR, and CTCRI, partnered with Isha Outreach to host the "Cultivation of Food Forest and Triphal Diversity Show 2024". The event took place at Pushkaram Agricultural College, Thiruvarangulam, Pudukkottai, on June 23, 2024. It showcased the diversity of mango, jackfruit, and banana varieties, drawing over 5,000 farmers and other stakeholders, and reaching over 10,000 through social media, with extensive media coverage. ICAR-NRCB presented various technologies beneficial to farmers, stakeholders, and entrepreneurs.

19th Parthenium Awareness Week

As part of the 19th "Parthenium Awareness Week", ICAR-NRCB organized a Parthenium Awareness Program on August 16, 2024, at its research farm.

31st Foundation Day & Kisan Mela with more emphasis on low Glycemic Index Banana

ICAR-NRCB celebrated its 31st Foundation Day and Kisan Mela on August 21, 2024, under the theme "Banana Diversity and Wealth from Waste." The Director, Dr. R. Selvarajan highlighted the institute's significant achievements, including the development of two new banana varieties, Kaveri Kanchan and Kaveri Vaman, as well as the successful organization of 87 training programs that benefitted over 6,000 stakeholders. The Chief Guest, Dr. Trilochan Mohapatra, lauded NRCB's contributions to R&D in banana cultivation and emphasized the importance of adopting

precision agriculture for sustainable farming. Among the key discussions, the relevance of low glycemic index bananas in promoting health was underscored for the benefit of diverse stakeholders.

Interactive Meet on "Strengthening TN: Trichy– International Hub for Agricultural Exports"

The ICAR-NRCB, Tiruchirappalli, in collaboration with TNAPEx, organized an interactive meeting on September 27, 2024, on "Strengthening Tamil Nadu Connectivity: Trichy–International Hub for Agricultural Exports." Dr. K. Alagusundaram, TNAPEx CEO, emphasized exportable agri-commodities to reach the state's economic goals, while Dr. R. Selvarajan of ICAR-NRCB highlighted the export potential of GI-tagged banana varieties.

Banana Festival and Kisan Diwas

As part of Swachhta Pakhwada 2024 and to honour the farmers while commemorating the birth anniversary of Shri Choudhary Charan Singh, ICAR-NRCB organized a Banana Festival and Kisan Diwas on December 23, 2024. The event was inaugurated by Dr. Sanjay Kumar Singh, Deputy Director General (Horticultural Science), ICAR, New Delhi. Two new facilities — the Common Incubation Centre and the Trainees' Hostel — were also inaugurated on this occasion. The event witnessed the participation of over 600 farmers, stakeholders, and dignitaries.

Training on advanced Banana tissue culture

A ten-day training programme on "Cutting- Edge Techniques in Banana Tissue Culture and its Applications" was conducted at ICAR-NRCB, Tiruchirappalli, from December 11-20, 2024. During the programme, Dr. R. Selvarajan highlighted the role of bioreactor technology in banana tissue culture and

acknowledged ICAR-NRCB's significant contributions to this field over the past 15 years.

Awareness program on Banana fiber Entrepreneurship

ICAR-NRCB and KVIC jointly organized an awareness programme on "Transforming Waste to Wealth: Unlocking the Value of Banana Fibre" on October 23, 2024. The programme was attended by more than 100 women stakeholders.

ICAR-NRCB Participated in CCI-Delta Agri & Food Expo 2024

ICAR-NRCB actively participated in the CCI-Delta Agri & Food Expo 2024, held from October 4- 6, 2024, at Thilagar Thidal, Thanjavur. The event was organized by the Chamber of Commerce & Industry, Thanjavur, and provided a platform for showcasing innovations from ICAR NRCB.

ICAR-NRCB Participated in AGRI INTEX-2024 during 11th - 15th July

The ICAR - NRCB actively participated in the "AGRI INTEX-2024" organized by CODISSIA from July 11-15, 2024 at CODISSIA Trade Fair Complex, Coimbatore. The event attracted 150,000 visitors, including farmers, entrepreneurs, and officials from Tamil Nadu, Kerala, Andhra Pradesh, and Karnataka.

IP Awareness program on Plant Variety Registration

Dr. R. Selvarajan, Director of ICAR-NRCB, chaired a session on "Plant Variety Registration" during the IP Awareness Week hosted by ICAR-NRCP, Solapur, on August 28, 2024. Sh. D. R. Choudhury, Joint Registrar of PPV&FRA, provided an in-depth Information of the plant variety registration process, emphasizing its importance in protecting breeders' and farmers' rights.

One day workshop on "Online digital marketing and branding in banana"

On February 9, 2024, ICAR-NRCB, Tiruchirappalli, organized a one-day workshop on "Online Digital Marketing and Branding in Banana". Chief Guest Ms. Pragati Gokhale, Founder of Marketmirchi, shared insights on connecting FPOs, farmers, and traders through digital platforms.

ICAR-NRCB participated in 96th ICAR Foundation and Technology Day

The ICAR - NRCB showcased around 100 banana varieties at the 96th Foundation and Technology Day of ICAR on July 15-16, 2024 in New Delhi. The Banana Diversity Show attracted the attention of Union Agriculture Minister Shri Shivraj Singh Chouhan and other distinguished dignitaries.

14. DISTINGUISHED VISITORS

S. No	Name of the Official	Date
1.	Dr. Sanjay Kumar Singh, Deputy Director General (Horticultural Science), ICAR, New Delhi	23.12.2024
2	Dr. Trilochan Mohapatra, Chairperson in the Protection of Plant Varieties and Farmers' Rights Authority	21.08.2024
3	Prof. V. Palanimuthu, Director, NIFTEM-T, Thanjavur	27.09.2024
4	Dr. V. Venkatasubramanian, Director, ICAR - Agricultural Technology Application Research Institute	21.08.2024
5	Dr. Shaik N. Meera, Director, ICAR-ATARI, CRIDA	21.08.2024
6	Mrs. Bimi G.B., Deputy Controller of Patents	26.04.2024
7	Dr. K. Alagusundaram, TNAPEx CEO	27.09.2024
8	Sh. D. R. Choudhury, Joint Registrar of PPV&FRA	28.08.2024
9	Dr. (Mrs.) Neeru Bhoosan, ADG (IP&TM)	30.01.2024
10	Dr. S.N. Sudhakar Babu, Drs. S.J. Rahman, Lokesh Naroliya, and Abhilasha Singh Mathuriya Chairmen and member of Central Compliance Committee	05.04.2024
11	K. Sakthivel (Project Lead , Start up TN Madurai MSME Department	23.10.2024
12	Top official from Agricultural Engineering Department -Agricultural Engineering Training Centre-Trichy	11.12.2024
13	Bineesh G.J (ICAR-CTCRI)	06.11.2024
14	Sai Lakshmi (KVK , Sirugamani)	17.05.2024
15	Postal Department staffs from central region ,Tiruchirappalli	08.11.2024
16	Mr. Vijayalayan , Founder, NR IAS Academy	28.02.2024
17	Dr. Pragati Gokhale, Marketmirchi	09.02.2024
18	Dr. R. Sugumar from Shri Jayarangha Nature Cure Hospital, Trichy	21.06.2024




Officials during IMC Meeting

S. No	Name of the Official	Date
1	Dr.V.B.Patel, ADG (Fruits & Plantation Crops), SMD (HS), New Delhi / Member (IMC)	09.09.2024
2	Dr.S.Saranya, Representative of Commissioner of Horticulture & Plantation Crops, Govt. of Tamil Nadu	
3	Dr.M.Sankaran, Head (Division of Fruit Crops), ICAR – IIHR, Bengaluru / Member (IMC)	
4	Dr.A.Ramesh Sundar, Head (Division of Crop Protection), ICAR – SBI / Member (IMC)	
5	Dr.R.H.Laxman, Principal Scientist, ICAR – IIHR, Bengaluru / Member (IMC)	
6	Dr.Aundy Kumar, Principal Scientist, ICAR – IARI, New Delhi / Member (IMC)	
7	Mr.S.B.Baburaj, FAO, ICAR – SBI, Coimbatore / Member (IMC)	
8	Mr.Basavaraj Mali Patil, Kalaburagi / Non-Official Member (IMC)	
9	Mr.R.Surya Kanth, Tiruchirappalli / Non-Official Member (IMC)	

Distinguished Visitors

15. EMPOWERMENT OF WOMEN

Extension-Outreach programme for women farmers

ICAR-NRCB organized various training programs for women farmers from various districts of Tamil Nadu and other states. In the reporting year, the total number of women beneficiaries was 5117. 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 groups	No. of Participants	No. of Women Participants
1	One day ATMA training on Capacity Development Programme for Farmers (CDPF)	2	72	**8**
2	Two days ATMA training on Capacity Development Programme for Farmers (CDPF)	5	225	**15**
3	Five Days days ATMA training on Capacity Development Programme for Farmers (CDPF)	2	41	**20**
4	One day exposure visit by Farmers (CDPF)	85	1685	**612**
5	One day exposure visit by Students (CDPS)	98	6717	**4425**
6	Entrepreneurs/ officials visit	6	90	**37**
	Total	**198**	**8830**	**5117**

Steps taken to encourage greater participation by women in events and activities

- Small-scale training programs were conducted to actively promote women's participation.
- Awareness sessions were organized for school and college students, especially girls, to familiarize them with NRCB products and technologies.
- Women entrepreneurs were motivated to explore opportunities in cottage and home-based industries.
- In collaboration with the Tamil Nadu Government's ATMA Scheme, specialized training was provided to women farmers and aspiring entrepreneurs.
- Information on various government schemes supporting women-led enterprises was widely disseminated to encourage more women to take up entrepreneurial venture.

NRCB hosts five-day CDP for economic empowerment of women

Training program on Utilization of banana sheath and its by-products for women empowerment to Women Entrepreneurs (from Lalgudi, Duraiyur of Trichy Dt. and Nachalur of Karur Dt.) under SC/SP programme, organized by ICAR-NRC Banana, Tiruchirappalli, Tamil Nadu during 8-12 Janaury 2024.

Banana Fiber- An entrepreneurial opportunity for women farmers

ICAR-NRCB, Tiruchirappalli, and KVIC, Chennai, jointly organized an awareness program on “Transforming Waste to Wealth: Unlocking the Value of Banana Fibre” on October 23, 2024, under the Gramodyog Vikas Yojana. A 12-day training for two batches of 10 artisans each was announced, with KVIC providing machines and NRCB offering technical support. Over 130 women benefited from the program, which included sessions on fiber extraction, value addition, and machinery.

16. PERSONNEL

16.1 Staff News

Posting

Name	Event	Date
Dr. G. Prabhu, Senior Scientist	Joined on transfer from ICAR - IARI, New Delhi	w.e.f. 01.01.2024
Dr. R. Saranya, Scientist (Plant Pathology)	Joined on transfer from ICAR – CAZRI, RRS-Jaisalmer	w.e.f. 11.07.2024

Appointment

Name	Event	Date
Ms. Akansha Kumari	Appointed as 'Assistant' on direct recruitment	w.e.f. 02.09.2024

Promotion

Name	Event	Date
Dr. P. Durai	Promoted from Assistant Chief Technical Officer (T-7/8) to Chief Technical Officer grade (T-9)	w.e.f. 03.04.2023
Mrs. C. Sagayam Jacqueline	Promoted from Senior Technical Officer (T-6) to Assistant Chief Technical Officer grade (T-7/8)	w.e.f. 01.01.2023
Mr. R. Pitchaimuthu	Promoted from Technical Officer (T-5) to Senior Technical Officer grade (T-6)	w.e.f. 01.01.2023
Mr. N. Marimuthu	Promoted from Technical Officer (T-5) to Senior Technical Officer grade grade (T-6)	w.e.f. 01.01.2023
Er. D. Ramachandramurthi	Promoted from Senior Technical Officer (T-6) to Assistant Chief Technical Officer grade (T-7/8)	w.e.f. 11.08.2023

Retirement

Name	Event	Date
Dr. S. Uma	Superannuated from the position of Principal Scientist	31.05.2024 (AN)
Mrs. S. Durgavathy	Superannuated from the position of Assistant	31.05.2024 (AN)
Mr. R. Kandamani	Superannuated from the post of Administrative Officer	28.06.2024 (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. R. Thangavelu	Principal Scientist (Plant Pathology)
4	Dr. M. Mayil Vaganan	Principal Scientist (Plant Biochemistry)
5	Dr. I. Ravi	Principal Scientist (Crop Physiology)
6	Dr. V. Kumar	Principal Scientist (Horticulture)
7	Dr. K.J. Jeyabaskaran	Principal Scientist (Soil Science)
8	Dr. K.N. Shiva	Principal Scientist (Horticulture)
9	Dr. S. Backiyarani	Principal Scientist (Biotechnology)
10	Dr. Dinesh Kumar Agarwal*	Principal Scientist (Plant Breeding)
11	Dr. M. S. Saraswathi	Principal Scientist (Horticulture)
12	Dr. M. Loganathan	Principal Scientist (Plant Pathology)
13	Dr. P. Suresh Kumar	Principal Scientist (Horticulture)
14	Dr. C. Karpagam	Principal Scientist (Agricultural Extension)
15	Dr. P. Giribabu	Senior Scientist (Nematology)
16	Dr. C. Anuradha	Senior Scientist (Biotechnology)
17	Dr. A. Mohanasundaram	Senior Scientist (Agricultural Entomology)
18	Dr. G. Prabhu	Senior Scientist (Agronomy)
19	Dr. K. Nagendran	Scientist (Plant Pathology)
20	Dr. R. Saranya	Scientist (Plant Pathology)
21	Dr.Shelake Pramod Shivaji	Scientist (Agricultural Structures and Process Engineering)

***On deputation as Registrar General in PPV & FRA, MoA&FW, GOI, New Delhi**

Technical Staff

Sl. No.	Name	Designation
1	Dr. S. Palanichamy	Chief Technical Officer (Lab)
2	Dr. P. Durai	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	Assistant Chief Technical Officer (Computer Programmer)
6	Mr. D. Ramachandramurthi	Assistant Chief 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	Senior Technical Officer (Field)
11	Mr. N. Marimuthu	Senior 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	Ms. Akansha Kumari	Assistant
7	Mr. R. Neela Mega Shyamala Kannan	Personal Assistant
8	Mrs. A.V. Suja	Upper Division Clerk
9	Mr. R. Mohanraj	Lower Division Clerk
10	Mr. V. Thangaraju	Lower Division Clerk
11	Mr. P. Kamaraj	Skilled Supporting Staff
12	Mr. V. Ganesan	Skilled Supporting Staff
13	Mrs. K. Mariammal	Skilled Supporting Staff
14	Mr. A. Kaspar	Skilled Supporting Staff

Superannuated from the post of Administrative Officer in the afternoon of 28.06.2024
Superannuated from the post of Assistant in the afternoon of 31.05.2024

List of IMC members

The constitution of IMC is as follows.

S.No.	Name of the official	Position	Address
1.	Dr. R. Selvarajan, Director	Chairman	ICAR – NRC for Banana, Tiruchirapalli
2.	Dr. V.B. Patel, ADG (Fruits & Plantation Crops)	Member	Horticulture Science Division of ICAR, New Delhi
3.	Dr. R. H. Laxman, Principal Scientist	Member	ICAR – IIHR, Bengaluru
4.	Dr. A. Ramesh Sundar, Principal Scientist	Member	ICAR – SBI, Coimbatore
5.	Dr. M. Sankaran, Principal Scientist	Member	ICAR – IIHR, Bengaluru
6.	Dr. Aundy Kumar, Principal Scientist	Member	ICAR – Indian Agricultural Research Institute, New Delhi
7.	The Director (Horticulture and Plantation Crops)	Member	Agriculture Complex, Chennai
8.	The Director of Horticulture	Member	Department of Horticulture, Government of Karnataka,

9.	The Dean (Horticulture)	Member	Horticultural College & Research Institute, TNAU, Lawley Road, Coimbatore
10.	The Finance & Accounts Officer	Member	ICAR – SBI, Coimbatore
11.	Mr. Basavaraj Mali Patil	Member (Non-Official)	Maka Layout, New Jewargi Road, Kalaburagi – 585 102
12.	Mr. R. Surya Kanth	Member (Non-Official)	Palayan Nallur, Mannachanallur Taluk, Tiruchirappalli – 621 005
13.	Mr. P. Murugan Administrative Officer I/c	Member Secretary	ICAR – NRC for Banana, Tiruchirappalli

17. OTHER INFORMATION

ABI Review Meeting

The Quarterly Review Meeting (QRM) of ABI for the period April–December 2023 was held under the chairmanship of Dr. (Mrs.) Neeru Bhoosan, ADG (IP&TM), ICAR, on January 30, 2024.

75th Republic Day Celebrations at ICAR-NRCB on 26-01-2024

The 75th Republic Day was celebrated at the Centre on January 26, 2024, with a flag hoisting by Dr. J. Poorani, Director in charge.

Viksit Bharat Sankalp Yatra (VBSY)

Under the Viksit Bharat Sankalp Yatra (VBSY) programme launched by the Government of India on 15th November 2023, a series of awareness campaigns were conducted by ICAR-NRCB staff across various districts of Tamil Nadu. In total, 364 Gram Panchayats were covered, reaching out to 50,203 beneficiaries.

Training for Official

A one-day Capacity Development Programme (CDP)-cum-Training was organized on 27th February 2024 for six officials from the District Rural Development Office, Saitual District, Mizoram.

ICAR-NRCB organized a series of Internship Training Programmes

Dr. C. Karpagam and Dr. A. Mohanasundaram coordinated a series of Comprehensive Internship Training Programmes on *Banana Improvement, Production, Protection, Post-Harvest Technology,* and *Extension* for B.Sc. (Agriculture) students from VIT, Vellore, and KIT, Coimbatore, held from 24th to 28th June 2024.

Additionally, Dr. Prabhu Govindasamy and Dr. K. Nagendran organized a 30-day internship programme on *Recent Advances in Biochemical and Biotechnological Techniques in Banana*, conducted from 20th May to 19th June 2024. A total of 32 postgraduate students from Avinashilingam University, Coimbatore, Dr. NGP Arts and Science College, Coimbatore, PSG College of Arts and Science, Coimbatore, Ethiraj College for Women, Chennai, Muthayammal College of Arts and Science, Rasipuram, and Bishop Heber College, Tiruchirappalli participated in the programme.

Dr. A. Mohanasundaram and Dr. M. Mayilvaganan organized an Internship Training Program for M.Sc. students (Zoology) from Bharathiar University, Coimbatore, on "Entomological, Nematological, and Pathological Techniques in Banana" from May 13 to 27, 2024, at ICAR-NRCB, Trichy.

A five-day internship programme was organized for M.Sc. Biochemistry students from Holy Cross College, Tiruchirappalli, on *"Techniques in Biochemistry and Biotechnology"* from 11th to 15th November 2024. The programme was coordinated by Dr. A. Mohanasundaram and Dr. M. Mayil Vaganan, who served as Course Directors.

10th International Day of Yoga

The 10th International Day of Yoga was observed at ICAR-NRCB. On this occasion, special guest Dr. R. Sugumar from Shri Jayarangha Nature Cure Hospital, Trichy, created awareness about Yoga, which establishes harmony between body and mind, leading to a happy, healthy, and stress-free life.

World IP Day

During the celebration, Mrs. Bimi G.B., Deputy Controller of Patents, Chennai, explained the processes for national and international patent filing, with special emphasis on the Patent Cooperation Treaty (PCT) and its requirements. She also detailed the procedural aspects of the PCT system, elucidating its fundamental principles and operational mechanisms. Dr. R. Selvarajan, Director, discussed IPR at ICAR and ICAR-NRCB, highlighting the need for a speedy IPR process, an effective system, and the importance of IP-oriented research.

Visit of Central Compliance Committee (CCC)

To monitor the Event Selection Trials (EST) of GE banana lines under confined field conditions, the Central Compliance Committee (CCC) of RCGM, headed by Dr. S.N. Sudhakar Babu and including members Drs. S.J. Rahman, Lokesh Naroliya, and Abhilasha Singh Mathuriya, visited the EST trials of PVA and iron at ICAR-NRCB on April 5, 2024.

78th Independence Day Celebrations at ICAR-NRCB

The ICAR-NRCB celebrated India's 78th Independence Day on August 15, 2024. Dr. R. Selvarajan, Director, ICAR-NRCB highlighted the institute's achievements and its commitment to advancing agricultural research and innovation.

Swachhta Hi Seva campaign 2024

ICAR-NRCB actively participated in the "Swachhta Hi Seva" campaign from September 17 to October 2, 2024, under the theme "Swabhav Swachhata–Sanskaar Swachhata". The campaign began with a Swachhta pledge and a plantation drive followed by interactive sessions with schoolchildren focussed on waste management. Engaging activities such as a waste-to-art competition,

human chain formation, rally, and temple cleanliness drive were organized to promote community awareness. Sanitation workers received specialized training to improve waste management practices, and their efforts were recognized with awards.

Swachhta Hi Seva and Swachhta Bharat Diwas 2024

As part of Swachhta Hi Seva 2024, ICAR-NRCB, organized awareness sessions for employees on September 27-28, 2024, focusing on social welfare linkages and benefits. Safety kits were distributed to sanitation workers. On October 2, 2024, Swachh Bharat Diwas was celebrated. The Director of ICAR-NRCB emphasized the importance of maintaining proper laboratory hygiene and cleanliness. The event concluded with a demonstration showcasing the transformation of Clean Technology Units (CTUs), reinforcing the institute's commitment to a cleaner and greener environment.

Training session on waste recycle management

Celebration of Swachhta Bharat Diwas and Prize Distribution

Distribution of Welfare Benefits

Mrs.T. Nirmala Devi, I.Po.S., Post Master General, Central Region, Tamil Nadu circle, Tiruchirappalli partcipated as chief guest in the closing ceremony of the "Hindi Pakhwada-2024" at the Centre on 15.10.2024

Swachhata Pakhwada 2024

Swachhata Pakhwada was organized from December 16-31, 2024. The event commenced with the Swachhata Pledge followed by awareness sessions on waste management and vermicomposting practices. On December 20, activities such as digitization of records, scrap disposal, and cleanliness drives were conducted. This was followed by a Miyawaki Plantation initiative to enhance greenery on the campus. Highlights of the Programme: Banana Festival, Drawing and Painting Competitions, Signature Campaign, Kitchen Garden Promotion, Swachhata Rally & Human Chain Formation. All the events were successfully coordinated by the Swachh Bharat Mission team, led by Dr. A. Mohanasundaram.

18. SUCCESS STORIES

Success Story I- Low Glycemic Banana – A sweet success story for Diabetics

Bananas are often discouraged for diabetics due to their high sugar content and glycemic index (GI), ICAR-NRCB's focused research has shown that Pisang Lilin, a traditional diploid banana grown in parts of Tamil Nadu and Kerala, has a low GI of just 51, making it safe for consumption by diabetics.

As part of its commitment to public health and inclusive nutrition, ICAR-NRCB evaluated over 15 popular banana cultivars; among them Pisang Lilin stood out with a consistently low glycemic response. By promoting Pisang Lilin through farmer trainings, public awareness, and nutritional education, ICAR-NRCB has taken a step toward creating healthy fruit-based dietary options.

Pisang Linin bunch | Pisang Lilin hand | Pisang Lilin fruits

Success Story II - Kaveri Vaaman: A Dwarf Revolution by ICAR-NRCB

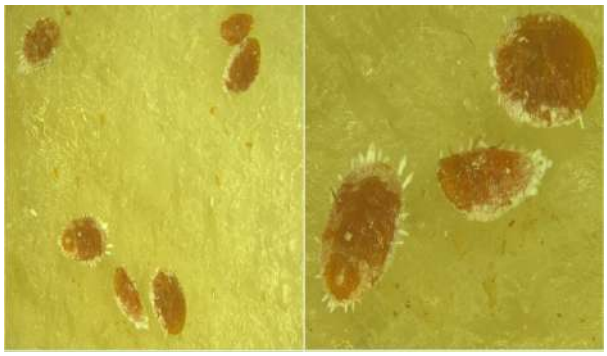
Kaveri Vaaman is India's first dwarf mutant banana variety, developed by BARC, Mumbai, and promoted by ICAR-NRCB. It grows to a compact height of 1.5–1.6 meters, making it resistant to lodging and easier to harvest. ICAR-NRCB conducted multi-location trials across several states, including Tamil Nadu, Karnataka, Kerala, Odisha, Assam, West Bengal, and Bihar. The variety has demonstrated an average yield of 50 tonnes per hectare, with potential yields reaching up to 60–65 tonnes per hectare. It has a short crop duration of 10–11 months and produces medium-sized cylindrical bunches weighing between 18–25 kg. Its strong pseudostem minimizes the need for propping, especially in wind-prone regions, thereby reducing cultivation costs.

Success Story III- Eco-Friendly Mealybug Control for Better Banana Yields

Mealybugs have emerged as a serious threat to banana crops in South India, infesting fruits and reducing market value. ICAR–NRCB, Tiruchirappalli, took swift action by identifying key fruit-infesting species like the Pink Hibiscus Mealybug, Jack Beardsley Mealybug, and Grey Pineapple Mealybug, especially in popular cultivars like Karpuravalli and Ney Poovan.

Instead of chemical sprays, ICAR-NRCB promotes eco-friendly control methods, intercropping with pulses, encouraging natural predators, and using biopesticides like *Beauveria bassiana* (EPF 22) and fish oil rosin soap. These measures control mealybugs effectively within 2–3 days while preserving beneficial insects. By empowering farmers with practical, safe, and sustainable solutions, ICAR-NRCB has helped reduce losses and improve banana quality, marking a major step forward in eco-smart pest management.

***Dysmicoccus neobrevipes* infestation on (a) fruits; (b) corm**



Mortality caused by neem+pongamia soap in *D. neobrevipes*

Success Story IV- ICAR NRCB bagged Best Stall at NHF 2024

Received the Best Stall Award for the Extension Exhibition at the National Horticulture Fair, 2024, organized by ICAR–Indian Institute of Horticultural Research (ICAR-IIHR), Bengaluru, held at ICAR-IIHR, Hessaraghatta, Karnataka, from 5th to 7th March 2024. The event witnessed participation from approximately 1,20,000 beneficiaries, including farmers, entrepreneurs, students, and stakeholders from across the country. The event was successfully coordinated by a team led by Dr. C. Karpagam

Success Story on Drone Technology - Farmers Success Stories

Feedback Reported

Name & Address of the Farmer	Photo of the Farmer	Feedback of the farmer
Name: V.A Subramanian **Address:** Agraharam, Varadarajapuram, Thottiyam, Trichy- 621215 **Banana Variety:** Ney Poovan		"The drone technology is very new to us because we have been using conventional sprayers for many years. When comparing this drone technology with conventional sprayers, the drone technology is very beneficial to us. Today, it is challenging to find farm labourers. Therefore, this drone technology saves us time and is very useful."
Name: T. Maheswaran **Address:** Pothanur, Paramathi Velur, Namakkal **Banana Variety:** Poovan		"We were not aware of drone technology before. The NRCB first demonstrated it to us. Using drones for spraying finished the task very quickly. Spraying for one acre was completed within 10 minutes using the drone. However, using conventional sprayers, it takes at least two to three hours for one acre. Therefore, drone technology saves us time and is very useful. Hence, we have decided to use drone technology in the future."

Name: Selvakumar
Address: Erasai, Theni
Banana Variety: Poovan

"Drone technology is very beneficial to us as it completes the spraying tasks faster than conventional sprayers. We have been cultivating bananas for many years on nearly 50 acres. Using conventional sprayers takes a lot of time. We have decided to buy a drone for spraying pesticides and nutrients on our banana fields. Henceforth, we will use drones for spraying nutrients and pesticides on our banana fields."

Name: Tamilselvan
Address: Near Annasilai, Kalakkadu, Tirunelveli
Banana Varieties: Nendran, Red Banana

"In our area, leaf spot disease is prevalent in bananas. The NRCB first arranged a demonstration of drone technology for spraying fungicides to control leaf spot disease. Spraying fungicides with drones was very beneficial compared to conventional sprayers. For controlling leaf spot disease, spraying on the top surface of the leaves is effective. Drone technology is beneficial as it uniformly sprays on the top surface of the leaves and completes the spraying tasks quickly."

Name: R.S Pandiyaraj
Address: Erasai, Theni
Banana Variety: Poovan

"Through the initiative of theNRCB, 'Banana Shakti' nutrients were sprayed in our area using a drone. The nutrients were sprayed uniformly and quickly using the drone. Therefore, we will use drones to spray 'Banana Shakti' nutrients in the future. The 'Banana Shakti' nutrients have significantly increased our yield. We thank the NRCB for demonstrating the drone technology to us."

Success story VI - Banana Sakthi" – A integral part of banana cultivation

Banana Sakthi, a farmer-friendly technology, was licensed and transferred to two ICAR KVKs in Namakkal and Karur districts and Srirangam Banana Farmer Producer Company Limited, Trichy. This mixture is being widely used by the farmers of Tamil Nadu and gaining popularity among the banana farming community.

Commercial production of Banana Sakthi at KVK, Namakkal

ANNEXURE

Meteorological Data

Month	Temperature (°C)		RH (%)	Rain Fall (mm)	Avg.Wind Speed ($m\ s^{-1}$)	Avg Sun Shine (hrs.)
	Max	Min				
JAN 2024	34.89	16.01	79.83	7.60	0.61	341.25
FEB 2024	35.09	16.20	73.65	0.00	0.68	294.25
MAR 2024	37.41	16.12	67.09	0.00	0.53	322.25
APR 2024	39.78	21.41	65.37	0.00	0.53	158.50
MAY 2024	44.74	23.42	69.52	115.60	1.07	289.00
JUN 2024	40.28	22.06	73.40	209.40	1.13	316.25
JUL 2024	40.12	21.99	60.28	5.20	2.19	306.00
AUG 2024	40.18	22.35	74.95	68.00	1.05	236.75
SEP 2024	36.50	22.17	57.42	3.60	2.05	298.00
OCT 2024	37.58	21.74	85.03	253.40	0.68	285.25
NOV 2024	35.60	20.92	95.98	194.21	0.39	203.75
DEC 2024	37.10	19.22	89.60	332.00	0.09	266.75

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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तोंगमलय मार्ग, थायनूर डाकघर
तिरुचिरापल्ली - 620 102, तमिल नाडु, भारत

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA
Thogamalai Road, Thayanur Post,
Tiruchirappalli - 620 102, Tamil Nadu, India
Phone - 0431-2618125
Email - director.nrcb@icar.org.in, Web: https://nrcb.org.in