ANNUAL REPORT

वार्षिक प्रतिवेदन

2022

भाकृअनुप – राष्ट्रीय केला अनुसंधान केंद्र

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

(ISO 9001:2015 Certified Institute)

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(भारतीय कृषि अनुसंधान परिषद)
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ICAR-NATIONAL RESEARCH CENTRE FOR BANANA
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PREFACE

I have been privileged to take over the reins as Director of the ICAR-National Research Centre for Banana, Tiruchirappalli, a premier institution dedicated to R&D on all aspects of banana production in India. In the last year, NRCB has made significant strides in coming up with new technologies catering to the needs of all sections of our stakeholders. I am glad to inform that during 2022, the Centre received the prestigious 'Cold Chain Award'given by the Confederation of Indian Industry's Food and Agriculture Centre of Excellence (FACE) for significant contributions made in the cold storage of fresh and processed products of banana. The Centre also received special appreciation from ICAR-AICRP (Fruits) for the release of three new cultivars, Kaveri Haritha, Kaveri Kanya and Kaveri Saba. We successfully conducted a National level Consultative workshop on 'Export of GI and traditional bananas: Present scenario, trade opportunities and way forward' during 21-22 December, 2022in association with APEDA, New Delhi. New initiatives during 2022 include 'Network project on Precision Agriculture', creation of 'Agri-Businesss Incubation Centre' to train and develop banana entrepreneurs and 'Drone Technology Demonstration' with financial support from DAC & FW, Govt. of India. The Centre has also started research on developing Nano formulation of 'Banana Shakthi', a popular micronutrient mixture with the technical support of SASTRA University, Thanjavur.

Salient research achievements of Crop Improvement section of the Centre include establishment of a first of its kind, exclusive field gene bank for crop wild relatives of *Musa* with 56 accessions at our research farm; registration of 2 genetic stocks and 14 ornamental banana hybrids with ICAR-NBPGR, New Delhi; standardization of protocol for storage and easy transport of germinated somatic embryos; development of promising hybrid progenies (932, 0213, 0207, 0528, 0538, 0567, 0515, 684, 959, 429, 820, 0009, 819 and 814) for nutritive values, pest and disease resistance traits; GCMS profiling of weevil resistant and susceptible genotypes of banana; molecular marker development for 25 commercial cultivars; identification of gene responsible for anthocyanin and development of *Musa* R gene database for identification of R genes. Besides, the Centre has done genetic fidelity testing for 1578 batches of tissue culture bananas of different popular cultivars.

Significant achievements in Crop Production and Post-Harvest Technology section include completion of nutrient dynamics studies on cvs. Nendran and Grand Nain; package of practices for banana leaf production and export of commercial and GI tagged bananas; smart packaging of red banana for export; encapsulation of β carotene in protein-modified banana starch complex and identification of banana bract extract as an effective food colorant.

In the Crop Protection section, major highlights during 2022 include report of five new insect pests on banana; identification of effective chemical insecticide and entomo-fungal pathogens for stem weevil management; identification of effective biocontrol consortia for management of *Fusarium* wilt TR4 in different banana growing states; characterization of different geographical isolates of *Fusarium* using VCG and molecular analysis; molecular characterization of effective PGPR isolates; and identification of promising *Fusarium* wilt resistant ITC accessions under sick-plot conditions. The emergence of outbreaks of CMV on banana in Maharashtra and Madhya Pradesh is a cause for concern and the Centre has been taking up focused work on this issue. Supply of 9550 virus free tissue culture plants to farmers is a significant contribution towards this.

For effective extension and dissemination of knowledge to all stakeholders, 19 on-campus and 13 off-campus training programs were conducted and novel initiatives such as *Kela Mela*, Banana Farmers-Banana Experts, etc. were started.In association with MANAGE, Hyderabad, the Centre organized an online training program 'Agripreneurship through banana-based technologies' and more than 100 banana stakeholders got benefitted.

During 2022, a revenue of Rs. 42.8 Lakh was generated through consultancy services, contract research and commercialisation of technologies to different banana stakeholders and Rs. 38.59 lakh was generated through genetic fidelity testing services. The Centre licensed its technologies such as Banana Shakthi, and other products like banana juice, banana fiber, banana wine and vinegar to various entrepreneurs across the country. MoA / MoU / MoCs were signed with ten research institutes / colleges / private companies for contract research, consultancy projects, research collaborations and student exchange.

I sincerely thank Dr. Himanshu Pathak, Secretary-DARE and Director General, ICAR, New Delhi for his valuable guidance and support. I profusely thank Dr. A.K. Singh, Deputy Director General (Horticultural Science), ICAR, New Delhi, for his inspiring and constant encouragement. Our thanks are also due to Drs. Sudhakar Pandey and V.B. Patel, Assistant Director Generals (Horticultural Science), ICAR, New Delhi, for their support and guidance. Sincere thanks are due to the SMD (Horticultural Science) for their cooperation. I am also thankful to the Chairman and members of QRT, RAC and IMC for their guidance. I acknowledge the unstinting support from the Scientists, Technical, Administrative and Supporting Staff of ICAR-NRCB who have stood by me in various institute activities.

(R. Selvarajan)

Introduction

The ICAR-National Research Centre for Banana is a premier R&D institution that caters to the needs of banana farmers and other stakeholders and has contributed immensely in increasing the production and productivity of Indian banana farmers. During 2022, the centre received 'Cold Chain Award' given by CII's Food and Agriculture Centre of Excellence (FACE) for significant contributions made by the Centre in the cold storage of fresh and processed products of banana. The Centre also received special appreciation from ICAR-AICRP (Fruits) for release of banana cultivars *viz*., Kaveri Haritha, Kaveri Kanya and Kaveri Saba. The Centre was established with the aim to increase the production and productivity of bananas and plantains through mission mode basic and strategic research approaches. The Centre has a research farm of 36.5 ha and a laboratory complex in 3.23 ha. The ICAR-NRCB also has a residential complex spread over an area of 0.80 ha in thecity. The Centre is located at 11.50°N latitude and 74.50°E longitude, 90 m above MSL and receives 800mm rain annually. The climate is warm and humid and the average minimum and maximum temperature are 25 and 35°C, respectively.

The Centre works on four major thrust areas of research, *viz.* Crop Improvement, Crop Production, Post-harvest Management and Crop Protection. The Institute has state-of-the-art research laboratories for tissue culture, biotechnology, soil science, water and nutrient management, physiology, biochemistry, entomology, nematology, plant pathology and post-harvest technology research.

During 2022, the Centre standardized protocol for export of fruits of traditional cultivar Red banana and with the collaboration of APEDA, New Delhi, fruits of red banana were successfully exported to Austria by air. The Centre has established research collaborations with Bioversity International, France; BRNS, Govt. Of India for management of Fusarium wilt, race 1 and TR4. The Centre collaborated with SASTRA University, Thanjavur for developing Nano formulation of 'Banana Shakthi' – A micronutrient mixture. With the financial support of ICAR, New Delhi, the Centre has initiated new projects on 'Precision Agriculture, Agri-Businesss Incubation Centre and management of *Fusarium* wilt TR4'. The Centre also initiated new line of research on 'Drone Technology Demonstration' with the financial support from DAC & FW, Govt. of India.

The Centre signed MoA / MoU / MoCs with 10 research institutes / colleges / private companies for research collaborations and student exchange. The Centre organized 19 on-campus capacity development programs and 13-off campus training programs to banana farmers, FPOs, Government officials, public and private entrepreneurs under various schemes including SC&SP program, ATMA-SSEPERS, NHM etc. A total of 20 peer reviewed research papers were published in high impact factor journals.

The Centre has 24 in-house research projects and 18 externally funded projects funded by various agencies like ICAR, DBT, PPV&FRA, BRNS, DST, NABARD, Bioversity International, DAC&FW, Government of India etc. The Centre periodically conducts Institute Research Council meet and Research Advisory Council meet to review the ongoing research projects and also monitor the progress made on the RAC and QRT recommendations.

Vision

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

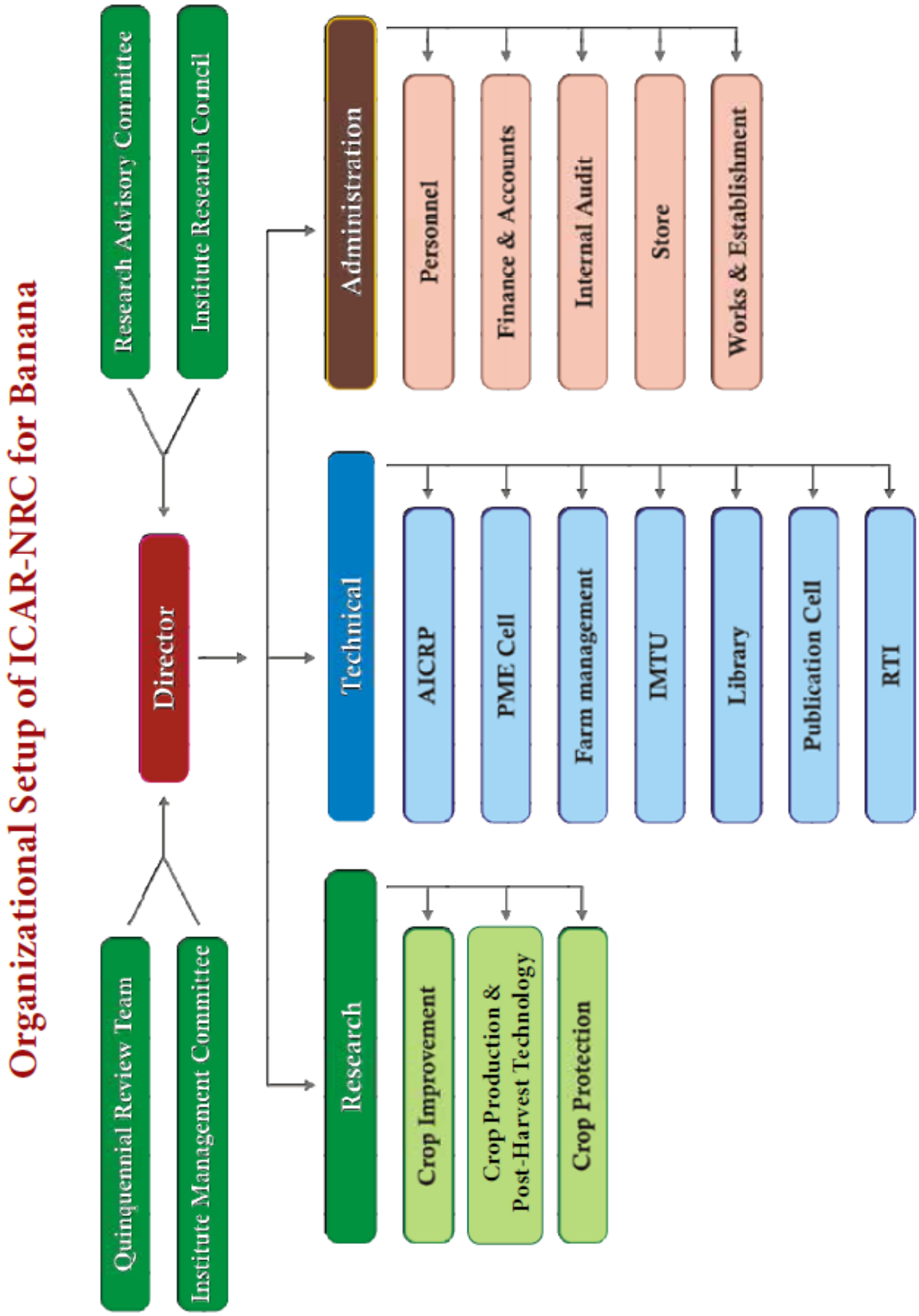
Mandate

- Basic, strategic and applied research on genetic resource management, crop improvement and production technologies for sustainable and enhanced production and utilization of banana.

- National banana gene bank management, coordination and validation of research for enhancing and sustaining the productivity of banana.
- Transfer of technology and capacity building of stakeholders for enhanced and sustained production of banana.
- Referral laboratory for monitoring the quality of micro-propagated banana plants.

Budget details for January – December, 2022	
Head of account	Expenditure (Rupees in Lakhs)
Equipment	75.12
Library	1.52
Furniture	18.97
I.T	6.71
Works	27.61
Establishment	1165.23
OTA	0.08
TA	12.09
Research Expenses	35.84
Operational Expenses	161.96
Infrastructure	142.91
Communication	8.04
Repair of equipment, vehicle	20.89
Office building	-5.09
Residential building	-0.64
Other admin. (Other TA)	8.62
HRD	1.07
Publicity & Exhibition	0.04
Miscellaneous	11.29
Pension &Retirement	0
P Loans & Advance	25
Total	1717.26
SCSP-Capital	5.9
SCSP-General	13.85
Grand Total	1737.01

A revenue of Rs. 80,59, 467/- was generated by the Centre during January–December, 2022.


Organizational Setup of ICAR-NRC for Banana
Research Advisory Committee
Institute Research Council
Director
Quinquennial Review Team
Institute Management Committee
Administration
Personnel
Finance & Accounts
Internal Audit
Store
Works & Establishment
Technical
AICRP
PME Cell
Farm management
IMTU
Library
Publication Cell
RTI
Research
Crop Improvement
Crop Production & Post-Harvest Technology
Crop Protection

EXECUTIVE SUMMARY

Crop Improvement

Ten accessions have been collected from primary and secondary sources and added to the gene bank. An exclusive gene bank for crop wild relatives of *Musa* with 56 accessions has been established at ICAR-NRCB, Tiruchirappalli, the first of its kind in India. Morpho-taxonomic characterization was done for 14 accessions using IPGRI Musa descriptor leading to the identification of genomic and subgroups. Two improved genetic stocks were registered and IC numbers for 14 ornamental banana hybrids and one dwarf clone of cv. Grand Naine obtained from ICAR-NBPGR, New Delhi. A micropropagation protocol has been standardized for Kaveri Kanchan using Somatic Embryogenesis Regeneration Vessel (SERV) bioreactor for both ECS and shoot tip explants. A protocol has been standardized for the storage and easy transport of germinated somatic embryos.

Promising hybrid progenies have been identified in evaluation trials. Progeny 932 is an open pollinated diploid progeny of P0480 (Kothia x Calcutta 4) that produced higher provitamin A content (156 µg of PVA /g of dry weight) than their parents. Based on screening, 12 Foc race 1 resistant hybrid progenies have been identified including two Matti x Cv. Rose based progenies (P0213 and P0207), four Kothia based progenies (P0528, P0538, P0567 and P0515), one Saba x Pisang Lilin based progeny (Pro. 684; IC 0642858), and five Pisang Awak based progenies.

NRCB selection 18 (Progeny No. 959) was found to be a stable performer with an average yield of 23.5kg/bunch for three consecutive years and it has better cooking qualities than Kaveri Saba and Monthan in terms of swelling power, water and oil holding capacity and solubility. Two diploid progenies (Pro. 429 - cv. Rose x Pisang Lilin; Pro. 820 - Udhayam x Pisang Lilin), two triploids (Pro. 0009 - Matti x Anaikomban; Pro. 819 – Udhayam x Calcutta 4) and one tetraploid (Pro. 814 - Bankela x Calcutta 4-1) were resistant to stem weevil and Foc race 1. In sick plot evaluation, seven Grand Naine mutant lines resistant to Foc race 1 were promising in terms of yield despite infection and the disease score was 2-5 (on a scale of 0-5). TBM 9 (Kaveri Vaamana), a dwarf mutant of cv. Grand Nain was found to be susceptible to Fusarium wilt races 1 and TR 4 and root lesion nematodes. Androgenic Ney Poovan tetraploid was found to be highly susceptible to corm and pseudostem weevils as against diploid Ney Poovan which was resistant. Similarly, both were susceptible to *Fusarium* wilt race 1 and moderately resistant to TR4. GCMS profiling led to the identification of volatile compounds common and unique to diploid and tetraploid and their biological functions have been defined and correlated with the resistance to biotic stresses like corm weevil and pseudostem borer.

SSR panel developed for use in DNA fingerprinting has been validated in 25 commercial varieties. Genic SSR marker (Ant-FH-SSR11), identified from F35H-1 gene present in the anthocyanin pathway, differentiated the purple and green parents of ornamental bananas and their progenies. The marker is likely to hasten the ornamental banana breeding cycle. The same could be used for distinguishing Red banana and its green variants and hence could be used in clonal fidelity testing of Red banana.

Guide RNA of Ma10_g00550 was cloned in pRGEB31 and confirmed through sequencing and further mobilized into Agrobacterium tumefaciens strain for use in ECS transformation towards the development of wilt Foc race 1 resistance through gene editing approach. A MusaRgene database has been developed for use as a primary resource of information on R genes from bananas and their relatives. R genes from other allele mining studies are also incorporated which will enable the identification of its homologues in related *Musa* spp.

Totally 2740 tissue cultured plants and 13710 suckers of banana varieties were supplied to banana growers. About 1,578 batches of tissue culture plants of cvs. Grand Nain, Ney Poovan, Karpuravalli, Red banana, Williams, Theni Nendran, Super Nendran, Poovan, Bantala, Malbhog, Jwari Bale and Nendran were tested for genetic fidelity using ISSR markers for TCPUs under contract services.

Crop Production and Post-Harvest Technology

Nutrient dynamics in cv. Nendran and Grand Nain in terms of total dry matter production, percent DMP fractions and nutrient accumulations of leaf, petiole, stem, corm, root, peduncle, bunch and bud at harvesting stage were worked out. In both cultivars, vermicomposting of residues after harvesting reduced the C/N ratio from 60/1 to 9/1 with a recovery of about 58.5% of N, 56.7% of P and 47.5% of K. In Ney Poovan, application of organic fertilizers (poultry manure @ 5 kg/pl + groundnut cake @ 1kg/pl + rural compost @ 3 kg/pl + wood ash @ 3 kg/pl) recorded the highest average bunch weight (9.9 kg), which was on a par with that of 100% inorganic fertilizer alone. The soil organic carbon content, cat ion exchange capacity, bulk density, porosity, and available soil moisture improved to desirable levels when poultry manure based organic combinations were applied. There were significant variations in microbial populations (colony forming units - cfu per gram of soil) in the post-harvest soil under various treatments.

Agro-techniques were standardized for newly released varieties viz., Kaveri Saba, Kaveri Haritha and Kaveri Kalki and ornamental banana hybrids. Clump management technology was also standardized for enhancing productivity in Ney Poovan and Kaveri Saba. Package of practices for cv. Ney Poovan for export markets was evaluated at the Centre's Experimental Farm and at a farmer's field in Mudalaipatti, Tiruchirappalli.

In field evaluation, drought stress in floral primordial stage resulted in delay in flowering in AAA, AAB and ABB genotypes compared to irrigated control with variations. Among AAA genotypes, Lacatan showed delayed flowering by 70 days, while Bharath Moni and Tulsi Manohar recorded earlier flowering compared to irrigated control. Almost all AAB genotypes showed prolonged the number of days to flowering except Octoman, Desi kadali, and Agni Malbhog under drought stress. Testing of effect of salt stress on germination showed that the Kaveri Saba and Karpuravalli germinated and surviving, Rasthali just germinated and did not survive and Grand Nain did no germinate at 50 mM NaCl. Bunch spray of 2,4-D at 30 ppm along with Brassinolides (2 ppm) in cv. Nendran recorded significant increase in fruit length (24.52%) and there was 8% increase at lower dosages of 10 ppm and 20 ppm.

The total fructan content and fructan types of fruit pulp of nine commercial cultivars and rhizomes of five cultivars were analyzed and varying contents of fructan types were found in the pulp with Monthan (ABB) and Nendran (AAB) having the highest amount of inulin-type fructans and Grand Nain possessed 1-kestotriose as predominant fructan. In rhizome of banana cultivars, 1,1-nystose was found as the major fraction. Alpha-tocopherol (vitamin E) content of leaves of 10 cultivars was quantified and found to be 4.2–6.4 mg/g of leaf tissue. Kaveri Saba and Monthan leaves had highest α-tocopherol of 6.4 and 6.2 mg/g respectively, followed by Grand Nain (5.9 mg/g) and lowest contents were detected in Nendran and Rasthali (4.23 mg/g). Among eight cultivars from the north-eastern region, Dudhsagar contained the highest amount of anthocyanins in flower bracts (68.78 mg/100g FW) followed by Jatikal (52.24 mg/100 g) and Jahaji contained the lowest (13.13 mg/100 g). Individual anthocyanin compounds in bracts of these eight cultivars were profiled using RP-HPLC, identified and quantified. The anthocyanin extracts of Jatikal, Simlou Manohar, Bhoji Manohar, Dudhsagar and Jahaji showed higher levels of total antioxidant activity and anthocyanins from flower bracts of Kechulepa, Borchamba and Desi kadali exhibited lower levels of total antioxidant capacity. All cultivars

with high cyanidin exhibited high level of total antioxidant activities and consequently higher nutraceutical potential.

Pre- and post-harvest techniques for leaf production in banana were standardized for popular varieties like Karpuravalli, Sakkai, Poovan, Progeny 183, and Naadu based on monthly production and in different combinations of mother plant + daughter suckers. Leaf area of various cultivars was in the order of Naadu (0.97 m^2) > Poovan (0.91m^2) > Karpuravalli (0.80 m^2). Leaf thickness was lowest in Karpuravalli (0.19 mm) with the best leaf quality.

Cold storage (13.5°C) of Red banana extended the shelf life by up to 23 days with improved quality and sensory attributes. Smart packaging based ripening indicator label for red banana was fabricated using ammonium molybdate with starch matrix and plasticizers and based on color change, extent of banana ripening could be assessed. Encapsulation of β-carotene in protein-modified starch complex was attempted and modified banana starch was found to be a better carrier material than gum acacia, which is commercially used as an encapsulation material next to maltodextrin. Effect of different additives on the structural characteristics of banana starch based bioplastic films was done.

Totally 114 Capacity Development Programs were conducted for 5920 beneficiaries including farmers, KVKs, FPOs and students. In all, 218 news items / stories / social media feeds were disseminated through mass and social media and 12 publications brought out to reach various stakeholders. A Joint workshop with MANAGE and a High-End Workshop (Karyashala) sponsored by DST were organized.

Crop Protection

The invasive Bondar's nesting whitefly (*Paraleyrodes bondari*) was found to be present on banana at very low levels. *Eupterote orientalis*, *Artaxa guttata*, and *Miltochrista violacea* were recorded as banana pests for the first time and the first two were found to be sporadic pests of all common cultivars. Severe foliar damage due to vegetable grasshopper, *Atractomorpha crenulata*, was observed in the early stage (3-4 month-old-crop) on cv. Ney Poovan, Nendran, Saba and Karpuravalli. Fipronil, cartap hydrochloride and spinosad were found to be the most effective candidates for use against pseudostem weevil with LC values of 0.006%, 0.125 % and 0.018%, respectively. Entomofungal pathogens *Beauveria brongniartii* 27, *B. bassiana* 22, *Metarhizium anisopliae* 50 and *B. brongniartii* 28 were found to cause significantly high mortality of pseudostem weevil in laboratory bioassays.

In field evaluation of bioagent consortia for the management of *Fusarium* wilt disease (TR4) on cv. Grand Nain at Falka block, Katihar District, Bihar, endophytic *Bacillus flexus* (Tvpr1) + Rhizospheric *Trichoderma asperellum* (NRCB3) resulted in significant increase in height (37.46%), girth (28.61%), leaf area (61.38%) and total number of leaves (40.74%) followed by Endophytic *Bacillus subtilis* ssp. *inaquosorum* (BS30) + rhizospheric *Bacillus haynesii* (BS17) combination (34.68% increase in plant height, 16.77% increase in girth and 55.66% and 33.33% increase in leaf area and total number of leaves, respectively). In similar trials at KK Patti, Tamil Nadu, endophytic *B. subtilis* ssp. *inaquosorum* (BS30) + Rhizospheric *B. haynesii* (BS17) followed by Endo. Rhizo. *T. asperellum* (NRCB3) + *B. flexus* (Tvpr1) proved to be potential candidates with the best plant parameters and the lowest internal wilt disease score of 0.5 and 0.8, respectively, on a 0-5 scale. In similar trials on cv. Ney Poovan at Hampi village, Hospet, Vijayanagar District, Karnataka, endophytic *B. subtilis* ssp. *inaquosorum* (BS30) + rhizospheric *B. haynesii* (BS17) followed by Endo. Rhizo. *T. asperellum* (NRCB3) + *B. flexus* (Tvpr1) proved to be the most effective with the lowest internal wilt disease score.

Characterization of Foc isolates revealed the presence of Foc TR-4 and Race 1 in the fields surveyed in Bihar, West Bengal and Uttar Pradesh. In VCG analyses VCGs 01216, 01213/16 belonging to TR-4 and VCG

01220, 0124 and 0125 belonging to Foc R1 were identified in Grand Nain. Four bacterial and five fungal endophytic and rhizospheric microbial isolates were found effective against Foc TR-4 and in further evaluation of various combinations under glasshouse conditions in cv. Grand Nain, Rhizo. *Trichoderma* sp. + Rhizo. *T. asperellum* completely suppressed the wilt in the corm (internal wilt disease score 0.0). Among bacterial combinations, endo. *B. subtilis* + rhizo. *B. subtilis* combination was effective against *Fusarium* wilt (disease score of 0.2). Liquid formulation of Endo. *B. subtilis* ssp. *inaquosorum*(BS30) + Rhizo. *B. haynesii* (BS17) applied at 0.5L per plant resulted in complete reduction of Foc TR-4 (disease score 0) as against control.

Based on 16s rDNA sequencing, PGPR isolates H7BC2 (OM188392.1), H8BC1 (OM188390.1), H6BC3 (OM188389.1), H4BC1 (OM188387.1) and H8BC2 (OM188391.1) were characterized as *Priestia aryabhattai* while H6BC2 (OM188388.1) was characterized as *P. megaterium*. Copper hydroxide (0.1-0.3%) was effective against all *Pectobacterium* isolates and specific *K. variicola* (1-1B-3) isolate while COC (0.2%) recorded significant inhibition of all *K. variicola* isolates and certain isolates of *Pectobacterium* sp.

Re-emergence of infectious chlorosis caused by CMV in TC plants in an epidemic proportion was recorded in Jalgaon District, Maharashtra (0–33.88%) and Burhanpur district, Madhya Pradesh (0–100%). The complete genome of CMV isolates infecting banana from Jalgaon and Burhanpur was sequenced and characterized and grouped into subgroup IB. Under time course studies, more than 70 major volatile organic compounds (VOC) were identified in BBTV-infected and healthy banana plants. Elite BSMYV free high-yielding TC Poovan plants were supplied to five KVKs and farmers with positive feedback on their performance. Virus indexing services and sale of virus detection kits generated a gross revenue of Rs.23,12,442/- and Rs 59,500/- respectively.

Immersion of suckers of Nendran in boiling water before planting for 45-60 seconds significantly reduced the nematode population and root galls and root knot nematodes were also completely absent. Parental lines Matti, Namarai, Cultivar Rose, Pisang Jajee and Lairawak and elite mutants TBM 9 and Grand Nain Mutant 1 were found susceptible to root lesion nematode, *Pratylenchus coffeae*.

Totally 110 ITC accessions were evaluated against Foc R1 (VCG 0124) under glasshouse conditions and eight resistant, 58 moderately resistant, 32 susceptible and 12 highly susceptible accessions identified. Cardaba-ABB (0394), PC-1205-AAAB (1260), Paka -AA (1254), FHIA-23-AAA (1265), FHIA-02-AAAB (0505), Williams-AAA (0570), Tjau Lagada -AA (0090) and GCTCV-119 -AAA (1282) were resistant. In field screening at Muthalapuram, Theni, Tamil Nadu also, all these ITC accessions except Cardaba were resistant to FocR1.

The recombinant coat proteins of BBrMV and CMV were expressed in bacterial expression systems and are utilized for large-scale production of monoclonal antibodies using the hybridoma technology. Totally 9550 virus-free tissue culture plants of Nendran, Red banana, Grand Nain, and other cultivars were supplied to SC farmers through KVKs under SC Sub-Plan.

Transfer of Technology

During 2022, around 6000 banana stakeholders visited the centre and got learned about the centre's technologies and research activities. The centre has conducted a total of 19 on-campus capacity development programs and 13 off-campus training programs to banana farmers, FPOs, Government officials, public and private entrepreneurs under various schemes including SC&SP program, ATMA-SSEPERS, NHM etc. For the benefit of banana stakeholders, the centre has made novel initiatives such as *Kela Mela,* Banana Farmers-Banana Experts etc. In association with MANAGE, Hyderabad, ICAR-NRCB organized an online training

program 'Agripreneurship through banana based technologies' and more than 100 banana stakeholders got benefitted. Seven radio talks were presented by the centre's scientists on banana. The centre has organized / participated in 15 exhibitions and showcased improved technologies to banana stakeholders.

Linkages and Collaborations

ICAR–NRCB has research collaborations with international institutes which include IITA, Nigeria; Alliance CIAT-Bioversity International, France; KUL, Belgium; and the University of Queensland, Australia. The institute has linkages with national institutes including Board of Research in Nuclear Sciences (BRNS); DST and DBT, New Delhi; APEDA, New Delhi; NABARD; VFPCK, Kerala; TNAU, Coimbatore; NIT, Tiruchirappalli and KNCET, Thottiyam, Tamil Nadu. The centre has research collaborations with other ICAR institutes including ICAR–NBPGR, New Delhi; ICAR–IIHR, Bengaluru, ICAR-IARI, New Delhi, ICAR-CPCRI, Kasaragod, ICAR-SBI, Coimbatore and ICAR–CIAE (RS), Coimbatore. The centre coordinates with ICAR-AICRP (Fruits) centers (11 nos.) working on banana.

During 2022, the Centre signed MoA / MoU / MoCs with ten research institutes / colleges / private companies for contract research, consultancy projects, research collaborations and student exchange. The centre in association with APEDA and TNBGF successfully exported Red banana to Austria. Tissue culture industries involved in banana mass propagation, farmers, exporters, state horticulture and agriculture departments and self-help groups are linked with the centre for various research and developmental activities.

HRD and Education

Under human resource development, 13 training programs were attended by the scientists of the centre. The centre has published 20 research papers in various journals of International and National repute. The centre in association with DST, Government of India, conducted one workshop to college faculty (Recent Trends in Biotechnology and their Applications) and two training programs ('High-End Workshop (*Karyashala*)' and 'Research facility training program on 'Omics and Bioinformatics') to post graduate students belong to different colleges. More than 25 students / research scholars have been pursuing their Master's and Doctoral programs at the centre.

Revenue Generated

A gross revenue of Rs. 80,59,467/- was generated by the centre during January–December, 2022.

कार्यकारी सारांश

फसल सुधार

प्राथमिक एवं गौण स्रोतों से केले के 10 परिग्रहणों का संकलन कर उन्हें जीन बैंक में शामिल किया गया। भाकृअनुप-राष्ट्रीय केला अनुसंधान केंद्र, तिरुचिरापल्ली में 56 परिग्रहणों (एक्सेसन) सहित *मूसा* (केला प्रजाति) की जंगली प्रजातियों के लिए एक विशेष जीन बैंक स्थापित किया गया है, जो भारत में अपनी तरह का पहला जीन बैंक है। आईपीजीआरआई (IPGRI) *मूसा* डिस्क्रिप्टर के उपयोग द्वारा जीनसंबंधी तथा उपसमूहों की पहचान हेतु 14 परिग्रहणों की संरचना वर्गिकी (मॉर्फो-टैक्सोनोमिक) का लक्षण वर्णन किया गया। केले के दो उन्नत आनुवंशिक (जेनेटिक) स्टॉक पंजीकृत किए गए और 14 सजावटी संकर केलों और भाकृअनुप-एनबीपीजीआर, नई दिल्ली से प्राप्त केले की ग्रैंड नैने किस्म के एक बौने क्लोन के लिए आईसी संख्याएं दर्ज की गईं। कावेरी कंचन किस्म हेतु ईसीएस और प्ररोह शीर्ष कर्तोतक (शूट टिप एक्सप्लांट्स) दोनों के लिए सोमैटिक एम्ब्रियोजेनेसिस रिजेनेरेशन वेसल (SERV) बायोरिएक्टर का उपयोग करके एक माइक्रोप्रोपैगेशन (सूक्ष्म प्रवर्धन) प्रोटोकॉल को मानकीकृत किया गया। अंकुरित हो चुके दैहिक भ्रूणों के भंडारण और उनके आसानी से परिवहन के लिए एक प्रोटोकॉल का मानकीकरण किया गया है।

मूल्यांकन परीक्षणों में आशावान संकर संततियों की पहचान की गई। प्रोजेनी 932 जो कि P0480 (कोठिया x कलकत्ता 4) की एक खुली परागित द्विगुणित संतति है जिसने अपने पैरेंट (जनकों) की तुलना में उच्च प्रो-विटामिन ए सामग्री (सूखे वजन का 156 µg पीवीए/ग्राम) सृजित की गई। स्क्रीनिंग के आधार पर 02 मैती x रोज़ किस्म पर आधारित संततियों (P0213 एवं P0207), 04 कोठिया पर आधारित संततियों (P0528, P0538, P0567 एवं P0515), 01 सबा x पिसांग लिलिन आधारित संततियों सहित 12 *Foc* रेस 1 प्रतिरोधी संकर संततियों की पहचान की गई है। (प्रोजिनी 684; आईसी 0642858) और 05 पिसांग अवाक आधारित प्रोजिनी या संततियां)।

एनआरसीबी चयन 18 (संतति संख्या 959) को लगातार तीन वर्षों तक 23.5 किग्रा/गुच्छ की औसत उपज सहित एक निरंतर उत्पादक किस्म (पर्फामर) पाया गया और फूलने की शक्ति, जल एवं तेल - धारण क्षमता एवं घुलनशीलता के मामले में इसे कावेरी सबा और मोंथन की तुलना में बेहतर पाक गुणों से सम्पन्न पाया गया। दो डिप्लॉयड अथवा द्विगुणित संततियाँ (प्रोजिनी 429 – किस्म रोज़ x पिसांग लिलिन; प्रोजिनी 820 - उदयम x पिसांग लिलिन), दो ट्रिपलोइड्स अथवा त्रिगुणित (प्रोजिनी 0009 - मैती x अनाइकोमबन; प्रोजिनी 819 - उद्यम x कलकत्ता 4) और एक टेट्राप्लॉइड अथवा चतुर्गुणित (प्रोजिनी 814 - बांकेला x कलकत्ता 4-1) को स्टेम वीविल (तने में लगने वाले घुन और *Foc* रेस 1 के मामले में प्रतिरोधी पाया गया।

बीमार प्लॉटों या खेतों के मूल्यांकन में *Foc* रेस 1 के विरुद्ध प्रतिरोधी ग्रैंड नैने की 07 म्यूटेंट वंशावलियों (लाइनें) को संक्रमण के बावजूद उपज के मामले में आशाजनक पाया गया और इनमें रोग का स्कोर 2- 5 के बीच पाया गया (0-5 के पैमाने पर)। दो द्विगुणित अथवा डिप्लॉयड प्रोजिनी (प्रोजिनी टीबीएम 9 कावेरी वामन्ना), ग्रैंड नैने किस्म के एक बौने म्यूटेंट (उत्परिवर्ती) को *फ्यूजेरियम विल्ट* (मुरझान) रेस 1, टीआर 4 एवं जड़ घाव सूत्रकृमि (नेमाटोड) के प्रति अतिसंवेदनशील पाया गया। एंड्रोजेनिक नेय पूवन टेट्राप्लोइड को कॉर्म एवं स्यूडोस्टेम वीविल्स के प्रति अति संवेदनशील पाया गया, जबकि द्विगुणित नेय पूवन को प्रतिरोधी पाया गया। इसी प्रकार इन दोनों को *फ्यूजेरियम विल्ट* (मुरझान) रेस 1 के प्रति सुग्राह्य जबकि TR4 के प्रति मामूली प्रतिरोधी पाया गया। जीसीएमएस प्रोफाइलिंग से डिप्लॉयड (द्विगुणित) एवं टेट्राप्लोइड (चतुगुर्णित) के लिए सामान्य एवं विशिष्ट वाष्पशील यौगिकों की पहचान संभव हुई और उनके जैविक कार्यों को स्पष्ट किया गया तथा कॉर्म वीविल और स्यूडोस्टेम बोरर जैसे जैविक तनावों के विरुद्ध प्रतिरोधिता सहित उन्हें सहसंबद्ध किया गया।

डीएनए फिंगरप्रिंटिंग में उपयोग के लिए विकसित एसएसआर पैनल को 25 वाणिज्यिक किस्मों के लिए मान्य किया गया है। जीन संबंधी एसएसआर मार्कर (एंट-एफएच-एसएसआर11) जिसकी पहचान एंथोसायनिन पाथवे में मौजूद एफ35एच-1 जीन से की गई को सजावटी केले के बैंगनी एवं हरे पैरेंट (जनकों) और उनकी संततियों से अलग होने (विभेदन) का कारक पाया गया। इस मार्कर से सजावटी केले के प्रजनन चक्र में तेजी आने की संभावना है। इसे रेड बनाना और इसके हरे रूपों में अंतर करने हेतु उपयोग में लाया जा सकता

है और इसलिए रेड बनाना के क्लोन की सत्यनिष्ठा (क्लोनल-फिडेलिटी) परीक्षण में इसका उपयोग किया जा सकता है।

Ma10_g00550 के पथप्रदर्शक (गाइड) RNA को pRGEB31 में प्रतिरुपित (क्लोन) किया गया और सीक्वेंसिंग (अनुक्रमण) द्वारा इसकी पुष्टि की गई तथा जीन संपादन विधि (जीन एडिटिंग एप्रोच) के माध्यम से विल्ट *Foc* रेस 1 प्रतिरोधिता विकसित करके ECS रुपांतरण में उपयोग के लिए *एग्रोबैक्टीरियम ट्यूमेफेशियन्स* स्ट्रेन में इसे सक्रिय (मोबिलाइज) किया गया। केले और उसकी प्रजातियों से R जीनों पर जानकारी के प्राथमिक स्रोत के रूप में उपयोग करने के लिए एक Musa Rgene (मूसा आर जीन) डेटाबेस विकसित किया गया है। एलील माइनिंग के अन्य अध्ययनों में भी R जीनों को शामिल किया गया है, जो संबंधित *मूसा* प्रजातियों में इसके समजातों (होमोलॉग्स) की पहचान करने में सक्षम होंगे। .

इस अवधि के दौरान केले का उत्पादन करने वाले किसानों को कुल 2740 टिश्यू कल्चर (ऊतक संवर्धित) पौधे तथा केले की विभिन्न किस्मों के 13710 सकर्स (अंतः भूस्तारी) की आपूर्ति की गई। केले की विभिन्न किस्मों जैसे ग्रैंड नैने, नेय पूवन, कर्पुरावल्ली, रेड बनाना, विलियम्स, थेनी नेंद्रन, सुपर नेंद्रन, पूवन, बंटाला, मालभोग, ज्वारी बेल और नेंद्रन के ऊतकों से तैयार (टिशू कल्चर्ड) पौधों के लगभग 1,578 बैचों का अनुबंध सेवाओं के तहत टीसीपीयू के लिए आईएसएसआर मार्करों का उपयोग करके उनकी आनुवंशिक निष्ठा (जेनेटिक फिडेलिटी) का परीक्षण किया गया।

फसल उत्पादन एवं फसलोपरांत (पोस्ट हार्वेस्ट) प्रौद्योगिकी

केले की किस्म नेंद्रन एवं ग्रेंड नैने में कुल शुष्क पदार्थ के उत्पादन के संदर्भ में पोषक तत्वों की गतिशीलता, फसल कटाई की अवस्था में (हार्वेस्ट स्टेज) में पत्ती, पर्णवृंत, तना, कंद एवं जड़, पुष्पावलि वृंत, गुच्छे और कली के प्रतिशत डीएमपी अंशों और पोषक तत्वों के संचय की गणना की गई। दोनों ही किस्मों में कटाई के बाद अवशेषों के वर्मीकम्पोस्टिंग ने C/N अनुपात को 60/1 से घटाकर 9/1 कर दिया जिसमें N की लगभग 58.5%, P की 56.7% और K की 47.5% की पुनर्प्राप्ति (रिकवरी) हुई। केले की नेय पूवन किस्म में जैविक उर्वरकों (कुक्कुट खाद को 5 किग्रा/प्लॉट + मूंगफली की खली को 1 किग्रा/प्लॉट + घरेलू खाद को 3 किग्रा/प्लॉट + बुरादा को 3 किग्रा/प्लॉट की दर से) को प्रयुक्त करने पर उच्चतम औसत गुच्छा वजन (9.9 किग्रा) दर्ज किया गया जो कि अकेले 100% अकार्बनिक उर्वरक को प्रयुक्त करने के समकक्ष था। जब कुक्कुट खाद से तैयार जैविक संयोजनों को प्रयुक्त किया गया तो मिट्टी में जैविक कार्बन सामग्री, कैटायन विनिमय क्षमता, थोक घनत्व, सरंध्रता तथा मिट्टी में उपलब्ध नमी में वांछनीय स्तर तक सुधार पाया गया। विभिन्न उपचारों में फसल-कटाई के बाद मिट्टी में सूक्ष्मजीवों (माइक्रोबियल) की संख्या में (कॉलोनी बनाने वाली इकाइयां - cfu प्रति ग्राम मिट्टी) में महत्वपूर्ण अंतर पाया गया।

नई जारी की गई किस्मों जैसे कावेरी सबा, कावेरी हरिता एवं कावेरी कल्कि तथा सजावटी संकर केले के लिए कृषि-तकनीकों का मानकीकरण किया गया। नेय पूवन और कावेरी सबा में उत्पादकता बढ़ाने के लिए क्लम्प प्रबंधन तकनीक का भी मानकीकरण किया गया। निर्यात के लिए केले की नेय पूवन किस्म की खेती करने की प्रक्रियाओं (पैकेज ऑफ प्रेक्टिस) का मूल्यांकन केंद्र के प्रायोगिक फार्म और मुदलाईपट्टी गांव, तिरुचिरापल्ली में एक किसान के खेत में किया गया।

खेतों में किए गए मूल्यांकन में, फूल खिलने की प्रारंभिक अवस्था में सूखा पड़ने के कारण सिंचित खेतों (कंट्रोल) की तुलना में एएए, एएबी एवं एबीबी जीनोटाइप में फूल आने में देरी हुई। एएए जीनोटाइपों में से लैकाटन किस्म में फूल आने में 70 दिनों तक की देरी पाई गई जबकि भरत मोनी एवं तुलसी मनोहर किस्म में सिंचित खेतों (कंट्रोल) की तुलना में फूल जल्दी आए। सूखे वाली दशाओं में ऑक्टोमन, देसी कदली और अग्नि मालभोग को छोड़कर लगभग सभी एएबी जीनोटाइपों में फूल खिलने के दिनों में देरी पाई गई। अंकुरण पर लवणता तनाव के प्रभाव के परीक्षण से पता चला कि कावेरी सबा एवं कर्पुरवल्ली में अंकुरण हुआ और वे जीवित रह सके, रस्थली में अंकुरण तो हुआ लेकिन वे जीवित नहीं रह सके और ग्रैंड नैने किस्म में तो 50 mM NaCl (सोडियम क्लोराइड) पर अंकुरण ही नहीं हुआ। नेंद्रन किस्म में ब्रेसिनोलाइड्स (2 पीपीएम) के साथ 30 पीपीएम पर 2,4-डी का बंच स्प्रे करने पर फलों की लंबाई (24.52%) में उल्लेखनीय वृद्धि दर्ज की गई तथा 10 पीपीएम और 20 पीपीएम की निम्न खुराक पर भी इसमें 8% की वृद्धि पाई गई।

केले की 09 व्यावसायिक किस्मों में फलों के गूदे और पांच किस्मों के प्रकंदों में कुल फ्रुक्टेन अंश एवं फ्रुक्टेन टाइप का विश्लेषण किया गया और मोंथन (एबीबी) और नेंद्रन (एएबी) के गूदे (पल्प) में फ्रुक्टेन जैसी अलग-अलग सामग्री पाई गई जिनमें इंन्युलिन टाइप फ्रुक्टेन की सर्वाधिक मात्रा पाई गई तथा ग्रैंड नैने में प्रबल फ्रुक्टेन के रूप में 1-केस्टोट्रियोज़ की उच्चतम मात्रा थी। केले की विभिन्न किस्मों के प्रकंदों (राइजोम) में 1,1-निस्टोस को प्रमुख अंश के रूप में पाया गया। 10 किस्मों की पत्तियों में अल्फा-टोकोफेरॉल (विटामिन ई) की मात्रा का निर्धारण किया गया और पत्ती के ऊतकों में इसे 4.2-6.4 मिग्रा/ग्राम के बीच पाया गया। कावेरी सबा एवं मोन्थन की पत्तियों में क्रमशः 6.4 और 6.2 मिग्रा/ग्राम का उच्चतम α-टोकोफेरोल था, इसके बाद ग्रैंड नैने (5.9 मिग्रा/ग्राम) और सबसे कम सामग्री नेंद्रन एवं रास्थली (4.23 मिग्रा/ग्राम) में पाई गई।

उत्तर-पूर्वी क्षेत्र में केले की 08 किस्मों में एंथोसायनिन की सबसे अधिक मात्रा (68.78 मिग्रा/100 ग्राम एफडब्ल्यू) दूधसागर किस्म के पुष्प कोष्ठकों में पाई गई और इसके बाद इसे जतिकल (52.24 मिग्रा/100 ग्राम) में जबकि जहाजी किस्म में इसे सबसे कम (13.13 मिग्रा/100 ग्राम) पाया गया। आरपी-एचपीएलसी का उपयोग करके इन आठ किस्मों के अलग-अलग खंडों में प्रत्येक एंथोसायनिन यौगिकों को पहचान कर उनका परिमाण नोट किया गया। जतिकल, सिमलोऊ मनोहर, भोजी मनोहर, दूधसागर और जहाजी के एंथोसायनिन अर्क ने कुल एंटीऑक्सीडेंट सक्रियता के उच्च स्तर को दिखाया जबकि केचुलेपा, बोरचंबा और देसी कदली के फूलों के सहपत्रों से एंथोसायनिन ने कुल एंटीऑक्सीडेंट क्षमता के निचले स्तर को प्रदर्शित किया। उच्च साइनिडिन वाली सभी किस्मों ने कुल एंटीऑक्सीडेंट गतिविधियों के उच्च स्तर का प्रदर्शन किया और परिणामस्वरूप उच्च न्यूट्रास्यूटिकल क्षमता प्रदर्शित की।

केले की लोकप्रिय किस्मों जैसे कर्पुरावल्ली, सक्काई, पूवन, प्रोजिनी 183 तथा नाडु में मासिक उत्पादन के आधार पर और मातृपौधे + डॉटर सकर्स (संतति भूस्तारी) के विभिन्न संयोजनों के लिए पत्ती उत्पादन हेतु कटाई पूर्व एवं कटाई बाद की तकनीकों को मानकीकृत किया गया। केले की विभिन्न किस्मों में लीफ एरिया (पत्ती क्षेत्रफल) को नाडु (0.97 वर्ग मीटर) > पूवन (0.91 वर्ग मीटर) > कर्पुरावल्ली (0.80 वर्ग मीटर) के क्रम में पाया गया। पत्ती की सर्वश्रेष्ठ गुणवत्ता के साथ कर्पुरवल्ली (0.19 मिमी) किस्म में पत्ती की मोटाई सबसे कम थी।

रेड बनाना को कोल्ड स्टोरेज (13.5°C) में रखने पर बेहतर गुणवत्ता और संवेदी विशेषताओं सहित केले की फलियों के उपभोग काल (शेल्फ लाइफ) को 23 दिनों तक बढ़ाया जा सकता है। रेड बनाना के लिए स्मार्ट पैकेजिंग से बने राइपेनिंग इंडिकेटर (पकने के संकेतक) लेबल को स्टार्च मैट्रिक्स एवं प्लास्टिसाइज़र के साथ अमोनियम मोलिब्डेट का उपयोग करके बनाया गया और उनके रंग में बदलाव के आधार पर केले के पकने की सीमा का आकलन किया जा सकता था।

प्रोटीन-संशोधित स्टार्च कॉम्प्लेक्स में β-कैरोटीन के संपुटीकरण (एनकैप्सुलेशन) का प्रयास किया गया और संशोधित केले के स्टार्च को *गम अकेशिया* (बबूल के गोंद) की तुलना में एक बेहतर कैरियर (वाहक) सामग्री पाया गया, जिसे माल्टोडेक्सट्रिन के बाद संपुटीकरण के लिए व्यावसायिक रूप से उपयोग में लाया जाता है। केला स्टार्च से बनी बायोप्लास्टिक फिल्मों की संरचनात्मक विशेषताओं पर विभिन्न योजकों के प्रभाव का भी अध्ययन किया गया।

किसानों, केवीके, एफपीओ एवं छात्रों को सम्मिलित करते हुए 5920 लाभार्थियों के लिए कुल 114 क्षमता विकास कार्यक्रम आयोजित किए गए। कुल मिलाकर, 218 समाचार /कहानियां/सोशल मीडिया आधारित जानकारी को मास एवं सोशल मीडिया के माध्यम से प्रसारित किया गया तथा विभिन्न हितधारकों के लिए 12 प्रकाशन निकाले गए। मैनेज के साथ मिलकर एक संयुक्त कार्यशाला और डीएसटी द्वारा प्रायोजित एक हाई-एंड वर्कशॉप (*कार्यशाला*) का आयोजन किया भी किया गया।

फसल सुरक्षा

आक्रामक बोंडार नेस्टिंग व्हाइट फ्लाई (*पैरालेरोडिस बोंडारी*) का प्रकोप केले की फसल में बहुत कम स्तर पर पाया गया। *यूप्टरोटे ओरिएंटेलिस, आरटेक्सा गुट्टाटा* एवं *मिल्टोक्रिस्टा वायोलेसिया* को पहली बार केले के कीट के रूप में दर्ज किया गया था और इनमें से प्रथम दो कीटों को केले की सभी किस्मों के छिटपुट कीट के रूप में पाया गया। केले की नेय पूवन, नेंद्रन, सबा एवं कर्पूरवल्ली किस्मों में फसल की प्रारंभिक अवस्था (3-4 महीने पुरानी फसल) में सब्जियों में पाए जाने वाले टिड्डे, *एट्रैक्टोमोर्फा क्रेनुलाटा*

(पाइर्गोमोर्फिडी) के कारण पत्तों का काफी नुकसान होते देखा गया। फिप्रोनिल, कार्टेप हाइड्रोक्लोराइड और स्पिनोसैड को क्रमशः 0.006%, 0.125% और 0.018% के एलसी मूल्यों सहित स्यूडोस्टेम वीविल के विरुद्ध सबसे प्रभावी कैंडीडेट पाया गया। एंटोमोफंगल रोगाणु *ब्यूवेरिया ब्रोंगनिआर्टी* 27, *बी. बेसियाना* 22, *एम. एनिसोप्लिया* 50 एवं *बी. ब्रोंगनियर्टी* 28 को प्रयोगशाला जैवपरखों में स्यूडोस्टेम वीविल की उच्च मृत्यु दर का कारण पाया गया।

बिहार के कटिहार जिले के फालका ब्लॉक में ग्रैंड नैने केले पर *फ्यूजेरियम* विल्ट रोग (TR4) के प्रबंधन हेतु बायोएजेंट *कंसोर्टिया* के खेतों पर मूल्यांकन में एंडोफाइटिक *बैसिलस फ्लेक्सस* (Tvpr1) + राइजोस्फेरिक *टी. एस्पेरेलम* (NRCB3) के परिणामस्वरूप पौधों की ऊंचाई (37.46%), परिधि (28.61%), पत्तियों का क्षेत्रफल (61.38%) और कुल पत्तियों की संख्या (40.74%) में उल्लेखनीय वृद्धि हुई और तत्पश्चात इसे एंडोफाइटिक *बैसिलस सबटिलिस* उपप्रजाति *इनएक्वोसोरम* (BS30) + राइजोस्फेरिक *बैसिलस हेनेसी* (BS17) के संयोजन (पौधे की ऊंचाई में 34.68%, परिधि में 16.77%, पत्तियों के क्षेत्रफल में 55.66% और पत्तियों की कुल संख्या में 33.33% की वृद्धि) में पाया गया। केके पट्टी, तमिलनाडु में किए गए इसी तरह के परीक्षणों में एंडोफाइटिक *बैसिलस सबटिलिस* उपप्रजाति *इनएक्वोसोरम* (BS30) + राइजोस्फेरिक *बैसिलस हेनेसी* (BS17) और उसके बाद एंडो. राइजो. *टी. एस्पेरेलम* (NRCB3) + *बेसिलस फ्लेक्सस* (Tvpr1) को 0-5 स्केल पर क्रमशः 0.5 और 0.8 रोग स्कोर सहित सर्वश्रेष्ठ पौध मापदंड तथा न्यूनतम आंतरिक विल्ट का प्रबल कैंडीडेट साबित हुए। कर्नाटक के विजयनगर जिले के हम्पी गांव, होसपेट में केले की किस्म नेय पूवन पर किए गए समान परीक्षणों में एंडोफाइटिक *बैसिलस सबटिलिस* उपप्रजाति *इनएक्वोसोरम* (BS30) + राइजोस्फेरिक *बेसिलस हेनेसी* (BS17) और तत्पश्चात राइजो. *टी. एस्पेरेलम* (NRCB3) + *बेसिलस फ्लेक्सस* (Tvpr1) को न्यूनतम आंतरिक विल्ट रोग स्कोर के साथ सबसे प्रभावी पाया गया।

बिहार, पश्चिम बंगाल और उत्तर प्रदेश में सर्वेक्षण किए गए खेतों में *Foc* आइसोलेट्स (वियोजकों) के लक्षण वर्णन में *Foc* TR-4 एवं रेस 1 की उपस्थिति का पता चला। VCG विश्लेषण में TR-4 से संबंधित VCGs 01216, 01213/16 और *Foc* R1 से संबंधित VCG 01220, 0124 और 0125 की ग्रैंड नैने में पहचान की गई। चार बैक्टीरियल और पांच फंगल एंडोफाइटिक तथा राइजोस्फेरिक माइक्रोबियल आइसोलेट्स को *Foc* TR-4 के विरुद्ध प्रभावी पाया गया और ग्लासहाउस दशाओं में ग्रैंड नेने किस्म के और अधिक मूल्यांकन में विभिन्न संयोजनों में राइजो. *ट्राइकोडर्मा* प्रजाति + राइजो. *ट्राइकोडर्मा एस्पेरेलम* ने कॉर्म (घनकंद) में विल्ट रोग को पूरी तरह से दबा दिया (आंतरिक विल्ट रोग स्कोर 0.0)। बैक्टीरियल संयोजनों में एंडो. *बैसिलस सबटिलिस* + राइजो. *बैसिलस सबटिलिस* संयोजन को *फ्यूजेरियम* विल्ट (रोग स्कोर 0.2) के विरुद्ध प्रभावी पाया गया। एंडो. *बैसिलस सबटिलिस* उप-प्रजाति *इनएक्वोसोरम* (BS30) + राइजो. *बैसिलस हेनेसी* (BS17) के द्रव सूत्रीकरण को 0.5 लीटर प्रति पौधे पर उपयोग करने पर कंट्रोल (गैरउपचार) की तुलना में *Foc* TR-4 (बीमारी स्कोर 0) में संपूर्ण कमी आई।

16s rDNA अनुक्रमण के आधार पर, PGPR वियोजकों (आइसोलेट्स) में H7BC2 (OM188392.1), H8BC1 (OM188390.1), H6BC3 (OM188389.1), H4BC1 (OM188387.1) और H8BC2 (OM188391.1) का *प्रीस्टिया आर्यभट्टाई* के रूप में लक्षण-वर्णन किया गया जबकि H6BC2 (OM188388.1) का लक्षणवर्णन *पी. मेगाटेरियम* के रूप में किया गया। कॉपर हाइड्रॉक्साइड (0.1-0.3%) को सभी *पेक्टोबैक्टीरियम* वियोजकों (आइसोलेट्स) और विशिष्ट रूप से *के. वेरिकोला* (1-1बी-3) आइसोलेट के खिलाफ प्रभावी पाया गया जबकि सीओसी (0.2%) ने *के. वेरिकोला* के सभी आइसोलेट्स तथा *पेक्टोबैक्टीरियम* प्रजाति के कुछ आइसोलेट्स का उल्लेखनीय तौर पर निषेध किया।

महाराष्ट्र के जलगाँव जिला (0-33.88%) और मध्य प्रदेश के बुरहानपुर जिले (0-100%) में महामारी के दौरान टीसी पौधों में सीएमवी के कारण हुई संक्रामक क्लोरोसिस को फिर से उभरते पाया गया। जलगाँव और बुरहानपुर से संक्रमित केले के सीएमवी वियोजकों के संपूर्ण जीनोम के अनुक्रमण एवं लक्षणवर्णन के बाद उसे उपसमूह आईबी में वर्गीकृत किया गया। समयगत अध्ययनों के तहत, बीबीटीवी से संक्रमित और स्वस्थ केले के पौधों में 70 से अधिक प्रमुख वाष्पशील कार्बनिक यौगिकों (वीओसी) की पहचान की गई। एलीट बीएसएमवाईवी मुक्त उच्च उपज वाले टीसी पूवन किस्म के पौधों को पांच केवीके और किसानों को दिया गया और उनसे प्राप्त प्रतिक्रिया सकारात्मक थी। वायरस इंडेक्सिंग सेवाओं और वायरस डिटेक्शन किट की बिक्री

से क्रमशः 23,12,442/- रुपये और 59,500/- रुपये का सकल राजस्व सृजित किया गया।

पौधारोपण से पूर्व नेंद्रन किस्म के सकर्स (अंत:भूस्तारी) को 45-60 सेकंड तक उबलते पानी में डुबोने से सूत्रकृमियों (नेमाटोड) की संख्या में काफी कमी आई साथ ही रूट गॉल और रूट नॉट नेमाटोड (जड़ गांठ सूत्रकृमि) को भी पूरी तरह से अनुपस्थित पाया गया। मातृत्व वंशावलियों (पेरेंटल लाइन्स) मैती, नमाराई, कल्टीवर रोज, पिसांग जाजी, लैरावाक तथा एलीट म्यूटेंट टीबीएम 9 और ग्रैंड नैने म्यूटेंट 1 को जड़ क्षति (रूट लेजन) सूत्रकृमि, *पी. कॉफे* के प्रति सुग्राही पाया गया।

ग्लासहाउस दशाओं में *Foc* R1 (VCG 0124) के विरुद्ध कुल 110 आईटीसी परिग्रहणों का मूल्यांकन किया गया जिनमें से 08 प्रतिरोधी, 58 मध्यम प्रतिरोधी, 32 अतिसंवेदनशील और 12 उच्च अतिसंवेदनशील परिग्रहणों की पहचान की गई। कार्डाबा-एबीबी (0394), पीसी-1205-एएएबी (1260), पाका -एए (1254), एफएचआईए-23-एएए (1265), एफएचआईए-02-एएएबी (0505), विलियम्स-एएए (0570), तजाऊ लगाडा -AA (0090) और जीसीटीसीवी-119 -एएए (1282) को प्रतिरोधी पाया गया। मुथलापुरम, थेनी, तमिलनाडु में खेतों पर की गई जांच (फील्ड स्क्रीनिंग) में कार्डाबा को छोड़कर ये सभी आईटीसी परिग्रहण *Foc* R1 के विरुद्ध प्रतिरोधी थे।

BBrMV और CMV के रिकांबिनेंट (पुनः संयोजक) कोट प्रोटीन को बैक्टीरियल एक्सप्रेशन सिस्टम में अभिव्यक्त करके हाइब्रिडोमा तकनीक के प्रयोग द्वारा उन्हें मोनोक्लोनल एंटीबॉडी के बड़े पैमाने पर उत्पादन के लिए उपयोग में लाया गया। एससी उप-योजना के तहत कृषि विज्ञान केंद्र (केवीके) के माध्यम से अनुसूचित जाति के किसानों को नेंद्रन, रेड बनाना, ग्रैंड नैने और अन्य किस्मों के ऊतकों से तैयार (टिशू कल्चर) 9550 वायरस-मुक्त पौधों की आपूर्ति की गई।

प्रौद्योगिकी का हस्तांतरण

वर्ष 2022 के दौरान लगभग 6000 केला उत्पादकों (स्टेकहोल्डर्स) ने राष्ट्रीय केला अनुसंधान केंद्र का दौरा किया और केंद्र द्वारा सृजित तकनीकों एवं अनुसंधान गतिविधियों के बारे में जाना। केंद्र ने केला किसानों, एफपीओ, सरकारी अधिकारियों, सार्वजनिक और निजी उद्यमियों के लिए एससी और एसपी कार्यक्रम, एटीएमए-एसएसईपीआरएस, एनएचएम आदि विभिन्न योजनाओं के तहत कुल 19 परिसरीय (ऑन-कैंपस) क्षमता विकास कार्यक्रमों और 13 परिसर से दूर (ऑफ-कैंपस) प्रशिक्षण कार्यक्रमों का आयोजन किया। केले के विभिन्न हितधारकों के लाभ के लिए इस केंद्र ने *केला-मेला*, केला किसान - केला विशेषज्ञ जैसी नई पहलों को प्रारंभ किया है। मैनेज, हैदराबाद के सहयोग से भाकृअनुप-एनआरसीबी ने एक ऑनलाइन प्रशिक्षण कार्यक्रम 'केला आधारित प्रौद्योगिकियों के माध्यम से कृषि उद्यमिता' का आयोजन किया जिसका लाभ 100 से अधिक केला उत्पादकों ने उठाया। केंद्र के वैज्ञानिकों द्वारा केले पर सात रेडियो वार्ताएं प्रस्तुत की गईं। केंद्र ने 15 प्रदर्शनियों का आयोजन या उनमें सहभागिता कर केला उत्पादकों को बेहतर तकनीकों का प्रदर्शन किया है।

संपर्क और सहयोग

भाकृअनुप-राष्ट्रीय केला अनुसंधान केंद्र का कई अंतरराष्ट्रीय संस्थानों जैसे आईआईटीए, नाइजीरिया; एलायंस सीआईएटी-बायोवर्सिटी इंटरनेशनल, फ्रांस; केयूएल, बेल्जियम और क्वींसलैंड विश्वविद्यालय, ऑस्ट्रेलिया के साथ अनुसंधान सहयोग है। संस्थान ने परमाणु विज्ञान अनुसंधान बोर्ड (बीआरएनएस) सहित कई राष्ट्रीय संस्थानों के साथ भी शोध संपर्क स्थापित किए हैं जिनमे डीएसटी एवं डीबीटी, नई दिल्ली; एपीडा, नई दिल्ली; नाबार्ड; वीएफपीकेके, केरल; टीएनर्एयू, कोयम्बटूर; एनआईटी, तिरुचिरापल्ली और केएनसीईटी, थोट्टियम, तमिलनाडु सम्मिलित हैं। राष्ट्रीय केला अनुसंधान केंद्र का भाकृअनुप-एनबीपीजीआर, नई दिल्ली सहित भारतीय कृषि अनुसंधान परिषद के कई अन्य संस्थानों के साथ भी अनुसंधान सहयोग है जिनमें भाकृअनुप - आईआईएचआर, बेंगलुरु, भाकृअनुप -आईएआरआई, नई दिल्ली, भाकृअनुप -सीपीसीआरआई, कासरगोड, भाकृअनुप -एसबीआई, कोयम्बटूर और भाकृअनुप -सीआईएई (क्षेत्रीय केंद्र), कोयम्बटूर जैसे संस्थान सम्मिलित है। यह केंद्र केले पर अखिल भारतीय समन्वित अनुसंधान परियोजना भाकृअनुप -एआईसीआरपी (फल) के 11 केंद्रों के साथ समन्वय का कार्य भी करता है।

वर्ष 2022 के दौरान केंद्र ने संविदात्मक अनुसंधान, परामर्श परियोजनाओं, अनुसंधान सहयोग और छात्रों के आदान-प्रदान के लिए दस अनुसंधान संस्थानों / महाविद्यालयों / निजी कंपनियों के साथ एमओए / एमओयू / एमओसी पर हस्ताक्षर किए। केंद्र ने एपीडा और टीएनबीजीएफ के साथ मिलकर ऑस्ट्रिया को रेड बनाना का निर्यात किया। ऊतक संवर्धन (टिश्यू कल्चर) द्वारा केले के व्यापक प्रवर्धन में शामिल उद्योग, किसान, निर्यातक, राज्य बागवानी एवं कृषि विभाग तथा स्वयं

सहायता समूहों को विभिन्न अनुसंधान एवं विकासात्मक गतिविधियों के लिए इस केंद्र से सम्बद्ध किया गया है।

मानव संसाधन विकास (एचआरडी) एवं शिक्षा

मानव संसाधन विकास के अंतर्गत राष्ट्रीय केला अनुसंधान केन्द्र के वैज्ञानिकों ने 13 प्रशिक्षण कार्यक्रमों में सहभागिता की। इस केंद्र ने अंतर्राष्ट्रीय एवं राष्ट्रीय ख्याति प्राप्त विभिन्न पत्रिकाओं में 20 शोध पत्रों को प्रकाशित किया है। राष्ट्रीय केला अनुसंधान केंद्र ने डीएसटी, भारत सरकार के सहयोग से विभिन्न महाविद्यालयों के स्नातकोत्तर छात्रों की कालेज फैकल्टी के लिए एक कार्यशाला (जैव प्रौद्योगिकी में हाल के रुझान और उनके अनुप्रयोग) और दो प्रशिक्षण कार्यक्रमों ('हाई-एंड वर्कशॉप (*कार्यशाला*)' और 'ओमिक्स एवं जैवसूचना विज्ञान पर शोध सुविधा हेतु प्रशिक्षण कार्यक्रम) का आयोजन किया। राष्ट्रीय केला अनुसंधान केंद्र में 25 से अधिक छात्र/ शोध अध्येता अपनी मास्टर और डॉक्टरेट कार्यक्रमों का अध्ययन कर रहे हैं।

राजस्व का सृजन

जनवरी-दिसंबर, 2022 के दौरान भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र द्वारा रु0 80,59,467/- का सकल राजस्व सृजित किया गया।

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

4.1.1 Improvement and management of banana genetic resources in the Indian subcontinent

Collection

During the reporting period, 10 germplasm accessions have been collected from primary and secondary sources, viz. Thiruvananthapuram, Kerala and Rajendra Prasad CAU, Pusa, Bihar & KRC College of Horticulture, Arabhavi, Karnataka respectively (Table 1).

Establishment of a separate genebank for banana crop wild relatives

This is the first of its kind in India for ex situ conservation of the genetic diversity of *Musa* spp. for evaluation against various biotic and abiotic stresses, quality traits and subsequent identification of resistant gene sources and for catering to the needs of the banana breeders across the country. The resistant gene sources identified could be utilized in the banana improvement programmes by introgression of genes from CWRs in to cultivated varieties. This exclusive genebank includes 11 *Musa* spp. and one related genus (*Ensete*). The maximum number of clones are present in *Musa balbisiana* (36) followed by *M. flaviflora* (6) and two clones in each of *M. acuminata*, *M. thomsonii, M. ochracea, M. velutina* and the remaining five *Musa* spp. namely *M. itinerans*, *M. cheesmani, M. nagensium, M. aurantiaca, M. rubra* with one clone each.

Table 1. Germplasm accessions collected

S. No.	Name	Source
1.	Mahaulia	Rajendra Prasad CAU, Pusa Bihar.
2.	Ornamental banana type (yet to be characterized)	Parasala, Trivandrum
3.	Budubale (ABB), Shanbale (ABB), Bargibale (AAB), Karibale (AAB), Mitli (AB), Sakkarabale (AAB), Budumitika (AAB), Rajapuri (AAB)	KRC College of Horticulture, Arabhavi, Karnataka

Table 2. Details of the crop wild relatives maintained at ICAR-NRCB, Tiruchirappalli

S. No.	Name of the species	No. of clones /type
1	*Musa balbisiana*	36
2	*Musa acuminata*	2
3	*Musa flaviflora*	6
4	*Musa itinerans*	1
5	*Musa cheesmani*	1
6	*Musa nagensium*	1
7	*Musa thomsonii*	2
8	*Musa ochracea*	2
9	*Musa velutina*	2
10	*Musa aurantiaca*	1
11	*Musa rubra*	1
12	*Ensete superbum*	1

Fig.1. Filed genebank of *Musa* crop wild relatives

Molecular characterization

Validation of SSR panel to be used in DNA fingerprinting

Twenty-five commercial varieties were characterized using the stress related SSR markers (28), which were retrieved from MusatransSSRDB based on drought, nematode and Sigatoka transcriptomics data, using Capillary gel electrophoresis system (QIAxcel Advanced system, Qiagen) for validation of the panel.

Twenty-four of the 28 SSR markers tested, produced reproducible and reliable bands. A total of 540 fragments were amplified and all were polymorphic. The average number of bands produced per primer was 22.5, ranging from 10 (F3&F5) to 39 (S3). The Rp varied from 6.94 (UBC 850) to 17.65 (UBC 812), with an average of 12.52. The PIC varied from 1.12 (F6) to 6.32 (N1), with an average of 3.67. MI varied from 8.51 (F5) to 31.75 (S3), with an average of 16.92.

Characterization

Morphotaxonomic characterization

Morpho-taxonomic characterization was done for 14 accessions using IPGRI Musa descriptors leading to the identification of genomes and subgroups (Table 3).

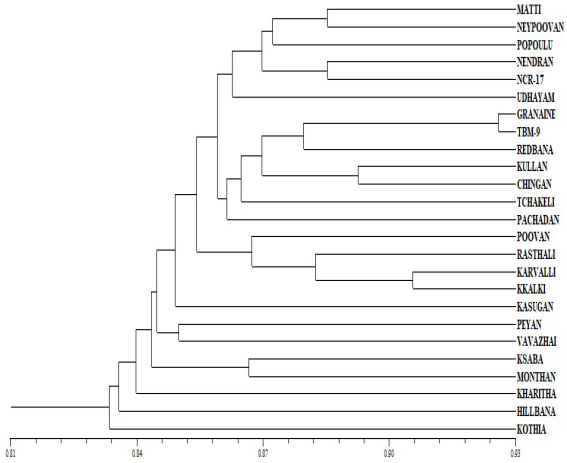


Fig. 2. Dendrogram generated using 24 stress related SSR markers

Table 3. List of accessions characterized

S. No.	NRCB accession No.	Name	Identified genome	Subgroup and Type
1.	2589	Sugantham	AAB	Mysore
2.	2590	MC-9402	BB	Elavazhai
3.	2591	Sonkela	AAB	Pome
4.	2593	Poyo	AAA	Robusta
5.	2594	Simla	BB	Attikol
6.	2595	M.balbisiana	BB	Bhimkol
7.	2596	Valery	AAA	Robusta
8.	2597	MC-9302	BB	Unique
9.		Local Banana I	AAB	Mysore

All the varieties tested were clustered based on the genomic and subgroups indicating the robustness of the panel except for few varieties.

Registration of genetic stock with ICAR-NBPGR, New Delhi

ICAR-NRCB has registered two improved genetic stocks which are resistant to root lesion nematode, Pratylenchus coffeae [Progeny 115 (IC No.0628011) and NPL 30 (IC No.0628037)] with ICAR-NBPGR, New Delhi. Passport data for 14 ornamental banana hybrids and one dwarf clone of cv. Grand Nain were submitted to ICAR-NBPGR, New Delhi and IC nos. were obtained (serially numbered from 644690 to 644704).

Regeneration systems in banana

Micropropagation technique has been standardized for Kaveri Kanchan using ECS and shoot tip explants. Protocol has been developed for large-scale propagation for both shoot tip and ECS explants using SERV bioreactor. In field evaluation no variation was observed among the bioreactor derived plantlets. A protocol has been standardized for secondary somatic embryogenesis in Sabri and field performance has confirmed their genetic stability. A protocol has been standardized for the storage and transport of germinated somatic embryos. Germinated somatic embryos of cvs. Red Banana, Quintal Nendran and Sabri have been supplied to private tissue culture companies, SAUs and State Departments as tabulated below.

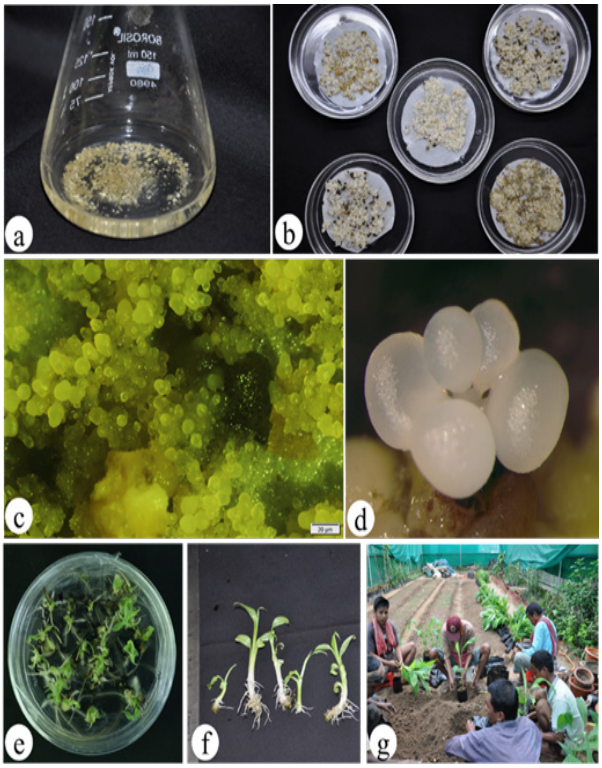


Fig. 3. Secondary somatic embryogenesis in cv.Sabri

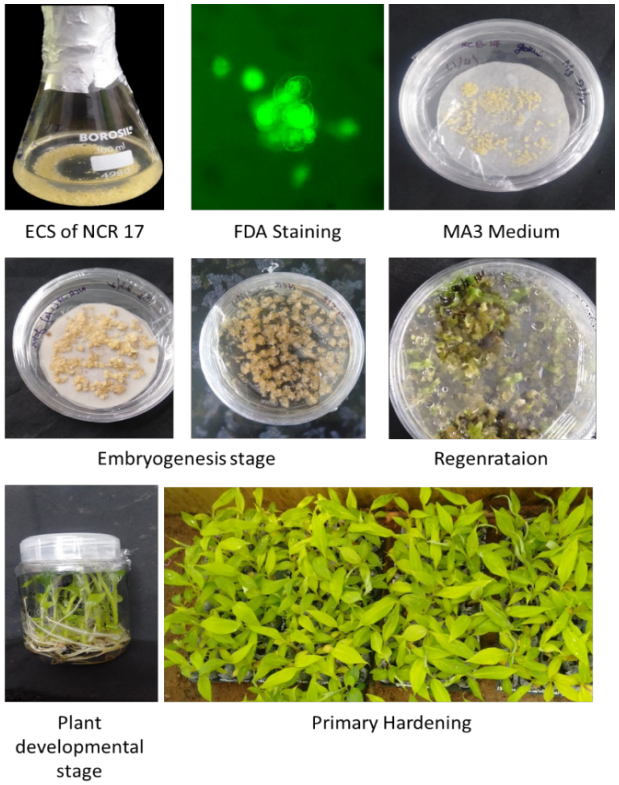


Fig. 4. Mass multiplication in new variety Kaveri Kanchan using ECS

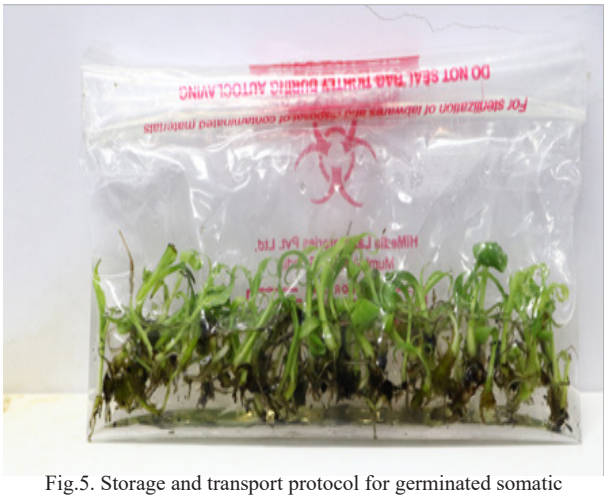


Fig.5. Storage and transport protocol for germinated somatic embryos

Genetic fidelity testing under contract services

About 1,578 batches of tissue culture plants of inclusive of cvs. Grand Nain, Ney Poovan, Karpuravalli, Red banana, Williams, Theni Nendran, Super Nendran, Poovan, Bantala, Malbhog, Jwari Bale and Nendran were tested for genetic fidelity using ISSR markers and reports issued, generating a revenue of Rs. 46.55 lakhs to the Institute.

Supply of planting material

Around 2,740 TC plants and 13,710 suckers of banana varieties have been supplied to interested banana growers.

4.1.2 Improvement of banana through conventional breeding

Evaluation of Saba based progenies for horticulture traits

A total of 31 Saba based progenies (including 3 open pollinated progenies) using six male parents have been developed. Of these,Progeny731 (Saba OP) and 733 (Saba x Calcutta 4) had poor bunch development whilethere was no flowering in Progenies 915 (Saba x Calcutta 4), 843 and P-826 (Saba x PJ) xP- 528(Kothia x Calcutta 4).All except Pro.183 of the remaining 27 progenies were parthenocarpic in nature. All the parthenocarpic progenies had residual female fertility except seven progenies. Pisang Lilin was found to be the best male parent for producing progenies with good horticulture traits and five progenies (Pro.183,Pro. 964,Pro.689,Pro.690 and Pro.691) recorded bunch weight significantly higher than or on par with the female parent Kaveri Saba (Table 5). Among the parthenocarpic progenies, five were found to be the best progenies based on bunch weight. Evaluationfor three consecutive years indicated the stable performance of all the progenies and Pro. 964 and Pro.959 were found to be the best for their stable yield, bunch appearance and good cooking quality (Table 6). Pro. 959 recorded 13.3% higher yield and 23.56% higher single fruit weight than the Kaveri Saba.

Evaluation of Poovan based progenies

A total of 15 Poovan based progenies (Eight progenies of Poovan x Pisang Lilin and 7 progenies of Poovan x Calcutta 4) were evaluated and all the progenies recorded shorter plant height (120-300 cm) than Poovan (320 cm) while the crop duration was longer (381-428 days) than female parent (369 days) except for progeny 876 with 20 days lesser duration. None of the Poovan based progenies recorded higher yield (3-10kg) than Poovan (18kg bunch weight) and total number of fruits (32-146) than Poovan (180 fruits/bunch) while two progenies (Pro. 954 and Pro. 955) recorded more number of fruits per hand (18) than Poovan (17).

Table 5. List of Saba based progenies showing better performance than Saba for horticulture traits

Female	Male	No. of Pro.	Progenies showing good traits than Female parent						Seeded	Parthenocarpy	No seed set upon crossing
Upon			Pl.ht (cm)	Duration (days)	Bunch wt (Kg)	No. of hands	Fingers/ hand	Total No. of fingers			
Saba	-	-	350	384	22	10	14	144	-	P	
Saba	Calcutta4-1	3	P0826, P0827, P0828	0	0	0	0	0	0	3	Pro.827
	Pisang Lilin	13	P0965	P0690, P0691	P0183, 9P064, P0689, P0690, P0691	P0684, P0685, P0826, P0689, P0691, P0964	P0183, P0690, P0689, P0691, P0834, P0964, P0965	P0964, P0689, P0691, P0834	183	12	688
	M.ochracea	2	0	0	0	P0651,P0652	P0651, P0652	P0651, P0652	0	2	0
	Calcutta 4	5	P0914	0	0	0	0	0	0	5	P0829, P0916
P0183	OP	2	P0735	0	P0959	0	0	0	0	2	P0735
Saba	P0183	1	P0580	0	0	0	0	0	0	1	P0580
P0183	P0528	1	P0811	0	0	0	0	0	0	1	P0811

Table 6. Evaluation of Poovan based progenies for horticulture traits

Progeny No.	Height (cm)	Girth (cm)	Bunch Wt. (Kg)	Hands/ bunch	Fruits/ Hand	Fruits/ bunch	Duration in days
Poovan	320	62	18	11	17	180	369
Poovan x Pisang Lilin							
P0876	185	77	3	4	8	32	346
P0877	195	50	4	8	15	120	390
P0904	205	50	3	5	17	80	394
P0905	260	65	10	9	15	130	398
P0954	120	33	9	8	18	143	381
P0955	130	37	7	8	18	140	399
P0957	290	59	2.5	7	12	85	388
P0958	290	59	3	7	12	84	392
Poovan x Calcutta 4							
P0906	300	68	8	9	14	125	402
P0907	290	52	2.5	5	14	70	398
P0908	290	70	6	11	12	135	413
P0909	270	68	3	10	15	146	421
P0910	280	60	4	6	11	65	415
P0911	255	62	3.5	7	14	99	428

Table 7. Ploidy level of the progenies

Female parent	Genomic status	No. of progenies			
		2x	3x	4x	>4x
Karpuravallli	ABB	11	0	33	0
Saba	ABB	4	10	13	3
Bhatmanohar	ABBB	0	5	12	3
Udhayam	ABB	3	1	10	2
Ennabenian	ABB	0	0	2	0
Poovan	AAB	0	5	9	0
Chinia	ABB	3	1	6	7
Kothia	ABB	41	0	0	0
Dhakshinsagar	ABB	0	0	2	0
Marabale	AAB	1	0	3	0
	Total	98	24	90	15

Comparison of progenies based on ploidy level

Ploidy analysis of 227 progenies obtained from various tetraploid, triploid, and diploid female parents hybridized with diploid parents, was done. In general, all triploid x diploid crosses produced higher number of tetraploid progenies except Kothia (ABB) crosses. Chinia, Saba and Udhayam based crosses produced progenies of all ploidy levels. (2x, 3x, 4x and > 4x). Ennabenian and Dhakshinsagar based crosses produced only tetraploid progenies. This revealed that most of the triploid progeneies produced both reduced and unreduced gametes. The production of maximum number of diploid progenies in the diploid x diploid confirmed that the diploid parents produced more reduced gametes.

Palynology of progenies

Palynology study was conducted in 30 progenies and all the tetraploid progenies were found to produce 2n gametes. Similarly, in case of Nendran based progenies, except NCR 17 and NCR 8 (n and 2n), all Nendran x cv. Rose produced 2n pollen grains whille all Nendran x Pisang Lilin and Nendran open pollinated progenies produced all types of pollen grains (n, 2n, 3n). In general, this study revealed the probability of production of 2n pollen grains is in higher number followed by 3n and n pollen grains. It was also observed that the fertility and germination of pollen grains are less in triploid progenies than the tetraploid and diploid progenies.

Evaluation of Progeny 932 (OP of Progeny 480 (Kothia X Calcutta 4)

Evaluation of P 932, an open pollinated progeny of P 480 (Kothia x Calcutta 4) and a diploid dessert banana, was done at Muthalapuram, Theni, Tamil Nadu. It produced a bunch of 9 kg with high provitamin A content (156µg of PVA /g of dry weight) while their parent recorded 6µg of PVA /g of dry weight.

Bunch characters of Progeny 0935 - IC 0642881, an open pollinated progeny of Saba x Pisang Lilin

The bunch characters of P 0935, an open pollinated progeny of P0686 (Saba x Pisang Lilin) resembled that of Bhimkol, a NE seeded cultivar except for the seediness trait. The variation has also been confirmed through molecular markers (Fig. 7)

Fig. 6. Carotenoid rich Kothia based Progeny 932

Fig. 7. Bunch characters of P 0935

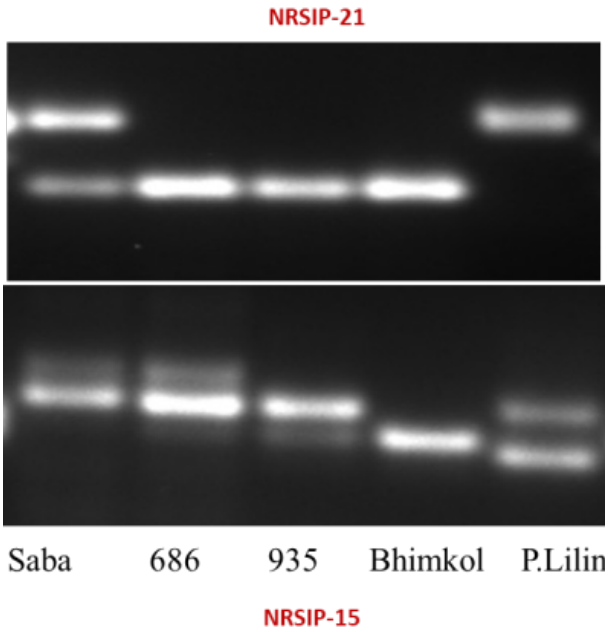


Fig. 8. Varition at moleular level

Progeny 792 (Udhayam x Pisang Lilin) (IC-0628027)

It is a polleniferous improved diploid having bunch characters similar to Cavendish group with parthenocarpic fruits. It showed moderately resistant reaction against Foc race 1 infecting Cavendish at hotspot area.

Screening of progenies against Foc race 1

Diploid progenies of Matti x cv. Rose

Evaluation of seven Matti x cv.Rose progenies against Foc race 1 infecting Cavendish (P0011, P0053, P0200, P0201, P0207, P0213, P0953) revealed that P0213 and P0207 were resistant and moderately resistant, respectively, under both pot culture and sick plot screening. Other progenies showed susceptible reaction under both conditions.

Kothia based progenies

Totally 34 Kothia based progenies were screened in the sick plot of Foc race 1 infecting Cavendish at Theni District. Of these, two Kothia x Calcutta 4 progenies (P0528, P0538), one Kothia x Calcutta 4-1 (P0567) and one Kothia x Pisang Lilin progeny (P0515) showed resistant reaction and IC number have been obtained for these progenies.

Table 8. Resistant reaction of Kothia based progenies against Foc race 1(VCG 0124) infecting Cavendish under sick plot conditions

Male parent	No. of progenies		Resistant reaction under hot spot		Resistant progenies under pot culture	IC number
	Available	Evaluated	Resistant	Susceptible		
Calcutta 4	26	26	2	24	P0528, P0538	IC-0628021, IC-0628022
Cv. Rose	4	1	-	-	-	-
Calcutta 4-1	4	4	1	3	P0567	IC-0628023
Pisang Lilin	7	3	1	2	P0515	IC-0628020
Total	41	34	6	28		

Saba x Pisang Lilin based progenies

In screening of Saba x Pisang Lilin based progenies (P0684, P0685, P0686, P0687, P0688, P0689, P0689, P0690, P0991) against Foc race 1, Pro. 684 (IC 0642858) showed resistant reaction both in pot culture and sick plot conditions.

Fig. 9. Fruit charcacters of P0684, resistant to Foc race 1 infecting Cavendish

Pisang Awak based progenies

Out of 11 Udhayam based progenies, tetraploid progeny namely P0434, and two diploid progenies namely P0792 and P0821 were resistant to *Foc* race 1under sick plot conditions. Five progenies of other Pisang Awak based progenies namely P0160 (3x), P0760, P0769, P0770, P0777 and P081 (4x), showed resistant reaction for *Foc* race 1.

Registration of root lesion nematode resistant progenies as genetic stock

Two nematode resistant progenies have been registered with ICAR-NBPGR for their resistance to *Pratylenchus coffeae.* P0115, a progeny of Karpuravalli x Calcutta 4-1, is a polleniferous and parthenocarpic diploid and could be used as a male parent in breeding program for improving *P. coffeae* resistance. NPL 30, a progeny of Nendran x Pisang Lilin, is a polleniferous and parthenocarpic Pome type that could be used as female and male parents in banana improvement program to incorporate *P. coffeae* resistance.

Fig. 10. Progeny 115 (IC No. 0628011)

Fig. 11. NPL 30 (IC No. 0628037)

A total of 9 progenies were screened against *Pratylenchus coffeae* in pot culture and only one tetraploid progeny showed resistant reaction while all the diploid progenies were susceptible (Table 9 and Fig. 12).

a) P0821 b) P0005

Fig. 12. Reaction of Progenies against *P. coffeae*

Table 9. Resistant reaction of various progenies against *P. coffeae*

Progeny No.	Parentage	Ploidy status	Reaction to *P.coffeae*
P0001	Calcutta 4-1 x Matti	2x	Susceptible
P0005	Karpuravalli x Calcutta 4-1	4x	Resistant
P0011	Matti x cv.Rose	2x	Susceptible
P0013	Anaikomban x Calcutta 4-1	2x	Susceptible
P0014	Anaikomban x Calcutta 4-1	2x	Susceptible
P0055	Namarai x Pisang Lilin	2x	Susceptible
P0109	Karpuravalli x Calcutta 4-1	2x	Susceptible
P0791	Udhayam x Pisang Lilin	2x	Susceptible
P0821	Udhayam x Pisang Lilin	2x	Susceptible

Screening of progenies against banana stem weevil (*Odoiporus longicollis*)

Totally 17 progenies were found to be resistant during 2019 and 2021. During 2022, in Ratoon II, all progenies except two, namely, cv. Rose x Pisang Lilin (Pro. 0429) and Matti x Anaikomban (Pro.0009), were screened under field conditions and no infestation was found in eleven progenies (Table 10). Totally 148 progenies were screened during 2021 and 2022, of which 104 had no pseudostem weevil infestation. Of these, 5, 25, 56, and 18 were diploid, triploid, tetraploid, and of unknown ploidy, respectively.

Table 10. Screening of progenies against banana stem weevil (*Odoiporus longicollis*)

Progeny Name	Parental details	Ploidy status	Per cent infestation
P0734	Udhaym x PisangLilin	4x	0
P0791	Udhayam x Pisang Lilin	2x	0
P0820	Udhaym x Pisang Lilin	2x	0
P0755	Karpuravalli x Pisang Jajee	4x	25
P0783	Karpuravalli x Calcutta 4-1	4x	25
P0817		4x	0
P0814	Bankela x Calcutta 4-1	4x	25
P0816		4x	0
P0819	Udhayam x Calcutta 4	4x	0
P0189	Udhayam x Pisang Jajee	4x	0
P0187	Bhatmanohar x Udhayam	4x	0
P0160	Bankela X Pisang Lilin	3x	0
P0685	Saba x Pisang Lilin	3x	0
P0691	Saba x Pisang Lilin	3x	25
P0731	Saba - OP	4x	0

Validation of SSR markers governing anthocyanin pigmentation using interspecific ornamental banana hybrids

Twelve genes from anthocyanin pathway had SSRs, primers were designed and validated in the ornamental parents (*M. ornata*, *M. rubra, M. velutina* and *M.a.* ssp. *zebrina*). Among these, AC-ARP SSR10 and Ant-FH-SSR11 were found to differentiate the parents (Fig. 13). But, one genic SSR marker (Ant-FH-SSR11), identified from F35H-1 gene present in anthocyanin pathway, was capable of differentiating the purple and green parents as well as their progenies (Fig. 14 & 15).

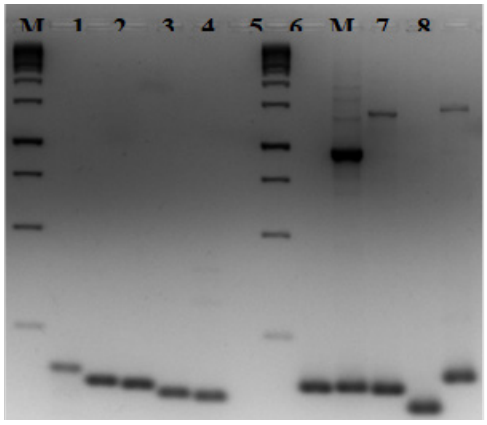


Fig. 13. Genic SSR markers AC- ARP -SSR10 and AC-FH-SSR11 differentiating the ornamental parents used in hybridization program. Lanes M – 1kb Gene ruler(SM 0313); Lane 1&7 – *M.ornata*; Lane 2&8 – *M.ac.* ssp. zebrina; Lane 3&9 – *M. rubra*;Lane 4&10 – *M. velutina*;Lane 5&11 – *M. velutina* variant and Lane 6 – Negative control.

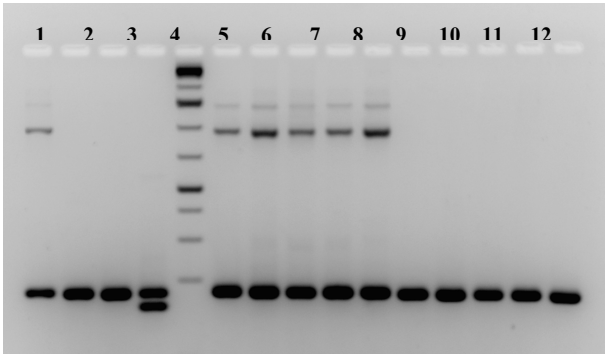


Fig. 14. Genic SSR markers AC-FH-SSR11 differentiating the ornamental parents and its hybrids. Lane 1 - (*M. a.*ssp.*zebrina*); Lane 2 -(*M.ornata*); Lane 3 - (*M. rubra*); Lane 4 - (*M. velutina*); Lane 5 - Marker 1 Kb plus (SM1331); Lane 6 to 10 (coloured hybrids between *ornata* x *zebrina*); Lane 11 to 15 (green hybrids from *ornata, rubra* and *velutina*)

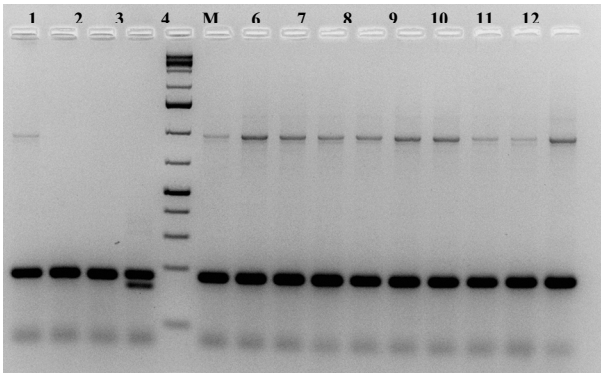


Fig. 15. Genic SSR markers AC-FH-SSR11 differentiating the ornamental parentsand its hybrids. Lane 1 - (*M. a.*ssp.*zebrina*); Lane 2 -(*M.ornata*); Lane 3 - (*M. rubra*); Lane 4 - (*M. velutina*); Lane M - Marker 1 Kb plus (SM1331); Lane 6 to 15 (coloured hybrids between *rubra* x *zebrina*)

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

Till date, phenotyping of all the 314 accessions and genotyping for 150 SSRs for 153 mini-core accessions have been completed. During the reporting period, confirmatory screening was taken up for 13 core collection accessions which showed resistance in the earlier pot screening trials and the results indicated that all showed infection and the disease score ranged from 2.2 (*M.a.*ssp. *burmannica*) – 4.4 (Ladies Finger, Hoobale and High Gate) and genotyping of 153 mini-core accessions has been completed for 25 genomic SSRs. The resistant and susceptible accessions identified based on phenotyping data were bulked separately and attempts were made to identify markers associated with fusarium wilt resistance, but only very few markers could be identified indicating the need for use of more number of markers for genotyping.

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

Mutants of cv. Grand Nain which showed resistance to race 1 / TR4 in pot culture were multiplied *in vitro* and subjected to sick plot screening at Theni, Tamil Nadu and all

were found promising in terms of yield (Table 13) despite infection with a disease score of 2-5 (on a disease scale of 0-5). TR 4 resistant lines identified from pot culture studies have been mass multiplied for evaluation in hotspot area.

Table 11. Screening of Grand Nain mutants to Foc under sick plot conditions at Theni, Tamil Nadu

S. No.	Race 1 / TR 4 resistant mutant line	Healthy plants with no external symptoms (%)	% infection	Average Disease score in the sick plot
1.	NRCBGNMG-1 (R1)	75.00	25.00	3.0
2.	NRCBGNME-2 (R1)	25.00	75.00	3.0
3.	NRCBGNME-1 (TR4)	18.75	81.25	3.0
4.	NRCBGNME-3 (TR4)	20.00	80.00	3.5
5.	NRCBGNME-13 (TR4)	33.33	66.67	2.0
6.	NRCBGNME-15 (TR4)	100.0	0.00	Yet to be taken
7.	NRCBGNMD-3 (TR4)	0.00	100.00	5.0

Status of mutagenized population of cv. Grand Nain

Six hundred plantlets developed by mutagenic treatment with various mutagens (Gamma irradiation alone–500; EMS alone-50; combined treatment of Gamma irradiation and EMS–50) are available in germination medium.

Mutated plants which were found to be resistant to race 1 in pot culture were cross checked for TR4 resistance and *vice versa*. Race 1 resistant line NRCBGNME 1 scored 3.57 for TR4 while TR4 resistant lines NRCBGNME 1, 3, 13 and 15 scored 3.33, 4.33, 3.33 and 4.00, respectively, for race 1. Similarly, TR4 resistant line NRCBGNMD 3 scored 4.00 for race 1.

Cv. Rasthali

About 22 lines of mutated Rasthali are being screened for drought tolerance under field conditions. Nine lines of mutated Rasthali are being evaluated in hotspot areas of Lalgudi, Thottiyam and Thuraiyur. Totally nine Fusarium wilt resistant mutants of cv. Rasthali were mass multiplied and one set of plants was subjected to pot screening against TR4. Four lines (NRCBRM 4, 6, 8 and 217) were moderately resistant and the rest five were susceptible.

Table 12. Screening of Fusarium wilt resistant mutants of cv. Rasthali in hotspot areas

S.No.	Line No.	Mutagen	Explant	Internal score
1	RM 03	EMS	ECS	3.75
2	RM 04	EMS	ECS	3.00
3	RM 06	EMS	ECS	3.00
4	RM 08	EMS	ECS	3.00
5	RM 13	EMS	ECS	3.25
6	RM 12	EMS	ECS	3.25
7	RM 15	EMS	ECS	3.25
8	RM 100	EMS	Shoot tip	3.25
9	RM 217	EMS	Shoot tip	3.00

TBM 9 and TBM 12

Mass multiplication of the dwarf mutants of cv. Grande Naine and 2000 plants are in the rooting stage.. TBM 9 was found to be susceptible to fusarium wilt races 1 and TR4 and root lesion nematode.

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

Screening of Ney Poovan diploid (NPD) and androgeneic Ney Poovan tetraploids (ANPT) against banana pseudostem stem weevil & banana corm weevil and *Fusarium* wilt

Totally 36 NNTP and four NPD plants were screened for banana pseudostem weevil (BPSW) and banana corm weevil (BCW), and the infestation level was measured at bi-weekly intervals. About 64 percent incidence was recorded in ANTP for BCW and BPSW however, no weevil incidence was recorded in NPD. Similarly, the internal corm discoloration score of androgenic ANPT and NPD (Fig.1 a-d) ranged from 3 to 4 (Susceptible) and 4 to 5 (Highly susceptible), respectively for Race 1. However, the internal score of only 3 (moderately resistant) was recorded in both NPD and androgenic ANPT for TR4 (Table 1).

Table 13. Internal corm discoloration score of androgenic Ney Poovan tetraploids (ANPT) and Ney Poovan diploid (NPD) for Race1 and TR4

Range /Mean	Androgeneic Ney Poovan tetraploid		Ney Poovan diploid	
	Race 1	TR4	Race 1	TR4
Range	3 to 4	3	4 to 5	3
Mean	3.6	3	4.4	3

Fig. 16. (a-d) Internal corm discoloration score of androgenic Ney Poovan tetraploids (ANPT) (a&b) and Ney Poovan diploid (NPD) (c&d) for Race1 (a&c) and TR4 (b&d)

Identification of volatile compounds in Ney Poovan diploid (NPD) and androgeneic Ney Poovan tetraploids (ANPT)

The volatiles were collected from the pseodostem and corm of androgenic Ney Poovan tetraploids (ANPT) and Ney Poovan diploid (NPD) and analyzed using GCMS (Fig.2 a-d). The volatile compounds which are common (Table 14) and also specific (Table 15) to ANPT and NPD are listed in the table. Tetradecanoic acid (an insect attractant) was 35-fold greater in pseudostem extract of ANPT (62.0%) than NPD (1.8%) (Fig.17 a-d) and the Tetradecanoic acid per cent peak area (28.9%) was recorded only in the corm extract of ANPT and not in NPD. Additionally, ANPT (8.0%) contains 10-fold more phenol (Antimicrobial activity) per cent peak area than NPD (0.8%). The presence of higher Tetradecanoic acid and lower phenols in ANPT may be one of the reasons for 100% infestation of banana weevils as compared to NPD (only 25% and 75% infestation of corm and pseudostem weevil, respectively).

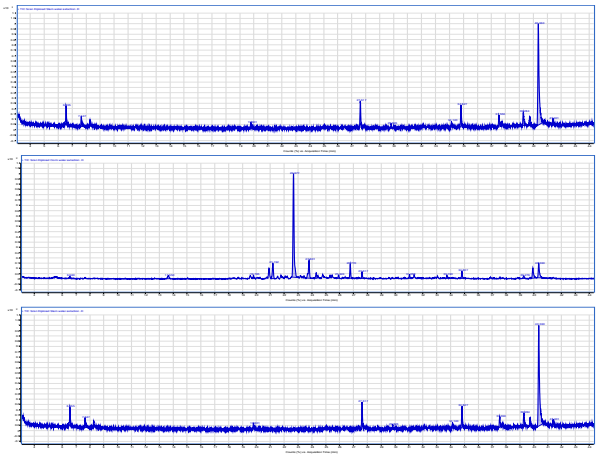


Fig. 17 (a-d). GCMS chromatogram of androgenic Ney Poovan tetraploid's corm (a) & pseudostem (b) and Ney Poovan diploid's corm (c) & pseudostem (d) extracts.

Table 14. List of volatile compounds common to Ney Poovan diploids (NPD) and androgeneic Ney Poovan tetraploids (ANPT)

Name of the compound	Functional Group	Biological functions	Peak area (%)			
			Pseudostem		Corm	
			4N	2N	4N	2N
Pentanoic acid, 3-methyl-	Carboxylic acids	Flavouring Agents	14.33	3.91	15.35	6.05
Hexanoic acid, 2-methyl-	Carboxylic acids	Polypropyl compounds	5.76	11.28	5.32	2.1
Tetradecanoic acid	Carboxylic acids	Insect acts as lipid anchor in bio-membranes (Insect attractant)	61.96	1.77	28.87	A
1-Hexanol, 2-ethyl-	Alcohols	Camphor like odour, used in making soaps, insecticides, germicides, dry cleaning, and plasticizers.	0.82	5.75	A	A
Phenol	Phenols	Antimicrobial Activity	0.83	8	A	A
Nonadecane	Hydrocarbons	Insect attractant compound	1.33	3.51	A	1.22
Octanoic acid	Carboxylic acids	Flavouring Agents	10.53	A	5.63	7.33
Phthalic acid, butyl undecyl ester	Esters	Flavouring Agents	A	A	4.41	7.46
5-Bromopentanoic acid, 2-phenylethyl ester	Diverse functional groups	Anti-microbial Activity	A	A	7.18	1.21
7-Benzoylheptanoic acid	Diverse functional groups	Anti-microbial Activity	A	A	3.31	2.27

A-Absent

Table 15. List of volatile compounds specific to Ney Poovan diploids (NPD) and androgenic Ney Poovan tetraploids (ANPT)

Name of the compound	Functional Group	Biological functions	Peak area (%)	
List of volatile compounds specific to pseudostem and corm extracts of androgenic Ney Poovan tetraploids (ANPT)			Pseudostem	Corm
Hexanoic acid	Carboxylic acids	Plasticizer, lubricants Poly compounds	3.47	6.29
Nonanoic acid	Carboxylic acids	Antimicrobial Activity	1.78	3.56
Heptanoic acid	Carboxylic acids	study the various metabolic pathways	A	5.73
Pentanoic acid, 4-methyl-	Carboxylic acids	Flavouring Agents	A	1.29
1-Octanol, 2,7-dimethyl-	Alcohols	Insect Skin compound,	A	4.14
2,2-Dimethoxybutane	Ethers	Plant Growth regulation	A	8.92
List of volatile compounds specific to pseudostem and corm extracts of Ney Poovan diploids (NPD)			Pseudostem	Corm
3-Tetradecene, (Z)-	Hydrocarbons	Plant growth stimulator.	1.64	A
Benzenemethanol, α-(1-ethenylpentyl)-α-methyl-	Alcohols	Tyrosine kinase enzyme inhibitors, Anti-inflammatoryagents.	1.54	A
Benzenepropanoic acid, 3,5-bis(1,1-dimethylethyl)-4-hydroxy-, methyl ester	Esters	Beetle Poisons	5.4	A
Dibutyl phthalate	Esters	Antimicrobial Activity	53.5	A
8-Benzoyloctanoic acid	Acid groups	8-Benzoyloctanoic acid	3.72	A
Benzoic acid, 4-ethoxy-, ethyl ester	Esters	Not intended for diagnostic or therapeutic use	A	50.33
Dichloroacetic acid, tetradecyl ester	Esters	Pesticide compounds	A	1.42
Cyclopentaneundecanoic acid, methyl ester	Esters	Precursor for cyclopentane monoterpenoid synthesis	A	1.23
1,2-Benzenedicarboxylic acid	Esters	Anticancer,antioxidant, Antimicrobial activity	A	5.29
Decane, 2, 3, 5, 8-tetramethyl-	Hydrocarbons	Antimicrobial Activity	A	8.85
1-Decanol, 2-hexyl-	Alcohols	Antimicrobial Activity	A	2.45
Tetradecane	Hydrocarbons	Antimicrobial activity	A	1.96

A-Absent

Exploitation of androgenic Ney Poovan tetraploids for the generation of euploids (haploids, diploids/doubled haploids, triploids and tetraploids)

Over 550 hybrids involving 2n x 4n crossing were generated for the first time in the world between a banana wild relative (Calcutta 4: *Musa kattuvazhana*, *M. acuminata* subsp. *burmannica* and *M. banksii* var. *singampatti* are conspecific) and androgenic Ney Poovan tetraploids (4n) created out

of diploid Ney Poovan cultivar (Fig. 18). Formation of euploids (Fig. 19) like haploids (3.9%), diploids/doubled haploids (70.5%), triploids (21.6%) and tetraploids (3.9%) was observed when ploidy analysis of 51 out of 550 F1 hybrids was done (Table 16). Both seeded (2 Nos.) and seedless (parthenocarpy) (8 Nos.) hybrid progenies were detected when 10 progenies were tested with a genic-SSR marker associated with parthenocarpy (Fig. 20)

Fig. 18. Secondary hardened hybrids generated through embryo culture from Calcutta 4 × androgenic Ney Poovan tetraploids cross

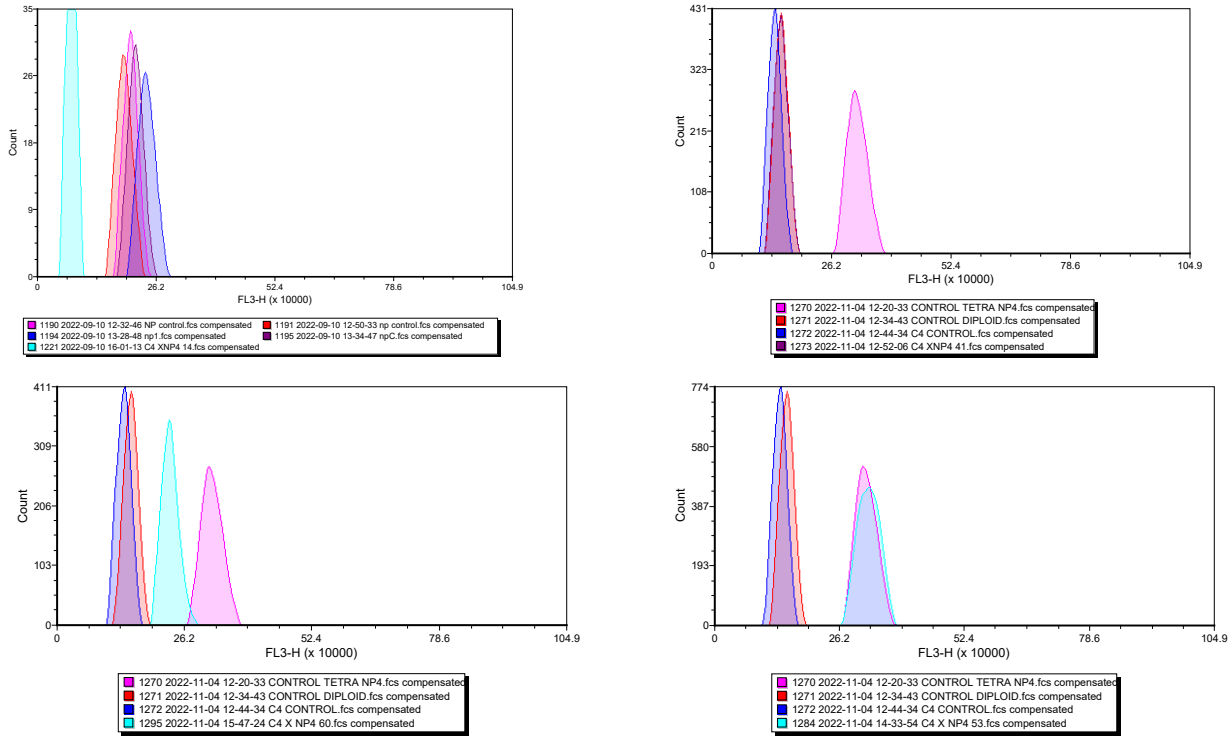


Fig. 19. (a-d) Flow cytometry detection of euploids like haploids (a), diploids/doubled haploids (b), triploids (c) and tetraploids (d) generated from a 2n x 4n crossing between Calcutta 4 and androgenic Ney Poovan tetraploids

Table 16. Flow cytometry analysis of euploids generated between Calcutta 4 and androgenic Ney Poovan tetraploid crosses

S.No	Sample	No. of events	Median	Geometric mean	CV	%
1	Ney Poovan diploid	3147	133971	134223	7.11	-
2	Calcutta 4	2841	119601	119894	7.42	-
3	Ney Poovan tetraploid	4864	299555	300942	6.07	-
4	Progeny (n)	317	58186	58451	7.60	3.9
5	Progeny (2n) or DH	3931	133200	133635	7.54	70.5
6	Progeny (3n)	3702	208971	210933	7.59	21.6
7	Progeny (4n)	7058	306383	305821	6.52	3.9

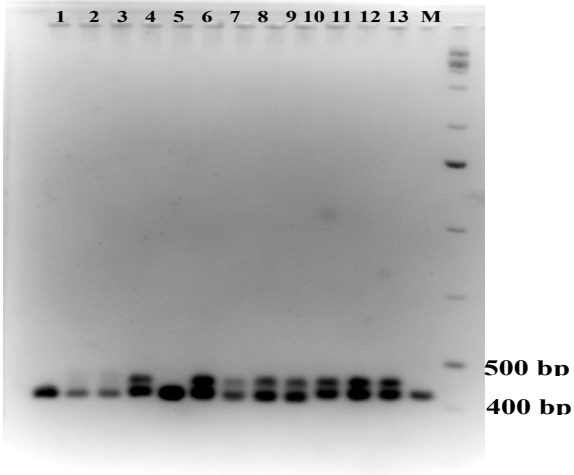


Fig. 20. Testing of genic-SSR marker associated with parthenocarpy with seeded (Lane 1: Calcutta 4), seedless (Lane 2&3: Ney Poovan diploid & androgenic Ney Poovan tetraploid) and hybrids from Calcutta 4 x androgenic Ney Poovan tetraploids crosses (Lane: 4 to 13). Lane 14 is a 1 Kb plus DNA ladder SM1333

4.1.6 Identification and evaluation of superior clones of cvs. Ney Poovan (AB) and Grand Naine (AAA)

Anthocyanin profiling of Red banana and its somaclonal virescent (green) variant using HPLC

Six major anthocyanin pigments were identified by high performance liquid chromatography (HPLC) in different parts of red banana and its virescent somaclonal variants (Table 1). However, four, one major anthocyanin pigments (Cyanidin 3 rhamnosides, Pelagornidin 3 rutinosides, Peonidin3 rutinosides and Malvidin 3 rutinosides) were identified only in the fruit peel of red banana and its virescent somaclonal variant, respectively (Fig. 21). Similarly, the total monomeric Anthocyanin (mg/100g fresh weight) content ranged from 4.17 to 46.52 in different parts of red banana and its variant. However, about two-fold higher anthocyanin content was recorded in the peel of red banana than its green variants.

A genic SSR marker (Ant-FH-SSR11) capable of differentiating the red banana and its green variant was also validated in their respective suckers. Hence this marker can potentially be used in the clonal fidelity testing of red banana suckers and its TC plantlets. The elite soma-clones of cv. Grande Naine (viz., clone Nos.17, 24, 25, 28, 32, 43, 48 & 52) with dwarf and high bunch yield were mass multiplied and field evaluated in the farmers' fields at Seepalakkottai and Gudalur of Theni, Tamil Nadu along with check (Normal Grande Nain). However, the growth and yield characters were non-significant between the elite clones and Grande Nain checks.

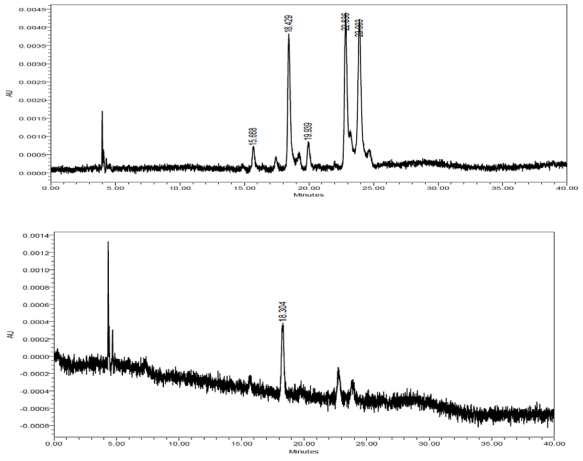


Fig. 21. HPLC Chromatogram of anthocyanins obtained from fruit peel of unripe red banana (a) and its virescent somaclonal variants (b) . Peak with RT 15.668 is Cyanidin 3 rhamnosides, RT 18.429/18.304 is Pelagornidin 3 rutinosides, RT 19.939 is Peonidin3 rutinosides and RT 22.836 is Malvidin 3 rutinosides. The first initial peaks, peak with RT 23.903 and last peaks are unknown artifact.

Table 17. IC numbers of 15 germplasm/hybrid lines (IC-644690 to IC-644704) received from ICAR-NBPGR

S.No.	Collector No.	IC No.	Botanical name	Cultivar/ Landrace name	Biological status	Frequency	Trait-specific characters
1	DR/PG/ MB/1/3	IC-0644690	*Musa* × *paradisiaca* L.	Dwarf Grande Naine	Elite line	Rare	A somaclonal variant of Grande Naine with 30% dwarf height (138-143 cm) and reduced leaf length (136-140 cm). The rachis appears with the presence of neutral / male flowers and withered bracts (on the whole stalk).
2	DR/AS/ MB/8/14	IC-0644691	*Musa* × *paradisiaca* L.	*Virescent* Red banana	Elite line	Rare	A somaclonal variant of red banana with virescent fruit colour at unripe stage and turns to yellow color upon ripening.
3	DR/1-30	IC-0644692	*Musa* × *paradisiaca* L.	Ney Poovan tetraploid (2n=44)	Genetic stock	Rare	Ney Poovan tetraploids (4n) (2n=2x=44) produced through anther culture of diploid Ney Poovan (2n=2x=22). Male fertile, drooping leaf habit, less number of hands and fruits than its diploid; Uniseriate fruits on the crown.
4	DR/SU/ MSS/ 30/R-Z7	IC-0644693	*M. rubra* Kurz × *M. acuminata* L. A. Colla subsp. *zebrina* (Van Houtte) R.E. Nasution.	Inter-specific ornamental banana hybrid	Breeding line	Frequent	Slightly upright bunch orientation; Leaf (abaxial) is moderate yellow green (RHS2019146C); Bract (outer) is moderate red (RHS2019179A); Bract (inner) is moderate reddish orange and fruit is strong yellow green (RHS2019144A).
5	DR/SU/ MSS/ 30/RZ-14	IC-0644694	*M. rubra* Kurz × *M. acuminata* L. A. Colla subsp. *zebrina* (Van Houtte) R.E. Nasution.	Inter-specific ornamental banana hybrid	Breeding line	Rare	Moderately upright bunch orientation; High anthocyanin ileaves (120 to 136 mg/100g); Leaf (abaxial) is moderately reddish brown (RHS2019177A); Bract (outer) is moderate reddish orange (RHS2019178B); Bract (inner) is moderate red (RHS2019179A) and fruit is moderate brown (RHS2019200D).

6	DR/SU/ MSS/2/ RZ-51	IC-0644695	*M. rubra* Kurz × *M. acuminata* L. A. Colla subsp. *zebrina* (Van Houtte) R.E. Nasution.	Inter-specific ornamental banana hybrid	Breeding line	Occasional	Slightly upright bunch orientation, high anthocyanin in leaves (113 to 135 mg/100g); Leaf (abaxial) is moderate reddish brown (RHS2019177A); Bract (outer) is Moderate reddish oragne (RHS2019178B); Bract (inner) is Moderate red (RHS2019179A) and Fruit is Moderate brown (RHS2019200D).
7	DR/SU/ MSS/2/ OZ-19	IC-0644696	*M. ornata* Roxb.× *M. acuminata* L. A. Colla subsp. *zebrina* (Van Houtte) R.E. Nasution.	Inter-specific ornamental banana hybrid	Breeding line	Occasional	High anthocyanin in leaves (204 to 220 mg/100g); Female sterile under open pollination with pencil like fruits, Leaf (abaxial) is Greyish purple (RHS2019N77A); Bract (outer) is Moderate red (RHS2019184B); Bract (inner) is Moderate purplish red (RHS2019185B) and Fruit is Dark red (RHS2019187A).
8	DR/SU/ MSS/24/ OZ-2	IC-0644697	*M. ornata* Roxb.× *M. acuminata* L. A. Colla subsp. *zebrina* (Van Houtte) R.E. Nasution.	Inter-specific ornamental banana hybrid	Breeding line	Rare	High anthocyanin in leaves (163 to 183 mg/100g); Female fertile under open pollination with seeded pulpy fruits, Leaf (abaxial) is Dark grayish red (RHS2019N186C); Bract (outer) is Moderate purplish red (RHS201959C); Bract (inner) is Strong purplish red (RHS201960C) and Fruit is Dark grayish red (RHS2019N186C).
9	DR/SU/ MSS/ 2/OZ-15	IC-0644698	*M. ornata* Roxb.× *M. acuminata* L. A. Colla subsp. *zebrina* (Van Houtte) R.E. Nasution.	Inter-specific ornamental banana hybrid	Breeding line	Rare	High anthocyanin in leaves (144 to 192 mg/100g); Moderately upright bunch orientation; Leaf (abaxial) is Dark grayish red (RHS2019N186C); Bract (outer) is Moderate purplish red (RHS201959C); Bract (inner) is Strong purplish red (RHS201960C) and Fruit is Dark grayish red (RHS2019N186C).

10	DR/SU/ MSS/ 17/OR-30	IC-0644699	*M. ornata* Roxb.× *M. rubra* Kurz	Inter-specific ornamental banana hybrid	Breeding line	Frequent	Upright bunch orientation with dull pink flower bud; Bract (outer) is Deep purplish pink (RHS201958D); Bract (inner) is Very light purple (RHS201975C) and Fruit is Strong yellow green (RHS2019144B).
11	DR/SU/ MSS/18/ OR-19	IC-0644700	*M. ornata* Roxb.× *M. rubra* Kurz	Inter-specific ornamental banana hybrid	Breeding line	Frequent	Upright bunch orientation with dark pink flower bud; Bract (outer) is Red purplish pink (RHS201961D); Bract (inner) is Deep purplish pink (RHS201970C) and Fruit is Light yellow green (RHS2019144B).
12	DR/SU/ MSS/ 2/OR-28	IC-0644701	*M. ornata* Roxb.× *M. rubra* Kurz	Inter-specific ornamental banana hybrid	Breeding line	Occasional	Upright bunch orientation with lilac colored lengthy flower bud; Bract (outer) is Strong purplish pink (RHS2019N74D); Bract (inner) is Strong purplish pink (RHS201967D) and Fruit is Strong yellow green (RHS2019144A).
13	DR/SU/ MSS/ 2/OR-29	IC-0644702	*M. ornata* Roxb.× *M. rubra* Kurz	Inter-specific ornamental banana hybrid	Breeding line	Occasional	Upright bunch orientation with Red purple colored short flower bud; Bract (outer) is Strong purplish pink (RHS201963C); Bract (inner) is Moderate purplish pink (RHS201965A) and Fruit is Strong yellow green (RHS2019145A).
14	DR/SU/ MSS/ 19/OM-8	IC-0644703	*M. ornata* Roxb. × *M. velutina* subsp. *markkuana* M.Sabu, A.Joe & Sreej.	Inter-specific ornamental banana hybrid	Breeding line	Rare	Upright bunch orientation with Red purple colored flower bud with persistent bracts; Bract (outer) is Light reddish purple (RHS2019NN74C); Bract (inner) is Strong reddish purple (RHS2019NN74D) and Fruit is Light yellow green (RHS2019145C).
15	DR/SU/ MSS/ 11/OM-1	IC-0644704	*M. ornata* Roxb. × *M. velutina* subsp. *markkuana* M.Sabu, A.Joe & Sreej.	Inter-specific ornamental banana hybrid	Breeding line	Rare	Upright bunch orientation with violet colored flower bud; Bract (outer) is Light purple (RHS2019N80D); Bract (inner) is Light purple (RHS201984C) and Fruit is Light yellow green (RHS2019145B).

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

Transcriptome analysis was carried out for resistant (cv. Rose) and susceptible (Matti, AA – TR4; Namarai, AA - race1) banana roots and corms in response to infection by *Fusarium oxysporum* f. sp. *cubense* race 1 (Cavendish infecting strain) and TR4 at different time intervals post inoculation (0, 2, 4, 6, 8 DPI). Foc infection led to induction of many well known defense-related genes, genes involved in signaling pathways, pathogenesis-related (PR) genes, transcription factors, signaling/ regulatory genes, cell wall modification genes, enzymes, hormone pathway genes, NBS-LRR, susceptibility factors and genes with other functions were analyzed and compared.

Macma4_03_g09360.1 (Ma03_g09130) showed higher expression in resistant cultivar (cv. Rose, AA) upon infection with both the Foc races, but, significant up-regulation was observed upon Foc TR4 than race1 infection. Macma4_10_g11850.1 (Ma10_t08140.1) showed significant upregulation in resistant cultivar (Manoranjitham, AAA) as compared to the susceptible cultivar (Grand Nain, AAA) upon *P. eumusae* infection. Macma4_06_ g25510.1 (Ma06_t23890.1) was significantly up-regulated in resistant cultivar (YKM5, AAA) than the susceptible cultivar (Nendran, AAB) upon *P. coffeae* infection (Fig. 22a and b).

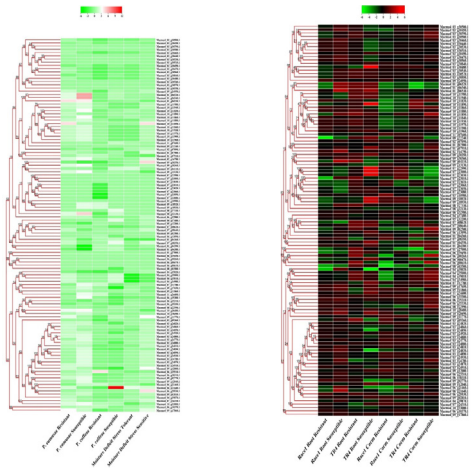


Fig. 22 a & b. A graphical representation of expression details of NBS genes under biotic and abiotic stresses in *Musa* cultivars [(1a) Eumusae leaf spot, nematode and drought, (1b) Foc race 1 and TR4].

Susceptibility factors (eight *dmr6* and one *dlo1*) were identified, amplified and their expression was studied in resistant and susceptible cultivars upon Foc, *P. eumusae* and *P. coffeae* infection. Twenty-five PR1 (Ma02_ g15050, Ma02_g15060, Ma04_g34800) were cloned from Foc race 1 and TR4 resistant and susceptible cultivars of banana and their expression was studied upon Foc race1 and TR4 infection. Expression of Ma10_g00490, Ma10_g00550, Ma10_g00570, Ma10_g00650 genes were studied upon Foc race1 (Cavendish infection strain) infection. Ma10_g00550 and Ma10_g00570 were found to be up-regulated in resistant than susceptible cultivars at different time intervals of Foc race1 infection. Guide RNA of Ma10_g00550 was cloned in pRGEB31 and confirmed through sequencing and further mobilized into *Agrobacterium tumefaciens* strain and used in ECS transformation. RGA3 (2.78kb) was cloned and sequenced from Grand Nain and full length RGA2 (~ 7kb) including the UTR region was amplified from resistant and susceptible cultivars. The promoter region of RGA2 was also amplified from resistant and susceptible cultivars. SSR marker associated with anthocyanin pigment was able to distinguish the red banana from its green variant and this marker was further validated in ornamental parents and their progenies. Thus, this SSR marker can be used to eliminate undesirable somaclonal variants from the lab without the need for additional *in vitro* plant culture in the field, as well as to distinguish purple ornamental progenies from green in order to save time and effort and to shorten the breeding cycle in the case of ornamental breeding.

A comprehensive analysis of the Nucleotide-Binding Site (NBS) disease resistance (R) gene family was carried out on classification, phylogenetic analysis, genome organization, evolution, cis-elements, differential expression, regulation by microRNAs and protein-protein interaction. A total of 116 and 43 NBS genes were identified and characterized from *M.acuminata* and *M.balbisiana*, respectively, and were divided into seven subfamilies. Ninety miRNAs were found to have targets in 104

NBS genes in the A genome. The MusaRgene database is complemented with complete details of 3598 R genes identified from eight *Musa* spp. and rice, *Arabidopsis,* sorghum along with its classification and separate modules on its expression under various stresses in resistant and susceptible cultivars and corresponding SSRs are provided. This database can be regarded as the primary resource of information on R genes from bananas and their relatives. R genes from other allele mining studies are also incorporated which will enable the identification of its homolog in related *Musa* spp (Fig. 23).

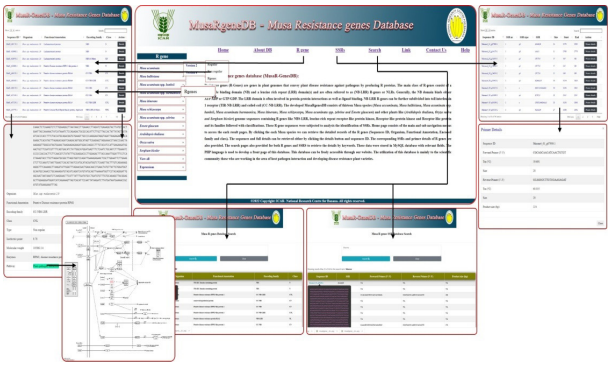


Fig. 23. Schematic diagram of MusaRgene database

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

Crop Production

4.2.1. Studies on nutrient dynamics in banana

The total dry matter production (DMP in t/ha) increased from 2.31 to 46.3 in Nendran banana, while it increased from 2.36 to 54.70, in Grand Nain banana during the growth period from 5 leaf stage to harvesting stage (Table 18 & 19). The percent DMP fractions and nutrient accumulations of leaf, petiole, stem, corm, root, peduncle, bunch and bud at harvesting stage of Nendran and Grand Nain given in the Fig. 24. In Nendran banana, the nutrient removal (kg/ha) through bunch harvest was worked out to be N-189.5, P-32.7, K-552.3, Cu-0.8, Mn-0.3, Zn-1.9 and Fe-2.4. The nutrients left out in the Nendran plant residues (kg/ha) were worked out to be N-297.01, P-88.9, K-518.0, Cu-2.8, Mn-4.8, Zn-4.3 and Fe-2.73. In Grand Nain banana, the nutrient removal (kg/ha) through bunch harvest was worked out to be N-222.1, P-30.6, K-605.9, Cu-0.7, Mn-0.5, Zn-1.4 and Fe-0.4. The nutrient left out in the Grand Naine plant residues (kg/ha) were worked out to be N-266.8, P-46.4, K-358.5, Cu-2.0, Mn-2.3, Zn-1.1 and Fe-5.5. In Nendran, the harvesting index (%) for DMP, N, P, K were 40.37, 38.95, 36.75, 51.60 while that of Grand Naine were 43.02, 45.43, 39.71, 62.83, respectively. In Nendran, the harvesting index (%) for Cu, Mn, Zn, Fe were 21.33, 6.50, 31.78, 48.20 while that of Grand Nain were 26.97, 18.18, 55.92, 7.30, respectively. In both the varieties, through vermicomposting of banana residues after harvesting, the C/N ratio reduced from 60/1 to 9/1 with a recovery of about 58.5% of N, 56.7% of P and 47.5% of K.

The cubic polynomial curves were derived to know the uptake (kg/ha) pattern of macro and micronutrients during 5 leaf stage to harvesting stage and were shown in the Fig. 25. The corresponding polynomial equations for all the nutrients in both the varieties of bananas are given Tables 20 & 21. In Nendran, the N uptake increased from 22.5 to 486.52 gradually with increasing rate, the P uptake from 6.17 to 88.98 in slow pace and the K uptake from 101.01 to 1070.28 rapidly with increasing rate from 5 leaf stage to harvesting. The similar trends were recorded in Grand Naine also, with increase of N uptake from 21.58 to 488.89, P uptake from 6.48 to 76.96 and K uptake from 106.09 to 964.51 during 5 leaf stage to harvesting.

Table 18. Dry matter and nutrient accumulation pattern at different growth stages in Nendran

Parameter	stage	Accumulation or uptake by								Total
		Leaf	Petiole	Stem	Corm	Root	Pedun-cle	Bunch	Bud	
Dry Matter (t/ha)	5L	0.58	0.10	0.73	0.75	0.15	-	-	-	2.31
	10L	1.44	0.19	2.28	1.76	0.26	-	-	-	5.93
	20L	4.17	0.31	3.80	4.16	0.42	-	-	-	12.86
	shoot	4.635	1.236	4.845	3.423	0.618	-	-	0.603	15.36
	Harvest	6.64	1.66	9.64	7.98	1.69	2.74	15.53	0.42	46.3
N (kg/ha)	5L	11.91	0.22	6.28	3.43	0.66	-	-	-	22.50
	10L	35.41	0.58	19.41	10.82	1.68	-	-	-	67.90
	20L	115.95	2.45	68.94	43.31	2.93	-	-	-	233.57
	shoot	160.75	11.09	95.54	21.76	3.69	-	-	14.41	307.24
	Harvest	168.19	8.34	76.87	36.31	7.3	25.21	161.81	2.49	486.52
P (kg/ha)	5L	1.85	0.24	2.19	1.63	0.26	-	-	-	6.17
	10L	4.80	0.74	7.55	4.66	0.54	-	-	-	18.29
	20L	14.57	1.20	14.84	10.51	1.03	-	-	-	42.15
	shoot	21.57	2.83	17.1	6.84	0.83	-	-	1.58	50.75
	Harvest	15.26	3.5	25.22	10.4	1.9	3.39	28.68	0.63	88.98
K (kg/ha)	5L	14.73	5.48	48.36	24.21	8.22	-	-	-	101.01
	10L	36.09	10.02	150.03	59.72	13.33	-	-	-	269.19
	20L	134.11	20.91	283.21	194.43	30.01	-	-	-	662.68
	shoot	122.32	86.55	376.37	114.47	30.34	-	-	24.75	754.8
	Harvest	132.96	28.04	263.16	76.92	16.94	129.06	420.98	2.22	1070.28
Cu (kg/ha)	5L	0.21	0.02	0.26	0.32	0.03	-	-	-	0.85
	10L	0.57	0.07	0.52	0.48	0.05	-	-	-	1.70
	20L	1.26	0.03	0.40	0.79	0.14	-	-	-	2.62
	shoot	0.91	0.21	0.81	0.7	0.18	-	-	0.04	2.85
	Harvest	0.24	0.07	1.18	1.07	0.28	0.08	0.66	0.03	3.61
Mn (kg/ha)	5L	0.53	0.07	0.61	0.41	0.10	-	-	-	1.72
	10L	0.85	0.05	1.24	0.55	0.04	-	-	-	2.74
	20L	0.85	0.05	0.71	0.85	0.16	-	-	-	2.62
	shoot	0.74	0.2	1.62	0.56	0.14	-	-	0.1	3.36
	Harvest	0.94	0.26	2	1.28	0.27	0.09	0.23	0.01	5.08
Zn (kg/ha)	5L	0.07	0.01	0.10	0.12	0.03	-	-	-	0.33
	10L	0.15	0.03	0.32	0.26	0.04	-	-	-	0.80
	20L	0.27	0.02	0.28	0.35	0.04	-	-	-	0.96
	shoot	0.9	0.28	0.99	0.78	0.18	-	-	0.13	3.26
	Harvest	1	0.06	1.69	1.48	0.02	0.06	1.92	0	6.23
Fe (kg/ha)	5L	0.82	0.11	0.90	0.59	0.02	-	-	-	2.44
	10L	1.18	0.12	1.50	0.85	0.11	-	-	-	3.75
	20L	2.08	0.17	1.38	1.30	0.19	-	-	-	5.13
	shoot	2.35	0.26	1.32	0.54	0.07	-	-	0.44	4.98
	Harvest	0.71	0.16	1.03	0.72	0.11	0.23	2.3	0.01	5.27

Table 19. Dry matter and nutrient accumulation pattern at different growth stages in Grand Nain

Parameter	stage	Accumulation or uptake by								Total
		Leaf	Petiole	Stem	Corm	Root	Pedun-cle	Bunch	Bud	
Dry Matter (t/ha)	5L	0.57	0.08	0.81	0.78	0.12	-	-	-	2.36
	10L	1.63	0.17	1.95	1.93	0.27	-	-	-	5.95
	20L	3.07	0.27	3.56	3.35	0.39	-	-	-	10.64
	shoot	4.55	1.21	5.82	4.74	0.61	-	-	0.59	17.53
	Harvest	5.84	1.46	10.82	11.57	1.48	4.16	19.00	0.37	54.70
N (kg/ha)	5L	11.18	0.21	6.23	3.40	0.56	-	-	-	21.58
	10L	35.84	0.51	17.58	10.52	1.49	-	-	-	65.94
	20L	69.21	0.81	30.33	17.29	2.20	-	-	-	119.84
	shoot	116.27	5.74	104.96	37.67	2.86	-	-	11.17	278.67
	Harvest	124.93	6.82	80.20	48.90	5.94	35.66	184.41	2.03	488.89
P (kg/ha)	5L	1.55	0.22	2.77	1.73	0.21	-	-	-	6.48
	10L	4.99	0.56	7.19	4.69	0.62	-	-	-	18.05
	20L	11.04	1.03	13.95	8.80	0.99	-	-	-	35.81
	shoot	11.82	2.33	20.43	7.22	0.63	-	-	1.17	43.60
	Harvest	10.03	2.31	21.31	11.47	1.28	3.86	26.29	0.41	76.96
K (kg/ha)	5L	16.18	4.06	49.47	29.33	7.05	-	-	-	106.09
	10L	48.29	10.32	122.09	84.51	14.60	-	-	-	279.81
	20L	103.34	18.79	277.52	164.27	29.09	-	-	-	593.01
	shoot	98.98	70.14	373.04	130.87	24.56	-	-	20.04	717.63
	Harvest	105.83	12.30	159.46	69.66	11.27	223.32	380.09	2.58	964.51
Cu (kg/ha)	5L	0.22	0.03	0.41	0.34	0.05	-	-	-	1.05
	10L	0.63	0.08	0.76	0.98	0.13	-	-	-	2.58
	20L	0.53	0.06	0.97	0.71	0.09	-	-	-	2.36
	shoot	0.45	0.13	0.87	0.86	0.11	-	-	0.03	2.45
	Harvest	0.25	0.07	0.69	0.86	0.11	0.12	0.60	0.00	2.70
Mn (kg/ha)	5L	0.47	0.05	0.62	0.68	0.08	-	-	-	1.90
	10L	0.69	0.05	0.76	0.83	0.09	-	-	-	2.42
	20L	0.78	0.05	0.84	0.86	0.08	-	-	-	2.61
	shoot	0.72	0.20	0.92	0.77	0.10	-	-	0.05	2.76
	Harvest	0.52	0.11	0.93	0.69	0.09	0.21	0.29	0.02	2.86
Zn (kg/ha)	5L	0.07	0.01	0.11	0.13	0.02	-	-	-	0.34
	10L	0.22	0.03	0.28	0.31	0.05	-	-	-	0.89
	20L	0.35	0.03	0.48	0.42	0.06	-	-	-	1.34
	shoot	0.48	0.15	0.65	0.59	0.10	-	-	0.07	2.04
	Harvest	0.58	0.03	0.20	0.23	0.04	0.07	1.30	0.00	2.45
Fe (kg/ha)	5L	0.65	0.11	0.54	0.43	0.11	-	-	-	1.84
	10L	0.82	0.11	1.18	0.81	0.23	-	-	-	3.15
	20L	1.83	0.13	1.55	1.26	0.15	-	-	-	4.92
	shoot	1.71	0.26	1.56	1.17	0.18	-	-	0.19	5.07
	Harvest	1.07	0.24	3.34	0.79	0.02	0.13	0.28	0.02	5.89

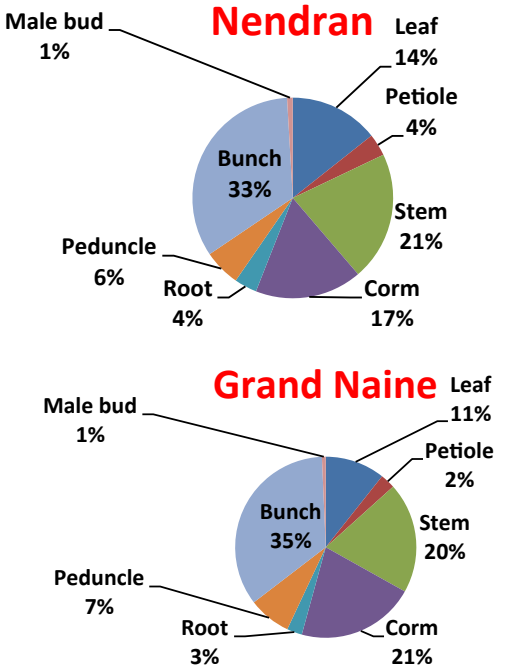


Fig. 1: Dry matter distribution at harvesting stage of bananas

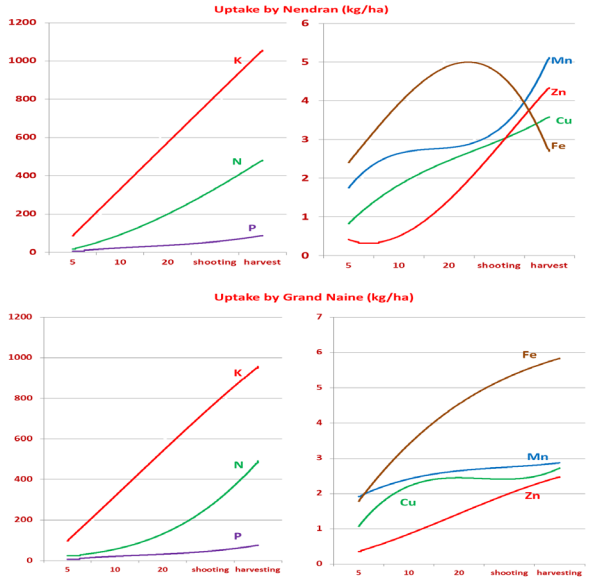


Fig. 2: Polynomial curves indicating nutrient uptake pattern from 5-leaf stage to harvest in bananas

Table 20. Cubic polynomial equations for nutrient uptake pattern of Nendran

Nutrients	Equations
Nitrogen	$y = -1.2217x^3 + 23.549x^2 + 12.581x - 18.264$
Phosphorus	$y = 1.4908x^3 - 10.777x^2 + 39.152x - 24.722$
Potassium	$y = -0.1625x^3 + 0.9789x^2 + 241.48x - 156.31$
Copper	$y = 0.0383x^3 - 0.4071x^2 + 1.9445x - 0.754$
Manganese	$y = 0.1767x^3 - 1.4286x^2 + 3.9348x - 0.936$
Zinc	$y = -0.0617x^3 + 0.7914x^2 - 1.8569x + 1.534$
Iron	$y = -0.1075x^3 + 0.3811x^2 + 1.1186x + 1.008$

Table 21. Cubic polynomial equations for nutrient uptake pattern of Grand Nain

Nutrients	Equations
Nitrogen	$y = 3.4917x^3 - 0.2336x^2 + 9.9848x + 10.472$
Phosphorus	$y = 1.615x^3 - 12.134x^2 + 40.361x - 24.1$
Potassium	$y = -1.435x^3 + 9.895x^2 + 199.72x - 111.22$
Copper	$y = 0.1042x^3 - 1.0746x^2 + 3.6312x - 1.598$
Manganese	$y = 0.0233x^3 - 0.2729x^2 + 1.1538x + 1$
Zinc	$y = -0.0158x^3 + 0.1389x^2 + 0.1848x + 0.044$
Iron	$y = 0.0175x^3 - 0.3404x^2 + 2.5121x - 0.41$

4.2.2. Organic banana farming for sustainable soil health and nutritional security

In Ney Poovan, the treatment M2 (*i.e.*, application of poultry manure @ 5 kg/pl + groundnut cake @ 1 kg/pl + rural compost @ 3 kg/pl + wood ash @ 3 kg/pl) recorded the highest average bunch weight of 9.9 kg, which was on a par with that of M4 (100% inorganic fertilizer alone). The other two organic treatments M1 and M3 recorded the bunch weight of 8.2 and 7.2 kg, respectively. The 100% inorganic fertiliser

application alone (M4) recorded bunch weight of 10.4kg while absolute control (M5-without any fertiliser or organic manure) recorded the bunch weight of 4.7 kg only. The post-harvest fruit quality parameters like fruit weight, pulp to peel ratio, TSS and acidity were determined among the different treatment combinations and are given in the Table 22.

Table 22. Effect of organic manures and inorganic fertilisers on Ney Poovan fruits

Sl. No.	Parameter	Treatments				
		M1	M2	M3	M4	M5
1	Fruit weight (g)	106.3 a	117.6 b	100.4 a	134.8 b	106.9 a
2	Pulp : Peel	3.24 a	3.70 b	3.05 a	3.78 b	2.63 a
3	TSS (°Brix)	30.6 b	31.8 b	30.5 b	30.2 a	28.7 a
4	Acidity	0.26 a	0.25 a	0.26 a	0.26 a	0.25 a
5	TSS/Acidity	115.9 b	125.7 c	115.3 b	114.3 a	113.2 a

The effect of continuous application of organic combinations and inorganic fertilisers alone in banana cultivation was studied under organic banana cultivation and the results are given in the Table 23. The soil organic carbon content, cation exchange capacity, bulk density, porosity, available soil moisture improved to desirable levels in the treatment M2, where poultry manure based organic combinations were applied, with duration.

Table 23. Effect of continuous application of organic manures and inorganic manures on post-harvest soils of banana

Soil parameters	Initial soil	Post-harvest soil (Grand Nain)						Post-harvest soil (Ney Poovan)					
		M1	M2	M3	M4	M5	CD (p<0.05)	M1	M2	MT3	M4	M5	CD (p<0.05)
pH	8.9	8.1	8.5	8.3	8.8	8.6	0.55	7.9	7.5	7.8	8.8	8.4	0.48
EC (dS/m)	0.21	0.2	0.2	0.19	0.28	0.22	NS	0.18	0.15	0.15	0.27	0.25	NS
Organic C (%)	0.11	0.51	0.58	0.39	0.24	0.22	0.262	0.59	0.68	0.46	0.21	0.22	0.316
CEC (cmol/kg)	9.4	15.1	21.7	18.3	10.2	10.4	8.29	16.8	24.2	20.2	11.4	10.5	9.07
Bulk Density (g/cc)	1.38	1.31	1.30	1.36	1.37	1.32	NS	1.27	1.25	1.31	1.37	1.31	0.105
Porosity (%)	40.3	43.3	43.7	41.1	40.7	40.1	NS	45.0	45.9	43.3	40.7	40.0	4.27
ASW at FC (%)	27.24	27.87	28.79	27.93	27.31	27.21	NS	29.42	30.17	28.55	26.95	27.19	2.438
Available N kg/ha	104	112	124	109	125	101	NS	120	127	117	128	94	NS
Available P kg/ha	4.5	5.1	5.8	4.9	4	4.1	1.29	5	5.9	5.3	4.3	3.7	1.45
Available K kg/ha	224	231	241	203	231	122	29.4	192	200	200	223	92	NS

Correlation of soil nutrient contents with nutrient uptake by plant at different growth stages

To study the level of matching of soil nutrient releasing pattern with nutrient uptake pattern of the banana crop to which different organic nutrient sources were applied, the Soil Nutrient Contents (SNC) of N, P, K, Ca, Mg, Fe, Cu, Mn, Zn and B in the rhizosphere were correlated to the corresponding Nutrient Uptakes by Plant (NUP) at different growth stages (Table 24). The correlation matrix was formed at 5-leaf, 10-leaf, 15-leaf, 20-leaf, shooting and harvesting stages. In the treatment M2 and M4 (inorganic only), the SNC at each plant growth stage recorded a highly significant

positive correlation coefficient (r) with NUP of the successive plant growth stage, starting from 5-leaf to harvesting stage. But in the M1 and M3, such significant positive influence of SNC at each growth stage on successive plant growth stage was not observed. Thus, this correlation study clearly indicated that the treatments M2 and M4 maintained a significant matching between soil nutrient releasing pattern and plant nutrient uptake pattern, throughout the plant growth and bunch yielding periods. The nutrient releasing patterns of M2 and M4 exactly coincided with nutrient uptake patterns of banana plants and produced higher yield than other treatment combinations.

Table 24. Correlation coefficients between the soil nutrient contents and nutrient uptakes at different growth stages of banana

Soil Nutrient Contents	Nutrient Uptake at					
	5 leaf stage	10 leaf stage	15 leaf stage	20 leaf stage	Shooting stage	Harvesting stage
	Nutrient Uptake at M1					
5 leaf stage	-0.249	0.229	-0.395*	0.544*	0.308	0.292
10 leaf stage		0.318	-0.094	0.447*	0.244	0.558*
15 leaf stage			0.315	-0.321	0.453*	0.580*
20 leaf stage				0.517*	0.358*	-0.276
Shooting stage					0.618**	-0.279
Harvesting stage						0.243
	Nutrient Uptake at M2					
5 leaf stage	-0.168	0.552*	0.329	0.373*	-0.292	0.256
10 leaf stage		-0.072	0.670**	0.665**	0.239	-0.111
15 leaf stage			0.522*	0.721**	-0.374*	0.144
20 leaf stage				-0.251	0.758**	0.405*
Shooting stage					0.142	0.692**
Harvesting stage						0.672**
	Nutrient Uptake at M3					
5 leaf stage	0.529*	0.328	0.395*	-0.421	-0.218	0.321
10 leaf stage		0.259	-0.271	-0.120	0.101	0.541*
15 leaf stage			0.186	0.613**	0.244	-0.419*
20 leaf stage				0.517*	0.358*	-0.276
Shooting stage					-0.288	0.479*
Harvesting stage						-0.399*
	Nutrient Uptake at M4					
5 leaf stage	0.327	0.511*	0.507*	-0.380*	0.277	-0.494*
10 leaf stage		0.173	0.623**	0.423*	-0.219	-0.448*
15 leaf stage			0.672**	0.643**	-0.113	0.509*
20 leaf stage				0.517*	0.525*	0.125
Shooting stage					-0.372*	0.757**
Harvesting stage						0.334

	Nutrient Uptake at M5					
5 leaf stage	-0.243	-0.419	0.317	0.421*	-0.149	0.525*
10 leaf stage		0.286	-0.244	0.627**	-0.431	0.607**
15 leaf stage			0.333	-0.172	-0.072	0.436*
20 leaf stage				0.519*	0.280	0.138
Shooting stage					-0.272	0.516*
Harvesting stage						0.425*

Soil microbial populations

There were significant variations in microbial populations (colony forming units - cfu per gram of soil) in the post-harvest soil with variations in treatments combinations. The highest fungal population 17.10 (cfu x 104 per gram) was maintained in the M2 and it was 52% and 38.7% more fungal population than that of M4 (inorganic only) and M5 (absolute control). The lowest fungal population was observed in M3 and M4 (inorganic only). The lowest actinobacteria population of 10.25 (cfu x 105per gram) was observed in the inorganic treatment M4 but the highest population was recorded in the M2 and it was 55% more than that of M4 and statistically on a par with that of M5. The highest soil bacterial population 60.60 (cfu x 106per gram) was recorded in the M3 and was 63.7% and 29.8% more than that of M4 and M5, respectively. The M2 recorded bacterial population of 54.80 and the lowest was recorded inM4 (Fig. 26).

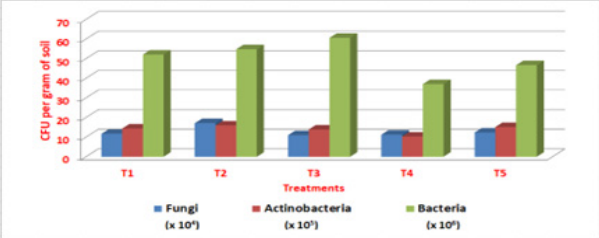


Fig. 26. Effect of different treatments on microbial populations of post-harvest soil

4.2.3. Developing agro-techniques for ICAR-NRCB released varieties and selections of banana

In the banana cv. Kaveri Saba, the fertilizer levels (F1: 200:30:300g NPK and F2: 200:30:400g NPK per plant), the spacing (S1-1.8 x 1.8 m^2 and S2-1.5 X 1.5 X 2 cm^2) were adopted for standardizing. The data on plant growth parameters, and leaf nutrient concentrations at the time of shooting and the data on yield parameters are given in the Tables 25a, b & c, respectively. The S1 recorded an average bunch weight of 17.6 kg but the S2 recorded 12.8 kg only. The bunch weight did not vary significantly with fertilizer levels.

Table 25a. Effect of fertilizer levels and spacing on growth parameters of Kaveri Saba

Height (cm)				Pseudostem girth (cm)				Phyllochron (leaves/ week)				Total leaf area (cm^2)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	252.2	266.9	259.6	S1	65.5	66.1	65.8	S1	0.83	0.90	0.86	S1	23216	26360	24788
S2	262.7	270.5	266.6	S2	61.4	59.9	60.7	S2	0.87	0.99	0.93	S2	21301	24892	23096
Mean	257.5	268.7			63.5	63.0			0.85	0.95			22258	25626	

Table 25b. Effect of fertilizer levels and spacing on yield parameters of Kaveri Saba

No. of fingers				No. of hand/bunch				Peduncle girth (cm)				bunch weight (kg)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	57.8	56.3	57.0	S1	8.3	8.0	8.2	S1	18.1	17.9	18.0	S1	17.3	17.9	17.6
S2	55.1	59.1	57.1	S2	8.3	8.5	8.4	S2	20.1	18.1	19.1	S2	13.3	12.3	12.8
Mean	56.4	57.7			8.3	8.3			19.1	18.0			15.3	15.1	

Table 25c. Effect of fertilizer levels and spacing on leaf nutrient concentration in Kaveri Saba

	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Calcium (%)			Magnesium (%)		
	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean
S1	2.10	2.80	2.45	0.16	0.21	0.19	2.80	3.50	3.15	0.38	0.61	0.50	0.16	0.37	0.27
S2	2.60	2.00	2.30	0.18	0.13	0.16	2.50	2.10	2.30	0.61	0.42	0.52	0.29	0.24	0.27
Mean	2.35	2.40		0.17	0.17		2.65	2.80		0.50	0.52		0.23	0.31	
	Iron (ppm)			Copper (ppm)			Manganese (ppm)			Zinc (ppm)					
	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean			
S1	88	92	90	24	32	28	113	97	105	34	42	38			
S2	89	91	90	30	34	32	121	92	107	31	30	31			
Mean	89	92		27	33		117	95		33	36				

In Kaveri Haritha also, the same fertilizer levels and the spacing pattern were adopted. The data on plant growth parameters, and leaf nutrient concentrations at the time of shooting and the data on yield parameters are given in the Tables 26a, b & c, respectively. The S1 recorded an average bunch weight of 18.5 kg but the S2 17.5 kg only. The F1 recorded the bunch weight of 18.9kg, which was significantly more than that of F2 (17.0 kg).

Table 26a: Effect of fertilizer levels and spacing on growth parameters of Kaveri Haritha

Height (cm)				Pseudostem girth (cm)				Phyllochron (leaves/ week)				Total leaf area (cm^2)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	240.4	264.8	252.6	S1	63.1	70.0	66.5	S1	0.85	0.85	0.85	S1	24063	25511	24787
S2	264.1	278.9	271.5	S2	60.6	61.8	61.2	S2	0.82	0.94	0.88	S2	20537	25759	23148
Mean	252.2	271.9			61.9	65.9			0.84	0.89			22300	25635	

Note: The mean values in same colour either in a row or in a column are not significantly different for each parameter

Table 26b: Effect of fertilizer levels and spacing on yield parameters of Kaveri Haritha

No. of fingers				No. of hand/bunch				Peduncle girth (cm)				bunch weight (kg)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	61.8	67.2	64.5	S1	8.8	9.3	9.1	S1	17.7	18.8	18.3	S1	17.9	19.0	18.5
S2	61.8	53.8	57.8	S2	8.8	8.3	8.6	S2	18.0	18.3	18.2	S2	19.9	15.1	17.5
Mean	61.8	60.5			8.8	8.8			17.9	18.5			18.9	17.0	

Table 26c: Effect of fertilizer levels and spacing on leaf nutrient concentration in Kaveri Haritha

	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Calcium (%)			Magnesium (%)		
	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean
S1	2.50	1.90	2.20	0.14	0.12	0.13	2.40	2.50	2.45	0.51	0.42	0.47	0.19	0.25	0.22
S2	2.10	2.20	2.15	0.18	0.11	0.15	1.90	2.00	1.95	0.43	0.31	0.37	0.28	0.22	0.25
Mean	2.30	2.05		0.16	0.12		2.15	2.25		0.47	0.37		0.24	0.24	
	Iron (ppm)			Copper (ppm)			Manganese (ppm)			Zinc (ppm)					
	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean			
S1	82	98	90	27	12	20	128	101	115	37	33	30			
S2	105	73	89	15	10	13	99	105	102	24	29	27			
Mean	94	86		21	11		114	103		31	26				

In Kaveri Kalki, the same fertilizer levels were adopted but three different spacing patterns were (S1-1.8x1.8 m^2, S2-2.1x2.1m^2 and S3-2.4x2.4 m^2) adopted. The data on plant growth parameters, and leaf nutrient concentrations at the time of shooting and the data on yield parameters are given in the Table 27a, b & c, respectively. There were no significant variations in bunch weight due to fertilizer levels. The S1 recorded significant higher bunch weight of 17.2 kg than that of S2 (15.5kg) and S3 (14.1kg), respectively.

Table 27a: Effect of fertilizer levels and spacing on growth parameters of Kaveri Kalki

Height (cm)				Pseudostem girth (cm)				Phyllochron (leaves/ week)				Total leaf area (cm^2)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	214.8	209.9	212.4	S1	86.4	91.2	88.8	S1	0.83	0.84	0.84	S1	24151	24186	24169
S2	202.3	199.3	200.8	S2	90.2	94.1	92.1	S2	0.82	0.85	0.84	S2	23063	23213	23138
S3	195.1	191.9	193.5	S3	89.9	90.6	90.2	S3	0.83	0.94	0.88	S3	21842	22034	21938
Mean	204.1	200.4			88.8	92.0			0.83	0.88			23018	23145	

Table 27b: Effect of fertilizer levels and spacing on yield parameters of Kaveri Kalki

No. of fingers				No. of hand/bunch				Peduncle girth (cm)				bunch weight (kg)			
	F1	F2	Mean		F1	F2	Mean		F1	F2	Mean		F1	F2	Mean
S1	105.7	103.0	104.3	S1	9.7	8.5	9.1	S1	25.7	24.6	25.1	S1	17.5	16.9	17.2
S2	96.6	111.0	103.8	S2	8.7	8.8	8.8	S2	21.5	22.8	22.1	S2	14.7	16.3	15.5
S3	106.9	111.7	109.3	S3	8.6	7.8	8.2	S3	21.9	20.6	21.3	S3	15.0	13.3	14.1
Mean	103.1	108.5			9.0	8.4			23.0	22.7			15.7	15.5	

Table 27c: Effect of fertilizer levels and spacing on leaf nutrient concentration in Kaveri Kalki

	Nitrogen (%)			Phosphorus (%)			Potassium (%)			Calcium (%)			Magnesium (%)		
	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean
S1	2.80	2.40	2.60	0.27	0.21	0.24	2.51	2.48	2.50	0.68	0.51	0.60	0.32	0.32	0.32
S2	2.43	2.84	2.64	0.18	0.21	0.20	2.35	2.18	2.27	0.51	0.60	0.56	0.28	0.31	0.30
S3	2.51	2.12	2.32	0.19	0.12	0.16	2.30	2.28	2.29	0.57	0.49	0.53	0.25	0.24	0.25
Mean	2.58	2.45		0.21	0.18		2.39	2.31		0.59	0.53		0.28	0.29	
	Iron (ppm)			Copper (ppm)			Manganese (ppm)			Zinc (ppm)					
	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean	F1	F2	Mean			
S1	98	105	102	30	31	31	120	141	131	40	42				
S2	89	100	95	21	24	23	91	108	100	28	34				
S3	89	75	82	27	19	23	109	85	97	34	27				
Mean	92	93		26	25		107	111		34	34				

Weed density, dry weight and species distribution was studied under three planting spacing *viz.*, 2.4×2.4 m, 2.1×2.1 m, 1.8×1.8 m and absolute control for Kaveri Kalki variety. Weed density and dry weight was found to decrease with decreasing planting geometry. Highest density of weeds was found in absolute control whereas minimum was in 1.8×1.8 m (Fig. 27). Numbers of species found were more in absolute control than other treatments. Under narrow plantation (1.8 ×1.8 m) very few species of weed like *Alternanthera polygnoides*, *Phyllanthus niruri* and *Digitaria sanguinalis* were dominant.

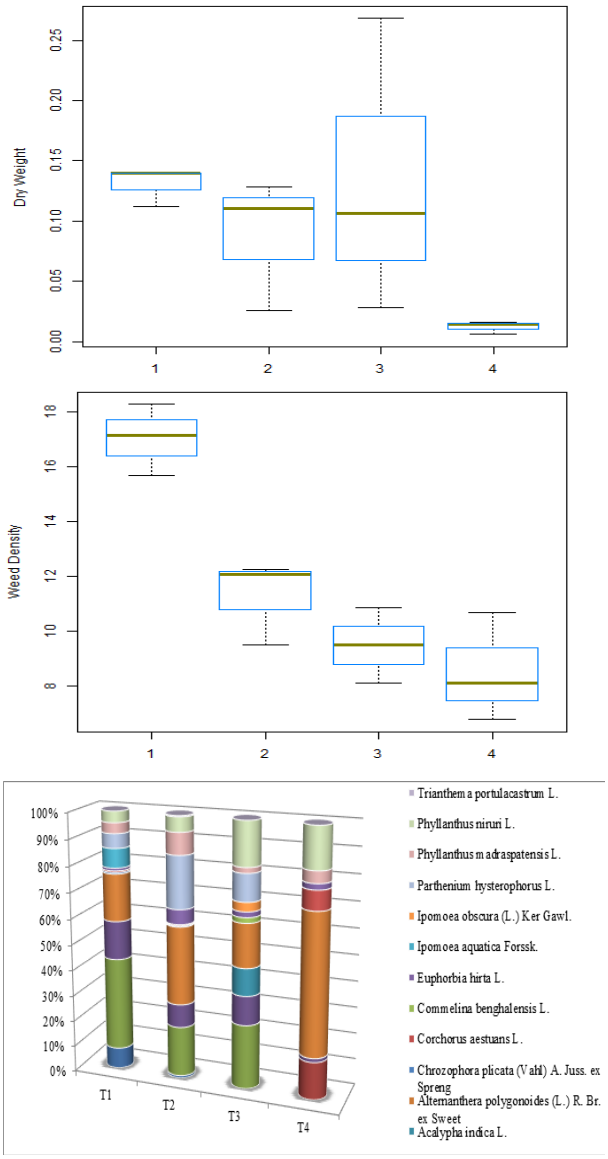
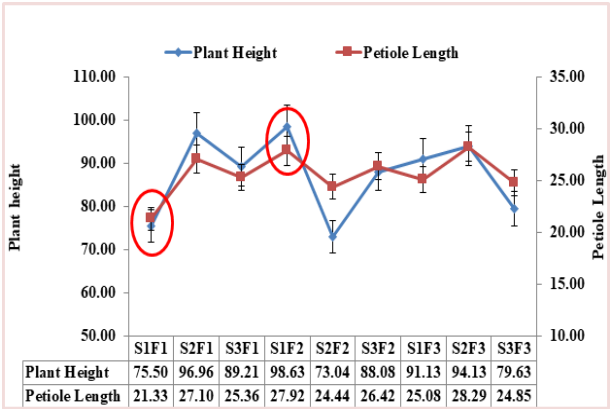


Fig. 27. Effect of planting geometry on weed population, dry weight and distribution (T1: Absolute control; T2: 2.4×2.4 m; T3: 2.1×2.1 m; T4: 1.8×1.8 m)

Standardization of agro-techniques for NRCB released varieties (Ornamental hybrids)

A field experiment was undertaken to investigate the effect of number of suckers and fertilizer levels on growth performance of ornamental hybrids in a split plot design. Main plot treatment consists of three levels *i.e.*, 3, 6 and 9 suckers per mat with three levels of fertilizers *viz.*, 33% of RDF, 66% of RDF, and 100% RDF (N-P_2O_5-K_2O: 200-30-300 g/plant) as sub-plot treatments. Initial results showed that maintaining 3 suckers with 66% RDF outperformed other treatment combinations (Fig. 28).



	S1F1	S2F1	S3F1	S1F2	S2F2	S3F2	S1F3	S2F3	S3F3
Plant Height	75.50	96.96	89.21	98.63	73.04	88.08	91.13	94.13	79.63
Petiole Length	21.33	27.10	25.36	27.92	24.44	26.42	25.08	28.29	24.85

Fig. 28. Growth performance of ornamental banana hybrid under different suckers and nutrient management

Ornamental hybrids (three crosses) were also evaluated in pots to study their growth and aesthetic values. Treatments consist of three levels of environmental growth conditions viz., M1: Shade net having 1000 to 3000 Lux light intensity, M2: Shade net having 3000 to 6000 Lux and M3: Under the roof having 9000 to 60,000 Lux with intermittent direct sunlight as main plot; and three levels of nutrients @ 7.5%, 15% and 30 % of RDF (100% RDF=N-P2O5-K2O: 200-30-300 g/plant), applied monthly in 12 equal splits as sub-plot. Among the three hybrids R×Z and O×Z performed better in E2 conditions with 30 % RDF whereas O×R has shown good growth in E2 with 15 % RDF level (Fig. 29).

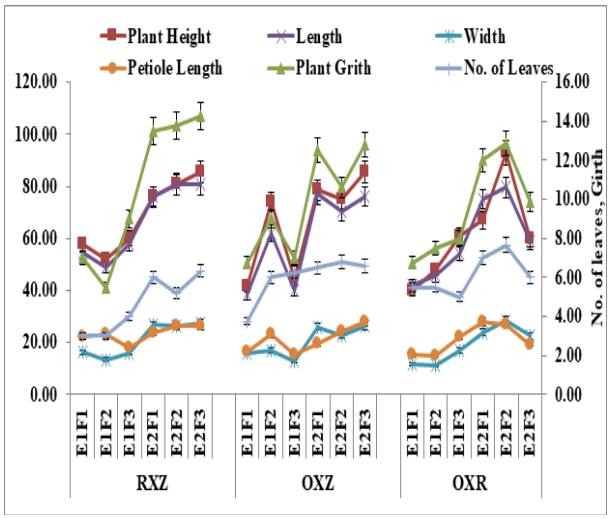


Fig. 29. Growth performance of ornamental banana hybrids under different environment and nutrient management (E1:1000 to 3000 Lux light intensity, E2: 3000 to 6000 Lux; F1 7.5% of RDF (N-P_2O_5-K_2O: 200-30-300 g/plant), F2:15% and F3: 30 % of RDF)

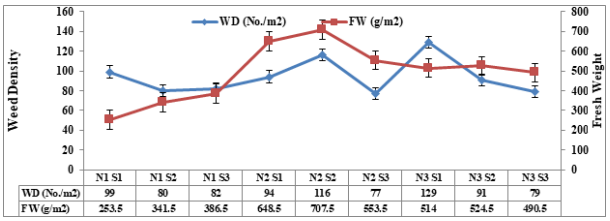
4.2.3 Development of clump management technology for enhanced productivity in banana

Clump management technology for enhancing productivity in banana was conducted in Ney Poovan and Kaveri Saba bananas. The treatments consisted on three levels of suckers populations such as S1: Mother plant + 2 suckers per clump and three levels of nutrition; S2: Mother plant per clump and three levels of nutrition + 3 suckers and S3: Mother plant + 4 suckers per clump and application of three levels of nutrition *viz.*, N1: 125% RDF per clump; N2: 150% RDF per clump and N3: 175% RDF per clump.

In Ney Poovan, the studies on weed dynamics showed presence of over 10 species of weeds predominantly *Cyperus rotundus*, *Cynodon dactylon*, *Trianthema portulacastrum* and *Stemodia viscosa*. Comparatively lesser weed intensity in the highly dense population of mother plant with 4 suckers and the weed density and fresh weight showed an increased trend with increasing fertilizer dose from 125% RDF to 175% RDF per clump (Fig. 30).

Analyses of samples for the plant nutrients revealed that the leaf nutrient concentrations ranged from of N (1.16%-2.38%), P (0.06-0.15%) and K (1.30-2.55%) decreased with increasing number of suckers per clump whereas the Ca, Mg and Na increased. However, the nutrient concentration showed increasing trend with increasing levels of applied nutrients from 125% RDF to 175 % RDF.

In both the mother plant as well as the first daughter sucker, among the three



	N1 S1	N1 S2	N1 S3	N2 S1	N2 S2	N2 S3	N3 S1	N3 S2	N3 S3
WD (No./m2)	99	80	82	94	116	77	129	91	79
FW (g/m2)	253.5	341.5	386.5	648.5	707.5	553.5	514	524.5	490.5

Fig. 30. Density and fresh weight of weeds under different population and levels of nutrition /clump

In the vegetative stage, the effect of both the number of suckers and levels of nutrition per clump was not reflected in CCM content of the experimental plants.

Similarly levels of nutrient application had no significant influence on the NDVI. However, the NDVI value decreased with increasing no. of suckers per clump (Fig. 31).

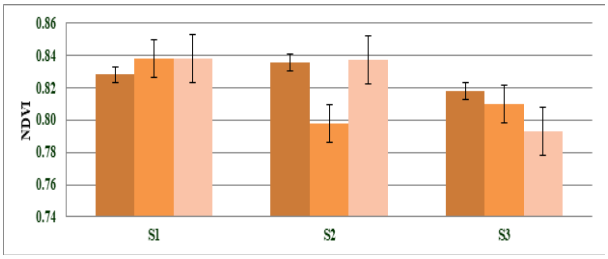


Fig. 31. Effect of no. of suckers and levels of nutrition/ clump on NDVI in Ney Poovan

populations per clump the number of hands and fingers per bunch as well as the weight, length and girth of the fruits found decreased gradually with increasing number of two, three and four suckers per clump (Fig. 32 & 33). Irrespective of the sucker population per clump among the three levels of nutrition *i.e.*, 125% RDF, 150% RDF and 175% RDF all the bunch and fruit characteristics recorded an increasing trend with increasing dosage however; all these parameters were on par in the treatments of application of 150% RDF and 175% RDF per clump.

Fig. 32. The bunches of Ney Poovan under different treatment combinations (Mother plant)

Fig. 33. The bunches of Ney Poovan under different treatment combinations (First Sucker)

The observations recorded on the nematode infestations as influenced by the sucker population and levels of nutrition per clump revealed that Root-lesion nematodes (*Pratylenchus coffeae*) and spiral nematodes (*Helicotylenchus multicinctus*) were observed in the root samples. However, the nematode damage was found to be below the threshold level (Root-lesion Index 1/2) and there was no significant difference among the treatments.

Post Harvest Technology

4.2.4 Development of pre- and post-harvest techniques for leaf production in banana

Month-wise leaf production in banana varieties

Leaf production from main and side suckers of five varieties, *viz.,* Poovan, Karpuravalli, Sakkai, Phirima wild and Progeny 183 were recorded at monthly intervals. Leaf production varied from 4.14 to 5.05 among the varieties and 4.35 to 4.98 among the months. Among the varieties, Karpuravalli produced the maximum number of leaves (5.05), followed by Sakkai (4.97), Poovan (4.84), and Progeny 183 (4.19). Among the months, maximum number of leaves were produced during July (4.98), followed by August (4.81), December (4.68), March (4.65), November (4.64) and January (4.57). Leaf production associated characters were also recorded for all the five varieties. Significant differences were observed for leaf thickness, total chlorophyll content and number of side suckers among the varieties. Leaf thickness varied from 0.18 to 0.28 mm, the minimum being with Sakkai and maximum being with Phirima wild. With respect to side suckers production, maximum side suckers produced by Karpuravalli (3.48), followed by Poovan (3.13), Sakkai (2.92) and Phirima wild (2.53). Colour index ('L', 'a', 'b') of leaves of these varieties showed 'L' (lightness) value varied from 36.78 to 48.28; 'a' value (greenness) from -17.00 to -25.00 and 'b' value (yellowness) from 20.68 to 38.06.

Number of suckers on leaf production

Leaf production of three varieties *viz*., Naadu, Poovan and Karpuravalli based on the number of suckers was done in different clumps of mother plant + daughter suckers with combinations like 1+3, 1+4 and 1+5. Significant variations ($P < 0.05$) were observed among the number of suckers, months and interactions between them. In general, 1+5 combination produced maximum number of leaves, irrespective of varieties. In Naadu, maximum number of leaves was obtained in 1+5 combination (13.12), followed by 1+4 combination (12.14). Production of leaves varied from 11.31 to 12.11, among the months. Maximum number of leaves was produced during October (12.11), followed by September (12.08), November and December (11.86 each), March (11.74) and August (11.72) and minimum number of leaves during January (11.31). In Poovan, 1+5 combination produced maximum number of leaves (14.06). Leaf production was maximum during August (14.05), followed by September (13.70), December (13.41), October (13.36), November (13.28). In Karpuravalli,

maximum number of leaves was produced by 1+5 combination (14.22), followed by 1+4 (12.46). Among the monthly intervals, August month produced maximum number of leaves (13.39), followed by July month (13.28), September (13.17) and November (13.06).Leaf area analysis recorded in the order of Naadu (0.97 m^2) >Poovan (0.91m^2) >Karpuravalli (0.80 m^2). On leaf thickness, Karpuravalli had the lowest (0.19 mm), while Poovan and Karpuravalli recorded 0.27 mm. The lower the leaf thickness, the better is the leaf quality.

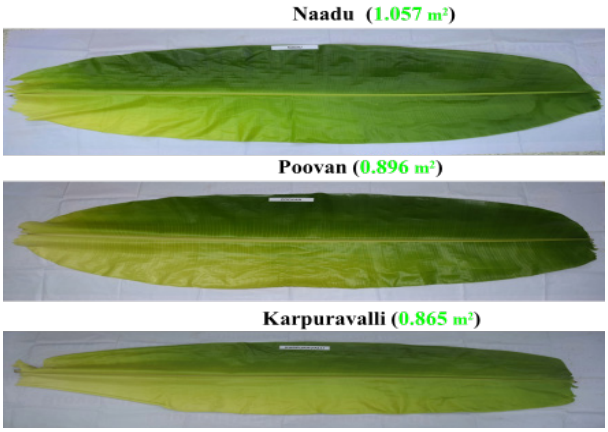


Fig. 34. Leaves of Naadu, Poovan and Karpuravalli

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

An experiment was carried out to study the effect of 'Red Banana' on quality, sensory parameters and shelf life under cold storage (13.5°C) and room temperature. The shelf-life of 'Red Banana' stored at 13.5°C with RH 85-90% without ethylene absorber was extended up to 23 days with improved quality attributes of pulp peel ratio of 2.29, firmness of 17.36 N,'L', 'a' and 'b' values of 38.93, 9.76 and 16.53, respectively; TSS of 20.35^{0}Brix, the acidity of 0.31%, total sugars of 17.28% and starch content of 1.58% at optimum ripening stage.

Growth parameters were recorded at 7th month after planting in Cv. Ney Poovan at the Centre's Experimental Farm as well as at the farmer's field in Mudalaipatti village, Tiruchirappalli (Fig. 36). At NRCB farm, 100% recommended dose of fertilizer (RDF) recorded maximum girth (75.80 cm), whereas the maximum height (339.16 cm) and leaf area (1.368 m^2) was recorded in 75% RDF and maximum number of leaves (16.83) with 100% RDF as soil application. At farmer's field in Mudalaipatti village, 100% RDF as soil application gave maximum height (365 cm), girth (75.50 cm) and leaf area (1.32 m^2), followed by 100 RDF fertigation with height of 364.25 cm, girth of 75 cm and leaf area of 1.08 m^2.

Fig. 35. Experiment field at NRCB farm (Ney Poovan-TC plants)

Fig. 36. Experiment field at Mudalaipatti farmer field (Ney Poovan-Sucker plants)

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

Effect of different additives on the structural characteristics of banana starch based bio plastic films

The hydrogen bond between bioplastics identified by the frequency shift of the broad bands of hydroxyl functional groups was studied. The peaks around 2950 cm^{-1} are ascribed to C-H aliphatic absorption peaks, whereas, the low intensity peaks 1680 cm^{-1} are indicative of bond water molecules within the starch. The characteristic peaks at 1004 cm^{-1} are assigned to C-O bond stretching of C-O-C groups in the anhydro-glucose ring of starch. These results manifested that all films showed absorption peaks in the same regions, irrespective of addictive and concentration. This reveals that they possess similar functional groups. As observed, the film shows a large amorphous area with crystalline peaks imbedded. The prime reflection peaks which contributed to the crystallinity of the films are located at 15.2, 17.1 and 23.1° which correspond to B-type diffraction pattern. The peak 2θ at 17° exhibited the formation of double-helical B-type crystalline. However, a newly defined peak immerged at ˜ 19°, which was attributed to the addition of PVA films. The peak observed at 19° corresponds to V-type crystalline structure which indicates the existence of amylose-glycerol interactions (Fig.37).

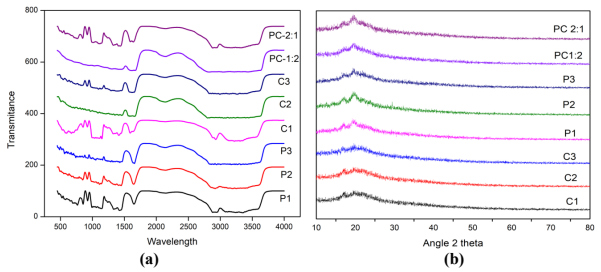


Fig.37 (a.) FTIR of starch based bioplastic films; (b): XRD pattern of bioplastic films

P1 - Starch + Glycerol+ PVA – (3:2:1); P2 - Starch + Glycerol+ PVA – (3:2:1.5); P3 - Starch + Glycerol+ PVA – (3:2:2); C1 - Starch + Glycerol+ CMC – (3:2:1); C2 - Starch + Glycerol+ CMC – (3:2:1.5); C3 - Starch + Glycerol+ CMC – (3:2:2); PC 1:2 - Starch + Glycerol+ PVA + CMC(3:2:1:2) PC 2:1 - Starch + Glycerol+ PVA + CMC; (3:2:2:1)

Smart packaging based ripening indicator label for red banana

Ammonium molybdate with starch matrix and plasticizers were used to develop smart packaging indicator labels for red banana. The color change in the ripeness indicator label was due to the reaction between ethylene gas emitted from fruits and ammonium molybdate added in the label. The indicator label of ammonium molybdate changed color from yellow to blue due to the redox reaction between molybdenum and ethylene gas (Fig.38). Thus it is concluded that the label resulted from this research has the potential to be used as ripeness indicator for fruits.

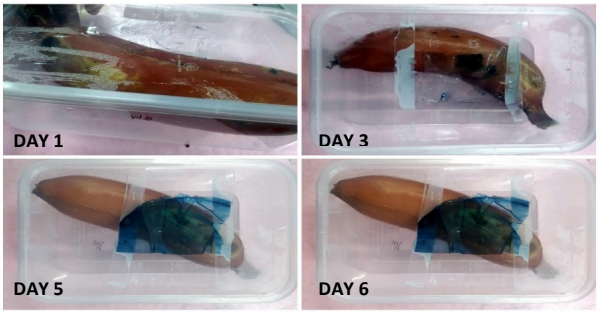


Fig. 38. Red ripening indication

Study of rheological static and dynamic viscosity behaviour of modified starches (MS) fitted with power law and H-B models

The points on the model fitted graph represented the average values of the readings in the rheogram and the fitted model values are represented by the continuous lines. Both the models fitted well with the experimental values of the obtained rheograms. However, the co-efficient determination (R^2) of the Herschel-Bulkley model were higher (0.997 for all starches) than the Power law model. The starch samples exhibited non-Newtonian fluid behaviour, where the green banana starch gels acted as non-Newtonian fluids. The native and modified starch gels showcased shear thinning behaviour owing to the flow behaviour index values lesser than 1 (0.36 – 0.55). The cleavage of a polysaccharide network of molecule during shearing could be attributed to this shear thinning behaviour. The shear stress increased with shear rate and attained a stable behaviour

with further increase in shear rate. This kind of behavioural pattern is a trait of pseudoplastic fluids. From the observation of Power law fitted model, the behaviour of AT sample was significantly different from other samples as it exhibited highest K value (7.46) and least n value (0.36). This evidences its enhanced shear thinning characteristic with greater magnitude of yield stress (7.55) and consistency coefficient (7.46). This could be attributed to the lower thixotropic behaviour, meaning that the starch gel does not have ability of regeneration of the structure post shear load phase. It is to be noted that all the studied modified starch samples exhibited pseudoplastic nature of behaviour with varying values of Herschel-Bulkley yield stress.

The oscillatory rheological behaviour of the starch gels were presented in Figure. For all the modifications, the storage modulus, (G') was greater than the loss modulus (G") throughout the entire frequency range. This high dynamic module of storage and loss modulus could be correlated with the high swelling power of respective starches as the visco-elastic behaviour of starch granules is attributed by the swelling nature. However, with respect to AT starch gel, there was a cross over phenomenon with storage modulus and loss modulus at a higher frequency around 10 Hz. Thus, from the amylose content and the solubility of AT starches it is proven that the starch gels of AT are not firmer. This is also evidenced with the rheological studies discussed further. The strength of the starch gels were determined using the tangent value (α) of the ratio of storage to loss modulus. The tan value is inversely proportional to gel strength. The increasing order of gel strength is AT (0.08) < HYP (0.105) < NS (0.19) < OX (0.33) < STMP (0.46) < CLP (0.65). The tan α value of all the starches is lesser than 1 indicating a prominent elastic behaviour.

Encapsulation of β carotene in protein-modified starch complex

Commercial β-carotene was initially dispersed in oil phase (olive oil). After homogenization and sonication, an emulsion was formed along with dispersion phase according to the following treatments T1- 10% Gum acacia, T2- 10% pea protein isolate, T3- 10% banana modified starch, T4- 5% gum acacia + 5% pea protein isolates and T5- 5% banana modified starch + 5% pea protein isolates. Freeze drying was done to encapsulate the β carotene with the starch- protein based wall material (Fig. 39).

T1 T2 T3 T4 T4

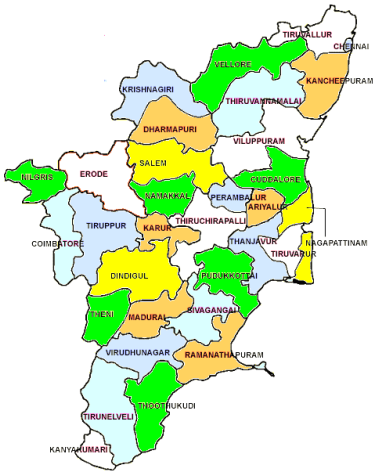
Fig. 39 Encapsulation of β carotene in different wall material complex by freeze-drying

From preliminary observations, it was identified that banana-modified banana starch behavior as a carrier material was way better than gum acacia, which is commercially used as an encapsulation material next to maltodextrin.

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

Several Capacity Development Programmes (CDP) have been conducted for different stakeholders.

Capacity Development Programme (CDP)	Nos.	Beneficiaries
One day CDP for farmers (Under ATMA, NHM, FPO etc.,)	10	330
Two days CDP for farmers (Under ATMA, NHM, FPO etc.,)	5	197
Three days CDP for farmers (Under ATMA, NHM, FPO etc.,)	6	207
One day Farmers exposure visit for farmers	22	744
Students CDP (PEV/Industrial visit/Study tour)	58	3942
Off campus training (With KVK,FPOs etc)	13	500
Total	**114**	**5920**



CDP for ATMA farmers – A state government collaboration (20 districts, 1000 farmers)

Upscaling the banana technologies through mass media and print media

Details	Nos.
No of News stories reported in dailies	37
No of dailies, YouTube covered NRCB News	132
No. of news stories reported in ICAR – NEWS (Online)	12
No. of video programme prepared for different occasions	5
No. of news stories reported in ICAR – NRCB Portal	12
No. of events uploaded in FB, Twitter	20

Ten institutional programmes, workshop have been coordinated at different level. Three days online collaborative capacity development programme on 'Agripreneurship through banana-based technologies – An avenue for *Atmanirbhar Bharat*' from 15 to 17 June 2022. Organized ten days High-End Workshop (*Karyashala*) on 'Recent advances in Banana improvement, production, protection, PHT, extension, and business arena for nutritional security in the era of *Atmanirbhar Bharat*" during 17-26 September 2022 in collaboration with DST- Science and Engineering Research Board (SERB), New Delhi. As part of the 75th India's Independence Celebration, ICAR-NRCB and Vidyarthi Vigyan Manthan jointly

organized an award ceremony for the student winners of the Science competition on April 6th at ICAR-NRCB. Around 12 different extension publications were published from extension unit during different occasions. Ten Scientific Advisory Meetings (SAC) have been attended and 20 advisories were recommended and they have been implemented in different districts in banana cultivation.

Manage Workshop

DST-SERB Workshop

Vidyarthi Vigyan Manthan

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

In the field evaluation of AAA, AAB and ABB banana genotypes for drought tolerance during floral primordial stage resulted in delay in flowering compared to irrigated control. The variations among all the genotypes recorded.

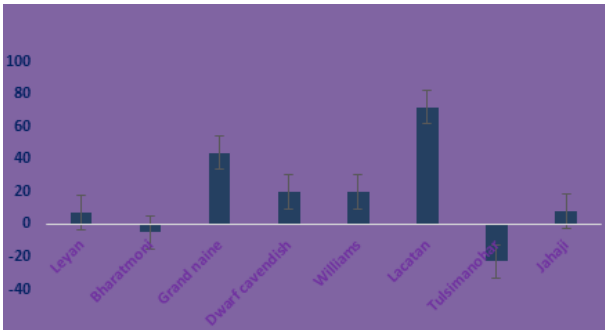


Fig.40. Difference on days to flowering in drought stressed banana (AAA) plants compared to irrigated control

Among AAA genotypes, the Lacatan genotype took longer days (nearly 70 days) to flower and some of the genotypes like Bharathmoni and Tulsi Manohar recorded earlier flowering compared to irrigated control (Fig. 40). In the ABB genotypes, almost all the AAB genotypes, which were subjected to drought stress prolonged the days to flowering, except Octoman, Desikadali, and Agnimalbhog (Fig .41).

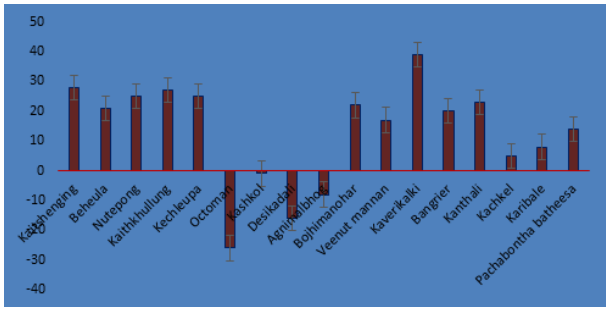


Fig. 41. Differnce on days to flowering in drought stressed banana (ABB) plants compared to irrigated control

The salt stress effect on germination of a few banana genotypes were evaluated under controlled condition. The Grand Naine (AAA) failed to germinate even at 50 mM NaCl and appeared to be very sensitive to salt stress. The cv. Rasthali (AAB), just germinated and no survival at 50 mM after producing 1-2 leaves. However, the Kaveri Saba (ABB), Karpuravalli (ABB) germinated and grown well and produced 4-5 normal leaves and surviving (Fig. 42).

Plant growth regulators like 2, 4, D bunch spray was given in three different concentration *viz* 10, 20, 30 ppm along with Brassinolides (2 ppm) in cv.Nendran. Observations on finger length and girth were revealed that 30ppm sprayed bunches recorded significant increase in fruit length (24.52%), whereas 10 ppm and 20 ppm recorded around 8% in fruit length. As such no significant changes in fruit girth was recorded in all the three concentration.

Fig. 43. Effect of different concentrations of salt (NaCl) on germination

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

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

Fructan types in commercial banana fruits pulp

The fructan types *viz.*, inulin, 1,1-nystose and 1-ketstotriose in pulp of nine commercial banana cultivars were analysed and estimated from the total fructans extracted from fruit pulp by HPLC-pulsed amperometric detection with anion exchange column. Inulin was also separately quantified by using Resorcinol reagent. Varying contents of these fructan types were found in the pulp of bananas. Among the banana cultivars, Grand Nain (AAA) pulp possessed 1-kestotriose as predominant fructan with 76.48 µg per g DW followed by inulin-type with 41.15 µg per g and 1,1-nystose with 34.46 µg per g. Monthan (ABB) and Nendran (AAB) (Fig. 44 and 45) had highest amount of inulin-type fructans with around 120 µg per g DW and the 1,1-nystose and 1-kestotriose contents were around 82 and 26 µg per g DW respectively. In varieties like Poovan (AAB), Rasthali (AAB), Karpooravalli (ABB) and NeyPoovan (AB), again 1-kestotriose was major fraction of fructans followed by inulin-type and 1,1-nystose. In analysing fructans contents in rhizome of five banana cultivars, 1,1-nystose was major fraction in the range of 128 to 416 µg per g DW with highest in Nendran and Monthan (Fig. 46). Inulin-type and 1-kestotriose are minor species of fructans found in the rhizome of the banana cultivars.

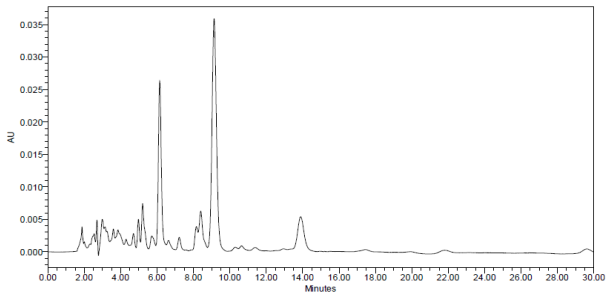


Fig. 44. Chromatogram of fructans type in pulp of Monthan; Three major peaks represent 1-kestotriose, inulin-type and 1,1-nystose

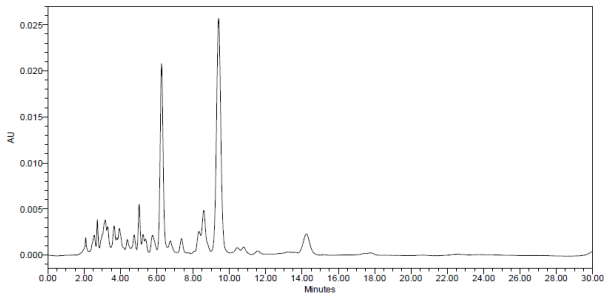


Fig. 45. Chromatogram of fructans type in pulp of Nendran; Three major peaks represent 1-kestotriose, inulin-type and 1,1-nystose

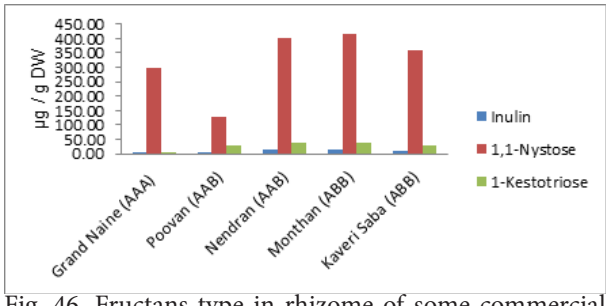


Fig. 46. Fructans type in rhizome of some commercial banana cultivars

Alpha-tocopherol (vitamin E) in banana leaf

Alpha-tocopherol (vitamin E) contents in third leaf of ten banana cultivars were extracted using acetonitrile:methanol (3:1), analysed by using RP-HPLC and quantified using authenticated standard (Fig. 47). The

α-tocopherol in the leaves of banana cultivars ranged between 4.2 and 6.4 mg/g of leaf tissue. The Kaveri Saba and Monthan leaves had highest α-tocopherol of 6.4 and 6.2 mg/g respectively followed by Grand Naine (5.9 mg/g) and lowest contents were detected in Nendran and Rasthali, which had 4.23 mg/g (Fig. 48). Young leaves of banana cultivars possessed more or less equal amount of α-tocopherol and matured leaves of commercial bananas had lower quantity.

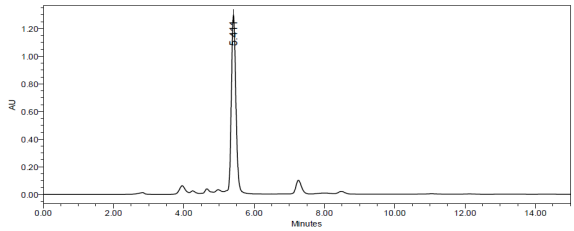


Fig. 47. Alpha-tocopherol (vitamin E) chromatogram in leaf of Kaveri Saba

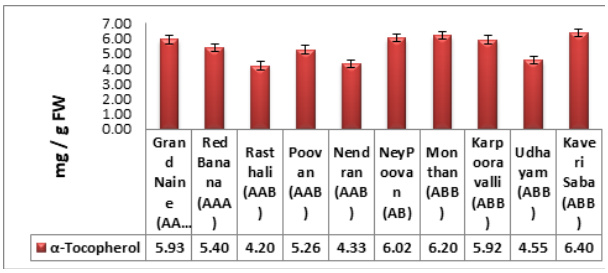


Fig. 48. Alpha-tocopherol contents in leaf of commercial banana cultivars

Anthocyanin compounds in flower bracts of NE region bananas

Total monomeric anthocyanins in flower bracts of eight more banana cultivars *viz.*, Jahaji (AAA), Bhorchampa (AAB), and Desikadali (AAB), Dudhsagar (AAB), Kechulepa (ABB), Jatikal (AABB), Simolou Manohar (ABBB) and Bhoji Manohar (ABBB) collected from North Eastern region were estimated using *p*H differential method. Among these cultivars, Dudhsagar contained highest amount of anthocyanins of 68.78 mg/100g FW followed by Jatikal with 52.24 mg/100 g. Jahaji contained lowest content of 13.13 mg/100 g (Fig. 49).

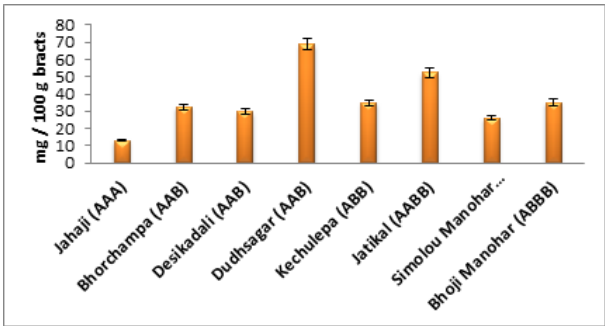


Fig. 49. Total monomeric anthocyanin contents in flower bracts some of the banana varieties of North Eastern region

Individual anthocyanin compounds in bracts of these eight banana cultivars were profiled using RP-HPLC, identified and quantified based on the peak area of the individual compounds. Two to three compounds were identified in various proportions and another two three compound identified. In bracts of Jatikal, Simolou Manonhar (Fig. 50) and Jahaji (Fig. 51), the predominant anthocyanin was cyanidin-3-rhamnoside and in Bhoji Manohar and Dudhsagar, cyanidin-3-rutinoside was the main compound. In Kechulepa and Desikadali, delphinidin-3-rutinoside was the major compound. The percentage of compounds in the flower bracts of banana varieties given in Table 28.

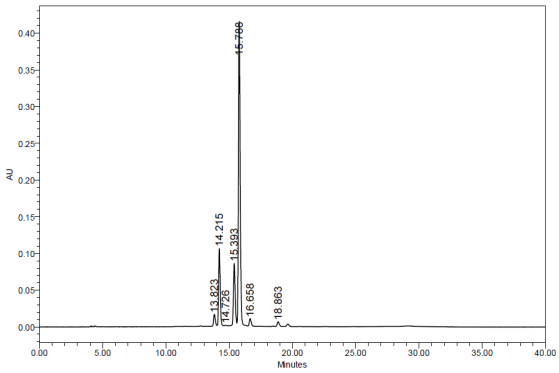


Fig. 50. Chromatogram of anthocyanins identified in bracts of Simolou Manohar (ABBB)

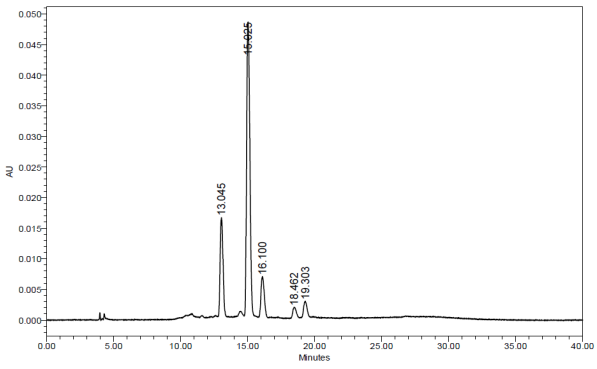


Fig. 51. Chromatogram of anthocyanins identified in bracts of Jahaji (AAA)

Table 28. Anthocyanins identified in flower bracts of NE region bananas

Variety	Cyanidin 3 rhamnoside (%)	Cyanidin 3 ruti-noside (%)	Delphinidin 3 rutinoside (%)	Pelargonidin 3 rutinoside (%)
Jatikal	68.31	4.68	-	16.43
Simolou Manohar	65.01	-	1.85	1.31
Bhoji Manohar	-	52.12	16.45	1.63
Dudhsagar	-	61.24	8.97	15.49
Kechulepa	-	2.40	54.80	-
Bhorchampa	-	12.27	-	-
Jahaji	64.69	-	9.31	3.78
Desikadali	-	-	44.16	1.49

Nutraceutical potential of flower bract anthocyanins

The antioxidant activities by using TEAC and ORAC assays of total monomeric anthocyanins of eight banana varieties from North Eastern region were assessed for their nutraceutical potential. Dried powder made of the extracted anthocyanin pigments from the flower bracts was used for measuring the antioxidant activities.

In both TEAC and ORAC assays, the anthocyanins extracts Jatikal, Simlou Manohar, Bhoji Manohar, Dudhsagar and Jahaji showed higher levels of total antioxidant capacity of above 91 and 186 µmol TE/ g DW respectively (Fig. 52 & 53). The flower bracts anthocyanins of Kechulepa, Borchampa and Desikadali exhibited lower levels of total antioxidant capacity with 58 and 113 µmol TE/ g DW in TEAC and ORAC assays. In earlier assays using anthocyanins from commercial banana cultivars, cyanidin as the predominant anthocyanidin compound exhibited higher degree of nutraceutical potentials. In similar way, the NE region banana varieties with higher cyanidin shows higher level of total antioxidant activities and consequently higher nutraceutical potential.

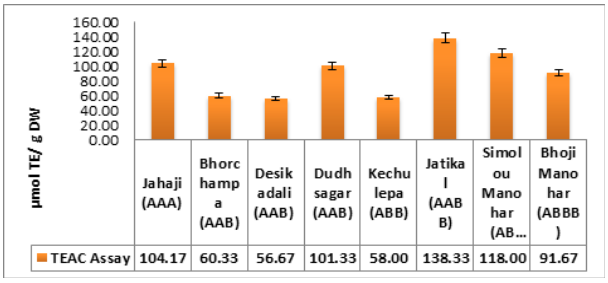


Fig. 52. Total antioxidant (TEAC) assay (µmol TE / 100 g FW) of anthocyanins of flower bracts of the banana varieties of North Eastern region

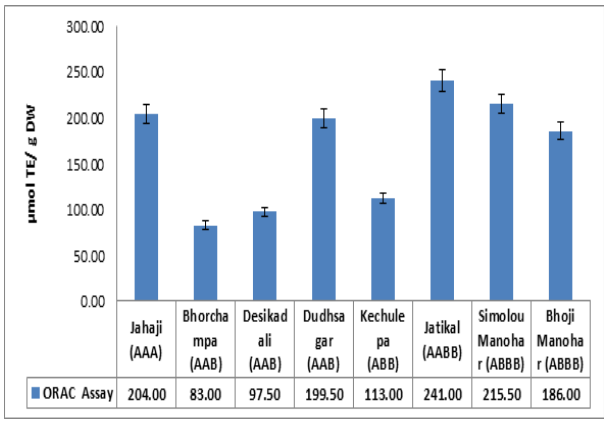


Fig. 53. Total antioxidant (ORAC) assay (µmol TE / 100 g FW) of anthocyanins of flower bracts of the banana varieties of North Eastern region

4.4 CROP PROTECTION

Pest mapping in bananas and plantains in India

The extent of spread of the exotic Bondar's Nesting whitefly (*Paraleyrodes bondari*) on banana was further monitored in 2021-22 and it was found to be present on banana at very low levels. *Simplicia cornicalis* was recorded as a fruit feeder from Tamil Nadu and Maharashtra for the first time. The hairy caterpillar *Eupterote orientalis* (Lepidoptera: Eupterotidae) was found to be a serious but sporadic pest of cultivars Nendran, Ney Poovan and Grand Nain in all localities surveyed in Trichy District, Tamil Nadu and the late larval stages were heavily parasitized by *Enicospilus*

sp. (Hymenoptera: Ichneumonidae). *Artaxa guttata* (Walker) (Lepidoptera: Erebidae), was recorded as an occasionally major pest of the cultivars Ney Poovan and Nendran in some pockets of Trichy and Karur Districts. The larvae were found to be parasitized by nr. *Disophrys* (Hymenoptera: Braconidae). *Miltochrista violacea* (Reich) (Lepidoptera: Erebidae), was also recorded as a new pest of banana for the first time.

Three grasshoppers were found to damage banana crop in Tamil Nadu. Localized outbreaks of vegetable grasshopper, *Atractomorpha crenulate* (Pyrgomorphidae), were observed in the early stage (3-4 month-old-crop) and the damage symptoms were pronounced on cv. Ney Poovan, Nendran, Saba and Karpuravalli. The leaf lamina was irregularly cut and completely defoliated in severe cases. The pest was active during July-October and the extent of damage was 73-85% in Ney Poovan and 33-38% in Nendran. Up to 75% of foliar damage was observed due to *Gesonula punctifrons* (Acrididae) on ornamental banana and leaf damage due to skeletonization was severe on plants near irrigation channels and the symptoms were indistinguishable from that caused by hairy caterpillars. All commercial cultivars were also damaged by *Neorthacris* spp. (Acrididae).

One new species of *Stethorus* predatory on banana mite pests and one new species of *Scymnus* predatory on the exotic Jack Beardsley mealybug, an emerging pest of banana, were discovered.

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

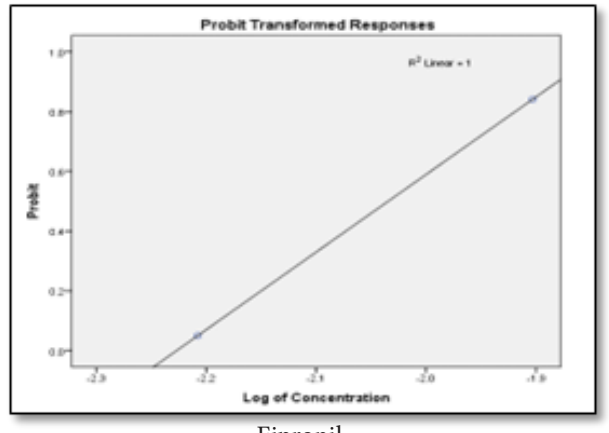
In vitro bioassays of entomopathogenic fungi, botanicals, and new insecticide molecules against banana pseudostem weevil (BPSW)

Selected isolates of entomopathogenic fungi (EPFs) (NRCB EPF *Metarhizium anisopliae* 09, 12, 36 & 50, *Beauveria brongniartii* 27& 28, and *B. bassiana* 22 @1.5×10^9 CFU/ml), eight insecticides and two botanicals were evaluated against *O. longicollis*in laboratory bioassays at ICAR-NRCB, Tiruchirappalli. Day-wise mortality was recorded for EPFs (11 days) and the insecticides (from 6h, up to six days). LC50 was calculated through probit analysis using SPSS (version 20). Among the EPFs, *B. brongniartii* 27 caused significantly higher mortality at 4-8 days after inoculation, and *B. bassiana* 22, *M. anisopliae* 50 and *B. brongniartii* 28 caused significantly higher mortality from the 5th to the 11th day after inoculation (66–78%). Among the insecticides, thiamethoxam, fipronil, spinosad, lambda cyhalothrin and cartap hydrochloride recorded 100% mortality after 6 days whereas botanicals were least effective and no mortality was recorded in the control. Fipronil, cartap hydrochloride and spinosad were most effective with LC values of 0.006%, 0.125 % and 0.018%with R^2 values of 1.00, 0.98 and 1.00 LC 50, respectively (Table 29 and Fig. 54).

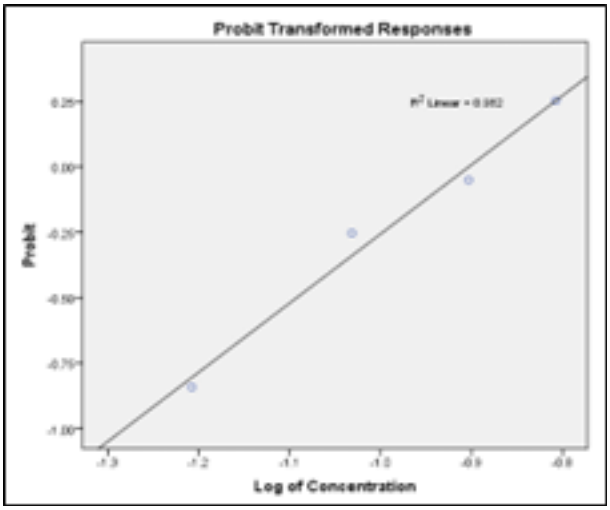
Table 29.Probit analysis of concentration-mortality response at 3 days post inoculation of insecticides against *O. longicollis*

Insecticide	LC_{50}	95% Confidence limits		Slope (SE)	$\chi 2$ (df=2)
		Lower	Upper		
Fipronil	0.006	0.004	0.008	7.907±1.792	1.217
Cartap hydro-chloride	0.125	0.100	0.206	2.37±0.883	0.172
Spinosad	0.018	0.006	0.025	5.798±1.162	1.846

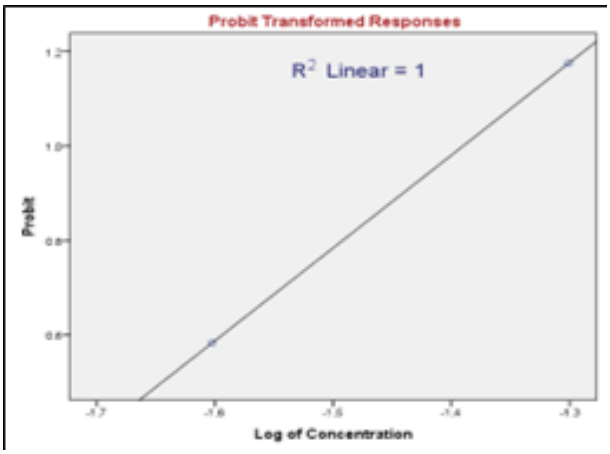
LC_{50}: estimated concentration that causes 50% mortality (SPSS version 20); χ^2=Chi-square value, df =degrees of freedom; slope ± standard error of the slope (covariates X are transformed using the base 10.000 logarithm).



Fipronil



Cartap hydrochloride



Spinosad

Fig. 54. Probit analysis of concentration-mortality response insecticides against *O. longicollis*

Field evaluation of identified semiochemicals against banana pseudostem weevil

Trapping of banana weevils on plant discs treated with pseudostem and leaf sheath juices of susceptible banana varieties was studied and discs treated with Nendran pseudostem juice and leaf sheath juice attracted more mean numbers of pseudostem weevil (2.2 no.) and corm weevils (2.8 no.) (Fig. 55) than the control (0.2 for both weevils).The attraction of *O. longicollis* to kairamonesin combination with use of blue LED light was investigated on banana germplasm (T1: Tetradecanoic acid (=Myristic acid); T2: Hexadecanoic acid (=Palmitic acid); T3: T1 + T2; T4: 9-Octadecenal; T5: Poovan leaf sheath extract; T6: Male BSW whole body extract; T7: Female BSW whole body extract; T8: Male BSW whole body extract; and T9: Control (n-hexane solvent) . Banana stem weevil was attracted in greater numbers (2.67) in T3 (mixture of T1 + T2) (Fig. 56), while corm weevil was recorded in more numbers (1.33) in T8.

Fig. 55. Trapping of banana weevil on plant disc method using pseudostem and leaf sheath juices of susceptible banana varieties

Fig. 56. Attraction of *O. longicollis* towards kairamones with blue LED

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

Multi-locational field evaluation of combination of bioagents for the management of Fusarium wilt disease in banana in India

Field trial in Bihar

A field experiment was conducted to evaluate five combinations of bioagents at Falka block, Katihar District, Bihar for the management of Fusarium wilt disease (TR4) using cv. Grand Nain. The treatment T2: Endophytic *Bacillus flexus* (Tvpr1) + Rhizospheric*T. asperellum* (NRCB3) resulted in significant increase in height (37.46%), girth (28.61%), leaf area (61.38%) and total number of leaves (40.74%). It was followed by T5: Endophytic *Bacillus subtilis* ssp. *inaquosorum* (BS30) + rhizospheric *Bacillus haynesii* (BS17) combination which recorded 34.68% increase in plant height, 16.77% increase in girth and 55.66% and 33.33% increase in leaf area and total number of leaves, respectively as compared to control. The observation on the wilt disease score is in progress.

Field trial in Tamil Nadu

A field study was conducted with five combinations of bioagents at KK Patti, Chinnamanur block, Theni District, Tamil Nadu, for the management of Fusarium wilt disease (Foc R1) in cv. Grand Nain. The treatment T5-Endophytic *Bacillus subtilis* subsp. *Inaquosorum* (BS30) + Rhizospheric *Bacillus haynesii* (BS17) recorded significant increase in plant height (34.68%), girth (52.64%), leaf area (59.18%) and total number of leaves (30.89%) followed by T2-Endo. Rhizo. *T. asperellum* (NRCB3) + *Bacillus flexus* (Tvpr1) which resulted in increase in plant height (29.24%), girth (49.09%), leaf area (56.74%) and total number of leaves (18.37%) as compared to control. The treatments T2 and T5 recorded the lowest internal wilt disease score of 0.5 and 0.8, respectively, on a 0-5 scale as against untreated control (5).

Field trial in Karnataka

In a field evaluation conducted with the above combinations of bioagents at Hampi village, Hospet, Vijayanagar District, Karnataka (R1) in cv. Ney Poovan for the management of Fusarium wilt disease (Foc R1) T5-Endophytic *Bacillus subtilis* ssp. *inaquosorum* (BS30) + rhizospheric *Bacillus haynesii* (BS17) recorded significant increase in plant height (30.55 %), girth (28.70%), (38.87%) and total number of leaves (28.22%) followed by T2-Endo. Rhizo. *T. asperellum* (NRCB3) + *Bacillus flexus* (Tvpr1) which recorded significant increase in plant height (27.77%), girth (23.25%), leaf area (26.85%) and total number of leaves (28.82%) as compared to control. Besides, the treatments T5 and T2 recorded the lowest internal wilt disease score of 1.3 and 0.6, respectively, as against untreated control (4.6) on a disease scale of 0-5.

Survey and characterization of *Foc* isolates from major banana growing states of India

A roving survey was conducted for Fusarium wilt disease incidence in major banana growing states, *viz*.. Bihar, West Bengal, Uttar Pradesh, and Karnataka. Wilt incidence ranged from 15 to 45% in Uttar Pradesh, 10 to 50% in West Bengal, 25 to 30% in Bihar, and 15 to 30% in Karnataka. From these states, totally 37 isolates of *Foc* were collected and all the isolates were able to cause wilt disease in cv. Grand Nain in pathogenicity / cross infection study . Further characterization of all the *Foc* isolates revealed the presence of *Foc* TR-4 and Race 1 in the fields surveyed in Bihar, West Bengal and Uttar Pradesh. In VCG analyses VCGs 01216, 01213/16 belonging to TR-4 and VCG 01220, 0124 and 0125 belonging to *Foc* R1 were identified in Grand Nain.

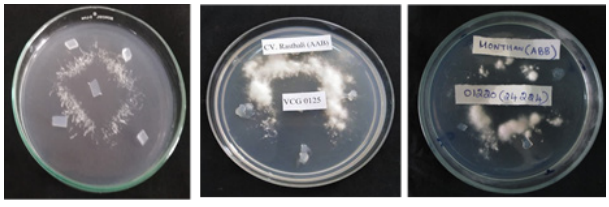


Fig. 57. VCG analysis of different isolates of Fusarium pathogen

Distribution of effector based SIX genes in different VCGs of *Foc* isolates of India

A total of 37 *Foc* isolates belonging to different VCGs such as 0124, 0125, 01213/16 and 01220 of race 1 and race 4 were collected from Bihar, U.P., West Bengal and Karnataka and all these isolates were characterized for the presence of effector based SIX genes by using SIX genes specific PCR primers. The results indicated that SIX 1, SIX 2, SIX 8, SIX 9 and SIX 13 were present in *Foc*TR4 isolates and SIX 1, SIX 4, SIX 6, SIX 9 and SIX 13 were present in *Foc*R1 isolates.

Microbiome analyses of *Foc*TR4 resistant and susceptible banana plants and evaluation against Fusarium wilt disease under glasshouse condition

A total of 60 bacterial and 30 fungal endophytic and rhizospheric microbes were isolated from resistant (10) and susceptible (03) cultivars of banana. All isolates were screened *in vitro* for their effectiveness against *Foc* TR-4 and four out of 60 bacterial isolates and five out of 30 fungal isolates were found effective. All the bacterial and fungal isolates effective against *Foc*TR4 were further evaluated in different combinations for the suppression of Fusarium wilt (TR4) under glasshouse conditions in cv. Grand Nain. The fungal combination Rhizo. *Trichoderma* sp. + Rhizo. *Trichoderma asperellum* completely suppressed the wilt disease in the corm (internal wilt disease score 0.0) as against untreated control which recorded the maximum disease score of 5.0 under glasshouse condition.

Fig. 58. Glasshouse evaluation of Rhizo *Trichoderma* spp. combinations for the suppression of Fusarium wilt disease (*Foc* TR4)

Among bacterial combinations, Endo. *Bacillus subtilis* + rhizo. *Bacillus subtilis* combination was effective against Fusarium wilt disease (disease score of 0.2) as against untreated control (disease score of 5.0) under glass house condition.

Fig. 59. Glasshouse evaluation of bacterial combination endo. *Bacillus subtilis* + rhizo. *Bacillus subtilis* for the suppression of *Foc* TR4

Validation of liquid formulation of bacterial bioagents for the management of Fusarium wilt Tropical race 4

The liquid formulation of biocontrol consortia for the management of Fusarium wilt disease Tropical race 4 was validated at different concentrations under glasshouse conditions. The application of liquid formulation of bacterial *consortia* endo. *Bacillus subtilis* ssp. *inaquosorum* (BS30) + Rhizo. *Bacillus haynesii* (BS17) applied at 0.5L per plant resulted in complete reduction of *Foc* TR-4 (disease score 0) as against the Foc alone applied in control (disease score - 5).

Fusarium alone | Endo. *Bacillus subtilis* ssp. *inaquosorum* (BS30) + Rhizo. *Bacillus hayanesii* (BS17)

Fig. 60. Validation of liquid formulation of bacterial bioagents for the management of Fusarium wilt Tropical race 4

In vitro evaluation of fungicides against *Foc*-TR4

Fungicides having different mode of actions were evaluated *in vitro* at different concentrations against *Foc* TR-4 . All tested fungicides at 1% and 0.5% caused 100% inhibition of *Foc* mycelial growth. However, Bavistin and Companion at 0.05% caused 100% inhibition of *Foc* mycelial growth.

Effect of flooding on Fusarium wilt disease (*Foc* TR4) in cv. Grand Nain

A pot culture study was conducted to study the effect of flooding from 10 to 90 days on the incidence of Fusarium wilt in cv. Grand Nain. The study revealed that continuous flooding for up to 90 days resulted in significant reduction of Fusarium wilt with an internal wilt disease score of 0.66 to 1.66 as against control (*Foc* inoculation but no flooding) which showed an internal score of 5.00.

4.4.4 Survey, etiology and management of rhizome rot of banana

Four low volume bacterial bio-formulations developed using the spray dryer facitity available at Sastra University, Thanjavur, Tamil Nadu had the desired CFU but significant growth enhancement of banana was achieved only in two formulations. Therefore, a modified low volume high shelf life bio-formulation was attempted. A combination consisting of bacterial cells, maltodextrin and lignite recorded higher shelf life (>10^9) after 6 months of storage than other combinations.

Molecular characterization of PGPR isolates

Based on 16s rDNA sequencing, effective PGPR isolates such as H7BC2 (OM188392.1), H8BC1 (OM188390.1), H6BC3 (OM188389.1), H4BC1 (OM188387.1) and H8BC2 (OM188391.1) were characterized as *Priestia aryabhattai* while H6BC2 (OM188388.1) was characterized as *P. megaterium.*

Chemicals for management of rhizome rot disease

In view of the ban imposed by the GOI on the use of antibiotics in agriculture from 2024, alternative chemicals (copper hydroxide and copper oxychloride-COC) at different concentrations were evaluated against rhizome rot isolates (*Pectobacterium* sp. and *Klebsiella variicola*). Copper hydroxide (0.1-0.3%) was effective against all *Pectobacterium* isolates and specific *K. variicola* (1-1B-3) isolate while COC (0.2%) recorded significant inhibition of all *K. variicola* isolates and certain isolates of *Pectobacterium* sp.

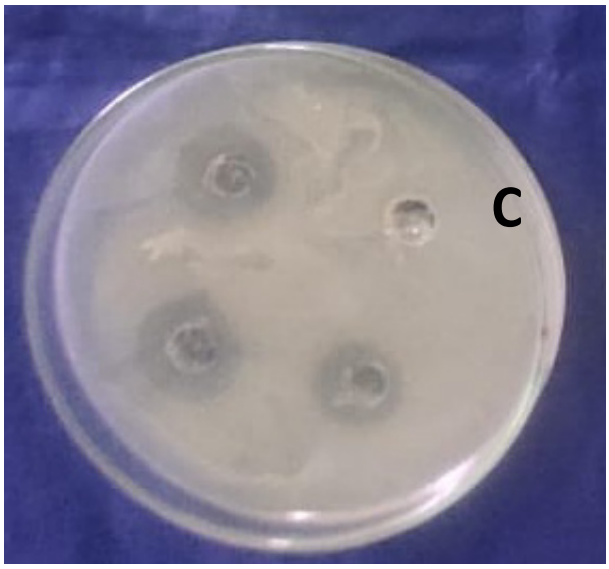


Fig. 61. Inhibition of *Pectobacterium* isolate by copper hydroxide

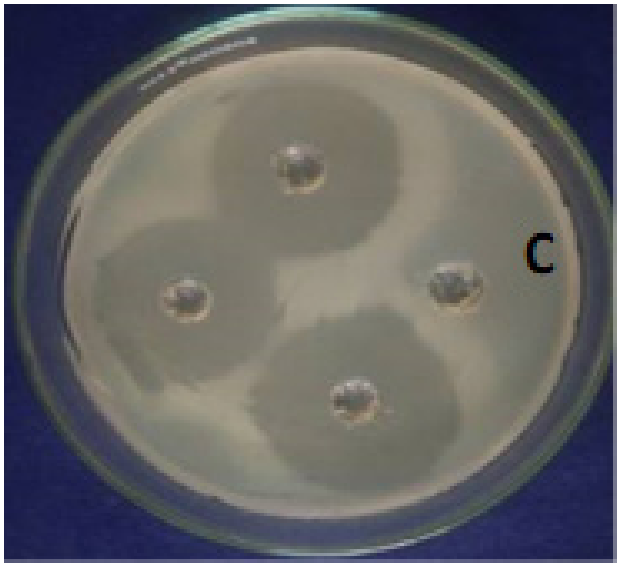


Fig. 62. Inhibition of *K. variicola* by copper hydroxide

4.4.4 Management of post-harvest diseases of banana

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

Recommended chemicals for two major diseases (Fusarium wilt and leaf spot), rhizome rot, nematode and pseudostem and corm borers were applied [(bleaching powder 6g/ pit, cartap hydrochloride @ 10 g/ plant, root dipping of TC plants in carbendazim (0.1%) for 30-45 minutes, pseudostem injection of 3 ml of 0.1% carbendazim solution, drenching of carbendazim (0.1%) @ 1 litre per plant, sprays of carbendazim 1g/l+ petroleum oil 10 ml/l on 150 days after planting (DAP), propiconazole 1 ml/l + petroleum oil 10 ml/l on 175 DAP, mancozeb 63%+carbendazim 12% (1g/l)+ petroleum oil 10 ml/l on 200 DAP, 1 g of trifloxystrobin 25.0% and tebuconazole 50.0% + petroleum oil 10 ml/l on 225 DAP, carbendazim 1g/l + petroleum oil 10 ml/l on 250 DAP, propiconazole 1 ml/l + petroleum oil 10 ml/l on 275 DAP and mancozeb 63%+carbendazim 12% (1g/l)+ petroleum oil 10 ml/l on 300 DAP, Pseudostem injection with monocrotophos @5 ml/plant (150 ml monocrotophos in 350 ml water)] and bud injection with imidacloprid @ 1ml (0.6 ml in 1 lit of water). on banana (cv. Grand Nain) at ICAR-NRCB farm at different intervals and suitable control was also kept for comparison.

Observations on fruit maturity, post harvest diseases, fruit quality and residues were made. A significant difference was observed between chemical applied treatments and control. With respect to yield, chemical treatments gave significantly higher bunch weight than the control and nearly 40% more yield could be achieved in chemical treatments. Besides premature ripening of fruits and finger drop were more common in untreated control when compared to chemical treatments. Fruit size was also significantly greater in chemical treatments (32-35 mm) than control (28.23 mm).

The chemical treatments were free from anthracnose and crown rot was also significantly less than control at room temperature. Similarly, the chemical treatments resulted in enhanced shelf life (6-8 d) when compared to control (4-5 d) at room temperature. At 13.5^{0}C storage, chemical treated fruits had a shelf life of 23-25 days while it was 16-18 days in control. Analysis of harvested fruits and pseudostem indicated the absence of chemical residues. A similar study is going on now on ratoon banana (cv. Grand Nain) with similar observations on pre- and post harvest stages.

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

Survey and molecular characterization of banana viruses

Surveys undertaken in Jalgaon District, Maharashtra and Burhanpur district, Madhya Pradesh revealed the re-emergence of infectious chlorosis caused by CMV in an epidemic proportion in TC plants. The CMV incidence was 0-33.88% and 0-100% in banana orchards surveyed in Jalgaon and Burhanpur Districts, respectively. Incidence of BBTV (1–14%), BBrMV (2–13%) and CMV (2–11%) was recorded in Theni District, Tamil Nadu, with BBTV and BBrMV incidence predominant in tissue cultured Red banana. In Sirumalai area, high incidence of BBTV and BBrMV was observed in some orchards. About 30% of the hill banana clumps were found to be infected with BBrMV, showing peculiar pink coloration on the pseudostem and mosaic on the bracts and leaves. The complete genome of CMV isolates infecting banana from Jalgaon and Burhanpur has been sequenced and characterized and grouped into subgroup IB (Fig. 10).

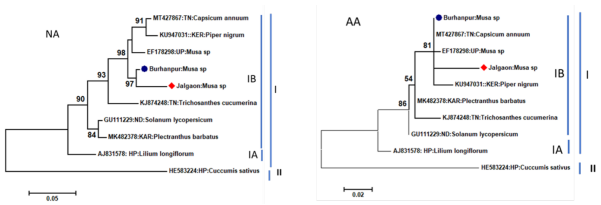


Fig. 63. Phylogenetic analysis of Nucleotide (NA) (Left) and amino acid (AA)(Right) sequence of CMV coat protein (CP) of CMV isolates infecting banana in Jalgaon and Burhanpur with respect to other Indian CMV isolates

Study of vector behaviour in banana – BBTV and black aphids, *Pentalonia nigronervosa*

An experiment was conducted to study the behaviour of black aphid, *Pentalonia nigronervosa,* the vector of BBTV. Under time course studies, more than 70 major volatile organic compounds (VOC) were identified in BBTV-infected and healthy banana plants. The various groups of VOC found in banana were esters, alcohols, aromatic hydrocarbon, hydrocarbon, carboxylic acid, ethers, and a few others. Healthy banana alone, healthy banana infested with non-viruliferous aphids and infested with viruliferous aphids, induced some unique VOC accumulation. In another study, 10,11,9 VOC were common in both healthy and BBTV infected. In infected plants, proportion of methyl salicylate was high (33.93%), and in healthy plants, Bicyclo [2.1.1]hexan-2-ol, 2-ethenyl- was emitted (15.23 %).In common, high levels of 2 VOCs(7-Benzoylheptanoic acid and NI 25) were detected in infected plants, whereas 7 VOCs were detected at high levels in healthy plants.

Effect of bioformulation on growth parameters of cv. Grand Nain under greenhouse conditions

Bioformulation mixtures of endophytic *Bacillus pumilus* and *B. subtilis*, rhizo *B. subtilis, Pseudomonas fluorescens*, *Trichoderma viride* and *Humicola* sp. isolated from cv. Grand Nain significantly increased the growth and physiological parameters such as pseudostem girth and height, number of leaves, phyllochron, and leaf area in biohardened TC plants under greenhouse conditions.

Field evaluation of BSMYV-free elite TC Poovan banana

In field evaluation, episomal BSMYV-free tissue culture-derived Poovan banana plants showed significant differences by way of enhanced growth and yield compared to sucker-grown plants.

Frontline Demonstrations (FLDs)

Elite BSMYV free high-yielding TC Poovan plants developed by ICAR-NRCB were supplied to five KVKs (Namakkal, Ariyalur, Perambalur, Kallakuruchi and Virudhasalam, Tamil Nadu), BRS (Kannara, Kerala) and farmers' fields located at Ganapathypallam, Perugamani, Lalgudi, and Thirukattupalli, Tamil Nadu. The beneficiaries' fields were monitored for disease incidence and plant quality and the performance of these plants was superior and there was no disease incidence compared to locally sourced plants by the farmers.

Virus indexing of TC mother plants

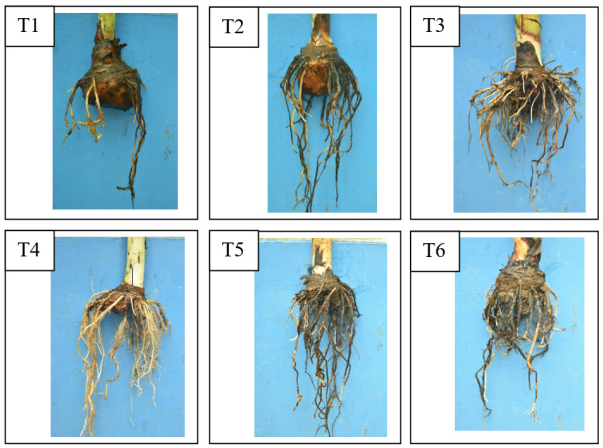
During 2022, 2828 TC banana samples from 14 TCPUs were tested for four viruses under contract service for virus indexing and a gross revenue of Rs.23,12,442 was generated. Germplasm accessions conserved in the field gene bank at different locations (ICAR-AICRP-Fruits - Arabhavi, Coimbatore, Gandevi, Jalgaon, Kannara, and Trichy centres) and mother plants used for ECS development were tested for the presence of viruses. Totally 189 germplasm samples from five AICRP-TF centres and 22 mother plants used for ECS development were tested for banana viruses. Virus detection kits developed for CMV, BBrMV, and BBTV were sold, generating revenue of Rs 59,500.

4.4.7 Investigations on *Musa* nematodes' diversity, biology, behaviour, interactions and its management

Boiling water treatment for managing nematodesin planting material

Planting materials (suckers) of cv. Nendran collected from nematode infested field were pared and immersed in boiling water (100°C) for different durations (15, 30, 45 and 60 seconds) and the treatments were compared with untreated pared and unpared suckers. Infection of root lesion nematodes (*Pratylenchus coffeae*) and root knot nematodes (*Meloidogyne incognita*) was found on the roots grown from the untreated suckers. Significant decrease in nematode population was observed in suckers

immersed in boiling water for 60 seconds. Further, root galls and root knot nematodes were completely absent on the roots from the suckers immersed in boiling water at and above 45 seconds.



T1	Paring and immersion of suckers in boiling water for 15 Seconds
T2	Paring and immersion of suckers in boiling water for 30 Seconds
T3	Paring and immersion of suckers in boiling water for 45 Seconds
T4	Paring and immersion of suckers in boiling water for 60 Seconds
T5	Control (Pared suckers)
T6	Control (Unpared suckers)

Fig. 64. Boiling water treatment for management of nematodes in planting material

Evaluation of *Musa* genotypes for resistance to root lesion nematode, *Pratylenchus coffeae*

Parental lines Matti, Namarai, Cultivar Rose, Pisang Jajeeand Lairawak were found susceptible to root lesion nematode, *Pratylenchus coffeae*.

Namarai Lairawak

Cultivar Rose Pisang Jajee

Fig. 65. Reaction of promising parental lines for resistance to root lesion nematode, *P. coffeae*

Elite mutants TBM 9 and Grand Nain Mutant 1 were found susceptible to root lesion nematode, *P. coffeae* which is on par with susceptible check, Grand Nain.

TBM 9 (58.4 nematodes / g root) Grand Nain Mutant 1 (75.4 nematodes / g root) Grand Nain (Susceptible check) (51.7 nematodes / g root)

Fig. 66. Reaction of elite mutant lines for resistance to root lesion nematode, *P. coffeae*

4.5 EXTERNALLY FUNDED PROJECTS

4.5.1 IITA – Collaborative project: Improvement of Banana for Smallholder Farmers in The Great Lakes Region of Africa - Enhancing Banana Production by Developing Fusarium Wilt-Resistant Varieties and Benefit Sharing with African Smallholder

Indian component - Breeding for improved banana with Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*) resistance

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

Chromosome doubled Ney Poovan tetraploid was used as male parent and crossed with Saba resulting in the development of three progenies with varied ploidies (2x, 3x and 4x).

ECS has been developed in various diploids and they are in various stages of development. The status of other diploid accessions used for polyploidization is as follows: Oryzalin treated cv. Rose ECS are in somatic embryo maturation stage; Kunnan and Agniswar are in primary hardening and other BB type accessions namely Bhimkol and Attiakolarein ECS multiplication stage.

High yielding Foc Race 1 resistant line, OSH 75 is being evaluated in farmer's field at four locations to confirm their performance in various banana growing districts of Tamil Nadu. The Foc race 1 resistant progenies developed at ICAR-NRCB are in shoot multiplication stage and ready for exchange with IITA partners.

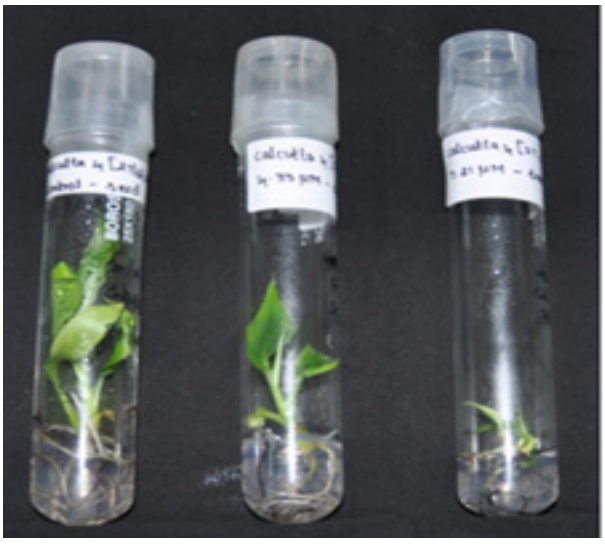


Fig. 67. Progenies of Saba x Ney Poovan tetraploid under rooting media

DBT-QUT funded Project

4.5.2 Biofortification and development of disease resistance in banana

Component I: Transfer and evaluation of Indian bananas with PVA constructs

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

RCGM approval has been obtained to receive the transgenic events from NABI, Mohali and transfer the transgenic events of ICAR-NRCB to NABI, Mohali; TNAU, Coimbatore; NAU, Gandevi and AAU, Dhubri. Similarly, approval has been obtained from RCGM to conduct the event selection trials under confined field conditions. Integration site of transgene has been detected for ten events and marker has been developed for identifying the independent transgenic events. Tissue culture plants of top 10 events are being multiplied for supply of transgenic plants to five centers (NABI, Mohali; ICAR-NRCB, Tiruchirappalli; TNAU, Coimbatore; NAU, Gandevi; AAU, Dhubri).

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

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

Five elite iron Grand Nain events (NRQIGN68- 20/47, NRQIGN53-19/15, NRQIGN68-20/36, BAQIGN53-19/84 and BAQIGN53-19/74) were multiplied using suckers and immature male flower buds for conducting event selection trials at five locations across the country. The Grand Nain events were transformed with iron constructs, pBMGF-DC-53 and pBMGF-DC-68, carrying OsNAS1 and OsNAS2 genes. A total of 90 plants are maintained as in vitro cultures. Besides, plants of 17 more elite events with more than 5-fold higher iron content than control fruit pulp are maintained in net houses. Explants obtained from those plants are subjected to multiplication through direct regeneration method. Genome walking and TAIL PCR were performed to identify the transgene integration sites. From the analysis, event NRQIGN68-20/47 carrying OsNAS2 gene was found to be integrated in chromosome 7 (Fig. 2) and an event-specific marker was also developed.

Event ID - NRQIGN68-'20/47

CHROMOSOME LOCATION - 7

chr07:37948545..37949051 - integrated within Scopoletin glucosyltransferase

T-DNA integration site on chromosome - 37949052

aaaaacgaagaagcttgcgttgtttggtcgcctggtgtctgccatctccaagagcttccgaatgtctcaggacttacacatactgttcttc-
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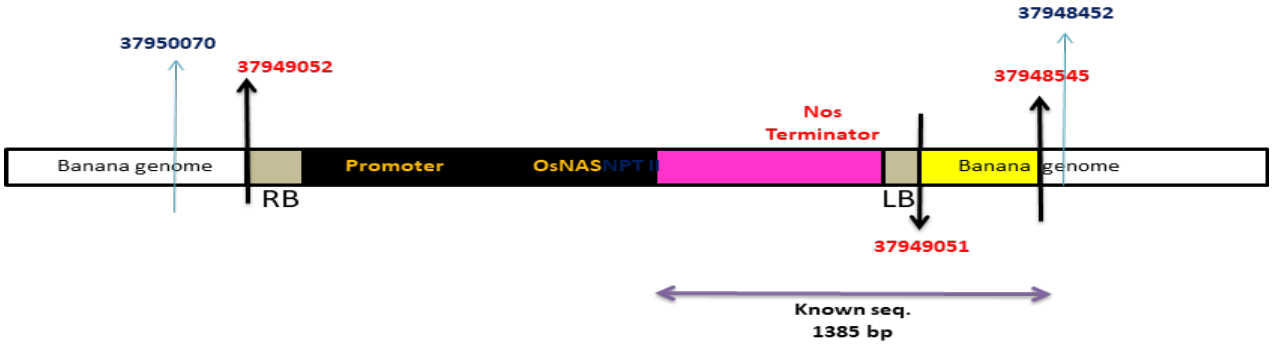


Fig. 68. Insert location details of iron construct with OsNAS2 of an event

PPV & FRA funded project

4.5.3 Framing crop specific DUS guidelines for banana (*Musa* spp.)

(M.S. Saraswathi and S. Backiyarani)

DUS characterization is in progress for two farmer's varieties *viz.*, Thottu Chingan and Kudhiraival Chingan. Conducted awareness program on PPV & FRA in association with DUS Nodal Centre, NRCB to farmers (30 Nos.) of Tirunelveli and Trichy districts, Tamil Nadu on 27 April, 2022 and 17 June, 2022 respectively. ICAR-NRCB has filed an application for registration of farmer's variety Ney Kadali (PPV & FRA No. DL1008220001/FV) and planting material of the same has been received and established in the DUS field. Two farmer's varieties (Chingan and Semmatti) and one Institute variety (Kaveri Sugantham) have been successfully registered with PPV&FRA, New Delhi and certificates have been received.

BRNS funded project

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

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

Embryogenic cell line has been developed from immature male flower buds of cv. Grand Nain.

The cells have been mutated using physical (Gamma irradiation -20Gy) and chemical mutagens (EMS 0.2% with 1 ½ hrs) and regenerated in MA3. Toxin based *in vitro* screening using Fusaric acid (0.1mM) and Beauvericin (6µM) is being carried out in the germination medium.

DST funded projects

4.5.5 Development of efficient IOT enabled plant disease pest detection system

(R. Selvarajan, R. Thangavelu and J. Poorani)

A novel and efficient compressed sensing inbuilt plant disease detection device is developed which uses a fore ground-based segmentation method and two-step feature extraction technique to detect and classify two of the major banana diseases. A database is created for banana bunchy top and leaf spot diseases by collecting images in real-time from the fields. The prototype of the proposed device has been developed and validated using the Raspberry pi board (Fig.69). The findings demonstrate that the suggested device achieves a classification accuracy of 97.33% and a detection accuracy of 96.75%.

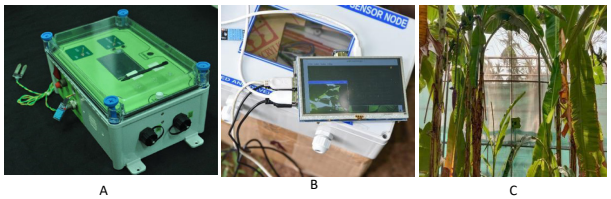


Fig. 69. Prototype developed and validated for efficient plant disease pest detection. A. Prototype. B. Prototype tested in real field; C. Prototype mounted on pole in net house, ICAR-NRCB Research farm

4.5.6 A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.)

(C. Anuradha)

ddRAD approach was successfully employed to unravel the genomic basis of seedlessness in bananas. This method yielded 83,61,089 SNPs from a panel of 200 accessions, and after filtering the data, 35,664 highly reliable markers were used for genetic diversity, population structure, and linkage disequilibrium analysis, which revealed high levels of admixture in most accessions. A GWAS on the parthenocarpic trait was performed on the panel using the Mixed Linear Model (MLM) and the General Linear Model (GLM) (GLM). Candidate genes and markers potentially linked to the seedless phenotype were identified. PCSSR3 was validated among all the diploid cultivars (AA diploids: 24, BB diploids: 26, AB diploids: 18) and the marker was able to differentiate the seeded from the parthenocarpic cultivars (Fig. 70). The same data is also used to identify the candidate genes and the markers associated with resistance to *Foc* race1 and TR4.

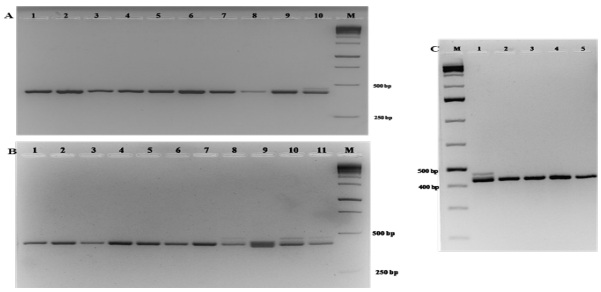


Fig. 70. Validation of PCSSR marker associated with parthenocarpy in BB diploids.

CGIAR / Bioversity International funded projects

4.5.7 Conservation and use of Genetic Resource – Evaluation of ITC Genotypes for their reaction to FoC R1 and TR4

(R. Thangavelu and S. Backiyarani)

Evaluation of ITC genotypes for their reaction to *Foc* Race 1 and TR4

Glasshouse condition

A total of 110 ITC accessions belonging to different genomic groups were evaluated under glasshouse conditions by artificial inoculation of *Foc* Race1 (VCG 0124), of which eight accessions were found resistant, 58 were moderately resistant, 32 were susceptible and 12 were found highly susceptible to *Foc* Race 1. The ITC accessions found resistant to *Foc* Race 1 were Cardaba -ABB (0394), PC-1205-AAAB (1260), Paka -AA (1254), FHIA-23-AAA (1265), FHIA-02-AAAB (0505), Williams-AAA (0570), Tjau Lagada -AA (0090) and GCTCV-119 -AAA (1282).

Field condition

Out of 103 ITC banana accessions evaluated for reaction to *Foc* Race 1 in hotspot at Muthalapuram, Theni District, Tamil

Nadu, 44 were found highly resistant, 13 were resistant, 11 were moderately resistant, eight were susceptible and 27 were found highly susceptible. Except Cardaba (ABB-0394), all the ITC accessions resistant to *Foc* Race 1 under glasshouse conditions were found resistant under field conditions as well.

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

(C. Karpagam)

The present study has been initiated recently to document the extent of adoption, dissemination process, and constraints in the adoption and dissemination of new or improved varieties in the banana production system exclusively with the status of three improved ITC accessions, viz., Saba (ABB-ITC 1138), Popoulu (AAB, Plantain), PisangLilin, FHIA-01, NamwaKhom (ITC 0659). The secondary data collection over the period shows thatPopouluhas been identified as a high yielding, dual purpose variety as a dessert and for chips making purpose. It has been recommended for cultivation in Karnataka, Odisha, Tamil Nadu, Assam, Kerala, Andhra Pradesh, and West Bengal. The trial with introduced clones of Popoulu was conducted at seven AICRP centres in India.

ICAR Funded Projects

4.5.9 ICAR-Network Project on Precision Agriculture

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

The soil moisture deficit stress and nitrogen stress on cv. Grand Nain influenced the days taken for flowering. Soil moisture deficit stress (3 bars) delayed flowering by 13-15 days compared to irrigated control. Similarly, early flowering by 15-17 days was recorded in N0 and N50 (0 and 50 % RDF), compared to N100 (RDF) treatments. The differential application of water, N and K was imposed in cv. Grand Nain. The N_0 treatment recorded early flowering and yellowing of leaves was captured by aerial drone imaging (Fig. 71).

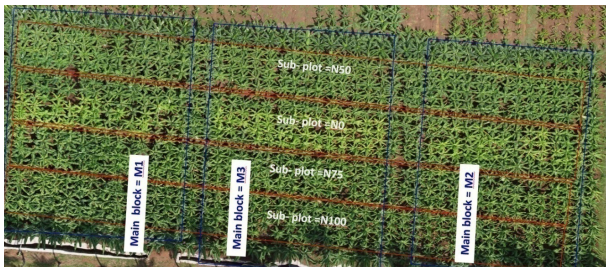


Fig. 71. Aerial image of banana field treated with different levels of N stress manifested as yellow canopy

4.5.10 Utilization of banana wastes for the development of symbiotic and designer foods through pre and pro-biotic approaches and to enhance the farmers' income

(P. Suresh kumar)

Optimization of dietary fiber (DF) extraction method from banana central core stem (BCCS) The enzymatic method of DF extraction from BCCS showed promising output when compared with other two methods in terms of total DF yield. DF can be divided into water-soluble and insoluble, recorded as SDF and IDF.

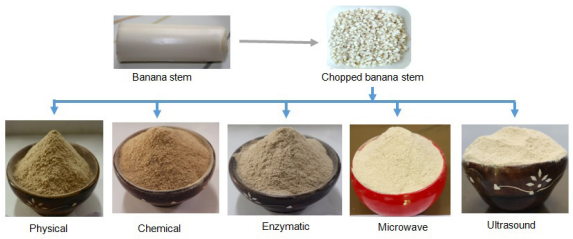


Fig. 72. Dietary Fiber extracted from BCCS by different methods

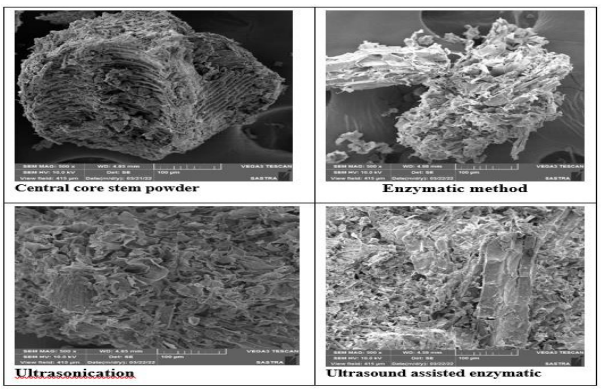


Fig. 73. SEM micrographs of dietary fiber from banana central core stem

Table 30. Physico-chemical properties of DF from BCCS extracted by different methods

	Physical	Enzymatic	Chemical	US	UAE	EAU
Moisture	3.35 ±0.33	4.56 ±0.56	4.58 ±0.43	5.07 ± 0.2	5.20 ± 0.2	6.37 ± 0.3
a_w	0.52 ±0.07	0.46 ±0.05	0.51 ±0.08	0.44 ± 0.03	0.38 ± 0.01	0.56 ± 0.01
Protein	3.41 ±0.02	1.15 ±0.03	1.32 ±0.06	2.08 ± 0.27	1.98 ± 0.27	0.82 ± 0.14
Fat	0.54 ±0.03	0.54 ±0.02	0.92 ±0.07	0.02 ± 0.16	0.01 ± 0.31	0.02 ± 0.42
Ash	0.31 ±0.08	0.56 ±0.07	0.53± 0.02	0.25 ± 0.02	0.25 ± 0.02	0.19 ± 0.01
Cellulose	39.18±10.43	40.28±0.58	40.53±0.67	39.03± 1.13	37.37 ± 0.15	41.22±0.31
TDF*	52.03±1.45	54.66±1.82	55.46±1.29	60.79± 0.25	57.06 ± 0.21	61.48±0.27
SDF#	4.81 ±0.12	3.32 ±0.36	3.24 ±0.31	5.38 ± 0.26	4.03 ± 0.26	4.26 ± 0.25
IDF+	50.22±1.45	52.34±1,82	52.22±1.27	54.41± 0.15	52.53 ± 0.24	56.22±0.16

* US- Ultrasonication method, UAE- Ultrasound assisted Enzymatic method, EAU- Enzymatic- Ultrasound method⁎-Total dietary fiber; #-Soluble dietary fiber; + - Insoluble dietary fiber

Pre-treatments resulted in efficient extraction of DF from BCCS. Comparatively, ultrasound assistance resulted higher TDF. Particle sizes of 14.62– 66.05 µm in EU, 15.28–63.29 µm in UE, and 23.02– 42.44 µm in US. Overall, the particle sizes of EU and UE were larger than US.

Influence of dietary fiber on rheological and textural characteristics of ice cream

Study was conducted to decipher the influence of the banana starch and DF on the physico-chemical and structural properties of icecream. Treatments were as follows; T1: no starch and no Dietary fiber; T2: 10% Banana starch; T3: 10 % Banana starch + 0.5% Dietary fiber; T4: 10 % Banana starch + 1 % Dietary fiber; T5: 10 % Banana starch + 2% Dietary fiber; T6: 10 % Banana starch + 3% Dietary fiber.

The proximate composition analysis showed that addition of fibers in icecream resulted in significant differences in moisture, protein and ash content. The a_w of ice cream samples was above 0.90, showing that it is a highly perishable food product. But the measurements were made at 25°C, i.e. at melted state, but at a frozen condition due to the non-availability of bound water frozen ice cream when stored at -18 °C had a longer shelf life.

Table 31. Physico-chemical properties of ice cream with banana central core stem dietary fiber (FWB)

	a_w	Total sugar (%)	Protein (%)	Fat (%)	TDF* (%)	WI+	Overrun (%)	Melting time (sec)
T1	0.94±0.01	6.72±0.28	7.19±0.55	11.84±0.31	1.31±0.13	77.28±0.11	45±0.12	503±0.17
T2	0.94±0.05	6.11±0.35	8.86±0.41	11.66±0.26	2.29±0.11	76.55±0.24	20±0.25	499±0.31
T3	0.91±0.03	6.33±0.31	9.69±0.52	11.43±0.34	3.37±0.21	75.25±0.13	20±0.31	505±0.11
T4	0.92±0.04	6.38±0.37	8.46±0.35	11.65±0.51	4.13±0.19	76.53±0.16	20±0.12	553±0.32
T5	0.91±0.03	6.33±0.31	9.69±0.52	11.43±0.34	3.37±0.21	75.25±0.13	20±0.31	505±0.11
T6	0.92±0.04	6.38±0.37	8.46±0.35	11.65±0.51	4.13±0.19	76.53±0.16	20±0.12	553±0.32

+WI- Whiteness index

*TDF- Total dietary fiber;

Addition of banana starch to ice cream samples resulted in improved WI values, but with increase in concentration of DF percentage, the values decreased. The addition of DF along with banana starch provided a significant reduction in melting rate. The enhanced water absorption capacity of DF may be attributed to significant increase in melting time of ice-cream. Over run (%) indicates the amount of air that gets incorporated during ice cream preparation.

Table 32. Texture analysis of ice cream with banana central core stem dietary fiber (FWB)

	Hardness	Adhesiveness	Resilience	Cohesion
C	663.48±13.23	774.77±21.23	0.24±0.02	0.98±0.05
C1	649.46±15.65	823.64±19.55	0.28±0.01	0.98±0.05
T1	768.75±17.23	492.20±18.23	6.17±1.11	0.98±0.05
T2	778.57±8.63	559.07±14.86	1.04±0.56	0.46±0.02
T3	747.05±15.89	840.54±19.25	5.12±0.88	0.71±0.01
T4	747.05±18.33	850.92±20.11	5.25±0.98	0.70±0.02

Studies on impact of different nitrogen sources on growth of *Saccharomyces cerevisiae* ATCC 9763 and banana wine production

Banana wine was prepared using banana juice and yeast culture of *Saccharomyces cerevisiae* ATCC 9763 at an inoculum level of 1, 5 and 10 per cent (*6 log cfu ml^{-1})*with different nitrogen sources (1 % (w/v)) peptone, DAHP, glutamine, glycine, leucine and the combination of glutamine, glycine and leucine amino acids. The best results were obtained in DAHP and the combination of amino acids, as a nitrogen source for the alcoholic fermentation for 8 days at 27 °C. Irrespective of the inoculum level and N source utilized, the live cell count continued to increase upto 90 h (10.8 – 12.1 log value) and then declined. However the biomass yield was found to maximum at 180 h, the point of completion of fermentation.

The yeast growth kinetic model fitting studies were done, in which it was found that the experimental pattern of biomass production using banana juice substrate by the strain *Saccharomyces cerevisiae* ATCC 9763 fit well with SGompertz and SLogistic models followed by a fitting comparison study showing SGompertz, the best fit model. The maximum on par values of 7.06 - 7.1 % (v/v) alcohol content was obtained using 5% and 10 % inoculum level using DAHP as N source, while maximum on par values of 6.06-6.1 % (v/v) alcohol content was obtained using 5% and 10 % inoculum level using amino acid combination of glutamine, glycine, leucine as N source. The wine produced using DAHP as N source resulted 3.94 pH, 9.75 °Bix TSS, 1.06 specific gravity, 90.93% moisture, 0.85% ash, 0.73 % titratable acidity, 9.98 g/100g total sugar, 0.52 g/100g reducing sugar, 0.30 g/100g total protein, 110.69 mg/100g total phenol and 38.53 mg/100g total flavonoids.

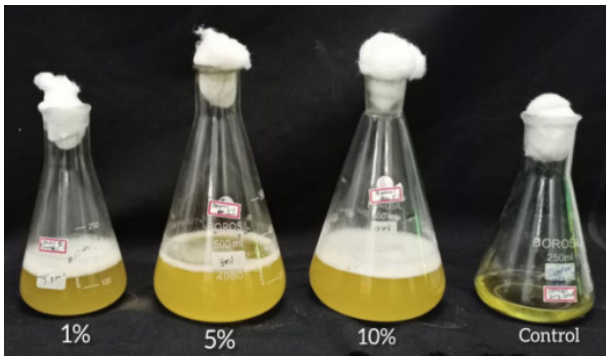


Fig 74. Banana juice fermentation to wine using 1,5 and 10% *Saccharomyces cerevisiae* ATCC 9763 inoculum levels using (a) DAHP (b) combination of amino acids

Banana vinegar

Converting banana wine to vinegar was initiated using *Acetobacter aceti* ATCC 15973. The banana wine was aerated and inoculated with 10% inoculum of acetic acid bacteria at a regulated temperature (28°C). The aerobic fermentation was allowed for seven days until the pH declined to 3. Isolation of acetic acid bacteria (AAB) using solid and submerged state fermentation using banana pulp and

wine was experimented. Screening of AAB was performed by spread plating of appropriate serial dilutions of the samples onto selective medium of GYC medium and standard ethanol medium. The selected isolates were analyzed using MALDI-TOF technique and were found to belong to *Lactobacillus,Tatumella, Acetobacter, Brevibacillus* and *Ralstonia.* Besides *Acetobacillus* sp., *Lactobacillus* sp. and *Brevibacillus* sp. are potential probiotics.

Isolation, characterization and identification of probiotic lactic acid bacteria for making synbiotic low-fat banana yogurt

Lactic acid bacteria (LAB) group of microorganisms were isolated from different banana sources namely: banana ripe fruit pulp, pseudo stem sap, raw banana fruit powder and ripe banana peel and milk using isolation techniques such as solid / liquid state fermentation and enrichment culture using quarter strength MRS medium. The log values of a total number of colony forming units obtained in MRS plating were 7.60 and 8.16 in liquid state fermentation and enrichment culture respectively. Based on the morphological characters and gram staining totally19 and 11 different isolates were obtained from liquid state fermentation and enrichment culture respectively summing up to 30 isolates. These 30 isolates were subjected to biochemical characterization: acid production assay and 12 isolates showed acid production among which 4 isolates namely LPM1, LPM2, MSL3 and EAAB1showed maximum acid production. Based on the acid production character, ten isolates were selected and identified using MALDI –TOF technique and the isolates were found to belong to genus: *Lactobacillus*, *Bacillus*, *Cupriavidus*, *Klebsiella*, *Citrobacter*, *Burkholderia*, *Moraxella* and *Raoultella*. The identified *Lactobacillus* sp.(two) and *Bacillus* sp.(one) isolates were further subjected to genomic identification using universal primers and based on the phylogenetic tree, were found confirmed to belong to the genera *Lactobacillus* sp. (*Lactobacillus* sp. LSM 3, *Lactobacillus* sp. LPM 2) and *Bacillus* sp.(*Bacillus* sp. EAAB 1). These isolates were tested for probiotic character of growth and survival in pH 2.0 and isolates *Lactobacillus* sp. LSM 3 and *Lactobacillus* sp. *Lactobacillus* sp. LSM 3 and *Lactobacillus* sp. LPM 2, the best was found to be made using skimmed milk (100ml) + 5% RPB + 0.5% gelatin + 0.5% WPC+ *Lactobacillus* sp. LSM3 in terms of both biochemical and sensory characters. Further studies are required for evidencing the probiotic characters of the isolate *Lactobacillus* sp. LSM3 and production standardization of the synbiotic low-fat banana yogurt followed by storage studies.

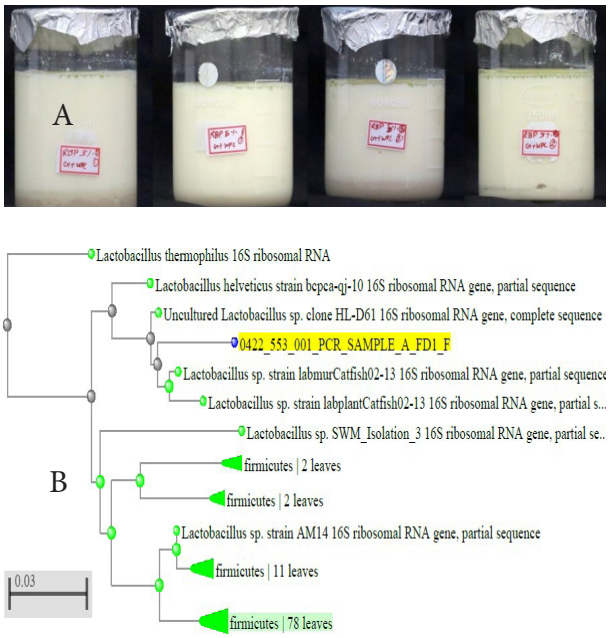


Fig. 75. (a) Low-fat banana yogurt prepared using selected probiotic LAB isolates *Lactobacillus* sp. LSM3 and *Lactobacillus* sp. LPM2 (b) Phylogenetic tree constructed using neighbor-joining method for the isolate *Lactobacillus* sp. LSM3

Minimal processing of banana rhizome

The banana by-product rhizome was processed and preserved using 0.1 % of KMS or Ascorbic Acid or Lemon grass oil with Acidity regulator INS 260 (Vinegar – 1000 ppm), firming agent INS 509 (Calcium Chloride - 600 ppm) in a PET bottle to have improved shelf life with addition of spices and condiments.

Fig. 76. Minimally processed rhizome (Control (a); 0.1% KMS (b), 0.1% Ascorbic acid (c) and 0.1% lemon grass oil (d))

The hardness value of the minimally processed rhizome was highest for control (129.3 ± 0.01) followed by treatments (KMS, Ascorbic acid, lemon grass oil) in each varieties. A similarly trend was observed for the resilience, cohesiveness, springiness, gumminess, chewiness.

Table 33. Texture profile analysis of minimally processed rhizome

Treatment	Hardness(g)	Adhesiveness (g.sec)	Resilience (%)	Cohesion	Springiness (%)	Gumminess
Control						
Grand Nain	129.3 ± 0.01	32.6 ± 0.3	2.7±0.01	1±0.01	82.3±0.02	127.3±0.3
Karpooravalli	100.3 ± 0.05	42.1 ± 0.7	2.02±0.01	1±0.01	50.9±0.05	145.3±0.7
Nendran	89.6 ± 0.07	47.9 ± 0.2	4.2±0.6	1±0.01	38.5±0.1	81.6±0.8
KMS(0.1%)						
Grand Nain	127.5±0.01	53.36±0.03	4.39±0.03	1±0.01	62.3±0.02	127.5±0.01
Karpooravalli	145.3±0.02	60.58±0.31	3.32±0.11	1±0.01	72.3±0.01	123.42±0.11
Nendran	81.82±0.3	59.40±0.11	2.72±0.02	1±0.01	85.35±0.05	157.7±0.02
ASCORBIC ACID (0.1%)						
Grand Nain	105.44±0.41	66.18±0.01	2.42±0.02	1±0.01	89.5±0.10	105.43±0.01
Karpooravalli	109.6±0.32	46.59±0.02	3.12±0.43	1±0.01	74.85±0.02	109.86±0.04
Nendran	141.4±0.6	87.78±0.13	2.38±0.21	1±0.01	90.1±0.03	141.92±0.23
LEMONGRASS OIL (0.1%)						
Grand Nain	164.9±0.02	34.5±0.2	2.35±0.02	1±0.01	76.35±0.02	90.86±0.21
Karpooravalli	165.1±0.31	60.36±0.11	2.32±0.021	1±0.01	38.9±0.03	164.8±0.01
Nendran	206.4±0.22	69.01±0.03	3.22±0.01	1±0.01	55.5±0.14	164.7±0.11

Effect of different drying conditions on the quality of dehydrated ripe banana

Effects of hot air drying (HAD), solar drying (SD),andsolar dryer with Phase changing material (PCM) on drying kinetics, physicochemical properties, were evaluated. The data obtained from the three driers was fitted to each model and the best model waschosen based on RMSE and the R^2 score. The model with the highest R score (andsubsequently having the lowest RMSE value) was chosen in each case. For the PCM dryer, both Weibull and Modified Page modelperformed the best, with an R value of 0.9954 and 0.9927 respectively. In case of the Hot Air Ovendryer, the Two Term exponential and Modified Page models were the best, with an R value of 0.9964

Table 34. Effects of drying techniques on texture profile analysis (TPA) of dehydrated banana.

Parameters	HAD	SOD	PCM
Hardness (g)	795.52±60.11	452.08±97.03	324.63±20.93
Cohesiveness	0.32±0.03	0.40±0.06	0.57±1.35
Adhesiveness (g. sec)	188.17±24.15	171.07±66.07	69.17±22.55
Chewiness	297.31±48.41	195.77±38.54	171.68±41.94
Springiness (%)	93.41±2.82	109.21±9.91	94.48±2.36
Resilience (%)	5.37±0.25	2.57±0.50	7.42±1.35

HAD- Hot air drying; SD- Solar drying; PCM- Solar drying with Phase changing material

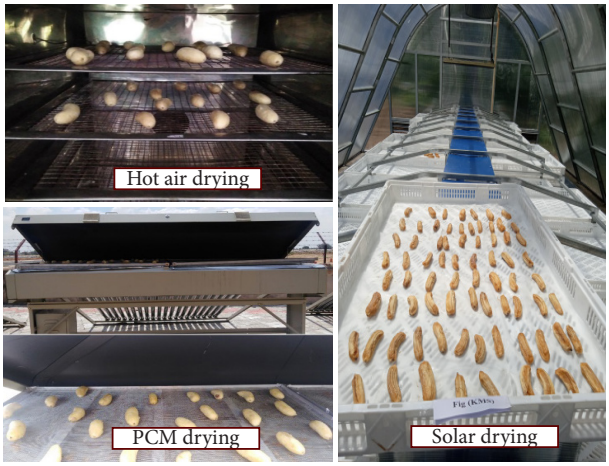


Fig. 77. Preparation of dehydrated ripe banana in different dryers

4.5.11Development of post-harvest handling and sensorbased smart packaging methods for the export of traditional banana varieties and nano-strip based digital health monitoring of banana

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

Physico-chemical characteristics, antioxidant properties and volatile compounds of eleven banana varieties

Plantain bananas recorded higher fruit weight than dessert bananas. Pulp to peel ratio were higher in Ney Poovan and Popoulu compared to cooking varieties indicating the presence of a thicker skin. Higher resistant starch (39% dry weight) was observed in Kaveri Saba and Monthan. Phenolics in ripe bananas were significantly higher than unripe stages. GCMS results showed the predominance of esters and hydrocarbons among banana varieties and the presence of unique volatiles like Linoelaidic acid, (9Z, 12Z)-octadeca-9,12-dienoic acid in Kaveri Sugantham. The predominant volatile compound was esters in Monthan, Kaveri Kalki, NCR 17 and TBM 9 which accounted for 63.04 %, 37.95 %, 35.57 % and 34.91 % of the total content, while compounds such as 1,2,3-trimethoxy-5-prop-2-enylbenzene, 1-O-butyl 2-O-decyl benzene-1,2-dicarboxylate, 1-O-butyl 2-O-(2-ethylhexyl) benzene-1,2-dicarboxylate and 3-methylbutan-1-ol accounted for 27.18 %, 26.49 %, 22.49 % and 16.04 % of total volatile compounds, respectively. PCA and cluster analysis data indicated that the biochemical parameters also varied with the genomic groups. The two PC's in PCA graph segregated the varieties into two major groups. The first group comprised of the dual purpose varieties such as Nendran and NCR 17. The second group comprised the cooking varieties such as Kaveri Saba, Monthan along with dessert varieties such as Popoulu and Grand Nain. In both unripe and ripe bananas Grand Nain and TBM 9 clustered together as both of them belonged to the same AAA genome and Cavendish subgroup. The dissimilarities between them are almost 23% in both cases which might be attributed to the plant stature and the fruit quality.

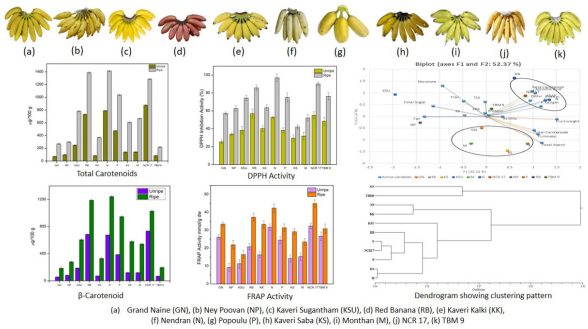


Fig. 78. Physico-chemical characteristics, antioxidant properties and volatile compounds of eleven b a n a n a varieties

Influence of ripening methods on the chemical characteristics and enzymatic activities of Grand Nain banana fruits

Different commonly used conventional ripening techniques namely Ethereal dip, Ethereal spray, Ethylene gas application using ripening chamber (100 ppm), smoke based ripening and calcium carbide. Fruits were sprayed with 2mL Ethrel diluted in 2L water. 4mL Ethephon was diluted in 2 L water and the fruits were dipped in it. Banana hands were kept in an air sealed 100 Sq. ft smoke chamber with 5-10 lighted incense sticks kept in one corner of the room. The fruits were kept in this smoke chamber for 24 hours. 2g of Calcium Carbide per Kg of Banana hands was weighed and kept in permeable paper inside the crates where the hands are kept. The crates were kept at 22°C

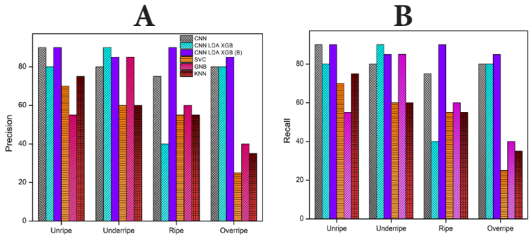
for 24 hours for color development. Upon introspection, the calcium carbide and smoke treated fruits showed highest firmness. The ripened fruits were analyzed for their physico-chemical properties, secondary metabolites and enzymatic activity.

Table 35. Effect of ripening agents and methods on the physico-chemical and enzymatic activity of Grand Nain banana

	Ethrel Spray (1mL/L)	Ethephon Dip (2mL/L)	Smoke	Fumigation (100 ppm)	Calcium Carbide (2g/Kg)
L	60.43±1.23	51.13±1.02	50.23±1.17	46.78±0.85	48.49±1.13
a*	-13.0±0.42	-14.1±0.23	-19.5±0.14	-3.53±0.67	-20.9±0.89
b*	30.70±1.03	13.2±0.29	25.0±0.83	23.5±1.01	24.2±0.98
Firmness (N)	5.6±0.54	13.3±0.43	16.1±0.98	3.9±0.24	16.6±0.30
Acidity (g/100g)	0.94 ±0.20	0.67±0.92	0.39±0.49	0.35±0.15	0.28±0.20
TSS (° Brix)	20.38±1.43	21.29±1.23	20.67±1.48	21.87±1.09	19.2±1.20
Moisture(g/100g)	74.25±2.23	72.12±2.40	74.06±2.01	73.24±2.89	71.49±2.14
Ash(g/100g)	0.83±0.23	0.42±0.19	0.162±0.28	0.18±0.39	0.13±0.30
Fat(g/100g)	0.14±0.21	0.03±0.11	0.08±0.19	0.04±0.18	0.04±0.09
Total Sugar(g/100g)	22.72±1.79	25.84±1.85	24.15±1.97	23.72±1.23	25.16±1.30
Total Starch(g/100g)	1.04±0.68	1.24±0.74	0.98±1.08	1.09±0.73	1.88±0.48
Total Protein(g/100g)	1.02±0.24	0.34±0.18	0.56±0.20	1.73±0.32	1.29±0.43
Total Phenol(mg/100g)	65.38±2.50	61.67±2.34	57.98±2.78	53.49±2.23	58.39±2.40
Total Flavonoids(mg/100g)	45.39±2.15	56.39±2.78	55.46±2.70	51.84±2.43	44.58±1.03
Poly phenol oxidase	3.76±1.01	2.38±0.98	2.19±1.12	3.76±1.04	3.10±1.08
Peroxidase	54.39±2.13	46.59±3.42	47.27±1.54	52.49±2.06	58.39±1.94

Developing computationally effective non-invasive intelligent ripeness grading technique for banana fruits using color and firmness

A completely non-invasive technique to identify four classes of banana fruits have been proposed using the duo of CNN-XgBoost with LDA (Convolution neural network – Extreme gradient Boost with Linear Discriminant Analysis). The experimental validation results of the proposed technique proved its supremacy over other existing machine learning and deep learning algorithms. While the major requirement of deep learning algorithms is to have a sufficiently large data set, the proposed scheme is capable to provide promising results with comparatively smaller data set. This serves as an initial step for classifying complex and clustered bananas using deep learning in industrial export and processing applications. In addition, the computational complexity of the proposed architecture is comparatively lesser with desired accuracy. This in turn reduces the burden of memory in the processor and hence aiding in effective energy utilisation. This proposed method of non-invasive technique could be used by the warehouse managers, exporters and to monitor the health of bananas on a real time basis.



Class wise Precision b Class wise Recall

CNN – Convolution Neural Network; CNN LDA XGB – Convolution Neural Network - XgBoost; CNN LDA XGB (B) - Convolution Neural Network – XgBoost with Bayesian optimization; SVC – Support Vector Classifier; GNB –Gaussian Naive Bayesian Classifier; KNN - k-Nearest Neighbors

Fig. 79. Developing computationally effective non-invasive intelligent ripeness grading technique for banana fruits using color and firmness

Two kinds of features have been manually extracted for each image features. Colour features are obtained in the form of RGB color histogram. he color values from 0 to 255 are binned into 14 bins creating 14*14*14 dimensional color histogram. Image texture gives information about spatial arrangement of color or intensities. Two dimensional dependence matrix called Gray level co-occurrence matrix (GLCM) is used for texture analysis. ij^{th} cell in Gray level co-occurrence matrix infers how many times i and j color value occur together with distance d and at angle Θ between them. Thus texture feature for each image is of multi dimensions (dissimilarity, correlation, homogeneity, energy, contrast). These properties are calculated for each GLCM. Thus, for ML algorithms a 14 X 14 X 14 +5 dimensional feature is used for prediction. The computational complexity of CNN, XgBoost and LDA are separately written as follows

- CNN (CNN feature extractor weights are frozen so considering only the fully connected layers): O (n_samples * n_ epochs * summation of each layer weight shape)
- LDA: O (nd^2)
- XgBoost:O (n_trees * height of trees * ***log*** n_sample)

The proposed model of CNN XgBoost does not suffer this problem as the time complexity scales only linearly with number of samples and there is no costly distance computations. The convolutional filter size and layer weights are also fixed regardless of the dataset size.

Table 36. Computational complexity and trainable parameters of conventional and proposed CNN architecture

Model	Computational complexity	Trainable parameters
VGG 16 CNN without modification	12.3 GMac	138.36 Million
Proposed model CNN	12.18 GMac	7.55 Million

GMac: Gaussian multiple-access channel

It is evident from results that, the proposed model has drastically lower number of parameters to learn when compared to conventional VGG16 CNN architecture. This is achieved by fixing the pre learnt weights at the VGG16 feature extractor part and replacing the classifier stage fully connected layers having many neurons with that having lower neurons.

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

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

Under this project, ABI interaction centre was established. Established customized video conference facility at committee room. Renovated existing/old Farm office room at NRCB Farm premises (civil and electrical works and furnishing), equipments/instruments/tools like Laminar flow chamber, printed books were purchased as an additional facility for the common incubation centre. One incubate, Mr. C. Arivumani, Imaya's Marketing, Trichy was registered for incubation and availed the incubation facilities for making banana based pickles. He has availed ABI facilities and produced 335 kg of banana based pickles and generated a revenue of Rs.7,690/ including registration and caution deposit. Fifty five Entrepreneurship Development Program (EDPs) and Agri-business Development/ Awareness Programs were given in various *fora* to 1261 beneficiaries. About 115 farmers, 30 other stakeholders and 620 Students from various colleges visited ABI and benefitted.

Eight publications (Compendium, Technical bulletin, Extension folder and leaf folder) were brought out. ABI was popularized through various platforms. Two value added products were developed under ABI as detailed below.

Development of *Upma* instant mix from Banana *rava* fortified with millets and quinoa

The development of *upma* instant mix from unripe Nendran banana rava and millets could be a potential solution to address the challenges of food security, malnutrition, and poverty in India. Standardization of *upma* instant mix was carried out based on sensory evaluation, proximate composition, physical properties, and cooking quality. The sensory evaluation suggested that the sample with 30% banana rava, 30% foxtail millet, 30% pearl millet, and 10% quinoa had good overall acceptability. The proximate composition of upma instant mix showed moisture content ranging from 0.77 to 1.88%, ash value ranging from 1.46 to 2.10%, crude fiber ranging from 6.07 to 9.07%, protein ranging from 9.97 to 11.27%, fat ranging from 0.72 to 3.20%, and carbohydrate ranging from 75.64 to 86.54%. The standardized upma instant mix was also cost-effective, with a cost ranging from Rs. 15-30 per serving. Thus, the use of locally available and affordable ingredients such as banana rava and millets can also provide a livelihood for small-scale farmers and boost the local economy.

Development of banana grits

Banana grits was developed from five different varieties of banana namely Nendran, Saba, Bangrier, Grand Nain and Red banana. Banana grits can be used as an alternative for cereal breakfast; this serves as an ideal ingredient for a healthy diet. The Banana grits was introduced to utilize the presence of resistant starch in bananas which is reported to improve the gut health. The grits were recorded with low moisture content ranging from 3.856 to 4.097%, protein ranging from 1.350 to 1.523%, high energy ranging from 338.41 to 399.78kcal/100g with less cooking time for the grits (8.68 minutes). With respect to the color index, the grits had a high 'L' value (58.36-68.48), a low 'a' value (-6.190 to -7.590), and a high 'b' value (23.39-25.23). Based on the results, it was concluded that grits made from Nendran bananas were the best choice, due to their improved quality parameters and bright yellow color.

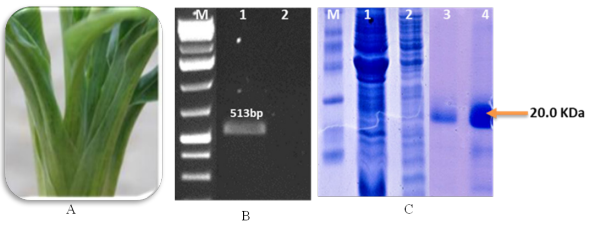
Fig. 80. ABI incubate, Mr. C. Arivumani group making banana based pickles under the brand name of *'Imayas'*

4.5.13 Development and utilization of diagnostics to viruses of banana under consortium research platform on vaccines and diagnostics

(R. Selvarajan and C. Anuradha)

Development of polyclonal antibodies-based ELISA kit for detection of banana bunchy top virus (BBTV)

Banana bunchy top viral coat protein fused with a 6xHis tag (~20 kDa) at the N-terminus was expressed in *E. coli* BL21(DE3) pLysS strain. The purified soluble state BBTV CP fusion protein was used as antigen to produce polyclonal antibodies (PAb) for developing ELISA-based kit. The produced PAb against the purified fusion protein successfully detected BBTV from banana samples in DAC-ELISA (Fig. 16) and was validated using banana leaf samples collected from various geographical locations.



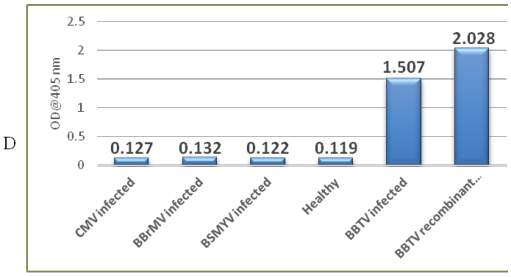


Fig. 81. Development of polyclonal antibodies-based ELISA kit for detection of banana bunchy top virus (BBTV). A. BBTV infected banana plant. B. PCR amplification of BBTV CP gene. Lane M: 1 kb DNA ladder; Lane 1: BBTV CP gene was amplified from DNA isolated from BBTV infected banana sample; Lane 2: No amplifcation in DNA isolated from Healthy banana sample. C. SDS-PAGE analysis of the rBBTVCP expressed as His-Tag fusion protein in *E. coli*. Lane M: Protein molecular weight; marker; Lane 1: Protein of the induced pellet pET28a-BBTV-CP; Lane 2: Proteins of the uninduced pellet pET28a-BBrTV-CP ; Lanes 3-4: Soluble form of Ni-NTA column-purified rBBTVCP protein. D. Specificity analysis of PAb against BBTV by DAC-ELISA

Large scale production of monoclonal antibodies for using recombinant CP of BBrMV and CMV

The recombinant coat proteins of BBrMV and CMV have been expressed in bacterial expression systems and are being utilized for the large-scale production of monoclonal antibodies (Mab) using the hybridoma technology. The Mab-based triple antibody sandwich enzyme-linked immune sorbent assay (TAS-ELISA) was developed and is being used routinely in the laboratory for testing tissue culture banana plantlets against BBrMV and CMV. Further, the monoclonal-antibodies are used and standardized to develop LFIA strip preparation for better sensitivity.

Standardization of the sampling protocol for BBTV detection in PCR

Both symptomatic and asymptomatic plants are recommended to sample the meristem and the youngest leaf for BBTV detection, due to these preliminary data and the fact that virus concentrations are usually highest in actively growing tissue. Among six BBTV components, BBTV-N was identified as a component abundantly present in BBTV-infected banana plants for PCR testing to ensure easy and sensitive detection.

Supply of virus-free planting materials

Totally 9550 virus-free tissue culture plants of cultivars Nendran, Red banana, and Grand Nain, and other cultivars were supplied to SC farmers through KVKs under SC Sub-Plan.

NABARD Funded Project

4.5.14 Establishment of banana macropropagation units in Tiruchirappalli District, capacity building and improvement of livelihood opportunities of farmers

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

Eight units were established at farmers' fields in six blocks of Tamil Nadu and in each unit two cycles of production have been completed. Technology has been transferred to KVK, Sandhiyur and this KVK received a project from NABARD to disseminate this technology to the women's self-help group. Hands on training on this nursery technology have been given to students of Department of Botany, Bishop Heber College, Tiruchirappalli, Tamil Nadu.

4.5.15 Design, development and validation of online banana trading platform for farmers of FPOs in Trichy District

(D. Ramajayam, R. Selvarajan, K.J. Jeyabaskaran and P. Suresh Kumar)

Substantial variation was recorded with respect to important bunch traits in seven commercial cultivars at Kattuputhur Agricultural Regulated Market and Tiruchirapalli Gandhi Market as summarized in the form of histogram (Table 37). The bunch weight ranged from 2.9 (Rasthali) to 35.0 Kg (Poovan) whereas, the average bunch weight was lowest in Karpuravalli (11.7 Kg) and highest in Poovan (16.0). The number of hands ranged from 4 to 15, 4 to 14, 4 to 11 and 3 to 7 in Karpuravalli, Poovan, Rasthali and Red banana, respectively. The total number of fruits per bunch ranged from 33 in Red banana to 351 in Poovan. The fruit length (cm) and girth (mm)

ranged from 8.0 to 17.0 & 23.9 to 47.7, 6.0 to 18.5 & 20.7 to 55.7, 6.5 to 19 & 23.9 to 49.3 and 13.0 to 26.0 & 39.8 to 66.8 in Karpuravalli, Poovan, Rasthali and Red banana, respectively.

Design and development of a web and mobile based application named 'I Trade Banana' has been completed (Fig. 82). Testing and validation of 'I Trade Banana'application is underway with 35 different farmers' data.

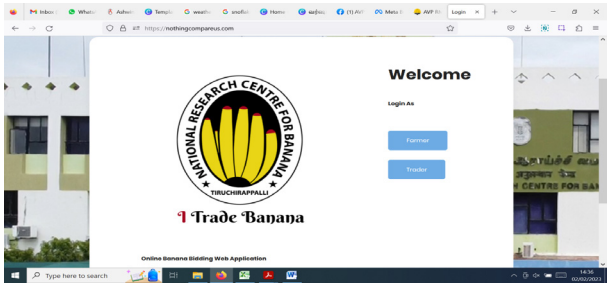


Fig. 82. Design of 'I Trade Banana' application.

Table 37. Variation recorded on bunch weight, fruit diameter and fruit length in different banana cultivars

Cultivars	Traits	N	Mini	Maxi	Mean	Median	Mode	Std Dev	Percentile							
									1st	5th	10th	Low Quar.	Up. Quar.	90th	95th	99th
Grande Naine	Bunch weight (kg)	100	8.6	33.5	19.7	19.1	17	4.6	9.3	12.6	14.4	16.5	23.2	26	27.3	31.4
	Fruit diameter (mm)	600	31.8	52.5	40.2	39.8	38.2	3.3	33.4	35	36.6	38.2	41.4	44.5	46.1	47.7
	Fruit length (cm)	600	12.5	27	20.2	20	21	2.4	14.5	16	17	18.5	22	23	24	25.3
Ney Poovan	Bunch weight (kg)	100	3.2	15.7	8.3	8	8	2.3	3.7	5.3	5.7	6.9	9.3	12.2	13.2	15.1
	Fruit diameter (mm)	600	24.8	49.3	33.2	33.4	31.8	3.1	25.5	28.6	28.6	31.8	35	36.6	38.2	40.6
	Fruit length (cm)	600	9	16.5	12.7	12.5	13	1.3	10	10.5	11	11.5	13.5	14.5	15	15.5
Karpuravalli	Bunch weight (kg)	132	4	32	11.72	9	9	6.29	4	5	5.6	7.1	15.03	21.5	24	28.5
	Fruit diameter (mm)	528	23.9	46.1	36.8	36.6	36.6	3.7	27	31.8	31.8	35	39.8	41.4	43	44.5
	Fruit length (cm)	528	7	17	12.35	12	12	1.67	9	10	10	11	13.5	14.5	15	16
Poovan	Bunch weight (kg)	143	4.45	35	16	15	8.5	6.25	6	8.1	9	11.25	19.5	24.75	27.5	33.5
	Fruit diameter (mm)	576	20.7	55.7	37.3	36.6	36.6	5	25.5	30.2	31.8	35	39.8	43	46.1	49.3
	Fruit length (cm)	576	6	18.5	12.01	12	13	2.22	7	8	9	10	14	15	15.5	17
Rasthali	Bunch weight (kg)	132	2.85	31.5	12.15	11.5	21	6.39	3.45	4.05	4.5	7	15.5	21	24	30
	Fruit diameter (mm)	528	27	60.5	39	39.8	39.8	4	30.2	31.8	33.4	36.6	41.4	43	44.5	47.7
	Fruit length (cm)	528	6.5	23	13.31	14	14	2.56	8	9	10	11.5	15	16.5	17	18
Nendran	Bunch weight (kg)	100	4.7	20.7	12.9	13	9	3.7	4.9	6.5	8.5	10	16	17.6	18	20.2
	Fruit diameter (mm)	600	35	57.3	43.7	44.5	44.5	3.4	36.6	38.2	39.8	41.4	46.1	47.7	49.3	50.9
	Fruit length (cm)	600	17	31	24.2	24	24	2.4	18	20	21	23	26	27	28	29

Red Banana	Bunch weight (kg)	100	5	20	12.5	13	15	3.1	5.3	7.5	8	10.3	15	16.5	17.5	19.5
	Fruit diameter (mm)	600	39.8	66.8	47.8	47.7	47.7	3.5	41.4	43	44.5	46.1	49.3	50.9	54.1	59.7
	Fruit length (cm)	600	13	26	20	20	19	2.2	15	16	17	18.5	21.5	23	24	24.5

DAC & FW, Govt. of India sponsored project

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

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

The project was initiated in January 2023 with the objective to cover 500 ha area of drone spray demonstration. ICAR-NRCB has initiated a technological backstopping of fungicide application through drone technology in Kalakkad block. An awareness meeting cum demonstration of drone technology for fungicide application was organized for the farmers at Thirukurungudi, Kalakkad block, covering about 25 acres. An awareness campaign was conducted at Varadarajapuram near Thottiyam, Tiruchirapalli, Tamil Nadu in collaboration with Thottiyam Banana Producers Group and micronutrient application through drone technology was demonstrated in 35 acres.

Fig. 83. Drone demonstrations

Drone Demonstration at Kalakkad

Drone Demonstration at Thottiyam

Drone Demonstration at Theni

Drone Demonstration at Varadharajapuram

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Radio Talks

Name of the Scientist	Topic	Date of broadcast	Channel
K.J. Jeyabaskaran	Live program on "Natural farming in banana" (*UzhavarUlagam*)	5 April, 2022	All India Radio, Tiruchirappalli
C. Karpagam	*Vazham Tharum Vaipukal* – (Agri. Infrastructure Fund, e-NAM ,ODOP)	1 August, 2022	
	Vazham Tharum Vaipukal – (SHC, PMKSY & Govt. schemes & support)	5 September, 2022	
	Vazham Tharum Vaipukal – (ATMA, Kisan Credit Card, Kisan Call Centre)	20 July, 2022	
	Kela Mela – ICAR-NRCB initiative in six districts of Tamil Nadu	13 April, 2022	
	Banana extension & Government schemes and support for small and marginal farmers	20 April, 2022	
	Vazham Tharum Vaipukal (Muthra, Startups, e NAM, Kisan rail, PMFBY)	18 July, 2022	

5.2 Television talks

Name of the Staff	Topic	Date of broadcast	Channel
R. Selvarajan K.N. Shiva P. Giribabu P. Durai	Live telecast on 'Banana varietal diversity and value added products from banana' during the Consultative Workshop on "Export of GI and Traditional Bananas: Present Scenario, Trade Opportunities and Way Forward"	22 December, 2022	Pasumai Vikatan Youtube (Live-Tamil)
P. Suresh Kumar	Workshop on GI and Traditional Bananas: Present scenario, Trade opportunities and way forward	22 December, 2022	News 7

5.3 Exhibitions conducted / participated

Name of the event	Organizer / Venue	Date	Name of the participants
World Pulse Day & *Kela Mela*	KVK, Karur, Tamil Nadu	10 February, 2022	S. Uma C. Karpagam V. Kumar K.J. Jeyabaskaran M. Loganathan
Kela Mela	KVK, Ariyalur, Tamil Nadu	15 March, 2022	C. Karpagam M. Loganathan

Kela Mela and One day Training Program under SC & SP program	CSC & RI, TNAU, Madurai, Tamil Nadu	23 March, 2022	K.N. Shiva M. Loganathan C. Karpagam
Krishi Unnati Mela and *Udhyan Mahotsav*	KVK - Dr. Rajendra Prasad CAU at Piprakothi, East Champaran Dist., Bihar	15-17 April, 2022	K.N. Shiva P. Ravichamy
Farmer - Scientist interaction and exhibition on *Bharatiya Prakritik Kristin Paddhati* – Natural Farming	ICAR-KVK, Pulutheri, Karur, Tamil Nadu	26 April, 2022	C. Karpagam K.J. Jeyabaskaran
Kela Mela	KVK, Cuddalore, Tamil Nadu	28April, 2022	C. Karpagam M. Loganathan
Kela Mela	KVK, Namakkal, Tamil Nadu	29 April, 2022	C. Karpagam
Kela Mela	KVK, Needamangalam, Tamil Nadu	30 April, 2022	C. Karpagam P. Sureshkumar
Banana and plantain chips /crisps (unripe and ripe sweet banana/plantain chips) of various brands	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	17 June, 2022	K.N. Shiva P. Sureshkumar P. Ravichamy K. Kamaraju
14th edition of Food Pro - 2022	CII at Chennai Trade Centre, Chennai, Tamil Nadu	6 August, 2022	S. Uma V. Kumar K.N. Shiva P. Sureshkumar
ICAR-NRCB's 29th Foundation Day and *Kisan Mela*	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	20 August, 2022	V. Kumar K.N. Shiva P. Durai P. Ravichamy K. Kamaraju
State level Farmers' Day-2022	AC & RI, TNAU, Madurai, Tamil Nadu	14-16 October, 2022	V. Kumar C. Karpagam P. Ravichamy A. Mohanasundaram M. Bathrinath
National level Exhibition on 'Expansion of horticulture value chain in India - Potential and opportunities'	Organized by NHB, Gurgaon at VAMINCOM, Pune University Campus, Pune, Maharashtra	1-2 November, 2022	V. Kumar
Farmers' *Mela - Uzhavar Kalanjiyam*	Vellore Institute of Technology, Vellore	14 December, 2022	C. Karpagam

Consultative Workshop on "Export of GI and Traditional Bananas: Present Scenario, Trade Opportunities and Way Forward"	ICAR-NRCB at Breeze Residency Tiruchirappalli, Tamil Nadu	21-22 December, 2022	V. Kumar K.N. Shiva P. Durai P. Ravichamy K. Kamaraju M. Bathrinath

5.4. Publicity

A total of 218 press releases on the ICAR-NRCB activities / ceremonies / technological information (popular articles) were sent to media and same was published in different national and local dailies including, digital print, YouTube channel, Tamil magazines / journal, AIR- farm division etc. for the benefit of the banana farmers.

Details	Nos.
No of News stories reported in dailies	37
No of dailies, YouTube covered NRCB News	132
No. of news stories reported in ICAR-NEWS (Online)	12
No. of video program prepared for different occasions	5
No. of news stories reported in ICAR-NRCB Portal	12
No. of events uploaded in FB, Twitter	20

5.5. Extension & Training

Around 6000 farmers including agricultural & horticultural officers, SHG, entrepreneurs, students and stakeholders visited ICAR-NRCB and they were explained about ICAR-NRCB activities / technologies. Under the outreach programs, ICAR-NRCB has trained more than 500 farmers across the country.

Capacity Development Program (CDP)	Nos.	Beneficiaries
One day CDP for farmers (Under ATMA, NHM, FPO etc.,)	10	330
Two days CDP for farmers (Under ATMA, NHM, FPO etc.,)	5	197
Three days CDP for farmers (Under ATMA, NHM, FPO etc.,)	6	207
One day Farmers exposure visit for farmers	22	744
Students CDP (PEV/Industrial visit/Study tour)	58	3942
Off – campus training (With KVK,FPOs etc)	13	500
Total	**114**	**5920**

Director, ICAR-NRCB felicitating woman banana farmer with supply of tissue culture banana plants during *Kela Mela* and World Pulse Day celebrations on 10 February, 2022

Release of publication during *Kela Mela* at CSC and RI, Madurai, Tamil Nadu on 23 March, 2022

Distribution of farm inputs under SCSP program of ICAR-NRCB at ICAR-KVK, Ariyalur, Tamil Nadu on 15 March, 2022

Release of publication during *Kela Mela* at KVK, Namakkal, Tamil Nadu on 29 March, 2022

Distribution of farm inputs under SCSP program of ICAR-NRCB at KVK, Needamangalam, Tamil Nadu on 30 March, 2022

Farmers visit at ICAR-NRCB Exhibition stall at AC&RI, TNAU, Madurai on 14-16 October, 2022

Farmer's trainees from Kalakkadu block, Tirunelveli district under ATMA scheme at ICAR-NRCB (26&27 May, 2022)

6. EDUCATION AND TRAINING

6.1 Students guided

Student Name	Degree	Project title	Chairperson
S. Aarthi	M.Sc. (Microbiology)	Bioprospecting plant growth promoting bacteria and fungi isolated from banana genotypes rhizosphere soil and influence on growth under aerobic condition by using coco peat	R. Selvarajan
Dharani Sen	M.Tech. (Biotechnology)	Assessing the relative presence of BBTV components in infected plants for designing a sensitive PCR- based detection	
N. Nithya	M.Sc. (Biochemistry)	Functional characterisation of chalcone synthase in banana fruit peels in relation to flavonoid biosynthesis	M. Mayil Vaganan
S. Keerthana	M.Sc. (Biochemistry)	Functional characterisation of chalcone isomerase in banana flower bracts in relation to anthocyanins biosynthesis	
C. Sharmila	M.Sc. (Biotechnology)	Responses of LRR genes against sigatoka disease in resistant and susceptible banana varities	S. Backiyarani
M. Maharif Banu	M.Tech. (Biotechnology)	Understanding the role of LRR genes in giving disease resistance to banana against sigatoka disease	
M. Satish Kanna	M.Sc. (Botany)	Validation of SSR panel consisting of drought and wilt specific markers in commercial banana (*Musa* spp.) varieties	M.S. Saraswathi
M. Kavioviya tamizhan	M.Sc. (Biotechnology)	Comparison of three electrophoretic methods for use in validation of SSR panel consisting of Sigatoka specific markers in commercial banana (*Musa* spp.) varieties	
C. Praveena	M.Sc. (Biotechnology)	Genotyping of commercial banana (*Musa* spp.) varieties using nematode specific markers for validation of SSR panel	
V. Sathya	M.Sc. (Biotechnology)	Effect of meta-topolin and different spectral LEDs on direct organogenesis of banana (*Musa* spp.) cv. Grand Naine (Cavendish, AAA) using immature male floral bud explants	
A. Maria Prisilla	M.Sc. (Biotechnology)	Studies on the irradiation methods of immature male flower buds of banana (*Musa* spp.) cv. Grand Naine (AAA, Cavendish)	
S. Bagavathi	M.Sc. (Microbiology)	Studies on effect of pre harvest application of chemicals on post harvest diseases of banana	M. Loganathan

T. Anjali	M.Sc. (Biotechnology)	Effect of culture media on improving anther culture response in ABB type commercial cultivars (Karpooravalli and Kaveri Saba)	D. Ramajayam
Bini San George	M.Sc. (Biotechnology)	Effect of culture media on improving antherculture response in AAA type commercial cultivars (Red Banana and Grande Nain)	
S. Aarthi	M.Sc. (Biotechnology)	Effect of IAA on the *in vitro* and *in vivo* germination of F1 hybrid (Calcutta-4 × Ney Poovan tetraploid) banana seeds	
P. Bhuvaneshwari	B.Tech. (Biotechnology)	Effect of GA_3 on the *in vitro* and *in vivo* germination of F1 hybrid (Calcutta-4 × Ney Poovan tetraploid) banana seeds	
N. Poovarasan	M.Sc. (Food Processing)	Optimization of dietary fiber extraction from banana central core stem and its application in probiotie dessert foods	P. Suresh Kumar
B. Monica	M.Sc. (Food Processing)	Exploring banana rhizome for the development of smart food products	
N.T. Atchaya	M.Sc. (Food Processing)	Optimization of process conditions of banana wine and vinegar production	
D. Praveen Kumar	M.Sc. (Microbiology)	Isolation, characterization and Identification of probiotic Lactic Acid Bacteria (LAB) for making of synbiotic low-fat banana yogurt.	
B.B. Ruby Malya	M.Sc. (Food Science and Nutrition)	Extraction of Dietary Fibre from banana central core stem using ultrasound assisted enzymatic method	
R. Birundha	M.Sc. (Biotechnology)	Identification and Characterization of Pathogenesis related protein-1 (PR-1) from Banana	C. Anuradha
P. Shanmugapriya	B.Tech. (Biotechnology)	Cloning and characterization of Pathogenesis related protein-1 (PR-1) from Grand Nain and *Musa acuminata* type Assam	

6.2 Trainings

6.2.1. On-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Extension based ATMA sponsored three days training program (Six nos.)	C. Karpagam A. Mohanasundaram P. Ravichamy	207	January-April, 2022
Extension based ATMA sponsored two days training program (Five nos.)	C. Karpagam A. Mohanasundaram P. Ravichamy	197	January-April, 2022

Extension based ATMA sponsored two days training program (Ten nos.)	C. Karpagam A. Mohanasundaram P. Ravichamy	330	January-April, 2022
Internship training program on 'Banana handling, processing technologies and entrepreneurial opportunities', to students of Bishop Heber College, Tiruchirapalli, Tamil Nadu	K.N. Shiva P. Suresh Kumar M. Mayil Vaganan	25	20 December, 2021 to 19 January, 2022
Internship training program on 'Banana handling, processing technologies and entrepreneurial opportunities', to students of Seethalakshmi Ramasamy College, Tiruchirapalli, Tamil Nadu	K.N. Shiva P. Suresh Kumar M. Mayil Vaganan	8	5-19 January, 2022
Internship training program on 'Banana handling, processing technologies and entrepreneurial opportunities' to M.Sc. (Food Science and Nutrition) Students of Seethalakshmi Ramasamy College, Tiruchirappalli, Tamil Nadu	K.N. Shiva P. Suresh Kumar M. Mayil Vaganan	8	10-24 January, 2022
Orientation-cum-training program for Project investigators of BIRAC-'Banana bio-fortification on conduct of event selection trials of GE banana events	S. Backiyarani M. Mayil Vaganan	12	1-2 February, 2022
Banana flour based low glycemic prebiotic extruded snacks like noodles, pasta and extraction, degumming, softening and utilization of banana fibre	K.N. Shiva P. Suresh Kumar	6	23-25 March, 2022
'Fortified basil seed suspended banana juice'		1	6 May, 2022
Hands on training on identification of embryogenic cells and multiplication procedure	S. Backiyarani	2	4-8 April, 2022
'Banana Wine' technology	K.N. Shiva P. Suresh Kumar	1	12 May, 2022
Low glycemic, prebiotic extruded snacks like noodles, pasta and extraction of cellulose and other utility compounds like pectin and hemicellulose	K.N. Shiva P. Suresh Kumar	1	6-9 June, 2022
'Banana wine and cost effective ripe banana powder'		4	9-10 June, 2022

Three days online collaborative capacity development programme with the National Institute of Agricultural Extension Management (MANAGE) on 'Agripreneurship through banana-based technologies – An avenue for *Atmanirbhar Bharat*'	C. Karpagam A. Mohanasundaram P. Giribabu Sagar Surendra Deshmukh S. Uma	50	15-17, June 2022
'Machinery for banana processing under Innovative Agricultural Engineering Technologies'	K.N. Shiva P. Suresh Kumar	78	17 June, 2022
DST-SERB sponsored training program on 'Omics and Bioinformatics' to college students	C. Anuradha S. Uma S. Backiyarani M.S. Saraswathi D. Ramajayam	25	25 June, 2022
DST-SERB sponsored training program on 'Induced mutation: A new paradigm in science' to research scholars pursuing M.Sc. and Ph.D.	M.S. Saraswathi C. Anuradha S. Backiyarani, D. Ramajayam	18	25 June, 2022
DST-SERB sponsored workshop on 'Recent trends in biotechnology and their applications' to faculty members of different colleges	C. Anuradha S. Uma S. Backiyarani M.S. Saraswathi D. Ramajayam	30	8 July, 2022
'Banana flour based extruded products like noodles, pasta and cost effective ripe banana powder'	K.N. Shiva P. Suresh Kumar	2	29-30 July, 2022
'Post-harvest handling, packaging, storage and ripening of banana for domestic and export market'	K.N. Shiva P. Suresh Kumar	1	11-12 August, 2022
'Banana flour based extruded products like noodles, pasta and cost effective ripe banana powder'		2	1-3 September, 2022
Ten days High-End Workshop (*Karyashala*) on "Recent advances in Banana improvement, production, protection, PHT, extension, and business arena for nutritional security in the era of *Atmanirbhar Bharat*" to research scholars pursuing M.Sc. and Ph.D.	C. Karpagam A. Mohanasundaram M. Mayil Vaganan P. Ravichamy S. Uma	31	17-26 September, 2022

Trainees of High-End Workshop (*Karyashala*) with Scientists of ICAR-NRCB

Distribution of certificates to banana farmers under the program Banana Experts (BF-BE)" on 29 January, 2022

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Good horticultural and marketing practices for enhancing domestic and export value for banana	K.N. Shiva V. Kumar R. Thangavelu	50	22-23 February, 2022
World Pulse Day & *Kela Mela*, held at KVK, Karur, Tamil Nadu	C. Karpagam K.J. Jeyabaskaran V. Kumar M. Loganathan S. Uma	150	10 February, 2022
Hands on training on banana cultivation to SC beneficiaries organized along with ICAR-KVK (CREED) held at Ariyalur, Tamil Nadu	M. Loganathan C. Karpagam	50	15 March, 2022
Harvesting, handling, packing and forwarding of Red Banana through air to European market	V. Kumar, K.N. Shiva R. Thangavelu P. Sureshkumar		15 March 2022

Hands on training on banana cultivation to SC beneficiaries held at CSC &RI, TNAU, Madurai, Tamil Nadu	M. Loganathan C. Karpagam K.N. Shiva	50	23 March, 2022
Hands on training on banana cultivation to SC beneficiaries held at KVK, Virudhachalam, Tamil Nadu	M. Loganathan C. Karpagam	40	28 March, 2022
Farmer-Scientist interaction & exhibition on *Bharatiya Prakritik Kristin Paddhati* – Natural Farming held at ICAR-KVK, Pulutheri, Karur, Tamil Nadu	C. Karpagam K.J. Jeyabaskaran	100	26 April, 2022
Training cum field demonstration on 'Scientific cultivation and post-harvest handling in banana' organized by VFPCK, Kerala in Sulthan Bathery, Wayanad	V. Kumar P. Suresh Kumar		28-29 April, 2022
"Good horticultural and marketing practices for enhancing domestic and export value for banana" to Technical Officers of Dept. of Agriculture & VFPCK, Banana Cluster - Thrissur, Kerala (Online)	K.N. Shiva V. Kumar R. Thangavelu	36	May, 2022
Hands on training on banana cultivation to SC beneficiaries held at Kulithalai, Karur District, Tamil Nadu	M. Loganathan	36	28 June, 2022
		50	30 June, 2022
Value addition in banana (including ABI) to the Assistant Engineers (AE)/Junior Engineers of Agricultural Engineering Dept., Tiruchirappalli, Tamil Nadu	K.N. Shiva	27	23 August, 2022
Opportunities for 'Value addition in banana and about the Agri-Business Incubation Facility' in the National campaign on *Poshan Abhiyan* and tree plantation at ICAR-KVK, Pulutheri, Karur, Tamil Nadu	K.N. Shiva	100	17 September, 2022
Farmers Mela (*Uzhavar Kalanjiyam*) held at Vellore Institute of Technology, Vellore, Tamil Nadu	C. Karpagam	1500	14 December, 2022
Training program on 'Banana processing and value addition', organized by SAMETI for the Officials of Perinthalmanna, Malappuram Dt., Kerala (Online)	K.N. Shiva	37	15 December, 2022
Hands on training on banana cultivation to SC beneficiaries held at KVK, Sirugamani, Tiruchirappalli, Tamil Nadu	M. Loganathan	50	29 December, 2022

ICAR-NRCB receives 'Cold Chain Award' of CII's Food and Agriculture Centre of Excellence (FACE) for significant contributions made by the centre in the cold storage of fresh and processed products of banana

TAMIL NADU AGRICULTURAL UNIVERSITY
AGRICULTURAL COLLEGE AND RESEARCH INSTITUTE
MADURAI-625104

STATE LEVEL
FARMERS' DAY - 2022

Award Certificate

This is to certify that ICAR-NRCB, Trichy has been awarded with "Best Stall Award" for having excelled in Exhibiting their achievements during the Exhibition organised as a part of TNAU Golden jubilee State Level Farmers' Day held at Agricultural College and Research Institute, Madurai during 14th - 16th, October 2022.

Director of Extension Education, TNAU, Coimbatore
Dean, AC & RI, Madurai
Vice Chancellor, TNAU, Coimbatore

कृषि विज्ञान केन्द्र
पिपराकोठी, पूर्वी चम्पारण, बिहार
डा० राजेन्द्र प्रसाद केन्द्रीय कृषि विश्वविद्यालय, पूसा, समस्तीपुर
पशु आरोग्य-सह-कृषि उन्नति मेला एवं उद्यान महोत्सव - 2022
प्रमाण-पत्र

प्रमाणित किया जाता है कि संस्था NRC ON BANANA
पता .....
कृषि विज्ञान केन्द्र, पिपराकोठी, पूर्वी चम्पारण में आयोजित तीन दिवसीय पशु आरोग्य-सह-कृषि उन्नति मेला एवं उद्यान महोत्सव-2022 (15-17 अप्रैल, 2022) में भाग लिया एवं "STALL" प्रदर्शनी में "ICARISAU" वर्ग में 2nd स्थान प्राप्त किया।

आयोजक सचिव
निदेशक प्रसार शिक्षा

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
ICAR-NRCB	Certificate of Appreciation from ICAR-AICRP (Fruits) for release of banana cultivars *viz*., Kaveri Haritha, Kaveri Kanya and Kaveri Saba
	'Cold Chain Award' of CII's Food and Agriculture Centre of Excellence (FACE) for significant contributions made by ICAR-NRCB in the cold storage of fresh and processed products of banana. Award received from the Governor of Maharashtra on 30 November, 2022 at Mumbai, Maharashtra
	'Best Stall Award' at TNAU Golden Jubilee State Level Farmers' Day-2022 held at AC & RI, Madurai during 14-16 October, 2022
	'Best Stall Award' at *Krishi Unnati Mela* and *Udhyan Mahotsav,* organised by KVK - Dr. Rajendra Prasad CAU held at Piprakothi, East Champaran Dist., Bihar during 15-17 April, 2022
R. Thangavelu	'A.K. Sarbhoy Memorial Award (2021)' by Indian Phtopathological Society during International conference on 'Plant Pathology: Retrospect and Prospects' held at SKN Agricultural University, Jobner-Jaipur, Rajasthan during 23-26 March, 2022
P. Suresh Kumar	'Fellow of Post-harvest Management of Horticultural Crops-2022' from Indian Academy of Horticultural Sciences at ICAR-IARI, Pusa, New Delhi on 2 December, 2022
C. Anuradha	'Best Article Award' for article entitled 'CRISPR-Cas 9 Genome Editing in Banana' - Published in AgriGate – An International Multidisciplinary Monthly e-Magazine
A. Mohanasundaram	'Professor T.N. Ananthakrishnan Award (biennium 2020-21)'; Young Scientist Award - Third position along with a cash award Rs. 10000 for contributions towards Indian lac insect *Kerria lacca*'s genenic resources, crop management and insect pest management during Professor T.N. Ananthakrishnan Awards Ceremony (biennium 2020-21) held on 9 August, 2022 at Zoological Survey of India, Southern Regional Centre, Chennai
	'Dr. M. Swamiappan Award' for outstanding contributions to Bio-intensive IPM organized by Society for Biocontrol Advancement, ICAR-NBAIR, Bengaluru on 15 December, 2022
	'Distinguished Scientist Award' in the field of Agricultural Entomology at National Conference on 'Horticulture: Enhancing Productivity and Mitigating Major Challenges' on 11 November, 2022 at Kalasalingam Academy of Research and Education, Krishnankovil, Tamil Nadu
	'Fellow of the Society for Biocontrol Advancement', Bengaluru in appreciation and recognition of outstanding achievements and contributions in the field of biological control of crop pests at ICAR-NBAIR, Bengaluru on 15 December, 2022
	First consolation prize in 'Hindi Elocution' organized by Town official Language Implementation Committee on 17 March, 2022 at Tiruchirappalli

7.2 Recognitions

Dr. R. Selvarajan, Director
Chairperson, Consultative workshop on 'Export of GI and traditional bananas: Present scenario, trade opportunities and way forward' jointly organized by ICAR-NRCB, Tiruchirappalli and APEDA, New Delhi held atTiruchirapalli, Tamil Nadu during 21-22 December, 2022
Member, Scientific program secretary and convener for plant virology at National conference of Virology (Online) on "Emerging and re-emerging viral diseases climate change impacts and mitigation" Organised by Department of Microbiology, AIIMS, Hyderabad Metropolitan Region, Telangana under the aegis of Indian Virological Society during 26-28 March, 2022
Member, technical and publication committee in XXX Annual convention cum International conference on 'Emerging and re-emerging viral infections impacting humans, animals, plants, fish and environment' organized by Indian Virological Society (IVS) and Division of Veterinary Microbiology & Immunology, Faculty of Veterinary Sciences and Animal Husbandry, Sher-e-Kashmir University of Agriculture Sciences and Technology-Kashmir, Srinagar during 5-6 November, 2022
Nominated as Co-PI in the in-house project on "Development of integrated disease management strategy for the ornamental nursery plants and loose flower crops" at ICAR- Directorate of Floricultural Research, Pune, Maharastra
Appointed as Member Secretary, RAC, ICAR -NRCB, Tiruchirappalli for the period of three years
Acted as a mentor for Dr. Jagan Obbinei, Assistant professor (senior), VIT school of agricultural innovations and advanced learning, VIT, Vellore under the DST-SERB scheme 'Teachers Associateship' for Research Excellence (TARE)
Nominated as a Chairman of the Selection Committee of Young Professional-I under theproject Virus testing Contract Service
Acted as a Co-chairman of Ph.D. scholar from the Department of Plant Pathology, College of Agriculture, J.N.K.V.V. Jabalpur, Madhya Pradesh
Acted as external examiner for the evaluation of M.Sc., and Ph.D. theses from Department of Plant Pathology, AC&RI, TNAU, Coimbatore and Department of Plant Molecular Biology, University of Delhi South Campus, New Delhi
Acted as external examiner for conducting the qualifying *viva-voce* examination of Ph.D. scholar of ICAR-IARI, New Delhi
Dr. S. Uma, Principal Scientist
Chief Guest at *Kela Mela*, KVK, Kulithalai, Karur, Tamil Nadu on 10 February, 2022
Chief Guest at National Science Day Week at Bishop Heber College, Tiruchirappalli on 22 February, 2022
Chief Guest at a conference held at Srimad Andavar College, Tiruchirappalli on 3 March, 2022
Addressed at Women's club, BHEL, Tiruchirappalli on 3 March, 2022
Valedictory address & Distribution of certificates at one day Entreprenuership Awareness Programme, organized by Bharathidasan University and MSME, GoI, Chennai on 11 March, 2022
Chaired a technical session at National conference on 'Fruit Production in Eastern Tropics of India' organized by CHES (ICAR- IIHR), Bhubanehswar during 24-26 March, 2022
Presentation in Symposium on 'Global Research in the Management on Banana Fusarium wilt TR4 on 25 March, 2022 (Online)
Chair person, Awards and certificates distribution ceremony of 'Vidyarthi Vigyan Manthan' organized by 'Ariviyal Sangam' at ICAR-NRCB, Tiruchirappalli on 6 April, 2022

Chief Guest - One day Inter-Collegiate Technical Fest, Bio-De-Fiesta 2022 organized by Department of Biotechnology, St. Joseph's College (Autonomous), Tiruchirappalli on 14 October, 2022
One of the organizing secretaries - Consultative workshop on "Export of GI and Traditional bananas: Present Scenario, Trade Opportunities and Way Forward" during 21-22 December, 2022
Dr. R. Thangavelu, Principal Scientist
Acted as Chairperson for the Technical Session 'Epidemiology and crop loss assessment' in IPSCONF2022 held at SKNAU, Jobner-Jaipur, Rajasthan during 23-25 March, 2022
Acted as one of the members of the Award Screening Committee (2022-23) for online evaluation of the various awards of the IPS Society, New Delhi
One of the organizing secretaries - Consultative workshop on "Export of GI and Traditional bananas: Present Scenario, Trade Opportunities and Way Forward" during 21-22 December, 2022
Dr. M. Mayil Vaganan, Principal Scientist
Nominated by DG-ICAR as an expert (Plant Biochemistry) to ICAR-IIHR, Bengaluru for Career Advancement Scheme of ARS Scientists for a period of one year
One of the Course Directors of DST-SERB sponsored High-End Workshop (*Karyashala*) on Recent advances in banana improvement, production, protection, PHT, extension and business arena for the nutritional security in the era of *Atmanirbhar Bharat* held during 17-26 September 2022
Member of Department Promotion Council of ICAR-NRCB for two administrative and technical staff in 2022
Convener, Technical session on 'Institutional support for enhancing banana trade' at Consultative workshop on export of GI and traditional bananas: Present scenario, trade oppurtunities and way forward at ICAR-NRCB, Tiruchirappalli during 21-22 December, 2022
Nodal Officer for celebration of International Year of Millets - 2023
Special Invitee for XXVI IMC of ICAR-NRCB, Tiruchirappalli
Dr. I. Ravi, Principal Scientist
Member in the selection committee to recruit a Finance Officer &a Estate Officer for IIFPT, Thanjavur, Tamil Nadu
Member in the DPC conducted by ICAR-NRCB
Evaluated a Thesis from Osmania University, Hyderabad and VIT, Vellore, Tamil Nadu
Dr. V. Kumar, Principal Scientist
Convener of one technical session at Consultative workshop on export of GI and traditional bananas: Present scenario, trade oppurtunities and way forward at ICAR-NRCB, Tiruchirappalli during 21-22 December, 2022
Recognized as the External Examiner, M.Sc. / Ph.D. programs by TNAU, Coimbatore, Tamil Nadu; UHS, Bagalkot, Karnataka and Annamalai University, Tamil Nadu
Observer of computer based test (CBT) for the post of Technical-1 conducted by ICAR-IARI at Tiruchirappalli during 28 February – 5 March, 2022
Member - Project review committee meet (Online) for the initial screening of the projects conducted by TDB, DST, New Delhi on 23 March, 2022
Organizer, *Swachhta Pakhwada- Kisan Diwas* on 23 December, 2022

Dr. K.J. Jeyabaskaran, Principal Scientist
Attended and presented one oral and two poster presentations at 'XII International Symposium on Banana : Celebrating banana organic production' in the 31st International Horticultural Congress (2022) held in Angers, France during 14-20 August, 2022
Dr. K.N. Shiva, Principal Scientist
Evaluated one Ph.D. and one M.Sc., thesis from UHS, Bagalkot, Karnataka;
Certificate of Excellence in Reviewing from Chief Managing Editor, *Current Journal of Applied Science and Technology*
Consultant to the Tamil Nadu Banana Producer Company Ltd., Tamil Nadu for the export project on "Commercial Sample Shipment of Indian grown 'Red Banana' to Europe Market" (Vienna, Austria) by air during 15-25 March, 2022
Peer reviewer, *Journal of Horticulture Science*, SPH, ICAR-IIHR, Bengaluru; *Journal of Spices and Aromatic Crops*, Indian Society for Spices, ICAR-IISR, Calicut, Kerala; *Current Journal of Applied Science and Technology*; *Journal of Food Science and Technology*, AFSTI, CSIR-CFTRI, Mysuru, Karnataka; *Indian Journal of Horticulture*, IAHS, New Delhi; *Agricultural Research Journal*, Punjab Agricultural University, PAU, Ludhiana
President, Agricultural Research Service Scientists' Forum, Tiruchirappalli Centre for the year 2022
Life Member - *Indian Agricultural Researcher's Association* (IARA), U.P.
Subject matter expert involved in finalizing the document of POP (Hi-tech Production and Post-harvest Technologies) of banana for policies and schemes to be implemented by TANHODA, Govt. of Tamil Nadu, Chennai
Nominated as member to participate in the Scientific Advisory Committee (SAC) Meet held at ICAR-KVK, Karur, Viruthachalam and cuddaore, Tamil Nadu
One of the organizing secretaries - Consultative workshop on "Export of GI and Traditional bananas: Present Scenario, Trade Opportunities and Way Forward" during 21-22 December, 2022
Dr. S. Backiyarani, Principal Scientist
External examiner for Research Advisory Sub Committee (RASC) conducted by SASTRA University SCBT RASC 2022 students for thesis evaluation
Recognised as DBT outside expert in IBSC at SASTRA TBI
External interview panel member for selection of Project Assistants
Rapporteur - ICAR-AICRP (Fruits) - Researcher's interactive meeting session on crop improvement Session IB - Varietal Improvement
Acted as examiner for Research Advisory Sub Committee (RASC) conducted by SASTRA University from 27-29 April, 2022
As a board member attended the Board Of Studies (BOS) meet, Department of Biotechnology and Bioinformatics, Bishop Heber College (Autonomous), Tiruchirappalli
Acted as external examiner for two M.Sc. theses of TNAU, Coimbatore and one Ph.D. thesis of ICAR-IARI, New Delhi
Dr. M.S. Saraswathi, Principal Scientist
Reviewer - *Physiology and Molecular Biology of Plants; Scientific Reports; Plant Cell Biotechnology and Molecular Biology; Agronomy Journal; Plant Cell Biotechnology and Molecular Biology; BMC genomics; South African Journal of Botany*
Evaluated one Ph.D. and two M.Sc. theses
External examiner for one Ph.D. candidate

Selection committee member for YPs, TAs and JPAs
Dr. M. Loganathan, Principal Scientist
Lead talk on 'Management of bacterial diseases of bananas' in an online international workshop on'Management of bacterial diseases of bananas', conducted by Tropical Fruits Network on 29November 2022 (online).
Doctoral committee external member for Ph.D student of VIT, Vellore
Dr. D. Ramajayam, Principal Scientist
Invited speaker to deliver a lecture on the topic of "Importance of sample purity in ploidy analysis" at webinar – Three P's of Ploidy: Polyploid, Purity and Problematic (Online) on 10 February, 2022
Dr. P. Suresh Kumar, Principal Scientist
One of the organizing secretaries - Consultative workshop on "Export of GI and Traditional bananas: Present Scenario, Trade Opportunities and Way Forward" during 21-22 December, 2022
Member - Cost fixation committee of NIFTEM, Thanjavur, Tamil Nadu
Management Representative - ISO 9001:2015 of ICAR-NRCB
Panelist - Crop Science - Sustainable agriculture: Crop production and Post-harvest Technology. Partnership meet on Bi-national Agri Cluster. Organized by Shastri Indo-Canadian Institute (SICI) held at NAHEP, KAB-II, Pusa, New Delhi on 10 October, 2022
Reviewer - *Frontiers in Food Nutrition*; *Cogent Food & Agriculture*; *Indian Journal of Horticulture*; *Journal of Food Processing and Preservation*; *Journal of Natural Fibers*; *NFS Journal*; *Frontiers in Plant Science*; *International Journal of Food Science and Technology*; *Food Bioscience*; *Journal of Horticultural Sciences*; *Scientia Horticulturae*; *International Journal of Biological Macromolecules*; *Journal of Packaging and Applied Chemistry; Food Characterization*; *Nutrition and Food Science Technology*
Thesis Evaluator for TNAU, Coimbatore, KAU, Thrissur and UHS, Bagalkot
Dr. C. Karpagam, Principal Scientist
External examiner for two Ph.D. and one M.Sc. theses from TNAU, Coimbatore
Member - Selection committee for the post of SMS at KVK, Theni, Tamil Nadu
Dr. P. Giribabu, Senior Scientist
Councillor (South zone), Executive Committee, Nematological Society of India, ICAR-IARI, New Delhi (2020-2022)
Member, Advisory panel, Brainstorming session on 'Researchable issues in Plant Nematology' held at Department of Nematology, TNAU, Coimbatore on 12 September, 2023
Course coordinator - MANAGE & ICAR-NRCB online collaborative training programme on 'Agripreneurship through Banana-based Technologies – An Avenue for *Atmanirbhar Bharat*' during 15-17 June, 2022
Acted as a mentor for Dr. Parthiban Subramanian, Assistant professor, National College, Tiruchirappalli under the DST-SERB scheme 'Teachers Associateship' for Research Excellence (TARE)
Life member - AgriGate - An International Multidisciplinary Monthly e-Magazine
Member and Fellow - Bose Science Society, Pudukkottai, Tamil Nadu
Nominated as observer in the computer based test conducted by ICAR, New Delhi for recruitment of AO and FAO held on 10 May, 2022
Evaluated one M.Sc. thesis from TNAU, Coimbatore

Member Secretary, Agricultural Research Service Scientists' Forum, Tiruchirappalli Centre for the year 2022
Dr. C. Anuradha, Senior Scientist
Acted as an external member for the selection of project associate, project fellow, YPs
Reviewer – *3 Biotech, Journal of Plant Pathology, Virus Disease, The Open Virology Journal, Malaysian Journal of Biochemistry and Molecular Biology (MJBMB), Vegetos, Genes*
Life member - World Society for Virology, Bose Science Society, AgriGate – An International Multidisciplinary Monthly e-Magazine
Fellow - Bose Science Society
Dr. A. Mohanasundaram, Scientist
Editor – *Agriculture and Food* (e-newsletter)
Reviewer - *Indian Journal of Entomology* and *Journal of Non Timber Forest Products*
Nominated as observer in the computer based test conducted by ICAR-IARI, New Delhi on 28 February 2022, 2, 4,5 March, 2022
Course coordinator - MANAGE & ICAR-NRCB online collaborative training programme on 'Agripreneurship through Banana-based Technologies – An Avenue for *Atmanirbhar Bharat*' during 15-17 June, 2022
Evaluated one M.Sc thesis
Organizing secretary - High–end workshop (Karyashala) on "Recent advances in banana improvement, production, protection, PHT, extension, and business arena for nutritional security in the era of *Atmanirbhar Bharat* held at ICAR-NRCB during 17-26 September, 2022
Dr. P. Ravichamy, Assistant Chief Technical Officer
Course Associate - MANAGE & ICAR-NRCB Online collaborative training programme on Agripreneurship through Banana-based Technologies – An avenue for *Atmanirbhar Bharat* at ICAR-NRCB during 15-17 June, 2022
Training Associate - High–end workshop (Karyashala) on "Recent advances in Banana Improvement, Production, Protection, PHT, Extension, and Business arena for nutritional security in the era of *Atmanirbhar Bharat* held at ICAR-NRCB during 17-26 September, 2022

8. LINKAGES AND COLLABORATIONS

Project Title	Collaborating Institute(s)
Improvement of banana for smallholder farmers in the great lakes region of Africa - Enhancing banana production by developing fusarium wilt-resistant varieties and benefit sharing with African smallholder	IITA, Nigeria; Bioversity International, France; NARO, Tanzania; University of Malaya; SLU, Sweden; Stellenbosch University, South Africa; Cornell University, USA; KUL, Belgium; University of Queensland, Australia; Nelson Mandela African Institution of Science and Technology, Tanzania; Institute of Experimental Botany, Czech Republic and EMBRAPA, Brazil
Bio-fortification and development of disease resistance in banana	Queensland University of Technology, Australia; NABI, Punjab; BARC, Mumbai; TNAU, Coimbatore; ICAR-IIHR, Bangalore
Conservation and use of Genetic Resource – Evaluation of ITC Genotypes for their reaction to FoC R1 and TR4	CGIAR / Bioversity International
Status of adoption behaviour of ITC accessions in India under the Banana production system and the constraint analysis in the dissemination process – An analytical study	
High-throughput screening for induced mutations in banana cv. Grand Naine (AAA) with Fusarium wilt (TR4) resistance	Board of Research in Nuclear Sciences (BRNS)
A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.)	DST, Govt. of India, New Delhi
Development of efficient IOT enabled plant disease pest detection system	
Framing crop specific DUS guidelines for banana (*Musa* spp.)	PPV & FRA, New Delhi
'Banana Shakti' Nano formulations – Effective delivery system of the micronutrient mixture for improved banana cultivation	SASTRA University, Thanjavur, Tamil Nadu
Sub Mission on Agricultural Mechanisation (SMAM) for implementation of its component no.1 under Drone Technology Demonstration	DAC & FW, Govt. of India
Development of protocol for export of banana to foreign countries	APEDA, New Delhi
Design development and validation of online banana trading platform for farmers of FPOs in Trichy District	NABARD
Establishment of banana macropropagation units in Tiruchirappalli District, capacity building and improvement of livelihood opportunities of farmers	

Collaborative research	ICAR-IARI, New Delhi; Regional Plant Resource Centre, Bhubaneswar
Research collaboration and student research	ICAR-CPCRI, Kasaragod, Karnataka Bishop Heber College (Autonomous), Tiruchirappalli, Tamil Nadu Department of Biotechnology & Microbiology, National College, Tiruchirappalli, Tamil Nadu Srimad Andavan Arts & Science College, Srirangam, Tamil Nadu
Students' training and research	UHS, Bagalkot
Mass multiplication of ICAR-NRCB banana varieties	Hi-Fi Biotech India Pvt. Ltd., Salem
'Knowledge Partner' in developing technologies towards value chain management, supporting banana export, organic production and waste utilization	Government of Andhra Pradesh
Developing imaging systems, electronic devices, solar energy applications in agriculture, nanotechnology and other fields by enlisting the students for internship and post graduate research programmes	NIT, Tiruchirappalli, Tamil Nadu
Developing various instruments for banana production and value addition	ICAR-CIAE (Regional Centre), Coimbatore, Tamil Nadu
Developing biosensors and imaging technology for pest detection, portable cable car conveyor system for the transportation of harvested bunches and to promote green technology through utilization of solar power and other fields	KNCET, Thottiyam, Tamil Nadu

9. PUBLICATIONS

9.1 Research Papers

9.1.1 International

Aasha Nandhini, S, Hemalatha, R, Radha, S, Shreya Gaur, Selvarajan, R.2022. A smart agriculturing IoT system for banana plants disease detection through inbuilt compressed sensing devices. *Research Square* DOI: 10.21203/rs.3.rs-2182006/v1.

Anuradha, C, Chandrasekar, A, Backiyarani, S, Thangavelu, R, Giribabu, P and Uma, S. 2022. Genome-wide analysis of pathogenesis-related protein 1 (PR-1) gene family from *Musa* spp. and its role in defense response during stresses. *Gene* **821**: 146334.

Anuradha, C, Chandrasekar, A, Backiyarani, S, Thangavelu, R, Uma, S. 2022. Genome-wide identification, characterization, and evolutionary analysis of NBS genes and their association with disease resistance in *Musa* spp. *Functional & Integrative Genomics* **23**(1): 1-18.

Anuradha, C, Chandrasekar, A, Backiyarani, S, Uma, S. 2022. MusaRgeneDB: An online comprehensive database for disease resistance genes in *Musa* spp.*3 Biotech* **12**(9): 1-12.

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Chowdary, VT, Manoj Kumar, V, Kishore Varma, P, Sreekanth, B, Srinivas Rao, V, Selvarajan, R and Balasubramanian, V. 2022. Characterization of Mungbean yellow mosaic India virus genome with a recombinant DNA-B in Southern Peninsular India. *Molecular Biology Reports*doi: 10.1007/s11033-022-07691-9.

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10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

Consultancy Services / Contract Research / Commercialization of Technologies

I	Consultancy Services / Contract Research			
S. No.	**Date**	**Name of the Technology**	**Address of the Client**	**Revenue (Rs. in Lakhs)**
1.	15.06.2022	Evaluation of efficacy of Poly4 (Polyhalite) on banana as source of potassium and secondary nutrients.	Sirius Minerals India Pvt. Limited., New Delhi.	1054078.00
2.	23.05.2022	Production of plantlets through embryogenic cell suspension culture	Horticulture Research Complex (HRC), Nagicherra, Tripura.	751188.00
			Total	**1805266.00**
II	**Commercialisation of Technologies**			
1.	12.01.2022	Banana Sakthi - Micronutrient mixer	Project Director, TNSRLM, Kanyakumari, Tamil Nadu	50000.00
2.	29.01.2022	Extraction, degumming, softening and utilization of banana fibres for making handicrafts and other utility products from sheath	Anita Roy, Kushinagar, Uttar Pradesh	25000.00
3.	11.02.2022	Banana Sakthi - Micronutrient mixer	Programme Coordinator, ICAR - Krishi Vigyan Kendra, TANUVAS, Namakkal, Tamil Nadu.	50000.00
4.	28.02.2022	Banana Sakthi - Micronutrient mixer	ICAR - Krishi Vigyan Kendra, Karur, Tamil Nadu	50000.00
5.	23.03.2022	Low glycemic prebiotic extruded snacks like noodles, pasta	Ameliorate Bioenergy Farmer Producer Co. Ltd, Kushinagar - 274 402, Uttar Pradesh	22500.00
6.	24 & 25.03. 2022	Extraction, degumming, softening and utilization of banana fibres for making handicrafts and other utility products from sheath	Ameliorate Bioenergy Farmer Producer Co. Ltd, Kushinagar - 274 402, Uttar Pradesh	22500.00
7.	28.03.2022	Nursery technology for banana	Bishop Heber College, Trichy.	10000.00

8.	21.04.2022	Banana Sakthi : Micronutrient Mixture	Mr. Niranjana Prabhu K.J, M/s. Ecophytocare India Private Limited, Mysore, Karnataka	50000.00
9.	06.05.2022	Fortified basil seed suspended banana juice	Thottiam Banana Producer Group, Member of Tamil Nadu Banana Producer Company Limited, Thottiam, Tiruchirappalli, Tamil Nadu	25000.00
10.	12.05.2022	Banana Wine	Mr. J. Jeano, Marayapuram, Kappukadu post, Kanyakumari, Tamil Nadu.	25000.00
11.	09 -13.05.2022	New Generation Tissue Culture System	Dr.K.S.Ravi, Innova Agri Bio Park Pvt. Ltd, Malur, Kolar, Karnataka	1125000.00
12.	09.06.2022	Banana Wine	Surachita Agro Producer Company Ltd, Maharashtra	22500.00
13.	14 - 15.06.2022	Nursery technology for banana	Sanjay Desai, Desai Consultants, Coimbatore	10000.00
14.	06&07.07.2022	Banana flour based low glycemic extruded snack products like noodles and pasta	M. Gurunathan, M/s Viyan Health World, Chennai	22500.00
15.	08 & 09.07.2022	Extraction of cellulose and other utility compounds like pectin and hemicellulose	M. Gurunathan, M/s Viyan Health World, Chennai	22500.00
16.	10.06.2022	Cost effective ripe banana powder	Surachita Agro Producer Company Ltd, Maharashtra	22500.00
17.	29.07.2022	Cost effective ripe banana powder	S. Devipriyadharshini, Thoothukudi	22500.00
18.	30.07.2022	Banana flour based low glycemic extruded snack products like noodles and pasta	S. Devipriyadharshini, Thoothukudi	22500.00
19.	11&12.08.2022	Post-harvest handling, packing, storage and ripening of banana for domestic and export markets	Althash Hussain, P.A., Palakkad District, Kerala	25000.00

20.	01.09.2022	Banana flour based low glycemic extruded snack products like noodles and pasta	Janarthanan. P, M/s. StayHealth Techculture Pvt Ltd, Coimbatore	22500.00
21.	02 & 03.09.2022	Cost effective ripe banana powder	Janarthanan. P, M/s. StayHealth Techculture Pvt Ltd, Coimbatore	22500.00
22.	13 &14.10.2022	Banana Central Core Stem Based Juice / RTS	C. Arivumani, M/s. Imaya Marketing, Tiruchirappalli	25000.00
23.	03.11.2022	Nursery technology for banana	ICAR - Krishi Vigyan Kendra, TNAU, Salem	10000.00
24.	09 &10.11.2022	Low fat fortified / flavoured banana chips	Ajith Singh K K, Kanniyakumari	25000.00
25.	17 & 18.11.2022	Low fat fortified / flavoured banana chips	Sudip Aryal, New Delhi	22500.00
26.	17 & 18.11.2022	Extraction and softening of banana fibre	Sudip Aryal, New Delhi	22500.00
27.	13.12.2022	Banana Sakthi : Micronutrient Mixture	Srirangam Banana Farmer Producer Company Limited, Vaazhndhu Kaatuvom Project, Andanallur, Srirangam, Tiruchirappalli	90000.00
			Total	**18,65,000.00**

III. Others

Signing of MoUs / MoCs / MoAs during 2022

S.No	Name of the company / Organization	Purpose	Date
1.	Waycool Food India Pvt Ltd, Chennai	Project Specific collaboration	17.01.2022
2.	St. Joseph's College, Trichy	Research Collaboration and Student Research	16.02.2022
3.	Bayer Crop Science Limited, Maharashtra	Project Specific collaboration	04.05.2022
4.	Horticulture Research Complex (HRC), Nagicherra, Tripura.	Consultancy project	01.06.2022
5.	Dhanam Agro (Bio) Tech, Krishnagiri	Project Specific collaboration	15.06.2022
6.	Sirius Minerals India Private Ltd, New Delhi	Contract Research	15.06.2022

7.	Cauvery Smart Foods & Agro Tech Pvt Ltd, Thanjavur	Project Specific collaboration	17.06.2022
8.	Assam Agricultural University, Jorhat, Assam	Student exchange and collaborative research	13.07.2022
9.	Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh	Student exchange and collaborative research	13.07.2022
10.	Kalasalingam Academy of Research and Education	Student exchange and collaborative research	20.10.2022

Supply of planting materials

Around 2740 tissue cultured plants and 13710 suckers of banana varieties have been supplied to banana growers. About 1578 batches of tissue culture plants of inclusive of cvs. Grand Nain, Nendran, Karpuravalli, Red Banana, Ney Poovan etc. have been tested for their genetic fidelity using ISSR markers and reports issued generating a revenue of Rs. 38.59 lakhs.

Licensing ICAR-NRCB Technology 'Banana Shakti- A Micronutrient Mixture' to three Stakeholders

ICAR-NRCB transferred its technology - *"Banana Shakti - A Micronutrient Mixture"* to the three different Stakeholders, *viz*., KVK, Namakkal, Tamil Nadu, Tamil Nadu State Rural Livelihood Mission (TNSRLM), Kanyakumari, Tamil Nadu and KVK, Karur, Tamil Nadu during February, 2022.

Licensing ICAR-NRCB Technology 'Banana Shakti-A Micronutrient Mixture' to three Stakeholders

ICAR-NRCB transferred 'Banana Juice' technology

ICAR-NRCB transferred basil seed suspended clarified banana juice technology to Thottiyam Banana Producer Company Ltd. – Member of Tamil Nadu Banana Growers Federation (TNBGF) on 6 May, 2022. Mr. G. Ajeethan, Managing Director, TNBGF along with Mr. V.A. Subramanian, Treasurer, TNBGF received the licence certificate.

Director, ICAR-NRCB transferred 'Banana juice technology' to TNBGF on 6 May, 2022

ICAR-NRCB transferred 'Banana wine and vinegar' technology

ICAR-NRCB transferred banana wine and vinegar making technology to Solapur based Surachita Agro Producer Company Ltd, Maharastra on 10 June, 2022. Mr. Ratnadeep Mohan More, Chief Executive Officer of the FPO received the licence certificate from Director, ICAR-NRCB.

ICAR-NRCB transferred 'Banana wine and vinegar making technology' to Surachita Agro Producer Company Ltd, Solapur, Maharastra on 10 June, 2022

ICAR-NRCB transferred technology 'Banana flour based extruded foods and snacks like pasta and noodles, banana fibre processing for utilizing the banana biomass', to Ameliorate Bioenergy Farmer Producer Co. Ltd, Kushinagar, Uttar Pradesh, one of the beneficiaries of MoFPI, PMFME scheme, under ODOP on 25 March, 2022

11. IRC / RAC / IMC MEETS

New team of RAC members for ICAR-NRCB

ICAR has constituted new members of Research Advisory Committee (RAC) for ICAR-NRCB for tenure of three years starting from 6 March, 2022. The details are as follows.

S. No.	Name of the official	Position
1.	Dr. N. Kumar, Former Vice Chancellor, TNAU, Coimbatore, Tamil Nadu	Chairperson
2.	Dr. P.C. Lenka, Former Professor, OUAT, Bhubaneswar, Odisha	Member
3.	Dr. S.K. Pareek, NIFTEM, Sonepat, Haryana	Member
4.	Dr. H.B. Singh, Former Professor, BHU, Varanasi, Uttar Pradesh	Member
5.	Dr. M. Ganapathi, BARC, Mumbai, Maharashtra	Member
6.	Dr. Jyothi Bhaskar, Professor & Head, Department of Fruit science, College of Horticulture, Vellanikara, KAU, Kerala	Member
7.	Two Non- official members nominated by Hon'ble MoA & FW in the IMC of the Institute	Members
8.	Dr. R. Selvarajan, Director, ICAR-NRCB, Tiruchirappalli, Tamil Nadu	Member
9.	Assistant Director General (Hort. Science II), ICAR, New Delhi	Member
10.	Dr. J. Poorani, Principal Scientist, ICAR-NRCB, Tiruchirappalli, Tamil Nadu	Member Secretary

XXV IRC meet

The 25th Institute Research Committee (IRC) of the centre was held on 17, 18 February and 17 March, 2022. Scientists of the centre made presentations of on-going projects' significant achievements and detailed discussions and deliberations were held.

25th IRC meet held at ICAR-NRCB

Visit of QRT of ICAR-AICRP (Fruits) team to ICAR-NRCB

The members of the quinquennial review team (QRT) of ICAR-AICRP (Fruits) visited ICAR-NRCB on 7 December, 2022. QRT members include Dr. D. Balasimha, Former Principal Scientist, ICAR-CPCRI, Vittal; Dr. K.P. Singh, Former Principal Scientist, ICAR-IIVR, Varanasi and Dr. S. Priya Devi, Principal Scientist ICAR-AICRP (Fruits), ICAR-IIHR, Bengaluru. Research activities of the ICAR-NRCB was deliberated and details on on-going trials including germplasm collection, characterization, conservation, evaluation and utilization, diagnosis of banana viruses in germplasm and planting materials used in experiments and evaluation of BSV free (Episomal BSMyV) tissue culture banana cv. Poovan, were discussed following which recommendation was given by the team. The team visited institute's laboratories and farm.

Institute Management Committee (IMC)

The XXVI Institute Management Committee (IMC) meeting of the Centre was held through online on 16 March, 2022. Salient research achievements made by the centre during 2021 were presented. Director, ICAR-NRCB briefed about the infrastructural developments taken place during the last year, and various issues pertaining to IMC were deliberated and discussed in the meet.

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

Human Resource Development

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

Name of the Staff	Name of the program	Organizers / Venue	Date
R. Selvarajan	DST sponsored training program on "Emotional Intelligence at Workplace" organized by Centre for Organisation Development (CoD) Hyderabad	Centre for Organisation Development, Hyderabad	31 October-4 November, 2022
M. Mayil Vaganan	NABL Assessors training (Level 2)	Indian Institute of Packaging, Mumbai	16-18 June, 2022
	Training program on 'Genetically Engineered Plants: Biosafety Considerations, Policies, Challenges and Detection Strategies'	ICAR-NBPGR, New Delhi	19-25 July, 2022
I. Ravi	Drones for Agricultural Development (Online)	MANAGE, Hyderabad	11-15 July, 2022
D. Ramajayam	MDP on 'Leadership Development (a Pre-RMP Program)'	ICAR-NAARM, Hyderabad	14-25 June, 2022
	Executive program in leadership and change management (Batch -02)'	IIM, Tiruchirappalli	February to December, 2022
P. Giribabu Arjun Singh	Analysis of Experimental Data (Online)	ICAR-NAARM, Hyderabad	17-22 January, 2022
C. Anuradha	IP Awareness / Training program under NIPAM (Online)	Intellectual Property Office, India	12 July, 2022
	RNA world: Advance bioinformatics for deciphering regulatory molecules	ICAR-IASRI, New Delhi	3-9 November, 2022
A. Mohanasundaram	Integrated Pest Management (IPM) for sustainable Agriculture (Online)	ICAR-NCIPM & MANAGE	9-13, May, 2022
	'Agripreneurship through banana-based technologies – An avenue for *Atmanirbhar Bharat*'	MANAGE, Hyderabad & ICAR-NRCB, Tiruchirappalli	15 -17 June, 2022

Arjun Singh	Advanced statistical techniques for data analysis using R	ICAR-IIRR, Hyderabad & SARR, Hyderabad	3-15 January, 2022
	ICAR-Short course on 'Concepts and mechanism of soil carbon sequestration and stabilization for soil health improvement and climate change mitigation'	ICAR-IISS, Bhopal	2-11 March, 2022
	Carbon finance for agriculture towards climate risk mitigation	MANAGE, Hyderabad	22 March - 1 April, 2022
P. Ravichamy	IP Awareness cum training program under NIPAM	National Intellectual Property Office, GoI, New Delhi (Online)	5 August, 2022
	Virtual training on Agripreneurship through Banana-based Technologies – An Avenue for "Atmanirbhar Bharat"	ICAR-NRCB, Trichy and MANAGE, Hyderabad	15-17 June, 2022
V. Selvaraj	Selection, adjustment, operation and maintenance of agricultural implements for field and horticultural crops	ICAR-CIAE, Bhopal	29 December, 2022 – 7 January, 2023
R. Pitchaimuthu	Analysis of Experimental Data	ICAR-NAARM, Hyderabad	19-28 December, 2022
V. Ganesan	Production of Arka fermented cocopeat and soilless cultivation of vegetables	ICAR-IIHR, Bangalore	19 March, 2022

12.2 Workshop / Seminar / Conference / Symposia / Scientific meet etc. attended by the Staff of ICAR – NRCB

Name of the Scientist	Details	Date
Staff of ICAR-NRCB	ICAR-NRCB - 29th Foundation Day & *Kisan Mela*	21 August, 2022
	Consultative workshop on 'Export of GI and traditional bananas organized by ICAR-NRCB and APEDA	21-22 December, 2022
	Rajbhasha - Hindi workshop	29 March, 2022
Scientific Staff of ICAR-NRCB	DGM-NABARD meeting held at ICAR-NRCB, Tiruchirappalli	11 October, 2022
	Midterm review meeting of ICAR-AICRP (Fruits) - Banana Centres (Online)	
	IXth Group Discussion of ICAR-AICRP on Fruits (Online)	8-11 March, 2022

S. Uma J. Poorani R. Thangavelu R. Selvarajan V. Kumar S. Backiyarani M.S. Saraswathi P. Suresh Kumar P. Giribabu A. Mohanasundaram	QRT meet of ICAR-AICRP on Fruits (Online)	7 December, 2022
R. Selvarajan R. Thangavelu V. Kumar K.J. Jeyabaskaran K.N. Shiva P. Suresh Kumar P. Giribabu	Online meet to discuss about collaborative programs on banana conducted by Bayer Crop Science Limited, New Delhi	15 February, 2022
J. Poorani R. Thangavelu R. Selvarajan M. Loganathan P. Giribabu	Lecture on ' Role of extension in dissemination of integrated pest management in the country' organized by ICAR-NCIPM, New Delhi	26 February, 2022
R. Selvarajan M.S. Saraswathi M. Loganathan	International conference on Fusarium wilt disease in Africa organized by Food and Agricultural Organisation of the United Nations (FAO), the Southern African Development Community (SADC) and Stellenbosch University (Online)	30 May to 1 June, 2022
S. Uma R. Thangavelu	International symposium on 'Global research in the management of Banana Fusarium wilt TR4 organized by IAEA, INIAP and IICA (Online)	24-25 March, 2022
	'International Conference on Banana Fusarium Wilt Disease in Africa' jointly organised by the FAO, Stellenbosch University and the Southern African Development Community (SADC) (Online)	30 May-1 June, 2022
S. Uma M. Mayil Vaganan	Orientation-cum-training programme for Project Investigators of BIRAC-Banana bio-fortification on conduct of event selection trials of GE banana events, held at ICAR-NRCB, Tiruchirappalli	1-2February, 2022

V. Kumar P. Suresh Kumar	Conference on 'Agriculture produce & export opportunity for farmers' jointly organized by APEDA, Govt. of India, New Delhi and Pollachi Chamber of Commerce & Industry (PCCI) at Pollachi	6-7 January, 2022
	CDP - 2nd Pre-Bid Conference conducted by the Dept. of Horticulture, Govt. of A.P. (Online)	4 April, 2022
	Meet on Theni banana cluster development program organized by the Dept. of Horticulture, Govt. of Tamil Nadu at HC & RI, Periyakulam	30 June, 2022
S. Uma V. Kumar P. Suresh Kumar	Meet on Theni banana cluster development program organized by APC & NHM at Chennai	28 June, 2022
S. Uma R. Thangavelu V. Kumar P. Suresh Kumar	7th edition of CII Cold chain awards ceremony / logistics event organized by the CII at Mumbai	30 November, 2022
M.S. Saraswathi C. Anuradha	TR4 Global Network - Webinar Series - TR4-Resistant Banana Varieties: From Selection to Market Demand organised by World Banana Forum, FAO, United Nations	19-20 January, 2022
M.S. Saraswathi M. Loganathan C. Anuradha	Global Research in the Management of Banana Fusarium Wilt TR4 – Equador organised by World Banana Forum, FAO, United Nations	24-25 March, 2022
S. Uma Arjun Singh	TOLIC joint Hindi workshop for the Rajbhasha officers, held at ICAR-NRCB, Tiruchirappalli	7 April, 2022
Dr. R. Selvarajan, Director		
Intangible technology transfers focusing on academic / research institutions and laboratories in chemical, petrochemical and biotechnology sectors conducted by Dept. of Biotechnology, Ministry of Science and Technology, Govt. of India (Online)		19 January, 2022
Institute bio-safety committee (IBSC) meet conducted by ICAR-CTCRI, Thiruvananthapuram (Online)		19 January & 21 September, 2022
Presentation of ARMS organized by Information & Communication Technology Unit, ICAR, New Delhi (Online)		2 February, 2022
National conference on 'Emerging and re-emerging viral diseases - Climate change impacts and mitigation', organised by Department of Microbiology, AIIMS, Bibinagar, Hyderabad Metropolitan Region, Telangana under the aegis of Indian Virological Society (Online)		26-28 March, 2022

National workshop cum-webinar on 'Gene editing - Basics to advanced applications in agriculture, pharma and health sectors' organized by Glostem Private Limited, Chandigarh, India (Online)	27 June - 3 July, 2022
PMC meet of Centre for Rural Education and Development (NGO) for the project on Rejuvenation of Sirumalai Banana Cultivation (RSBC) being implemented in Sirumalai held at Sirumalai, Dindugal, Tamil Nadu	30 June, 2022
National workshop on 'Management of cucumber mosaic virus disease of banana' jointly organized by Confederation Horticulture Associations of India (CHAI) in association with All India Banana Growers Associations, held at Raver, Jalgaon, Maharashtra	30 September, 2022
XXX Annual convention cum International conference on 'Emerging and re-emerging viral infections impacting humans, animals, plants, fish and environment', organized by Indian Virological Society (IVS) and Division of Veterinary Microbiology & Immunology, Faculty of Veterinary Sciences and Animal Husbandry, Sher-e-Kashmir University of Agriculture Sciences and Technology-Kashmir, Shalimar, Srinagar, India held at SKUAST-Kashmir, Shalimar, Srinagar	5-6 November, 2022
Dr. S. Uma, Principal Scientist	
Board meet, TNAU, Coimbatore	19 January, 2022
CSIR-FTT/FTC – 3rd Review meet (Online)	20 January, 2022
SMD Horticulture meet on revision of the merged schemes documents (Online)	28 January, 2022
CGIAR Centers review meet	7 February, 2022
Special Governing Board Meet, NIFTEM, Thanjavur (Online)	14 March, 2022
Feasibility studies of banana and sugarcane cultivation in Lakshadweep (Online)	24 March, 2022
Webinar on 'Good Agricultural Practices' organized by KPMG, Andhra Pradesh	8 April, 2022
ICAR Institute Directors' Conference, New Delhi	13 April, 2022
Meet on the status of NOC from States for conduct of EST of GE banana, arranged by BCIL, New Delhi	21 April, 2022
Bio-fortification Project PMC meet (Online)	5 May, 2022
Departmental Promotion Committee of ICAR-NRCB Scientist	7 May, 2022
Board meet, TNAU, Coimbatore (Online)	16 May, 2022
Meet on promotion of Scientist of ICAR-CTCRI, Tiruvananthapuram under CAS (Online)	18 May, 2022
Annual meet of IITA Project at Tanzania	23-24 May, 2022
CJSC meet of ICAR	17 June, 2022
Meet on Banana Cluster Program organized by Government of Tamil Nadu at Chennai	28 June, 2022
Meet on NOC related issue of GE Banana (Online)	7 July, 2022
SAC meet, PPRC, Bhubaneswar	22 July, 2022
Meet on 'Processing opportunities' conducted by ICAR-AICRP (Fruits)	21 August, 2022

Sectoral Committee Meet on Horticulture Sciences at NASC, New Delhi	14-15 September, 2022
Governing Body Meet of ITPGRFA hosted by PPV & FRA at New Delhi	19-24 September, 2022
Sectional Committee Meet for selection of suitable candidates for Academy's Fellowship / Associateship and Young Scientist Awards	7 October, 2022
Interaction with Women in Science & Technology for research areas and career planning session of open forum at STREE 2020 at New Delhi	24 November, 2022
Dr. R. Thangavelu, Principal Scientist	
International conference on 'Plant Pathology: Retrospect and Prospects' held at SKN Agricultural University, Jobner-Jaipur, Rajasthan	23-26 March, 2022
National symposium on 'Novel strategies in plant stress diagnosis and management', organized at Dr Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh	6-7 May, 2022
Dr. M. Mayil Vaganan, Principal Scientist	
Meet on promotion of Scientist of ICAR-IIHR, Bangalore under CAS (Online)	11 February, 2022
Competency enhancement programme for effective implementation of training functions by nodal officers of HRD, ICAR organized by ICAR-NAARM, Hyderabad (Online)	21-23 February, 2022
Annual review meet of BIRAC - Banana bio-fortification project organized by DBT-Biotechnology Industry Research Assistance Council, New Delhi (Online)	5 May, 2022
XIII Institute bio-safety committee meet (IBSC) held at ICAR-NRCB, Tiruchirappalli	15 November, 2022
Dr. V. Kumar, Principal Scientist	
District mission committee meet to review the implementation of NHM & MI schemes in Tiruchirappalli District	5 January, 2022
Participated in the 'CDP-Banana-1st Pre-Bid conference on Call for Proposals for selection of Implementing Agencies (IAs)' at Chennai	2 March, 2022
Webinar on 'Are disasters gender neutral?' organizers by the publishers of know disaster magazine	2 April, 2022
GAP - Knowledge dissemination webinar	8 April, 2022
Interface meet with Lakshadweep Administration to finalize the technologies and development programs for the U.T. of Lakshadweep Islands held at Kavarati	11-12 April, 2022
Conducted survey and feasibility study for the cultivation, processing and value addition in banana in the Lakshadweep Islands	13-16 April, 2022
Project evaluation committee meet of Technology Development Board, DST, New Delhi at Vadipatty, Madurai	21-22 July, 2022
Dr. K.J. Jeyabaskaran, Principal Scientist	
NHM - Review meeting convened by the DDH, Tiruchirapalli under the chairmanship of the District Collector, Tiruchirapalli	26 September, 2022

Dr. K.N. Shiva, Principal Scientist	
National e-workshop and e-showcasing horticulture startup opportunity in Eastern India: Connecting youth to agri-startup ecosystem by ICAR-Research Complex for Eastern Region, Patna (Online)	26 February, 2022
National seminar on 'Fruit production in eastern tropical region of India – Challenges and opportunities' organized by CHES, Bhubaneshwar, and SPH, ICAR-IIHR, Bengaluru (Online)	24-26 March, 2022
National dialogue on 'Extension services for efficient delivery of horticultural technologies: A way forward' organized by ICAR-IIHR, Bengaluru (Online)	21-22 May, 2022
XV Scientific Advisory Committee (SAC) meet, ICAR-KVK, Karur, Tamil Nadu	20 December, 2022
Dr. S. Backiyarani, Principal Scientist	
26th IMC meet of ICAR-NRCB, Tiruchirappalli (Online)	16 March, 2022
47th meet of 'Plant Germplasm Registration Committee' (Online)	29 March, 2022
Dr. M.S. Saraswathi, Principal Scientist	
NSIP meeting organised by NSIP and IITA	4 May, 2022
Prospects of Varieties/Crops Developed through Genome Editing (regulatory framework, technologies and experience) organized by PPV&FRA, New Delhi under Indo-German Co-operation on Seed sector development	24 May, 2022
SVRC meeting at Secretariat, Chennai	7 January, 2022
DUS meeting (virtual) with Plant Genome Saviour Community Awardees organized by PPV&FRA, New Delhi	12 January, 2022
BARC project proposal presentation meeting organized by BRNS, DAE, Mumbai (Online)	29 March, 2022
APAR online organized by IASRI, New Delhi & ICAR-ICT Unit, New Delhi (Online)	19 April, 2022
49th Plant Germplasm Registration Committee meeting organized by ICAR-NBPGR, New Delhi (Online)	8 December, 2022
DUS Review meeting organized by PPV & FRA, New Delhi	10-11 November, 2022
Dr. C. Karpagam, Principal Scientist	
Scientific Advisory Committee Meet, KVK, Namakkal, Tamil Nadu	9 March, 2022
Scientific Advisory Committee Meet, KVK, Sirugamani, Tamil Nadu	1 December, 2022
Scientific Advisory Committee Meet, KVK, Ariyalur, Tamil Nadu	31 December, 2022
Dr. P. Giribabu, Senior Scientist	
National webinar on 'Nematode pests of horticultural crops and their management' organized by ICAR-DFR, Pune, Maharashtra	30 April, 2022
Brainstorming session on 'Researchable issues in Plant Nematology' held at Department of Nematology, TNAU, Coimbatore	12 September, 2023

Dr. C. Anuradha, Senior Scientist	
National workshop on 'Genome Editing : Basics to advanced applications in Agriculture, Pharma and Health sector' organized by Glostem, in association with Indian National Young Academy of Sciences	27 June - 3, July, 2022
Webinar on 'International Biodiversity Day' on the topic 'Global gene banks and biodiversity management for sustainable agriculture' organized by NAAS, New Delhi	22 May, 2022
Dr. A. Mohanasundaram, Scientist	
Seventh National conference on 'Biological Control' organized by Society for Biocontrol Advancement held at ICAR–NBAIR, Bengaluru	15-17 December, 2022
Mr. Arjun Singh, Scientist	
National Hindi Webinar-Ansh: 2022 organized by CSIR-NAL, Bengaluru	21-22 April, 2022
Recent advances for managing sustainable soil health and crop production organized by GKV Society, Agra (Online)	18-20, February 2022

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

ICAR-NRCB and APEDA jointly organized consultative workshop on 'Export of GI and traditional bananas'

ICAR-National Research Centre for Banana, Tiruchirappalli and Agricultural and Processed Food Products Export Development Authority (APEDA), New Delhi jointly organized a two day consultative workshop on 'Export of GI and traditional bananas: Present scenario, trade opportunities and way forward' during 21-22 December, 2022.

Dr. M. Angamuthu, IAS, Chairman, APEDA, New Delhi was the Chief Guest of inaugural session and Mr. C. Samayamoorthy, IAS, Agricultural Production Commissioner, Agriculture and Farmers Welfare & Secretary to Government of Tamil Nadu graced the occasion as Special Guest. Ms. Rajalakshmi Devaraj, IDAS, Addl. DGFT, Chennai; Dr. V. Geethalakshmi, Vice Chancellor, TNAU, Coimbatore and Dr. K.M. Indiresh, Vice-Chancellor, UHS, Bagalkot; Dr. V.B. Patel, ADG (Horticultural Science-II), ICAR, New Delhi were the Guests of Honour. The inaugural session was presided over by Dr. R. Selvarajan, Director, ICAR-NRCB, Tiruchirappalli. On the occasion, six publications were released and three awards were distributed to banana FPO's / technology disseminators for conservation of GI bananas. More than 300 participants attended the export workshop and an exhibition was also organized wherein more than 100 varieties and land races of banana bunches and fruits were displayed.

The consultative workshop was conducted in three technical sessions in two days. There were 30 keynote lectures delivered by experts of banana export, supply chain management, government policies, marketing and PPV&FRA.

The Plenary session of the workshop was held on 22 December, 2022. Dr. M.K. Shanmugasundaram, IAS, Development Commissioner, MEPZ,SEZ, Chennai was the Chief Guest and Dr. Dinesh Kumar Agarwal, Registrar General, PPV&FRA, New Delhi and Mr. Alex Paul Menon, IAS, Joint Development Commissioner, MEPZ, SEZ, Chennai were the Guests of Honour. Dr. R. Selvarajan, Director, ICAR-NRCB in his concluding remarks, informed that there is a greater potential to export traditional Indian bananas as 32 million NRIs present all over the world besides targeting westerners. He opined that by exporting traditional bananas will create market for as unique flavor of those bananas attract higher demand. He said many more varieties including Matti and Thella Chakrakeli are cultivated in a restricted locations have to be protected by registering them as GI based on their distinct characters.

In valedictory session, a technical bulletin on protection of plant varieties and farmers' rights authority and a virtual image gallery titled 'Diversity of bananas and plantains – A glimpse' were released by the Chief Guest. He also gave away the certificates to persons who have participated and made stalls in banana exhibition.

Chief Guest, Dr. M. Angamuthu, IAS, Chairman, APEDA, New Delhi inaugurated the GI and traditional banana exhibition

Release of publications during the plenary session of consultative workshop on 'Export of GI and traditional bananas'

ICAR-NRCB Foundation Day & *Kisan Mela*

ICAR-National Research Centre for Banana, Tiruchirappalli celebrated its 29th Foundation Day as *Kisan Mela* on 20 August, 2022. Dr. (Smt.) Poonam Malakondaiah, IAS, Chief Commissioner & Special Secretary to Government of Andhra Pradesh has graced the occasion as Chief Guest. Dr. (Ms.) R. Brindha Devi, IAS, Director, Horticulture & Plantation Crops / Managing Director, TANHODA was Special Guest. Dr. Anitha Karun, Director, ICAR-CPCRI, Kasaragod, Dr. Debi Sharma, ICAR-IIHR, Bengaluru and Dr. Murugesa Boopathy, Former Vice Chancellor, TNAU, Coimbatore were the Guests of Honour. The event was presided over by Dr. S. Uma, Director, ICAR-NRCB, Tiruchirappalli.

Dr. J. Poorani, Principal Scientist, ICAR-NRCB, Tiruchirappalli gave the welcome address. Presidential address was given by Dr. S. Uma, Director, ICAR-NRCB, Tiruchirappalli. In her address, she quoted 'Science for development and for the common people'. She narrated the importance of banana in Indian economy and role of ICAR-NRCB in making India as the leading banana producer in the world. She mentioned development of new cultivars *viz*., Kaveri Vamana, Kaveri Kanchan, ornamental banana hybrids, and Nano formulation of micronutrient mixture 'Banana Shakthi' as last years' research achievements. She also mentioned 'bioreactors for mass multiplication of traditional cultivars, sea protocol for export of traditional bananas to Europe and certification of over 400 million tissue culture plants' were the significant achievements of the centre. She assured the farmers of developing Fusarium wilt race 1 tolerant banana cultivar and app based virus diagnostic method in near future. She also announced that the centre is developing common incubation centre worth of Rs. 2.5 crore at the institute and digital marketing platform for banana marketing. She emphasized the importance of IoT, artificial intelligence and drone in banana cultivation.

By releasing the centre's various publications, Chief Guest Dr. (Smt.) Poonam Malakondaiah, IAS, Chief Commissioner & Special Secretary to Government of Andhra Pradesh conveyed her best wishes to ICAR-NRCB for its commendable research on banana. Special Guest Dr. (Ms.) R. Brindha Devi, IAS, Director, Horticulture & Plantation Crops / Managing Director, TANHODA explains the role and supportive measures of TANHODA for banana farmers. Guests of Honour, Dr. Anitha Karun, Director, ICAR-CPCRI, Kasaragod and Dr. Debi Sharma, Director, ICAR-IIHR, Bengaluru congratulated team NRCB for bagging Sardar Patel outstanding ICAR institute-2020 award and lauded the institute for its scientific achievements and technologies developed. Dr. Murugesa Boopathy, Former Vice Chancellor, TNAU, Coimbatore mentioned MoU signed between ICAR-NRCB and Hifi biotech., Salem in multiplication of tissue culture plants of cultivar Udhayam. Leading banana farmers, Mr. Ajeethan, TNBGF, Thottiyam and Mr. Mahadhanapuram Rajaram addressed the farmers and praised the role of ICAR-NRCB in banana cultivation in Tamil Nadu and other states.

ICAR-NRCB celebrates its 29th Foundation day and *Kisan Mela* on 20 August, 2022

The Chief Guest inaugurated the exhibition stall to the public. Products made of banana and other crops, farm inputs and other farm related materials were kept in different stalls for the benefit of farming community. During inaugural session, publications on value added products of banana; Agribusiness Incubation Centre; nutritive values of banana flower and Government schemes for banana farmers were released. Prizes for best banana farmer, entrepreneurs and banana germplasm conservation were distributed. Best employee award was also given to NRCB staff under

technical and administrative staff categories. Dr. V. Kumar, Principal Scientist, ICAR-NRCB, Tiruchirappalli gave vote of thanks. On the occasion, two technical presentations were made by Dr. R. Thangavelu, Principal Scientist (Plant Pathology) and Dr. K. N. Shiva, Principal Scientist (Horticulture) under the theme 'Advances in Production, Post-Harvest Technologies and Value Addition in Banana'.

ICAR-NRCB and MANAGE conduct training program on 'Agripreneurship on banana based technologies'

ICAR-National Research Centre for Banana, Tiruchirappalli joined hands with National Institute of Agricultural Extension Management (MANAGE), Hyderabad and organized an online three days training program titled 'Agripreneurship through banana-based technologies – An avenue for *Atmanirbhar Bharat*' from 15 to 17 June, 2022.

Inaugural session of the training program was held on 15 June, 2022. Chief Guest of the session, Dr. S. Uma, Director, NRCB, Tiruchirappalli welcomed the trainees and informed about various technologies developed and entrepreneurship opportunities available with NRCB. She urged the trainees to start their own business venture using the expertise available with NRCB and MANAGE. Course director, Dr. C. Karpagam, Principal Scientist (Agricultural Extension), NRCB, Tiruchirappalli gave a brief introduction about the extension objectives of the training program. Other course director, Dr. Sagar Surendra Deshmukh, Associate, MANAGE informed the trainees about the scope and objective of agripreneurship and role of MANAGE in facilitating business start-ups. Welcome address and vote of thanks were delivered by Senior Scientists of NRCB, Dr. A. Mohanasundaram and Dr. P. Giribabu respectively.

The training program covered interactive lectures from expert scientists of ICAR-NRCB, Tiruchirappalli, ICAR-ATARI, Bangalore, ICAR-IIHR, Bangalore, MANAGE, Hyderabad and VIT, Vellore. NRCB technologies *viz.*, newly developed varieties, macropropagation, bioreactors for micropropagation, *Banana Shakti* – a micronutrient mixture, virus diagnostic kits, post- harvest management and value added products were explained in detail. Apart from this, role of MANAGE, ICAR-ATARI in promoting agricultural extension and agriprenuership, licensing procedure for establishing agribusiness venture and agripreneurial ecosystem were also deliberated.

This training program aimed to give an opportunity to farmers, entrepreneurs, officials of KVK and SAU about technologies that are developed at NRCB and entrepreneurial principles, procedures and processes for establishing a successful agribusiness start up. Around 100 trainees attended the training program and got benefitted.

Research facility training program on 'Omics and Bioinformatics'

A DST-SERB sponsored training program titled 'Omics and bioinformatics' was conducted at ICAR-NRCB on 25 June, 2022. This one day training was attended by 18 research scholars from Bishop Heber College (Autonomous); Srimad Andavan Arts and Science College (Autonomous) and National College, Tiruchirappalli, Tamil Nadu. The trainees were exposed to 'Bioinformatics, Biological Databases and internet resources for Bioinformatics analysis, Basic Linux commands for Bioinformatics, Sequence retrieval from NCBI and from other databases, Bioinformatics tools: BLAST, Bio-Edit, ORF identification, translate, Phylogenetic analysis, Protein databases: CDD, pI, Mwt, Signal Peptide, Sub-cellular localization, PPI network, Protein structure prediction and analysis: 3D structure visualization tools, Microsatellite mining and Primer Designing, MicroRNA identification and target predictions, Next Generation Sequencing, GBS and ddRAD Sequencing - Reduced-representation sequencing approaches'. The training was inaugurated by Dr. S. Uma, Director, ICAR-NRCB and the training program end up with valedictory function and certificate distribution to the participants.

Workshop on 'Recent trends in biotechnology and their Applications'

Under the Scientific Social Responsibility (SSR) Policy of DST-SERB, a workshop was organised to faculty members of nearby colleges of Tiruchirappalli District on topics of scientific area of research undertaken under the DST-SERB project 'A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.)' on 'Recent trends in biotechnology and their applications' at ICAR-NRCB on 8 July, 2022. The workshop was attended by 30 faculty members belong to Bishop Heber College (Autonomous), Tiruchirappalli, Srimad Andavan Arts and Science College (Autonomous), Tiruchirappalli, National College, Tiruchirappalli, St. Joseph's College, Tiruchirappalli, EVR-Periyar College, Tiruchirappalli, Thandai Hans Rover College, Perambalur, Govt College of Arts and Science, Ariyalur. Faculty members specialized in botany, zoology biotechnology, bioinformatics, biochemistry etc have attended the workshop. The workshop covered topics on recent advances in biotechnology such as 'Advanced tissue culture techniques of banana – A case study, Advances in anther culture Techniques, *Omics* in crop improvement and genome editing for crop improvement'. The training was inaugurated by Dr. S. Uma, Director, ICAR-NRCB and the during valedictory function, Chief Guest, Dr. C. Vanniarajan, Dean, Anbil Dharmalingam Agricultural College and Research Institute (TNAU), Tiruchirappalli distributed certificates to the participants.

High–End workshop for research scholars

ICAR-National Research Centre for Banana, Tiruchirappalli organized DST-SERB funded, ten days 'High-End Workshop (*Karyashala*)' on 'Recent advances in banana improvement, production, protection, PHT, extension, and business arena for nutritional security in the era of *Atmanirbhar Bharat*' during 17-26 September, 2022. The workshop was specifically designed for Post graduate students and Ph.D. scholars to expose them to contemporary technological advancements in banana crop. 31 M.Sc. and Ph.D. research scholars from six states of the country attended the workshop. The valedictory session of the training program was held on 26 September, 2022. On the occasion, Dr. S. Uma, Director, ICAR-NRCB addressed the trainees and wished them for their future endeavours. Chief Guest, Dr. Nicolas Roux, Team Leader, Bioversity International, France emphasized the various opportunities available for scholars in crop research and development at the global level. Further, he mentioned the opportunities for research scholars in the Consultative Group for International Agricultural Research CGIAR. The 10 days workshop covered lectures and practical sessions on various aspects of banana improvement, production, protection, PHT, extension and business opportunity available in the banana production system. Lectures were delivered by experts from ICAR-NRCB and other ICAR institutes, TNAU, VIT, Vellore, and Xanthus Institute of Goa.

Trainees of High-end workshop along with Scientists of ICAR-NRCB and Chief Guest Dr. Nicolas Roux, Team Leader, Bioversity International, France

Distribution of certificates by Chief Guest Dr. Nicolas Roux, Team Leader, Bioversity International, France along with Dr. S. Uma, Director and Course co-ordinators of ICAR-NRCB

14. DISTINGUISHED VISITORS

Name	Date
Dr. (Smt.) Poonam Malakondaiah, IAS, Special Chief Secretary to Government of Andhra Pradesh, Agri & Cooperation Dept., Amaravati	31 January, 2022
Smt. Ch. Padmavathi, Dy. Director (Horticulture), Government of Andhra Pradesh	
Mr. A. Anbarasu, IAS, Advisor and Secretary, Lakshadweep Administration	1 March, 2022
Dr. P. Sabanayaham, Tamil Nadu State Secretary, Vijnana bharati	6 April, 2022
Mr. Gopal Parthasarathy, State Co-coordinator, Vijnana bharati	
Prof. J. Jeyakanthan, Head, Dept. of Bioinformatics, Alagappa University, Karaikudi	
Dr. B.M.K. Reddy, Andhra Pradesh State Biodiversity Board; Dr.G.P.D.Reddy, Scientist, Pulivala, YSR Horticulture University	18-19 April, 2022
Dr. C. Vanniarajan, Dean, Anbil Dharmalingam Agricultural College and Research Institute, TNAU, Tiruchirappalli	8 July, 2022
Mr. Shankar B. Patil Munenakoppa, Minister for Handloom and Textile, Sugar Cane Development, Govt. of Karnataka	21 July, 2022
Dr. (Smt.) Poonam Malakondaiah, I.A.S., Chief Commissioner & Special Secretary to Government of Andhra Pradesh	20 August, 2022
Dr. (Ms.) R. Brindha Devi, I.A.S., Director, Horticulture & Plantation Crops / Managing Director, TANHODA	
Dr. Anitha Karun, Director, ICAR-CPCRI, Kasaragod	
Dr. Debi Sharma, Director, ICAR-IIHR, Bengaluru	
Dr. Murugesa Boopathy, Former Vice Chancellor, TNAU, Coimbatore	
Mr. G.P. Sharma, Joint Secretary (Finance), ICAR, New Delhi	2 September, 2022
Dr. Nicolas Roux, Team Leader, Bioversity International, France	26 September, 2022
Mr. G. Santhanam, Deputy General Manager, NABARD, Chennai Mr. Mohan Karthick, Deputy District Manager, NABARD, Tiruchirappalli	11 October, 2022
Dr.Trushar Shah, Bioinformatician, Integrated Breeding Platform, IITA	19 October, 2022
Dr.Vishnuvardhan Reddy Banda, Agri-Scientist of IITA (International Institute of Tropical Agriculture)	**7 December, 2022**
Dr. M. Angamuthu, IAS, Chairman, APEDA, New Delhi	21 December, 2022
Mr. C. Samayamoorthy, IAS, Agricultural Production Commissioner, Agriculture and Farmers Welfare & Secretary to Government of Tamil Nadu	
Ms. Rajalakshmi Devaraj, IDAS, Addl. DGFT, Chennai	
Dr. V. Geethalakshmi, Vice Chancellor, TNAU, Coimbatore	
Dr. K.M. Indiresh, Vice-Chancellor, UHS, Bagalkot	
Dr. V.B. Patel, ADG (Horticultural Science-II), ICAR, New Delhi (Online)	

Dr. M.K. Shanmugasundaram, IAS, Development Commissioner, MEPZ,SEZ, Chennai	22 December, 2022
Dr. Dinesh Kumar Agarwal, Registrar General, PPV&FRA, New Delhi	
Mr. Alex Paul Menon, IAS, Joint Development Commissioner, MEPZ, SEZ, Chennai	

Visit of Mr. Shankar B. Patil Munenakoppa, Minister for Handloom and Textile, Sugar Cane Development, Govt. of Karnataka to ICAR-NRCB

15. EMPOWERMENT OF WOMEN

ICAR-NRCB organised a training program for women farmers

ICAR-NRCB organized two days training program for 40 women farmers from Kalakkad, Tirunelveli District, Tamil Nadu under ATMA scheme. On the occasion, awareness about the ATMA scheme, Integrated Nutrient Management and value addition from banana fibre, different Government schemes *viz*., PM Kisan, KCC, and RKVY were given in detail.

Women trainees of ATMA scheme with Director and staff of ICAR-NRCB

Banana fibre processing - Wealth from waste technology transferred to woman entrepreneur

ICAR-NRCB gave license and transferred an eco-friendly technology for processing banana fiber to Ms. Anita Roy, Woman entrepreneur and District trainer, PMFME scheme, Kushinagar, Uttar Pradesh on 29 January 2022. The technology will be used to prepare value added products *viz*., garments, ropes, mats, carpets, cushions, cushion covers, bags, baskets, table cloths etc. from banana fiber.

Ms. Anita Roy, woman entrepreneur receiving licence certificate from Director, ICAR-NRCB

ICAR-NRCB and Srirangam Banana Producer Company signed an MOA for transfer of technology 'Banana Shakti' to women banana farmers

To uplift the women banana farmers, Srirangam Banana Producers Organization, a FPO started '*Vazhlndhu Kattuvom'* (Lets' live) scheme from the financial assistance received from Business Innovation Fund by the District Project Management unit, Tiruchirappalli, Tamil Nadu. In order to help the women farmers, ICAR-NRCB made an agreement with the FPO by signing transfer of technology (ToT) for production of '*Banana Shakti* – A micronutrient mixture' on 13 December, 2022. Around 1200 women farmers will get benefitted through this agreement. Mr. I. Aroon Joshva Rusewelt, DEO, VKP, Tiruchirappalli and Karur and S. Murugesan, DEO, MSSRF were present during signing of the agreement.

ICAR-NRCB signed agreement for transfer of technology '*Banana Shakti*' to Srirangam Banana Producers Organization to uplift the women farmers of Tiruchirappalli, Tamil Nadu

About 2000 women including students, SHG members and other women entrepreneurs from different parts of country visited NRCB and learnt various technologies available at NRCB on Crop Improvement, Crop Production, Crop protection and Postharvest Managements etc.

16. PERSONNEL

16.1 Staff News

Appointment

Name	Event	Date
Dr. R. Selvarajan, Principal Scientist	Assumed charge as Director, ICAR–NRC for Banana, Tiruchirappalli	w.e.f. 8 December, 2022 (Afternoon)

Deputation

Name	Event	Date
Dr. Dinesh Kumar Agarwal, Principal Scientist	Assumed charge as Registrar General, PPV&FRA, New Delhi on deputation basis for a period of five years	w.e.f. 18 May, 2022 (Afternoon)

Promotion

Name	Event	Date
Dr. P. Giribabu, Senior Scientist	Promoted from the post of Senior Scientist (Level 12 – RGP 8000/-) to the post of Senior Scientist (Level 13A – RGP 9000/-)	w.e.f. 26 June, 2020
Dr. C. Anuradha, Senior Scientist	Promoted from the post of Senior Scientist (Level 12 – RGP 8000/-) to the post of Senior Scientist (Level 13A – RGP 9000/-)	w.e.f. 10 February, 2021
Dr. A. Mohanasundaram, Scientist	Promoted from the post of Scientist (Level 11 – RGP 7000/-) to the post of Senior Scientist (Level 12 – RGP 8000/-)	w.e.f. 20 April, 2019
Dr .S. Palanichamy, Chief Technical Officer	Promoted from the post of Assistant Chief Technical Officer to the post of Chief Technical Officer	w.e.f. 18 March, 2022
Dr .P. Ravichamy, Assistant Chief Technical Officer	Promoted from the post of Senior Technical Officer to the post of Assistant Chief Technical Officer	w.e.f. 1 May, 2020
Mr. V. Selvaraj, Senior Technical Officer	Promoted from the post of Technical Officer to the post of Senior Technical Officer	w.e.f. 5 March, 2022
Mr. T. Sekar, Senior Technical Officer	Promoted from the post of Technical Officer to the post of Senior Technical Officer	w.e.f. 10 March, 2022
Mr. K. Kamaraju, Senior Technical Officer	Promoted from the post of Technical Officer to the post of Senior Technical Officer	w.e.f. 10 March, 2022
Mr. V. Manoharan, Technical Officer	Promoted from the post of Senior Technical Assistant to the post of Technical Officer	w.e.f. 18 June, 2022
Mr. R. Neela Mega Shyamala Kannan, Personal Assistant	Promoted from the post of Steno Gr.III to the post of Personal Assistant	w.e.f. 26 April, 2022

TRANSFER / POSTING

Name	Name of the institute already worked	Date
Mr. M. Krishna Murthy, Private Secretary	Transferred to ICAR-CIBA, Chennai as Principal Private Secretary	27 August, 2022
Mr. A. Kaspar, Skilled Supporting Staff	Transferred from ICAR-CARI, Izatnagar, Bareilly, Uttar Pradesh	7 February, 2022

16.2 Staff position

Scientific Staff

Sl. No.	Name	Designation
1	Dr. R. Selvarajan	Director
2	Dr. J. Poorani	Principal Scientist (Entomology)
3	Dr. S. Uma	Principal Scientist (Horticulture)
4	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
5	Dr. M. Mayil Vaganan	Principal Scientist (Plant Biochemistry)
6	Dr. I. Ravi	Principal Scientist (Crop Physiology)
7	Dr. V. Kumar	Principal Scientist (Horticulture)
8	Dr. K.J. Jeyabaskaran	Principal Scientist (Soil Science)
9	Dr. K.N. Shiva	Principal Scientist (Horticulture)
10	Dr. S. Backiyarani	Principal Scientist (Biotechnology)
11	Dr. Dinesh Kumar Agarwal*	Principal Scientist (Plant Breeding)
12	Dr. M.S. Saraswathi	Principal Scientist (Horticulture)
13	Dr. M. Loganathan	Principal Scientist (Plant Pathology)
14	Dr. D. Ramajayam	Principal Scientist (Horticulture)
15	Dr. P. Suresh Kumar	Principal Scientist (Horticulture)
16	Dr. C. Karpagam	Principal Scientist (Agricultural Extension)
17	Dr. P. Giribabu	Senior Scientist (Nematology)
18	Dr. C. Anuradha	Senior Scientist (Biotechnology)
19	Dr. A. Mohanasundaram	Senior Scientist (Agricultural Entomology)
20	Mr. Arjun Singh	Scientist (Agronomy)

*On deputation as 'Registrar General', PPV & FRA, New Delhi

Technical Staff

Sl. No.	Name	Designation
1	Dr. S. Palanichamy	Chief Technical Officer (Lab)
2	Dr. P. Durai	Assistant Chief Technical Officer (Lab)
3	Dr. P. Ravichamy	Assistant Chief Technical Officer (Journalism)
4	Ms. T. Anithasree	Assistant Chief Technical Officer (Lab)
5	Ms. C. Sagayam Jacqueline	Senior Technical Officer (Computer Programmer)
6	Mr. D. Ramachandramurthi	Senior Technical Officer (Civil Overseer)
7	Mr. V. Selvaraj	Senior Technical Officer (Field)

8	Mr. T. Sekar	Senior Technical Officer (Lab)
9	Mr. K. Kamaraju	Senior Technical Officer (Lab)
10	Mr. R. Pitchaimuthu	Technical Officer (Field)
12	Mr. N. Marimuthu	Technical Officer (Lab)
13	Mr. M. Bathrinath	Technical Officer (Field)
14	Mr. V. Manoharan	Technical Officer (Driver)

Administrative, Audits & Accounts and Supporting Staff

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

Dr. R. Selvarajan assumed the charge of Director, ICAR-NRCB, Tiruchirappalli, Tamil Nadu on 8 December, 2022

17. OTHER INFORMATION

Republic Day celebration

The 73rd Republic Day was celebrated at the centre on 26 January, 2022 with flag hoisting by Dr. S. Uma, Director and sweets were distributed. In her Republic Day address to the staff, she appreciated the scientists and staff for the achievements made by the centre during 2021. She urged everyone to work hard to scale new heights in their endeavours. All staff of the centre, students and public from the nearby villages took active participation in the celebration.

Director, ICAR-NRCB hoisting National flag during Republic Day celebration

Independence Day celebration

India's 76th Independence Day was celebrated on 15 August, 2022 at Institute premises with enthusiasm and Nationalistic fervour. Dr. S. Uma, Director, ICAR-NRCB hoisted the National flag and delivered the Independence Day address. Sweets were distributed.

Independence Day celebration at ICAR-NRCB

Anti-Terrorism Day

ICAR-NRCB observed **'Anti-Terrorism Day'** on 21 May, 2022 with an objective to **wean away the youth from terrorism and the cult of violence** by highlighting the sufferings of common people and show as to how it is prejudicial to the National interest. On the occasion, the staff of the centre took **'Anti-terrorism pledge'.**

International Yoga Day celebration

Eighth International Yoga Day was celebrated at ICAR-NRCB on 21 June, 2022. On the occasion, Mr. T. Navaneetha Krishnan, PG Diploma (Yoga), M.Sc. (Yoga) delivered a guest lecture and gave training by doing different '*asanas*'.

Staff of ICAR-NRCB celebrates International Yoga Day by practicing different '*asanas*'

ICAR-NRCB and *Vidyarthi Vigyan Manthan* felicitated winners of 'Science Competition'

As part of the 75th India's independence celebrations, ICAR-NRCB and *Vidyarthi Vigyan Manthan* jointly organized an award ceremony for the winners of the science competition held for school children on 6 April, 2022 at the centre. *Vidyarthi Vigyan Manthan* conducted state level online science talent search examination for school students of Tamil Nadu and Puducherry during the month of November and December 2021. A total number of 10,480 students participated in the competition, of which 55 students got selected and declared as winners. During prize distributing ceremony, Dr. S. Uma, Director, ICAR-NRCB congratulated the prize winners and gave cash prize, certificate and memento to the winners. Inaugural address was delivered by Dr. P. Sabanayaham, Tamil Nadu State

Secretary, *Vijnanabharati*. Prof. J. Jeyakanthan, Head, Dept. of Bioinformatics, Alagappa University, Karaikudi, Tamil Nadu delivered thematic address. Welcome address was given by Dr. C. Karpagam, Principal Scientist, ICAR-NRCB and Dr. P. Boomi, Assistant Professor, Dept. of Bioinformatics, Alagappa University, Karaikudi, Tamil Nadu proposed vote of thanks. The event was arranged by Mr. Gopal Parthasarathy, State Co-coordinator, *Vijnanabharati*.

Distribution of certificates to the winners of science competition organized by *Vidyarthi Vigyan Manthan* during award ceremony held at ICAR-NRCB

ICAR South Zone Sports Meet 2022

ICAR Sports Meet, 2022 for South zone was held in Hyderabad during 22-25 November, 2022. Staff of ICAR-NRCB actively participated in the sports event with highest number of sports contingents ever including women contingents for the first time from the centre.

Visit of Minister, Govt. of Karnataka to ICAR-NRCB

Mr. Shankar B. Patil Munenakoppa, Hon'ble Minister for Handloom and Textile, Sugar Cane Development, Govt. of Karnataka and his team of officials visited ICAR-NRCB on 21July, 2022. The Hon'ble Minister had an interactive session with the scientists and visited research farm and laboratories.

Mr. Shankar B. Patil Munenakoppa, Hon'ble Minister for Handloom and Textile, Sugar Cane Development, Govt. of Karnataka and his team with Director, ICAR-NRCB

Team NRCB at ICAR Sports Meet 2022 for South zone held in Hyderabad during 22-25 November, 2022

18. SUCCESS STORY

Export of red banana fruits to Austria

Ethnic varieties of India like Ney Poovan, Red Banana, Poovan, Nendran and Rasthali offer a greater export market in other countries. Expert team comprising Drs. S. Uma, R. Thangavelu, V. Kumar, K.N. Shiva and P. Suresh Kumar, ICAR-NRCB, in association with APEDA, New Delhi and TNBGF, Thottiyam, Tamil Nadu joined together for export of red banana fruits to Austria.

On 15 March, 2022, Scientists of ICAR-NRCB visited banana fields located in Theni, Tamil Nadu and selected disease free farms and tagged the ideal bunches with right maturity and color. The bunches were carefully harvested and brought to pack house for further operations *viz*., washing, grading, sorting, weighing and vacuum pulled packing (10.5 kg net weight). About 1068 Kgs of packed cartons were airlifted from Bangalore after undergoing the Phytosanitary inspection at Innova agri-bio park, Bangalore. The fruits reached Vienna, Austria by air on 18 March, 2022 and were collected by a refrigerated truck and transported to ripening chambers. The ripened fruits were inspected by importers on 26 March, 2022 and certified as extremely colorful and disease free, without injuries. It was by far the best ever quality of fruits imported by them.

Development of protocol for successful export of red banana fruits from India to Austria *via* air by ICAR-NRCB

ANNEXURE – I

I. Institute projects

Name of the Project	Principal Investigator
Crop Improvement	
Improvement and management of banana genetic resources in the Indian subcontinent	S. Uma
Improvement of banana through conventional breeding	S. Backiyarani
Development of trait specific markers for *Fusarium* wilt resistance through association mapping studies in banana (*Musa* spp.)	M.S. Saraswathi
Improvement of cv. Grande Naine (Cavendish – AAA) for *Fusarium* wilt resistance through non-conventional breeding	M.S. Saraswathi
Production of doubled haploids for improvement of bananas (*Musa* spp.)	D. Ramajayam
Identification and evaluation of superior clones of cv. Ney Poovan (AB) and Grand Naine (AAA)	D. Ramajayam
Identification of resistant gene candidate(s) in banana for race1and tropical race 4 of *Fusarium oxysporum* f.sp. *cubense*	C. Anuradha
Crop Production & Post Harvest Technology	
Studies on nutrient dynamics in banana	K.J. Jeyabaskaran
Organic banana farming for sustainable soil health and nutritional security	K.J. Jeyabaskaran
Developing agro-techniques for ICAR-NRCB released varieties and selections	K.J. Jeyabaskaran
Development of clump management technology for enhanced productivity in banana	V. Kumar
Development of pre- and post-harvest techniques for leaf production in banana	K.N. Shiva
Developing integrated package of practices for export of selected commercial and GI tagged varieties of Indian bananas	K.N. Shiva
Novel smart delivery systems for developing high value nutraceutical foods using banana and exploring non-food applications	P. Suresh Kumar
Effective utilization of different extension methods and mass media for holistic transfer of banana technologies for different stakeholders in banana production system	C. Karpagam
Physiology & Biochemistry	
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
Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower	M. MayilVaganan
Crop Protection	
Pest mapping in bananas and plantains of India	J. Poorani

Eco-friendly management of banana pseudostem weevil (*Odoiporuslongicollis* Olivier) and banana scarring beetle (*Basilepta* spp.)	A. Mohanasundaram
Integrated management of Tropical race 4 of *Fusarium* wilt disease in banana	R. Thangavelu
Survey, etiology and management of rhizome rot of banana	M. Loganathan
Management of postharvest diseases of banana	M. Loganathan
Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan
Investigations on *Musa* nematode's diversity, biology, behavior, interactions and its management	P. Giribabu

II. ICAR funded projects

Name of the Project	Principal and Co-Investigator(s)
Network Project on Precision Agriculture	I. Ravi R. Selvarajan K.J. Jeyabaskaran P. Suresh Kumar
Establishment of Agri-Business Incubation Centre under ICAR-National Agriculture Innovation Fund (Component – II)	K.N.Shiva P. Suresh Kumar V. Kumar, K.J. Jeyabaskaran D. Ramajayam
Utilization of banana wastes for the development of symbiotic& designer foods through pre & pro-biotic approaches and to enhance the farmers income (ICAR-LBSOYSA)	P. Suresh Kumar
Developing of post-harvest handling and sensor based smart packaging methods for the export of traditional banana varieties and nano-strip based digital health monitoring of banana (ICAR-NASF)	P. Suresh Kumar K.N. Shiva V. Kumar R. Thangavelu S. Uma
Integrated management of Fusarium wilt, Tropical race 4 – A devastating strain on banana	R. Thangavelu M. Loganathan C. Anuradha S. Uma
Development and utilization of diagnostics to viruses of banana under Consortium research platform on vaccines and diagnostics	R. Selvarajan C. Anuradha

III. Projects funded by other agencies

Name of the Project	Principal and Co-Investigator(s)
Bioversity International – IITA funded project	
Improvement of Banana for Smallholder Farmers in The Great Lakes Region of Africa - Enhancing Banana Production by Developing Fusarium Wilt-Resistant Varieties and Benefit Sharing with African Smallholder	S. Uma S. Backiyarani R. Thangavelu M.S. Saraswathi R. Thangavelu
DBT-QUT funded project	
Biofortification and development of disease resistance in Banana	
Component - 1: Transfer and evaluation of Indian banana with pro Vitamin A (PVA) constructs	S. Backiyarani S. Uma M. MayilVaganan
Component - 2: Transfer and evaluation of Indian banana with Iron constructs	M. MayilVaganan I. Ravi K.J. Jeyabaskaran
PPV & FRA fundedproject	
Framing crop specific DUS guidelines for banana (*Musa* spp.)	S. Uma M.S. Saraswathi S. Backiyarani
BRNSfunded project	
High-throughput screening for induced mutations in banana cv. Grand Naine (AAA) with Fusarium wilt (TR4) resistance	M.S. Saraswathi S. Uma R. Thangavelu S. Backiyarani
DST fundedproject	
A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.) (DST-SERB)	C. Anuradha
Development of efficient IOT enabled plant disease pest detection system	R. Selvarajan R. Thangavelu J. Poorani
DBT funded project	
'Banana Shakti' Nano formulations – Effective delivery system of the micronutrient mixture for improved banana cultivation	K.J. Jeyabaskaran D. Ramajayam
CGIAR/Bioversity International funded projects	
Conservation and use of Genetic Resource – Evaluation of ITC Genotypes for their reaction to FoC R1 and TR4	R. Thangavelu S. Backiyarani
Status of adoption behaviour of ITC accessions in India under the Banana production system and the constraint analysis in the dissemination process – An analytical study	C. Karpagam
DAC & F W, Govt. of Indiafunded project	

Sub Mission on Agricultural Mechanisation (SMAM) for implementation of its component no.1 under Drone Technology Demonstration	C. Karpagam M. Loganathan I. Ravi K.J. Jeyabaskaran
NABARD funded projects	
Design development and validation of online banana trading platform for farmers of FPOs in Trichy District	D. Ramajayam R. Selvarajan K.J. Jeyabaskaran P. Suresh Kumar
Establishment of banana macropropagation units in Tiruchirappalli District, capacity building and improvement of livelihood opportunities of farmers	S. Uma R. Karthic S. Backiyarani M.S. Saraswathi
Establishment of Common Incubation Centre. PMFME scheme.	P. Suresh Kumar K. N. Shiva

IV. Consultancy project

Name of the Project	Funding Source	Principal Investigators
Production of Sabri plantlets through Embryogenic cell suspension culture	HRC, Nagichera	S. Uma S. Backiyarani M.S. Saraswathi

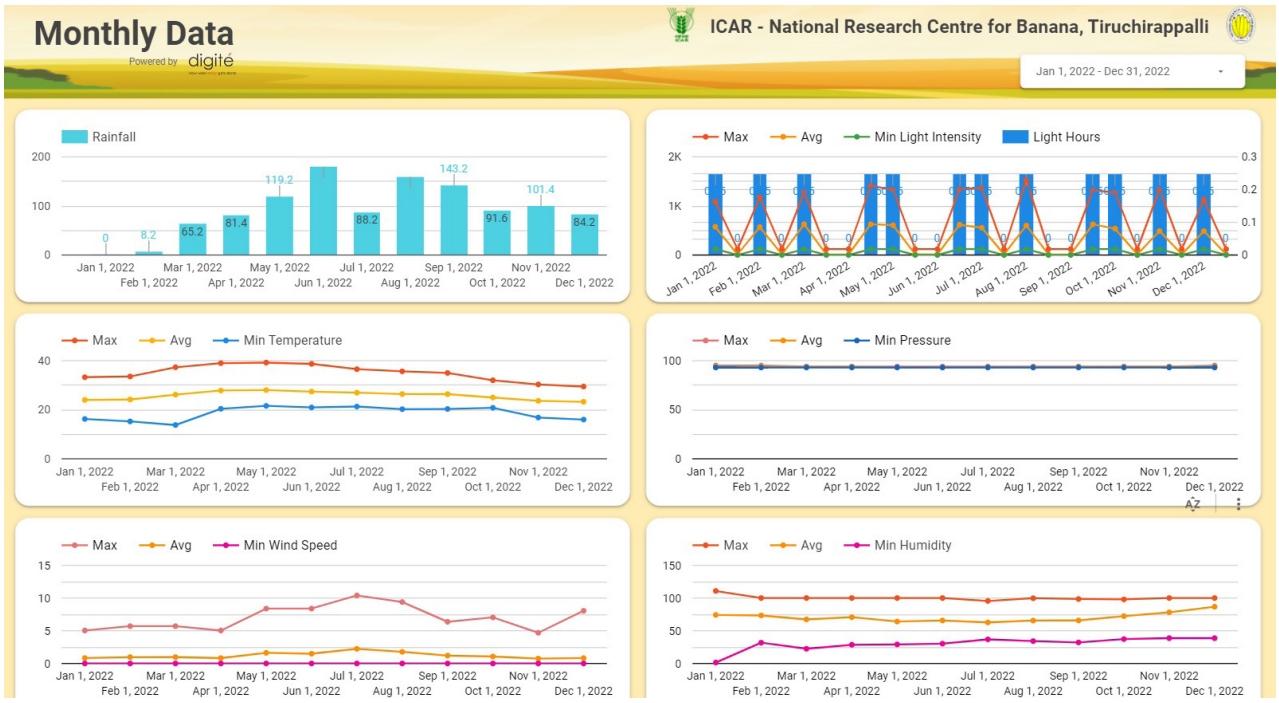
I. Contract research project

Name of the Project	Funding Source	Principal Investigator
Macro-propagation Technology	Shri. Jayeshbhai Nathubhai Patel, JARVI Nursery, Gujarat	S. Backiyarani
Evaluation of efficacy of Poly4 (Polyhalite) on banana as source of potassium and secondary nutrients	Anglo Americans Crop Nutrients India Private Limited, New Delhi	K.J. Jeyabaskaran
Evaluation of efficacy of Potassium Schoenite on banana as potassium source	Gujarat Boron Derivatives Pvt. Ltd., Baroda, Gujarat	K.J. Jeyabaskaran
Study on the efficacy of an automated irrigation and fertigation solution using Internet of Things (IoT) enabled sensors and satellite imaging to optimize yield and quality of Grand Nain banana in Karnataka – Phase -I	Digite Infotech Pvt. LtdCentral MIDC Road, Opposite SEEPZ, Andheri East, Mumbai, Maharashtra	I. Ravi

ANNEXURE – II

METEOROLOGICAL DATA

Months / Year	ETᵒ	Min. Temp (ºC)	Max. Temp (ºC)	Rainfall (mm)	Min. RH (%)	Max. RH (%)	Wind speed (Km / hr)	Sunshine (hrs)	Mean Pressure
Jan-22	4.05	20.66	28.94	0.00	41.82	95.48	1.09	8.88	94.00
Feb-22	4.35	18.71	30.20	8.20	41.24	99.88	0.98	9.46	93.97
Mar-22	5.13	20.00	33.79	65.20	33.97	98.58	0.98	9.83	93.82
Apr-22	5.44	22.59	35.23	81.40	38.44	98.24	0.83	10.02	93.74
May-22	5.97	23.04	35.22	119.20	38.86	88.61	1.64	10.02	93.25
Jun-22	5.80	22.64	34.31	180.20	40.44	88.49	1.51	10.39	93.28
Jul-22	6.16	23.24	32.70	88.20	43.74	78.49	2.26	10.22	93.30
Aug-22	5.72	22.39	32.23	159.80	46.81	82.95	1.84	9.87	93.30
Sep-22	5.31	21.93	32.35	143.20	46.47	83.73	1.22	9.92	93.60
Oct-22	4.51	21.79	30.00	91.60	53.83	88.84	1.04	9.28	93.80
Nov-22	3.71	20.55	28.01	101.40	57.01	96.20	0.76	8.80	93.97
Dec-22	3.42	20.16	27.28	84.20	64.17	99.09	0.84	8.56	93.94
				1122.60					



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किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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