वार्षिक प्रतिवेदन
Annual Report 2021

Indian Council of Agricultural Research

National Award of Excellence for Agricultural Institutions

SARDAR PATEL OUTSTANDING
ICAR INSTITUTION AWARD 2020
(Small Institute)

is presented to

ICAR–National Research Centre for Banana
Tiruchirapally

16 July, 2021
New Delhi

(T. Mohapatra)
Secretary (DARE)
Director General (ICAR)

(Narendra Singh Tomar)
Union Minister of Agriculture & Farmers Welfare
Govt. of India

भाकृअनुप – राष्ट्रीय केला अनुसंधान केंद्र

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

(ISO 9001:2015 Certified Institute)

वार्षिक प्रतिवेदन
ANNUAL REPORT
2021

भाकृअनुप
ICAR

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र
(भारतीय कृषि अनुसंधान परिषद)
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ICAR-NATIONAL RESEARCH CENTRE FOR BANANA
(Indian Council of Agricultural Research)
Thayanur Post, Thogamalai Road, Tiruchirappalli - 620 102, Tamil Nadu, India

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PREFACE

In the year gone by, the ICAR-NRCB scaled new heights and made significant achievements in research and outreach in spite of the difficulties faced due to the second wave of Covid-19. I am glad to mention that it was a momentous year for the ICAR-NRCB as the recipient of the prestigious Sardar Patel Outstanding ICAR Institution Award 2020 in the category of small Institutes. This outstanding feat could not have been achieved but for the encouragement and support received from the DG, DDG (Hort. Science), ADGs (Hort. Science), ICAR, New Delhi, and the hard work and contributions of the scientists, technical, administrative and other staff of ICAR-NRCB.

Significant research milestones in the Crop Improvement Section include: identification of promising ITC accessions resistant to Fusarium wilt, race 1 and elite clones, *viz*. NRCB selection 15 (for dwarfness) and 16 (high beta carotenoid content); evaluation of mineral composition of 121 banana cultivars and identification of suitable cultivars for different mineral requirements; field evaluation of NRCB selection 18, *etc*. Other significant research strides include the development of ICT tools for banana hybridization program, development of Fusarium wilt resistant Grand Nain mutant and identification of markers associated with Fusarium wilt, anthocyanin pigments, *etc*.

In the Crop Production Section and Post-Harvest Technology Section, nutrient dynamics were worked out for cvs. Grand Naine and Nendran. Agro-techniques were developed for the newly released cultivars. In clump management studies, mother plants with four suckers gave significantly higher yield. Cultivars with high yield potential for leaf industry were identified. Banana starch and its physical and chemical properties were quantified. Biofilms were prepared and evaluated. Drought resistant / tolerant cultivars and drought mitigating chemicals were identified. Anthocyanin profiling and quantification was done for a few north-eastern banana cultivars. Flavonoids of fruit pulp and fructans of banana were evaluated and identified. Transgenic banana with iron rich events were identified and multiplied.

In the Crop Protection Section, significant achievements during 2021 include the identification and documentation of seven new insect pests of banana and four active predators of banana aphids and deposition of 50 entomofungal pathogen cultures at ICAR-NBAIM, Mau, U.P. Race pattern of Fusarium wilt in five districts of Tamil Nadu was studied. Promising phosphate solubilising bacterial isolates were identified. An economical, rapid method of mass production of *Trichoderma* spp. in rice gruel medium was developed. Novel markers were developed for early detection and monitoring of virulent strains of *Foc*STR4. Effective biocontrol agents against Fusarium wilt Race 4 were identified based on field evaluation. Effective isolates of biocontrol agents to post-harvest diseases and potential PGPR isolates were identified and formulated. About 85 germplasm accessions were screened for BBTV. A triple antibody sandwich ELISA (TAS-ELISA) was standardized and validated against BBrMV and CMV and a TAS-ELISA kit was developed. In Nematology, hybrids resistant to root-lesion nematodes were identified. Application of salicylic acid was found effective against root-lesion nematode and Zimmu leaf extract was effective against both root-lesion and root-knot nematodes under *in vitro*.

In a first of its kind, the Centre came up with a sea shipment protocol during 2021 that enabled the successful export of Nendran bananas to the United Kingdom *via* sea route. The Centre established research collaborations with IIITDM, Kancheepuram for effective utilization and value addition of banana pseudostem fibre and MoA / MoU / MoCs were signed with 12 research institutes / colleges / private companies for research collaborations and student exchange. Totally 28 training programs for banana stakeholders were organized and lectures and demonstration of technologies via radio and television programs reached a large audience. As many as 23 peer reviewed research papers were published in high impact factor journals.

I sincerely thank Dr. T. Mohapatra, Secretary-DARE and Director General, ICAR, for his valuable guidance and support. I profusely thank Dr. A. K. Singh, Deputy Director General (Hort. Sci.), ICAR, New Delhi, for his inspiring and constant encouragement. Our thanks are also due to Drs. V. Pandey and B. K. Pandey, I/c Assistant Director Generals (Hort. Science), ICAR, for their untiring support and guidance. Sincere thanks are due to the staff members of SMD (Hort. Science) for the continuous support and cooperation extended to ICAR-NRCB. 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 at this difficult time.

(S.Uma)

2. 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. The Indian Council of Agricultural Research has recognized the services of the Centre and conferred the prestigious 'Sardar Patel Outstanding ICAR Institution Award 2020' to NRCB in the category of small Institutes.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 11.50ºN 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 35ºC, 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 2021, the Centre developed a sea shipment protocol that enabled the successful export of Nendran bananas to the United Kingdom.The Centre has established research collaborations with IIITDM, Kancheepuram for effective utilization and value addition of banana pseudostem fibre and signed MoA / MoU / MoCs with 12 research institutes / colleges / private companies for research collaborations and student exchange. The Centre organized 28 training programs for banana stakeholders and lectures were delivered and technologies demonstrated by effective use of mass media like radio and television. As many as 23 peer reviewed research papers were published in high impact factor journals.

The Centre has 23 in-house research projects and 34 externally funded projects funded by various agencies like ICAR, DBT, PPV&FRA, DAE, DST, NABARD, Bioversity International, Gates Foundation etc.The Centre periodically conducts Institute Research Council meets 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.

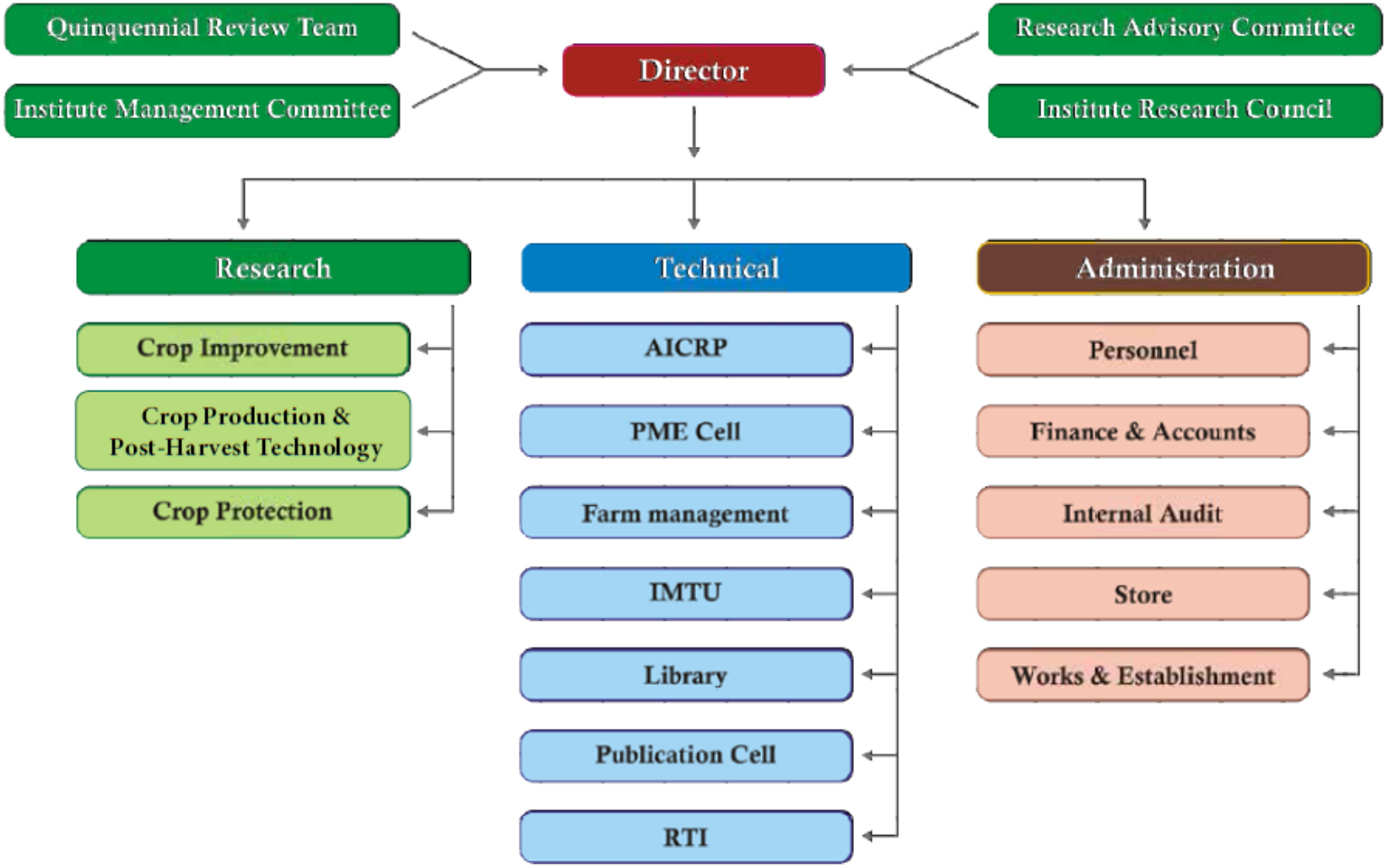
Mandate

- 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 the year 2021-2022	
Head of account	Expenditure (up to 31 January, 2022)
Equipment	7
Library	
Establishment	874.01
OTA	0.08
TA	3.99
Research Expenses	39.76
Operational Expenses	122.17
Infrastructure	96.12
Communication	5.53
Repair of equipment, Vehicle, etc.	18.02
Office building	34.35
Residential building	17.89
Other admin. (Other TA)	12.76
Publicity & Exhibition	0.66
HRD	0.83
Miscellaneous	7.71
Pension& Retirement	15.13
P Loans & advances	0.5
Total	1256.51
TSP-Capital	1.21
SCSP- Capital	5.6
SCSP-General	60.66
Grand Total	1323.98

A revenue of Rs. 23, 04, 820/- was generated by the centre during January–December, 2021.

Organizational Setup of ICAR-NRC for Banana



Crop Improvement

During 2021, six accessions were collected from primary and secondary sources and added to the gene bank. Morpho-taxonomic characterization was done for three accessions using IPGRI *Musa* descriptor leading to the identification of genomic and subgroups. The centre has registered five improved genetic stocks with ICAR-NBPGR, New Delhi. About 121 commercially cultivated Indian cultivars were analyzed for nine minerals using ICP-OES. The results indicated that consumption of 100 g of banana pulp can contribute fairly to the daily requirement of Mn > Ca > Mg > Fe > Zn > K > Na and > P in the ascending order in Indian adults (men and women with sedentary/moderate/ heavy physical activity) according to the revised RDA (Recommended dietary allowances) / AI (Adequate intake) values notified by the ICMR. Field evaluation of the ITC and other exotic accessions at ICAR-NRCB has led to the identification of three promising accessions with resistance to Fusarium wilt race 1, *viz.* ITC 1307, 1437 and IITA 75. Mass multiplication and evaluation of ITC accessions led to the selection of elite clones for dwarfness (NRCB selection 15), high beta carotenoid (NRCB selection 16) and high yield with Foc race 1 resistance (NRCB selection 17).

The performance of NRCB selection 18 (Progeny No. 959) was stable with an average yield of 23.5kg/bunch for three consecutive years and it has better cooking quality than Kaveri Saba and Monthan. 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) exhibited resistance for pseudostem weevil and Foc race 1. One open pollinated (OP) progeny of Namwakhom was found to be dwarf with a mini bunch which could be exploited commercially for its suitability to terrace garden and aesthetic value. ICT tools have been developed for the effective management of Banana Genetic Resources and Hybridization Programme. Inter-specific ornamental banana hybrids have been developed and are being evaluated in 12 centers under the ICAR-AICRP on Floriculture.

NRCBGNMG 1, a Grand Nain mutant derived from Gamma irradiated ECS (35 Gy), which was resistant to Foc race-1 (with a disease score 1.08) in pot culture and sick plot conditions, was further multiplied and evaluated in the hotspots of Theni, Tamil Nadu and results indicated that they yielded better than cv. Grand Nain. Elite clonal selections of cv. Grand Nain for dwarfness and high yield were mass multiplied and are being evaluated in the farmers' fields for the stability of these specific, desirable traits.

Analysis of the transcriptome data for Foc race 1 and TR4 is in progress. Expression studies of MaPR-1 genes in banana revealed their role in biotic and abiotic stresses in general and Fusarium wilt in particular. Genic SSR markers for Foc race 1 and TR4 have been developed and validated. A genic SSR marker associated with anthocyanin pigment was identified and validated in Red banana, Sannachenkadali, Chenkadali, *M. acuminata* ssp. *zebrina*, *M. ornata*, *M. rubra* and F1 population of *M. ornata* and *M.acuminata* ssp. *zebrina* and it differentiated the purple from the green bananas.

In vitro regeneration protocols have been standardized for recalcitrant varieties like Poovan, Rasthali, Red Banana, Ney poovan, cv. Rose, Williams, etc. Around 1127 tissue cultured plants and 5300 suckers of varieties have been supplied to banana growers. About 431 batches of tissue cultured cvs. Grande Nain, Nendran, Karpuravalli, Red Banana, and Ney Poovan were tested for their genetic fidelity using ISSR markers and reports issued, generating a revenue of Rs. 12.72 lakhs to the Institute.

During the growth period of 5-leaf stage to 20-leaf stage, the total dry matter production (t/ha) in cv. Nendran increased from 2.31 to 12.86, while in cv. Grand Nain, it increased from 2.35 to 10.64. The nutrients uptake (kg/ha) in Nendran and Grand Nain followed different paths depending on the nutrient with N increased from 22.5 to 233.57 gradually with increasing rate in Nendran and in Grand Nain, the N uptake increased steadily from 21.59 to 119.85. The nutrient uptake in 5-leaf and 10-leaf stages in organic banana farming was highest in 100% inorganic fertilizer and lowest was in absolute control in 5-leaf stage and highest was in poultry manure @ 5 kg/pl + groundnut cake @ 1 kg/pl + rural compost @ 3 kg/pl + wood ash @ 3 kg/pl) in 10-leaf stage.

In developing agro-techniques for ICAR-NRCB released varieties and selections, the phyllochron was more in 200:30:400 g (F2) NPK level than in 200:30:300 g NPK (F1) level at all the plant densities from 10-leaf stage onwards in Kaveri Saba. In Kaveri Harita, the phyllochron was higher with F1 in S1 density planting than in S2 density till 10-leaf stage and then it was in reverse from 15-leaf stage onwards. In Popoulu, higher the levels of fertilizers, higher the phyllochron at 5-leaf stage and the reverse was true from 10-leaf stage onwards, irrespective of planting densities and in Kaveri Kalki, F2 recorded higher phyllochrons than F1 during 5-leaf stage to 15-leaf stage, irrespective of planting densities.

In clump management of Ney Poovan, mother plant with four suckers (S4) recorded the longest total clump duration of 595.6 days with highest bunch weight of 42.1 kg and a total yield of 73.2 t/ha. In Poovan also, S4 recorded the longest clump duration of 643.6 days, and highest bunch weight of 69.2 kg per clump with a total fruit yield of 96.2 t/ha. Comparing the three levels of the nutrition in terms of total bunch weight (kg/clump) and total yield (t/ha), 175% RDF was comparable with 150% RDF in both Ney Poovan and Poovan In both cultivars., highest BC ratio of 3.64 and 2.81 were respectively recorded for S4. The 125% RDF per clump recorded the highest microbial population both at flowering and harvesting stages.

In experiment for evaluation of ornamental banana hybrids under field and pot culture conditions, the initial trend showed that 3 suckers with 66% RDF is the best performing treatment combination in field and shade net with light of 3000 to 6000 Lux and 30% of RDF performed better in pots.

Among Poovan, Karpuravalli, Sakkai, Phirima wild and Progeny 183 evaluated for leaf production, Karpuravalli produced the maximum number of leaves (5.00) while Phirima wild (3.88) produced minimum number of leaves. Total chlorophyll content in leaves varied from 5.40 mg/g in Karpuravalli to 12.43 mg/g in Progeny 183. Maximum side suckers were produced by Karpuravalli (3.48), followed by Poovan (3.13). Studies of leaf production in Naadu, Poovan and Karpuravalli based on different number of suckers showed maximum number of leaves was obtained in 1+5 (mother plant + number of suckers) combination in all varieties with 13.15, 12.63 and 13.01 respectively. Naadu recorded highest leaf area of 0.97 m^2 while Karpuravalli recorded lowest leaf thickness of 0.27 mm and Naadu recorded the highest total chlorophyll content of 10.51 mg/g.

Acid thinning and oxidation modification of starch powders significantly increased the lightness when compared with native banana starch and light transmittance was found to increase initially, but decreased for all the modified starches as the storage days increased. Swelling power increased with increase in temperature for all types of modification. Biofilms were prepared from biological materials for protecting food products and extending their shelf life. Edible films were also developed using starch and additives such as carrageenan gum, CMC, gum Arabica, gum tragacanth.

In physiology, the field evaluation of 53 banana genotypes belonging to different genomes against soil moisture deficit stress at floral primordial initiation stage showed significant reduction of plant height and girth by 12.34 to 29.67% in all genotypes and increased the duration of flowering by 17.50 - 42.05 days. ABB genotypes, Nendran and Rasthali and AAA genotypes, Leyan and Lacatan were found susceptible with maximum yield reduction by 35%. By biochemical indicators, *Musa balbisiana*, Bhimkol, Manohar and Paglapahad Wild-2 of BB genome recorded better drought tolerance. Testing germination of some banana genotypes, Grand Nain failed to germinate whereas Kaveri Saba and Karpuravalli germinated and grew well. Foliar application of 50 mM sodium silicate before imposition of drought recorded higher RWC, leaf pigments and osmolytes.

In biochemistry, profiling and quantification of anthocyanins from flower bracts of ten banana cultivars of North Eastern India showed 5-6 anthocyanin compounds. In Suti Jahaji, Gobin Tulci and Vennutmannan, cyanidin was the predominant compound whereas in Borkal Baista, Bharatmoni and Kaithkullung, pelargonidin was the major compound. Assessing nutraceutical potential of anthocyanins of flower bracts of fifteen commercial banana varieties using TEAC and ORAC assays showed Monthan (ABB), Saba (ABB), Udhayam (ABB) and Popoulu (AAB) exhibited higher antioxidant activity commensurate with cyanidin contents.

Gallocatechin was the predominant flavonoid compound in fruit pulp of bananas. Among the commercial bananas, Monthan (ABB), Karpooravalli (ABB), Udhayam (ABB) and Saba (ABB) contained high amounts of gallocatechin of around 45, 42 and 39 mg/100 g pulp. In assessment of nutraceutical potential of flavonoids from fruit pulp, the high gallocatechin containing banana cultivars, Monthan (ABB), Karpooravalli (ABB), Udhayam (ABB) and Saba (ABB) showed higher levels of antioxidant activities of around 95.0 µmol TE / 100 g. Monthan, Nendran and Udhayam possessed higher levels of fructans in both pulp and peel and fructans in pulp of these varieties was more than 180 µg/g. Extraction and estimation of alpha-tocopherol from banana leaf was standardized with retention time of 5.5 min in HPLC. In transgenic development, five elite iron Grand Nain events with *Os*NAS1 and 2 genes with more than six-times higher iron mineral content in fruit were multiplied through shoot tip culture using sword suckers and a total of 150 plants of the five elite events are generated.

Crop Protection

Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi, a recently reported exotic invasive pest in India, was recorded on banana from Karur and Trichy districts of Tamil Nadu. All the life stages were found on banana and the extent of damage was low. *Spodoptera exigua, Simplicia cornicalis, Gesonula punctifrons, Atractomorpha crenulata*, *Zeugodacus cucurbitae*, and *Rastrococcus invadens* were recorded as new pests of banana. Larvae of mango looper, *Perixera illepidaria* and coconut defoliator, *Phalacra vidhisara,* were found to migrate to banana for pupation in large numbers but did not feed on banana.

Three coccinellids (*Cheilomenes sexmaculata*, *Pseudaspidimerus trinotatus*, and *Scymnus nubilus*) and one brown lacewing (*Micromus timidus*) were found to be active predators of banana aphid in the field during winter. The biology of *S. nubilus*, the most efficient predator, was studied in the laboratory. There were four larval instars and the total development from egg to adult emergence took 15–19 days. The egg, larval, prepupal and pupal period lasted 4.5±0.53, 7.88±0.88, 1.50±0.46 and 3.0±0.76 days, respectively. About 50 cultures of entomofungal pathogens were deposited in NBAIIM, Mau, for obtaining accession numbers.

Fusarium wilt infected rhizome samples from five districts of Tamil Nadu (Kanyakumari, Tirunelveli, Tuticorin, Tiruchirapalli and Namakkal) were studied and VCG groups identified. Two potential phosphate solubilizing bacteria, *Enterobacter hormaechii* ssp. S*akuensis* (PSB52) and *Leclercia decarboxylata* (PSB54), were field evaluated in cv. Ney Poovan. Combined application of two nutrient solubilizing bacteria along with rock phosphate enhanced the activity of alkaline phosphatase enzyme by 300–500% over control. An economical, rapid method of mass production of *Trichoderma* spp. in rice gruel medium was developed and 50 kg of formulation sufficient to apply on one acre of banana could be produced within 3-5 days at a low cost of Rs.10.

Novel markers were developed for early detection and monitoring of virulent strains of *Foc*STR4. Field trials using three consortia of bioagents were done for the management of Fusarium wilt (TR4) on cv. Grand Nain in Siswabazar of Maharajganj district in Uttar Pradesh. *Bacillus flexus* (TVPr1) + rhi. *Trichoderma* spp. (NRCB3) was found to be the best.

One rhizospheric and seven endophytic bacterial isolates were evaluated against *Foc* TR4 in cv. Grand Nain under glasshouse conditions. After 3 months, the endophytic *Bacillus subtilis* ssp. *spizizenii* (T4) recorded the lowest disease score as against the *Foc* TR4 alone inoculated plants. In a similar study using six rhizospheric and one endophytic *Trichoderma* spp. isolates, rhizospheric *T. asperellum* (NRCB3) (T3) recorded the lowest disease score. All the bioagents significantly increased the biometric attributes. Similar evaluation of a combination of effective bacterial and fungal isolates of endophytic and rhizospheric origin revealed that the treatment (T6) with rhizospheric *T. asperellum* (NRCB3) in combination totally suppressed the disease and significantly increased the plant growth.

In vitro evaluation of fungal and bacterial biocontrol agents of endophytic and rhizhospheric origin, principal compounds extracted from *Trichoderma* and Zimmu against postharvest diseases (*Lasiodiplodia theobromae* and *Colletotrichum musae*) indicated that rhiz. *Trichoderma* spp. (NRCB3) and *T. harzianum* were effective against *C. musae,* the principal compound 3 from Zimmu was most effective against both, but none was effective against *L. theobromae*. *In vitro* testing of PGPR, Actinobacteria and fungicides recommended for Fusarium wilt and leaf spot against *L. theobromae* and *C. musae* showed significant levels of inhibition of both, with two actinobacteria (Act 16 and Act 10) against *C. musae* and PGPR (H8BC1, H7BC2 and H6BC2) against *L. theobromae* causing the maximum inhibition. All the fungicides inhibited *L. theobromae* at significant levels.

Molecular characterization of three rhizome rot isolates (NPK-3-48, GTC-5 and 1-1B-3) obtained from Ney Poovan, Grand Nain and Thellachakkarakeli was done by PCR amplification of the beta-subunit of RNA polymerase gene (*rpo*B) and their identity was confirmed as *K. variicola*.

Microencapsulated formulations of four PGPR isolates (H4BC1, H6BC2, H6BC3 and H7BC2) were found to have the desired CFU but enhanced growth of the seedlings was achieved only with H6BC3 and H7 BC. Among eight PGPR isolates evaluated on cv. Grand Nain during primary hardening stage using soilless medium, all isolates except BCB 2-4 enhanced the growth of the seedlings within a month, with H7BC2 and H8BC2 proving to be better than the rest. Among 28 Actinobacteria studied, Act 15 and Act 14 could decompose banana waste material at a faster rate.

Diploid germplasm accessions (26 AA diploids, 36 BB diploids and 23 AB diploids) were screened for resistance to BBTV. A triple antibody sandwich ELISA (TAS-ELISA) was standardized and validated using field samples

against BBrMV and CMV and a TAS-ELISA kit was developed using two antisera. To detect and characterize the virus infecting banana and tomato, MinION sequencing approach was used and dual infection was recorded in banana. Complete genomes of BBrMV, CMV, and TSWV were detected and characterized.

In rapid screening of *Musa* genotypes based on dead roots to total roots ratio and root-lesion index, Kunnan (AA), Karthobiumtham (ABB), and *Musa balbisiana* (BB) were found resistant and Anaikomban (AA) was susceptible. Cvs. Kaveri Saba and Kaveri Kalki were found to be moderately resistant to root-knot nematode. In pot culture, foliar application of salicylic acid @ 200 and 500µM concentration at 24hrs prior to inoculation of root-lesion nematode on tissue cultured cv. Grand Nain reduced the root population by 72 and 60%, respectively, over control after 3 months. Zimmu leaf extract caused > 90% mortality of root-lesion and root-knot nematodes *in vitro* at or above 50% concentration at 48hrs and 72hrs of exposure. Sampling on NRCB hybrids showed progeny NPL 30 and 115 as resistant to root-lesion nematode.

An automatic disease identification system was developed for banana bunchy top disease (BBTD) and banana mosaic (CMV). An app has been created for acquiring the images of banana diseases and pests from the farmers.

Sequencing and analysis of the corm and rhizosphere microbiome of banana cultivars classified as resistant (9) and susceptible (4) using Nanopore platform indicated that fungal community abundance and diversity were higher in resistant varieties than in susceptible, in both corm and rhizosphere soil and the abundance of Fusarium species complex and *Aspergillus flavus* increased in the rhizosphere soil of resistant and susceptible varieties.

Transfer of Technology

During 2021, six radio talks and series of talks by Director, ICAR-NRCB and 14 scientists on various cultivation aspects of banana were broadcasted in '*Makkal TV*'. The Centre has participated in 5 exhibitions / workshops and displayed improved technologies to farmers. The Centre also conducted 8 FLD / OFT and demonstrated the developed technologies. We also conducted 28 on-campus trainings to farmers, entrepreneurs, scientists, students and transgender entrepreneurs. Four off-campus trainings were given to farmers. The centre also conducted 3 National webinars and 8 Capacity Development Programs for graduate students.

Linkages and Collaborations

ICAR–NRCB has research collaborations with international institutes which include IITA, Nigeria; Bioversity International, France; KUL, Belgium; and the University of Queensland, Australia. The institute has linkages with national institutes including BARC, Mumbai; DST and DBT, New Delhi; APEDA; 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 and ICAR–CIAE (RS), Coimbatore. Under DBT-NER, more than 50 institutes located in different parts of the country are associated with ICAR-NRCB. ICAR–NRCB also coordinates with ICAR-AICRP (Fruits) centers (11 nos.) working on banana. During 2021, the Centre signed MoA / MoU / MoCs with 12 research institutes / colleges / private companies for research collaborations and student exchange. 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, 23 training programs were attended by the scientists of the centre. The scientists of the Centre published 23 research papers in various journals of International and National repute. The institute received the prestigious Sardar Patel Outstanding ICAR Institution Award - 2020 in the category of small Institutes. Dr. S. Uma, Director, ICAR-NRCB was awarded 'Dr. (Mrs.) Prem Dureja Endowment Award – Biennium 2019-2020'. The Centre also received 5 'Best Oral Presentation Award' and 3 'Scientist Award'. During 2021, three students successfully completed their Ph.D. and 30 students were pursuing B.Tech., M.Tech., M.Sc., Ph.D. and postdoctoral research at the centre.

Revenue Generated

A gross revenue of Rs. 23,04,820/- was generated by the centre during January–December, 2021.

कार्यकारी सारांश

फसल सुधार

वर्ष 2021 के दौरान, प्राथमिक और द्वितीयक स्रोतों से 06 परिग्रहणों का संग्रह करके उन्हें जीन बैंक में शामिल किया गया। आईपीजीआरआई मूसा डिस्क्रिप्टर का उपयोग करके जीनोमिक और उपसमूहों की पहचान के लिए 03 परिग्रहणों का आकृतिक–वर्गिकीय लक्षण वर्णन किया गया। इस केंद्र ने भाकृअनुप–एनबीपीजीआर, नई दिल्ली में 05 उन्नत आनुवंशिक स्टॉक को पंजीकृत कराया। आईसीपी–ओईएस का उपयोग करते हुए 09 खनिजों के लिए लगभग 121 व्यावसायिक रूप से खेती वाली भारतीय किस्मों का विश्लेषण किया गया। परिणामों ने संकेत दिया कि आईसीएमआर द्वारा अधिसूचित संशोधित आरडीए (अनुशंसित आहार एलाउंसेज)/एआई (पर्याप्त सेवन) मानों के अनुसार 100 ग्राम केले के गूदे के उपभोग से भारतीय वयस्कों (निष्क्रिय/मध्यम/भारी शारीरिक श्रम करने वाले पुरुष एवं महिलाएं) के उद झ ं झ उह झ थम झ ंद झ ज्ञ झ छं और झ च की दैनिक जरूरत को पूरा करने में आरोही क्रम में अच्छा योगदान दे सकती है। भाकृअनुप–एनआरसीबी में आईटीसी एवं अन्य विदेशी परिग्रहणों के खेतों में मूल्यांकन करके फ्यूजेरियम विल्ट रेस 1 अर्थात आईटीसी 1307, 1437 और आईआईटीए 75 के विरुद्ध प्रतिरोधी 03 आशाजनक परिग्रहणों की पहचान की है। आईटीसी परिग्रहणों के बड़े पैमाने पर गुणन और मूल्यांकन के कारण बौनेपन (एनआरसीबी सेलेक्शन 15), उच्च बीटा कैरोटीनॉयड (एनआरसीबी सेलेक्शन 16) और थ्वब रेस 1 की प्रतिरोधी (एनआरसीबी सेलेक्शन 17) सहित उच्च उपज वाले उत्कृष्ट प्रतिरूपों (क्लोनों) का चयन किया जा सका।

एनआरसीबी सेलेक्शन 18 (संतति संख्या 959) का प्रदर्शन लगातार तीन वर्षों तक 23.5 किग्रा/गुच्छे की औसत उपज के साथ स्थिर था और कावेरी सबा और मोन्थन की तुलना में इसमें बेहतर कुकिंग गुणवत्ता पाई गई। दो द्विगुणित संततियाँ (प्रोजिनी 429 – किस्म रोज़ ग पिसांग लिलिन; प्रोजिनी 820 – उदयम ग पिसांग लिलिन), दो त्रिगुणित (प्रोजिनी 0009 – मैटी ग एनाईकोम्बन; प्रोजिनी 819 – उदयम ग कलकत्ता 4) और एक चतुर्गुणित (प्रोजिनी 814 – बांकेला ग कलकत्ता 4–1) ने स्यूडोस्टेम वीविल और फ़ोक रेस 1 के प्रतिरोध का प्रदर्शन किया। नामवाखोम किस्म की एक मुक्त परागण (ओपी) संतति को एक छोटे गुच्छे सहित बौनी किस्म पाया गया जिसका व्यावसायिक और टैरेस गार्डन में सजावट के लिए उपयोग किया जा सकता है। केले के आनुवंशिक संसाधनों एवं संकरण कार्यक्रम में प्रभावी प्रबंधन के लिए आईसीटी उपकरण विकसित किए गए हैं। भाकृअनुप – अखिल भारतीय पुष्प संवर्द्धन समन्वित परियोजना के 12 केंद्रों में अंतर–विशिष्ट सजावटी केले के संकर विकसित किए गए और उनका मूल्यांकन किया जा रहा है।

गामा विकिरण ईसीएस (35 ळल) से उपचारित ग्रैंड नैन म्यूटेंट से व्युत्पन्न एनआरसीबीजीएनएमजी 1, जो गमलों (पॉट कल्चर) और बीमार प्लॉट दशाओं में थ्वब रेस रेस –1 (रोग स्कोर 1.08) के विरुद्ध प्रतिरोधी है, का बहुगुणन किया गया और थेनी, तमिल नाडु के मुख्य स्थलों (हॉटस्पॉट्स) में उसके मूल्यांकन से प्राप्त परिणामों से यह संकेत मिला कि इसने ग्रांड नैन किस्म से बेहतर उपज का प्रदर्शन किया। ग्रांड नैन किस्म के उत्कृष्ट क्लोनल सेलेक्शन का बौनेपन और उच्च उपज के लिए बड़े पैमाने पर बहुगुणन किया गया तथा कथित विशिष्ट एवं वांछनीय लक्षणों की स्थिरता के लिए किसानों के खेतों में इसका मूल्यांकन किया जा रहा है।

थ्वब रेस 1 और ज्च्4 के लिए ट्रांसक्रिप्टोम आंकड़ों का विश्लेषण कार्य चल रहा है। केले में ड्ंच्–1 जीन के अभिव्यक्ति अध्ययन (एक्सप्रेशन स्टडी) में सामान्यतः जैविक एवं अजैविक तनावों तथा विशेष रूप से फ्यूजेरियम विल्ट में उनकी भूमिका को स्पष्ट किया। थ्वब रेस 1 और ज्च्4 के लिए जीनिक एसएसआर मार्कर को विकसित कर उनकी पुष्टि की गई। एंथोसायनिन वर्णक (पिगमेंट) से सम्बद्ध एक जीनिक एसएसआर मार्कर की पहचान करके उसकी रेड बनाना, सन्नाचेनकदली, चेनकदली, एम. एक्यूमिनाटा उपप्रजाति जेबरीना, एम. ऑरनाटा, एम. रुबरा एवं ए. ऑरनाटा तथा एम. एक्युमिनाटा उपप्रजाति जेबरीना की एफ1 पॉपुलेशन में पुष्टि की गई तथा इसने हरे केले से बैंगनी (पर्पल) अंतर को अलग किया।

केले की कठिनाई से सवंर्धित होने वाली (रिकेलसिट्रेंट) किस्मों जैसे पूवन, रस्थली, रेड बनाना, नेय पूवन की किस्म रोज, एवं विलियम्स आदि के लिए इन विट्रो पुनर्जनन प्रोटोकॉल को मानकीकृत किया गया है। केला उत्पादकों को लगभग 1127 ऊतक संवर्धित पौधे और विभिन्न किस्मों के 5,300 सकर्स की आपूर्ति की गई। ऊतक संवर्धित किस्मों –ग्रांड नैन, नेंद्रन, कर्पुरावल्ली, रेड बनाना, और नेय पूवन के लगभग 431 बैचों का आईएसएसआर मार्करों के उपयोग द्वारा उनकी आनुवंशिक सत्यनिष्ठा की जांच की गई तथा प्राप्त रिपोर्ट को जारी किया गया, जिससे संस्थान को 12.72 लाख रुपये का राजस्व प्राप्त हुआ।

फसल उत्पादन

केले की पांच पत्तियों से 20 पत्तियों तक वृद्धि अवधि के दौरान, नेंद्रन में कुल शुष्क सामग्री का उत्पादन 2.31 से बढ़कर 12.86 (टन/हे0) हो गया, जबकि ग्रैंड नैन किस्म में यह 2.35 से बढ़कर 10.64 (टन/हे0) हुआ। केले की नेंद्रन एवं ग्रैंड नैन किस्म में पोषक तत्वों का उदग्रहण (किग्रा/हे0) के अलग–अलग पथ थे जो पोषकों पर निर्भर करता है, नाइट्रोजन में 22.5 से 233.57 तक की धीमी वृद्धि से नेंद्रन में अपटेक बढ़ती दर के साथ जबकि ग्रैंड नैन में,

नाइट्रोजन उद्ग्रहण (एन अपटेक) निरंतर रूप से 21.59 से 119.85 तक बढ़ा। केले की जैविक खेती में पौधे की 5–पत्ती एवं 10–पत्ती चरणों में पोषक तत्वों के अपटेक की मात्रा को 100: अकार्बनिक उर्वरक में उच्चतम तथा 5–पत्ती चरण वाले पूर्ण नियंत्रण में न्यूनतम पाया गया और कुक्कुट खाद को 5 किग्रा/पीएल + मूंगफली की खली को 1 किग्रा/पीएल + ग्रामीण खाद को 3 किग्रा/पीएल + लकड़ी की राख को 3 किग्रा/पीएल की दर से देने पर 10 पत्तियों वाली अवस्था में सर्वाधिक पाया गया।

भाकृअनुप–एनआरसीबी द्वारा जारी किस्मों एवं चयनों के मामले में कृषि–तकनीक विकसित करने में, कावेरी सबा में 10–पत्तियों से आगे की सभी पौध–सघनताओं (प्लांट डेंसिटीज) में फाइलोक्रॉन को 200:30:300 ग्राम एनपीके ($Eफ_1$) स्तर की तुलना में एनपीके स्तर 200:30:400 ग्राम ($Eफ_2$) में अधिक पाया गया। कावेरी हरिता में, फाइलोक्रोन को 10–पत्तियों वाली अवस्था तक $Eस_2$ सघनता की तुलना में $Eस_1$ सघनता वाले रोपण $Eफ_1$ में अधिक पाया गया और फिर 15–पत्तियों वाली अवस्था से इसका क्रम विपरीत हो गया। पोपोलु किस्म में उर्वरकों का स्तर जितना अधिक था, 5–पत्तियों वाली अवस्था में फ़ाइलोक्रोन को अधिक पाया गया जबकि रोपण सघनता कुछ भी हो पर 10–पत्तियों की अवस्था से इसका विपरीत क्रम पाया गया जबकि कावेरी कल्कि में $Eफ_1$ की तुलना में $Eफ_2$ में 5 से 15–पत्तियों तक की अवस्था में रोपण सघनता पर विचार किए बिना उच्च फ़ाइलोक्रोन दर्ज किया गया। नेय पूवन के गुल्म (क्लंप) प्रबंधन में, चार सकर्स ($Eस_4$) वाले मातृ वृक्ष (मदर प्लांट) में 595.6 दिनों की सर्वाधिक क्लंप अवधि दर्ज की गई, जिसमें गुच्छे का सर्वाधिक वजन 42.1 किग्रा एवं कुल उपज 73.2 टन/हे0 पाई गई। पूवन में भी, $Eस_4$ में 643.6 दिनों की लंबी क्लंप अवधि तथा 96.2 टन/हे0 कुल फल उपज सहित 69.2 किग्रा/क्लंप सर्वाधिक गुच्छा वजन पाया गया। कुल गुच्छा वजन (किग्रा/क्लंप) तथा कुल उपज (टन/हे0) के संदर्भ में पोषण के तीन स्तरों की तुलना में, 175: आरडीएफ को नेय पूवन एवं पूवन दोनों में 150: आरडीएफ के साथ तुलनीय पाया गया। दोनों किस्मों में, उच्चतम बी:सी अनुपात क्रमशः 3. 64 एवं 2.81 को $Eस_4$ में दर्ज किया गया। 125: उर्वरकों की संस्तुत डोज (आरडीएफ) प्रति गुल्म देने पर फूल एवं फलों की तुड़ाई के चरणों में उच्चतम सूक्ष्मजीवी संख्या दर्ज की गई।

खेत एवं गमलों में लगाए गए सजावटी केला संकरों के मूल्यांकन हेतु किए गए प्रयोग के प्रारंभिक रुझान में खेतों और शेड नेट में 66: आरडीएफ के साथ 3 सकर्स को सर्वोत्तम प्रदर्शन वाला उपचार संयोजन पाया गया जबकि गमलों में 3,000 से 6,000 लक्स प्रकाश और 30: आरडीएफ के प्रयोग को बेहतर पाया गया।

केले की पत्तियों के उत्पादन के लिए पूवन, करपुरावल्ली, सक्काई, फ़िरिमा जंगली एवं प्रोजिनी 183 का मूल्यांकन किया गया जिसमें करपुरावल्ली किस्म से अधिकतम संख्या में पत्ते (5.00) प्राप्त हुए जबकि फ़िरिमा जंगली (3.88) में न्यूनतम संख्या में पत्ते मिले। पत्तियों में कुल क्लोरोफिल सामग्री को करपुरावल्ली में 5.40 मिग्रा/ग्राम से लेकर प्रोजिनी 183 में 12.43 मिग्रा/ग्राम के बीच पाया गया। करपुरावल्ली में अधिकतम साइड सकर्स (पार्श्व चूषक) (3.48) उत्पन्न हुए और इसके बाद इन्हें पूवन (3.13) में पाया गया। नाडु, पूवन और कर्पुरावल्ली में सकर्स की विभिन्न संख्या के आधार पर पत्तियों के उत्पादन पर किए गए अध्ययन से पता चलता है कि सभी किस्मों में क्रमशः 13.15, 12.63 और 13.01 के साथ 1 + 5 (मातृ पौधे + सकर्स की संख्या) के संयोजन में अधिकतम संख्या में पत्ते प्राप्त हुए। नाडु में सबसे अधिक पत्ती क्षेत्रफल 0.97 वर्ग मीटर दर्ज किया गया, जबकि करपुरावल्ली में पत्ती की न्यूनतम मोटाई 0.27 मिमी और नाडु में कुल अधिकतम क्लोरोफिल सामग्री 10.51 मिग्रा/ग्रा दर्ज किया गया।

स्टार्च पाउडर की अम्ल विरलता (एसिड थिनिंग) और ऑक्सीकरण संशोधन ने देशी केले के स्टार्च की तुलना में हल्केपन में उल्लेखनीय वृद्धि की और प्रकाश संप्रेषण में प्रारंभिक वृद्धि पाई गई, लेकिन भंडारण के दिनों में वृद्धि होने पर सभी प्रकार के संशोधित स्टार्च में कमी आई। सभी प्रकार के संशोधनों में तापमान में वृद्धि के साथ फुलाव (स्वेलिंग पावर) में वृद्धि हुई। खाद्य उत्पादों की सुरक्षा और उपयोग अवधि (शेल्फ लाइफ) को बढ़ाने के लिए जैविक सामग्री से बायोफिल्म तैयार की गई। स्टार्च एवं योज्य (एडिटिव्स) जैसे कैरेजेनन गम, सीएमसी, गम अरेबिका, गम ट्रैगैकैंथ का उपयोग करके भोज्य फिल्में भी विकसित की गईं।

शरीर क्रिया विज्ञान में, विभिन्न जीनोमों से संबंधित 53 केले के जीनरूपों का पुष्पन की प्रारंभिक अवस्था में मृदा नमी की कमी से होने वाले तनाव के खेत मूल्यांकन में सभी जीनोटाइप में पौधों की ऊंचाई और परिधि में 12.34 से 29.67: तक की उल्लेखनीय कमी दिखाई और पुष्पन अवधि में 17.50 – 42.05 दिनों की वृद्धि प्रदर्शित की। एबीबी जीनोटाइप, नेंद्रन, रस्थली और एएए जीनोटाइप, लेयन और लैकाटन को अधिकतम उपज में 35: की कमी के साथ अतिसंवेदनशील पाया गया। जैव–रासायनिक संकेतकों के अनुसार, मूसा बलबिसियाना, भीमकोल, मनोहर, बीबी जीनोम के पगलापहाड़ वाइल्ड–2 ने सूखे के प्रति बेहतर सहिष्णुता दिखाई। केले के कुछ जीनरूपों के अंकुरण संबंधी परीक्षणों में ग्रैंड नैने किस्म अंकुरित होने में विफल रही जबकि कावेरी सबा और कर्पुरावल्ली में बेहतर अंकुरण एवं बढ़वार देखी गई। सूखे की स्थिति आरोपित करने के पूर्व, 50 उड सोडियम सिलिकेट का पत्तियों में अनुप्रयोग से उच्च आरडब्ल्यूसी, लीफ पिगमेंट और ऑस्मोलाइट्स दर्ज किए गए।

पूर्वोत्तर भारत की केले की दस किस्मों के फूलों के ब्रेक्ट से एंथोसायनिन की संरचना एवं मात्रा के जैव रासायनिक अध्ययन में 5–6 एंथोसायनिन यौगिक प्रदर्शित हुए। सुति जाहाजी, गोबिन टलकी और वेन्नुतमानन में, साइनाइडिन एक प्रबल यौगिक था जबकि बोरकल बैस्ता, भारतमोनी और कैथकुलुंग में पेलार्गोनिडिन को प्रबल यौगिक पाया गया। टीईएसी एवं ओआरएसी एसेज (परख) का उपयोग करके वाणिज्यिक केले की 15 किस्मों के पुष्प ब्रेक्टों के एंथोसायनिन की न्यूट्रास्युटिकल क्षमता के आकलन में मोन्थन (एबीबी), सबा (एबीबी), उद्यम (एबीबी) और पोपोलु (एएबी) ने साइनाइडिन सामग्री के अनुरूप उच्च एंटीऑक्सीडेंट सक्रियता का प्रदर्शन किया। केले के फलों के गूदे में गैलोकैटेचिन को प्रबल फ्लेवोनोइड यौगिक पाया गया। वाणिज्यिक केले–मोन्थन (एबीबी), कर्पूरावल्ली (एबीबी), उद्यम (एबीबी) और सबा (एबीबी) में अधिक मात्रा में गैलोकैटेचिन की मात्रा पाई गई जो लगभग 45, 42 एवं 39 मिग्रा/100 ग्राम गूदा थी। फलों के गूदे से फ्लेवोनोइड्स की न्यूट्रास्युटिकल क्षमता के आकलन में अधिक गैलोकैटेचिन युक्त केले की किस्मों जैसे मोन्थन (एबीबी), कर्पूरावल्ली (एबीबी), उद्यम (एबीबी) और सबा (एबीबी) ने 95.0 µउवस ज्म/100 ग्राम एंटीऑक्सीडेंट सक्रियता प्रदर्शित किया। मोंथन, नेंद्रन और उद्यम किस्मों के गूदे एवं छिलके में फ्रुक्टेन का उच्च स्तर पाया गया और इन किस्मों के गूदे में फ्रुक्टेन की मात्रा 180 µह/ग्राम से अधिक थी। एचपीएलसी में 5.5 मिनट के प्रतिधारण समय के साथ केले के पत्ते से अल्फा–टोकोफेरोल के निष्कर्षण एवं आकलन का मानकीकरण किया गया। ट्रांसजेनिक विकास के अंतर्गत केले के फलों में, व्छै1 सहित 05 उत्कृष्ट आयरन ग्रैंड नैन इवेंट और 06 गुना से अधिक लौह खनिज सामग्री वाले 2 जीनों का सोर्ड सकर्स का उपयोग करके शूट टिप कल्चर द्वारा बहुगुणन किया गया और पांच उत्कृष्ट ईवेंट वाले कुल 150 पौधे उत्पन्न किए गए।

फसल सुरक्षा

भारत में हाल ही में तमिलनाडु के करूर एवं त्रिची जिलों में बोंडर्स नेस्टिंग सफेद मक्खी (व्हाइट फ्लाई), पैरालेरोडिस बोंडारी पेराची, एक विदेशी आक्रामक कीट को केले की फसल पर दर्ज किया गया। केले की फसल में इस कीट के जीवन–चक्र के सभी चरणों को पाया गया और इनके द्वारा होने वाला नुकसान कम था। स्पोडोप्टेरा एक्सिगुआ, सिम्पलिसिया कॉर्निकेलिस, गेसोनुला पंक्टिफ्रोंस, एट्रैक्टोमोर्फा क्रैनुलाटा, ज्यूगोडेकस कुकुर्बिटे, और रैस्ट्रोकोकस इन्चेडेंस को केले के नए नाशीकीटों के रूप में दर्ज किया गया। मैंगो लूपर, पेरिक्सेरा इलिपिडेरिया और नारियल निष्पत्रकों (डिफोलिएटर), फेलाक्रा विधिसारा, के लार्वा को बड़ी संख्या में प्यूपीकरण के लिए केले की ओर पलायन करते पाया गया किंतु वे केले से आहार ग्रहण करते नहीं पाए गए।

सर्दियों के दौरान खेतों में केले के माहू (एफिड) के विरुद्ध तीन कोकिनेलिड्स (चेइलोमेनेस सेक्समाकुलाटा, स्यूडोस्पिडिमेरस ट्रिनोटेटस और स्किमनस न्यूबिलस) और एक ब्राउन लेसविंग (माइक्रोमस टाइमिडस) को सक्रिय परभक्षी पाया गया। सबसे कुशल परभक्षी, एस. न्युबिलस की जैविकी का प्रयोगशाला में अध्ययन किया गया। इनमें चार लार्वा इंस्टार पाए गए और डिंब से वयस्क होने तक के विकास में 15–19 दिन लगे। अंडे, लार्वा, प्री–प्यूपल एवं प्यूपल अवधि क्रमशः 4.50.53, 7.880.88, 1.500.46 और 3.00.76 दिनों तक रही। परिग्रहण संख्या प्राप्त करने हेतु एनबीएआईआईएम, मऊ में एंटोमोफंगल रोगजनकों की लगभग 50 संवर्द्धों को जमा किया गया।

तमिलनाडु के पांच जिलों (कन्याकुमारी, तिरुनेलवेली, तूतीकोरिन, तिरुचिरापल्ली और नमक्कल) से फ्यूजेरियम विल्ट से संक्रमित प्रकंदों के नमूनों का अध्ययन करके वीसीजी समूहों की पहचान की गई। केले की किस्म नेय पूवन का खेतों में दो संभावित फॉस्फेट घुलनशील बैक्टीरिया, एंटरोबैक्टर होर्मेची उपप्रजाति साकुएंसिस (पीएसबी 52) तथा लेकलर्सिया डिकार्बोक्सिलाटा (पीएसबी 54) के लिए मूल्यांकन किया गया। रॉक फॉस्फेट के साथ दो पोषक तत्वों के घुलनशील जीवाणुओं के संयुक्त अनुप्रयोग ने कंट्रोल (नियंत्रण) की तुलना में क्षारीय फॉस्फेट एंजाइम सक्रियता को 300–500: तक बढ़ा दिया। चावल के मांड (राइस ग्रुएल) वाले मीडियम में ट्राइकोडर्मा प्रजातियों के बड़े पैमाने पर उत्पादन की एक किफायती एवं त्वरित विधि को विकसित किया गया तथा एक एकड़ केले की फसल पर प्रयुक्त करने के लिए 50 किग्रा फॉर्म्युलेशन को 3–5 दिनों के भीतर मात्र 10 रुपये की लागत पर तैयार किया जा सकता है।

थ्वब एसटीआर 4 के विषाणुजनित उपभेदों की शीघ्र पहचान एवं निगरानी के लिए नए मार्कर विकसित किए गए। उत्तर प्रदेश के महाराजगंज जिले के सिसवाबाजार में ग्रैंड नैन किस्म पर फ्यूजेरियम विल्ट (टीआर4) के प्रबंधन के लिए बायोएजेंट के तीन संकायों (कंर्शोसिया) का उपयोग करके फील्ड परीक्षण किए गए। बेसिलस फ्लेक्सस (टीवीच्त1) + तीपण ट्राइकोडर्मा प्रजाति (एनआरसीबी3) को सबसे अच्छा पाया गया।

ग्लासहाउस की दशाओं में ग्रैंड नैन किस्म में थ्वब एसटीआर4 के विरुद्ध एक मूल परिवेशी (राइजोस्फेरिक) और सात अंतःपादपी (एंडोफाइटिक) बैक्टीरियल वियोजकों का मूल्यांकन किया गया। 3 महीने के बाद अंतःपादपी बेसिलस सबटिलिस की उपप्रजाति स्पिज़िजेनी (टी4) ने थ्वब एसटीआर4 के विरुद्ध टीकाकृत पौधों के मुकाबले सबसे कम रोग स्कोर दर्ज किया। इसी प्रकार के एक अध्ययन में 06

राइजोस्फेरिक एवं एक एंडोफाइटिक ट्राइकोडर्मा प्रजाति के उपयोग में वियोजक राइजोस्फेरिक टी. एस्परेलम (एनआरसीबी3) (टी3) में सबसे कम रोग स्कोर दर्ज किया गया। सभी जैवकारकों (बायोएजेंटों) ने बायोमेट्रिक गुणों में उल्लेखनीय वृद्धि दिखाई। अंतः पादपी एवं मूल परिवेशी मूल के प्रभावी बैक्टीरियल एवं फंगल वियोजकों के संयोजन के समान मूल्यांकन से पता चला है कि राइजोस्फेरिक टी. एस्पेरेलम (एनआरसीबी3) के साथ उपचार (टी6) ने रोग को पूरी तरह से दबा कर पौधे की बढ़वार में काफी वृद्धि प्रदर्शित की। एंडोफाइटिक एवं राइजोस्फेरिक मूल के कवकीय एवं जीवाणुवीय जैवनियंत्रक (बायोकंट्रोल) एजेंटों के इन विट्रो (प्रयोगशाला) में किए गए मूल्यांकन में सस्योपरांत (पोस्टहार्वेस्ट) रोगों के विरुद्ध ट्राइकोडर्मा और ज़िम्मू से निष्कर्षित प्रमुख यौगिकों (लेसियोडिप्लोडिया थियोब्रोमे एवं कोलेटोट्राइकम मुसे) से यह इंगित हुआ कि मूल परिवेशी ट्राइकोडर्मा प्रजाति (एनआरसीबी3) एवं टी. हर्जेनियम को सी. मुसे के विरुद्ध प्रभावी पाया गया, जिम्मू से प्राप्त प्रमुख यौगिक 3 को दोनों के विरुद्ध सर्वाधिक प्रभावी पाया गया, किंतु एल. थियोब्रोमे के विरुद्ध इनमें से कोई भी प्रभावी नहीं पाया गया। पीजीपीआर के इन विट्रो परीक्षण में फ्यूजेरियम विल्ट एवं लीफ स्पॉट दोनों के प्रति एल. थियोब्रोमे तथा सी. मुसे के विरुद्ध अनुशंसित एक्टिनोबैक्टीरिया एवं कवकनाशियों ने महत्वपूर्ण निरोधात्मक स्तर दिखाया, जिसमें सी. मुसे के विरुद्ध दो एक्टिनोबैक्टीरिया (एक्ट. 16 एवं एक्ट. 10) तथा एल. थियोब्रोमे के विरुद्ध पीजीपीआर (एच8बीसी1, एच7बीसी2 तथा एच6बीसी2) ने अधिकतम अवरोध पैदा किया। सभी कवकनाशियों ने एल. थियोब्रोमी के प्रति उल्लेखनीय स्तरों पर अवरोधन प्रदर्शित किया।

नेय पूवन, ग्रैंड नैन एवं थैल्ला चक्करकेली के तीन विगलित प्रकंदों (राइज़ोम रॉट) से प्राप्त वियोजकों (एनपीके–3–48, जीटीसी–5 तथा 1–1बी–3) का आणविक लक्षणवर्णन आरएनए पॉलिमरेज़ जीन (तचवठ) के बीटा–सबयूनिट के पीसीआर विस्तारण द्वारा किया गया और के. वेरिकोला के रूप में उनकी पहचान की पुष्टि की गई।

पीजीपीआर के 04 वियोजकों (एच4बीसी1, एच6बीसी2, एच6बीसी3 तथा एच7बीसी2) के सूक्ष्म–संपुटित (माइक्रोएन्कैप्सुलेटेड) सूत्रण (फॉर्मूलेशन) को वांछित सीएफयू से युक्त पाया गया, लेकिन, केवल एच6बीसी3 तथा एच7बीसी में ही पौध (सीडलिंग) में बढ़ती वृद्धि पाई गई। मृदा रहित माध्यम में, प्राथमिक दृढ़ीकरण अवस्था के दौरान केले की ग्रैंड नैन किस्म पर पीजीपीआर के 08 वियोजकों में से सिर्फ बीसीबी 2–4 को छोड़कर शेष सभी वियोजकों ने एक महीने के भीतर पौध (सीडलिंग) की बढ़वार में वृद्धि की और उनमें से भी एच7बीसी2 एवं एच8बीसी2 को शेष की तुलना में बेहतर पाया गया। अध्ययन किए गए 28 एक्टिनोबैक्टीरिया में से एक्ट.15 एवं एक्ट.14 को केले के अपशिष्ट पदार्थों को तेजी से विघटित कर सकने वाला पाया गया।

बीबीटीवी के विरुद्ध प्रतिरोधिता के लिए द्विगुणित जर्मप्लाज्म परिग्रहणों (26 एए द्विगुणित, 36 बीबी द्विगुणित तथा 23 एबी द्विगुणित) की जांच की गई। ठठतडट एवं ब्डट के प्रति फील्ड नमूनों का उपयोग करके एक ट्रिपल एंटीबॉडी सैंडविच एलिसा (टीएएस–एलिसा) का मानकीकरण एवं पुष्टि की गई तथा दो एंटीसेरा का उपयोग करके एक टीएएस–एलिसा किट को विकसित किया गया। केले एवं टमाटर को संक्रमित करने वाले विषाणु का पता लगाने और उसके लक्षणवर्णन के लिए डपदप्छ सीक्वेंसिंग एप्रोच का उपयोग किया गया और केले में दोहरा संक्रमण दर्ज किया गया। ठठतडटए सीएमवी और टीएसडब्ल्यूवी के संपूर्ण जीनोमों का पता लगाकर उनका लक्षणवर्णन किया गया।

कुल जड़ अनुपात में से मृत जड़ों एवं जड़–घाव सूचकांक के आधार पर मूसा जीनोटाइप की त्वरित स्क्रीनिंग में, कुन्नन (एए), कार्थोबियमथम (एबीबी), और मूसा बेलबिसियाना (बीबी) को प्रतिरोधी पाया गया जबकि एनाइकोम्बन (एए) को अतिसंवेदनशील पाया गया। कावेरी सबा एवं कावेरी कल्कि को जड़–गांठ सूत्रकृमि (रूट–नॉट नेमाटोड) के प्रति मध्यम प्रतिरोधी पाया गया।

गमलों में लगाए गए ऊतक संवर्द्धित केले की ग्रांड नैने किस्म में जड़–विक्षति सूत्रकृमियों के इनोकुलेशन (टीकाकरण) से 24 घंटे पहले 200 एवं 500 µड सांद्रता वाले सैलिसिलिक एसिड के पर्णीय अनुप्रयोग से 3 महीने के बाद कंट्रोल (गैर उपचार) की तुलना में जड़ों की संख्या को क्रमशः 72 और 60ः तक कम कर दिया। प्रयोगशाला (इन विट्रो) में ज़िम्मू की पत्तियों के 50ः या इससे अधिक सांद्रता वाले अर्क से उपचारित करने के 48 एवं 72 घंटे पर जड़–विक्षति एवं जड़–गरंठ सूत्र कृमियों में 90ः मृत्यु दर पाई गई। एनआरसीबी के संकरों से नमूना लेने पर प्रोजिनी एनपीएल 30 एवं 115 को जड़–विक्षति सूत्रकृमि के विरुद्ध प्रतिरोधी पाया गया।

केले के गुच्छेदार शीर्ष रोग (बीबीटीडी) तथा केला मोज़ेक (सीएमवी) के लिए एक स्वचालित रोग पहचान प्रणाली विकसित की गई। केले के रोगों और किसानों से नाशीकीटों के चित्रों की प्राप्ति हेतु एक ऐप तैयार किया गया है।

नैनोपोर प्लेटफॉर्म का उपयोग करते हुए केले की किस्मों के कॉर्म तथा परिवेशी सूक्ष्मजीवों (राइजोस्फीयर माइक्रोबायोम) के अनुक्रमण और विश्लेषण में इन्हें प्रतिरोधी (9) एवं अतिसंवेदनशील (4) के रूप में वर्गीकृत किया गया जिससे इस बात का संकेत मिला कि सुग्राह्य किस्मों की तुलना में प्रतिरोधी किस्मों के कॉर्म एवं परिवेशी मृदा में कवकों की प्रचुरता एवं विविधता अधिक है तथा प्रतिरोधी एवं सुग्राह्य किस्मों की मूल परिवेशी मृदा में फ्यूजेरियम प्रजाति कॉम्प्लेक्स एवं एस्परगिलस फ्लेवस की प्रचुरता पाई गई।

प्रौद्योगिकी हस्तांतरण

वर्ष 2021 के दौरान 'मक्कल टीवी' में केले की खेती के विभिन्न पहलुओं पर निदेशक, भाकृअनुप–एनआरसीबी और 14 वैज्ञानिकों द्वारा छह रेडियो वार्ता और वार्ताओं की श्रृंखला का प्रसारण किया गया। केंद्र ने 5 प्रदर्शनियों/कार्यशालाओं में सहभाग किया और किसानों को उन्नत तकनीकों का प्रदर्शन किया। केंद्र ने 8 एफएलडी/ओएफटी का भी आयोजन किया तथा विकसित प्रौद्योगिकियों का प्रदर्शन किया। संस्थान द्वारा किसानों, उद्यमियों, वैज्ञानिकों, छात्रों और ट्रांसजेंडर उद्यमियों के लिए 28 परिसरीय (ऑन–कैंपस) प्रशिक्षणों का संचालन किया गया। किसानों के लिए 04 गैर–परिसीय (ऑफ कैंपस) प्रशिक्षण भी दिया गया। संस्थान द्वारा अधिस्नातक छात्रों के लिए 3 राष्ट्रीय वेबिनार और 8 क्षमता विकास कार्यक्रमों का भी आयोजन किया गया।

संपर्क एवं सहयोग

भाकृअनुप–एनआरसीबी ने कई अंतरराष्ट्रीय संस्थानों के साथ अनुसंधान सहयोग किया है जिसमें आईआईटीए, नाइजीरिया; बायोवर्सिटी इंटरनेशनल, फ्रांस; केयूएल, बेल्जियम तथा क्वींसलैंड विश्वविद्यालय, ऑस्ट्रेलिया शामिल हैं। केंद्र ने बीएआरसी, मुंबई; डीएसटी एवं डीबीटी, नई दिल्ली; एपीडा; नाबार्ड; वीएफपीके, केरल; टीएनएयू, कोयंबटूर; एनआईटी, तिरुचिरापल्ली और केएनसीईटी, थोटियाम, तमिलनाडु जैसे राष्ट्रीय संस्थानों के साथ भी अनुसंधान संपर्क स्थापित किए हैं। इस केंद्र ने भाकृअनुप–एनबीपीजीआर, नई दिल्ली; भाकृअनुप –आईआईएचआर, बेंगलुरु, भाकृअनुप –आईएआरआई, नई दिल्ली, भाकृअनुप –सीपीआरआई, कासरगोड और भाकृअनुप –सीआईएई (आरएस), कोयंबटूर सहित भारतीय कृषि अनुसंधान परिषद के अन्य कई संस्थानों के साथ अनुसंधान सहयोग किया है। डीबीटी–एनईआर के तहत देश के विभिन्न हिस्सों में स्थित 50 से अधिक संस्थान भाकृअनुप–एनआरसीबी से जुड़े हुए हैं। भाकृअनुप –एनआरसीबी द्वारा अखिल भारतीय समन्वित फल अनुसंधान परियोजना (एआईसीआरपी) के केला पर शोधरत 11 केंद्रों के अनुसंधान कार्य का समन्वय भी किया जाता है। वर्ष 2021 के दौरान इस केंद्र ने 12 अनुसंधान संस्थानों/महाविद्यालयों/निजी कंपनियों के साथ अनुसंधान सहयोग एवं छात्रों के आदान–प्रदान हेतु एमओए/एमओयू/एमओसी पर हस्ताक्षर किए हैं। विभिन्न अनुसंधान एवं विकास गतिविधियों के लिए बड़े पैमाने पर केले के प्रजनन में शामिल ऊतक–संवर्धन उद्योग, किसान, निर्यातक, राज्य बागवानी एवं कृषि विभाग तथा स्वयं सहायता समूह (एसएचजी) इस केंद्र से जुड़े हुए हैं।

मानव संसाधन विकास एवं शिक्षा

मानव संसाधन विकास के तहत इस केंद्र के वैज्ञानिकों ने 23 प्रशिक्षण कार्यक्रमों में सहभागिता की। केंद्र के वैज्ञानिकों ने अंतरराष्ट्रीय और राष्ट्रीय ख्याति प्राप्त विभिन्न पत्रिकाओं में 23 शोध पत्र प्रकाशित किए। इस संस्थान को छोटे संस्थानों की श्रेणी में प्रतिष्ठित सरदार पटेल उत्कृष्ट आईसीएआर इंस्टीट्यूशन अवार्ड – 2020 से सम्मानित किया गया। डॉ. एस. उमा, निदेशक, भाकृअनुप–एनआरसीबी को 'डॉ. (श्रीमती) प्रेम दुरेजा एंडोमेंट अवार्ड – द्विवार्षिक 2019–2020' प्रदान किया गया। केंद्र को वर्ष 2021 के दौरान, 5 'सर्वश्रेष्ठ मौखिक प्रस्तुति पुरस्कार' एवं 3 'वैज्ञानिक पुरस्कार' भी दिए गए। इस केंद्र पर तीन छात्रों ने अपनी पीएच.डी. उपाधि को सफलतापूर्वक पूर्ण किया और 30 छात्र बी.टेक., एम.टेक., एम. एससी., पीएच.डी. और पोस्टडॉक्टरल अनुसंधान कार्य कर रहे हैं।

सृजित राजस्व

जनवरी–दिसंबर, 2021 के दौरान केंद्र द्वारा रुपये 23,04,820/– का कुल राजस्व सृजित किया गया।

4. RESEARCH ACHIEVEMENTS

4.1.1 CROP IMPROVEMENT

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

Collection

During the reporting period, six germplasm accessions have been collected from primary and secondary sources, *viz.* Thiruvananthapuram, Kerala and ICAR-CIARI, Andaman & Nicobar Islands, respectively (Table 1).

Characterization

Morphotaxonomic characterization

Morpho-taxonomic characterization was done for three accessions using 24 descriptors leading to the identification of genomes and subgroups (Table 2).

Table 1. Germplasm accessions collected

S. No.	Name	Source
1.	Horn plantain	Parasala, Thiruvananthapuram, Kerala
2.	*Musa indandamanensis* (Seeds)	ICAR-CIARI, Andaman & Nicobar Islands
3.	*Musa indandamanensis* (Seedlings)	
4.	Local Banana	
5.	Local Banana II	
6.	Local Banana III	

Registration of genetic stock with ICAR-NBPGR, New Delhi

ICAR-NRCB has applied for registration of five improved genetic stocks with ICAR-NBPGR, New Delhi and the details of the same are provided in the Table 3.

Table 2. List of accessions characterized

S. No.	NRCB accession No.	Name	Identified genome	Subgroup and Type
1.	2616	Neyvediyakadali	AA	Unique
2.	2619	KNR 290	AB	Unique
3.	2620	Makkale Potty	AAB	Pome

Table 3. Improved genetic stocks of ICAR-NRCB

S. No.	Accession No. and Name	IC No.	Genome	Special trait
1.	NRCB Acc. No. 0045-Borchampa	IC- 250498	AAB	Resistant to *Fusarium oxysporum* f. sp. *cubense* (Foc) race 1
2.	NRCB Acc. No. 009 -Borjahaji	IC - 250462	AAA	Resistant to Foc race 1
3.	NRCB Acc. No. 0050 -Karthobiumtham	IC -250503	ABB	Resistant to Foc race 1 and root-lesion nematode, *Pratylenchus coffeae*
4.	NRCB Acc. No 0197	IC- 250650	AAB	Resistant to Foc race 1
5.	NRCB Acc. No. 0608	IC -251061	AAA	Resistant to Foc race 1

Field evaluation of ITC accessions at ICAR-NRCB, Tiruchirappalli

Field evaluation of the ITC accessions at ICAR-NRCB has led to the identification of three promising accessions with resistance to Fusarium wilt race 1 and they are briefly described in Table 4 and Fig.1.

Fig. 1. Field evaluation of ITC accessions

Table 4. Field evaluation of ITC accessions

S. No.	ITC No.	Acc. Name	Special traits
1.	ITC 1307	SH 3640	Medium tall (2.6-2.7 m), tolerant to Sigatoka, high yielding (20-22 kg), 8 hands / bunch, 14-16 fruits / hand, long fruits (20 cm long), taste is good like Ladan. Resistant to Fusarium wilt (Foc) race 1.
2.	ITC 1437	TMB2 x 9128-3	Lengthy bunch with 18 to 20 hands, hands loosely packed, and the fruits turn completely towards the peduncle. Fruits are 14-15 cm in length with 8 cm circumference, pulp is orange in colour with good taste. Resistant to Foc race 1.
3.	IITA	IITA 75	Medium tall (2.5 to 2.7 m), bunch weight 18–22 kgs, 7-9 hands of fruits, compactly packed. Lengthy fruits (20-21 cm long), sweet in taste. Resistant to Foc race 1 and moderately resistant to Foc TR4.

Evaluation of promising selections made at ICAR-NRCB

NRCB selection 15: This is a high yielding clonal selection from Williams (0608) which is resistant to Foc race 1. This recorded 12% higher yield than Williams.

NRCB selection 16: This is a clonal selection from ITC 0533 with high beta carotenoid content (91 µg / g of dry fruit) which is 20% higher than ITC 0553 (73 µg / g of dry fruit) and average yield (12 kg) which is under mass multiplication for further evaluation. This selection is found to be moderately resistant to Foc TR 4 in pot screening.

NRCB selection 17: This is a clonal selection from ITC 1437 with lengthy bunches possessing 18 to 20 hands, which are loosely packed and the fruits turn completely towards the peduncle. Fruits are 14-15 cm long with 8 cm circumference and the pulp is orange with good taste. Resistant to Fusarium wilt (race 1) under sick plot and moderately resistant to TR 4 in pot screening.

Screening of ITC accessions for *Fusarium* wilt resistance (Race 1) under sick plot conditions of Theni, Tamil Nadu

All 124 ITC accessions have been screened for *Fusarium* wilt resistance (Race 1) under sick plot conditions of Theni, Tamil Nadu and the details of the resistant accessions are presented in table 5.

Screening of ITC accessions for *Fusarium* wilt resistance (Race 1) in pot culture

Totally 50 ITC accessions were screened for *Fusarium* wilt resistance (Race 1) in pot culture conditions and the results indicated that 21 accessions were resistant, 26 were moderately resistant and three were susceptible (Table 6).

Table 5. Reaction of ITC accessions to *Fusarium* wilt in sick plot evaluation

S. No.	Level of Resitance	No. of accessions	Diploids	Triploids	Tetraploids
1.	Highly Resistant	45	21	17	6
2.	Resistant	13	7	2	4
3.	Moderately Resistant	13	4	9	-
4.	Susceptible	10	-	9	-
5.	Highly Susceptible	27	4	18	-
	Total	113	36	55	10

Table 6. Reaction of ITC accessions to *Fusarium* wilt in sick plot evaluation

Resistant	Susceptible
FHIA -23 (ITC-1265), Saba1 (ITC-138), Yangambi KM -5 (ITC-1123), Bluggoe (ITC-1404), Pisang Mas (ITC-0653), Pisang Jari buaya (ITC-0312), cv. Rose (ITC-0712), Blue Torres Strait Island(ITC-0338), Guineo(ITC-0005), Pisang Nangka (ITC-1062), Robusta (ITC-0574), Pisang Berangan (ITC-1287), PV-03-44 (ITC-1262), Microcarpa (ITC-0253), Tjau Lagada (ITC-0090), Pisang Lemak Manis(ITC-1183), FHIA 21 (ITC-1306), Zebrina (ITC-1319), Petite Naine (ITC-0654), Safed Velchi (ITC-0245), Gu Nin Chio(ITC-0442)	Ney Poovan (0459), Figue Pome Geante (0269); Pisang Awak (0213)

Screening of ITC accessions for *Fusarium* wilt resistance (TR 4) under sick plot conditions of Katihar, Bihar

Totally 112 ITC accessions have been planted in the sick plot at Katihar, Bihar for resistance screening against *Fusarium* wilt (TR4) and the trial is in progress.

Screening of AAA accessions for Fusarium wilt resistance (Race 1 and TR4) in pot culture

Totally 33 AAA accessions in 3-5 replicates were challenge inoculated with race 1 and TR4 separately in pot culture and the disease scoring was done after five months of spore inoculation and the scoring data are presented in Table 7.

Table 7. Screening of AAA accessions for Fusarium wilt resistance (Race 1 and TR4)

S. No.	Accession No.	Genome	Name of the accession	Reaction to Fusarium wilt	
				Race 1	TR 4
1	1419	AAA	Manoranjitham	R	R/MR
2	0378	AAA	Lacatan	R	MR
3	0161	AAA	Chenkadali	R	MR
4	1065	AAA	Pachakappa	R	MR
5	2231	AAA	Amritsagar	R	MR
6	0111	AAA	Singapur	R	MR
7	0032	AAA	Bharat Moni	R	S
8	0017	AAA	Manjahaji	R	MR/S
9	0639	AAA	Yangambi KM5	R	MR/S
10	1653	AAA	Madhukar	R/MR	MR

11	2558	AAA	Kamal Vikas 1	R/MR	S
12	2575	AAA	Kaveri Sugantham	R/MR	S
13	0012	AAA	Jahaji	MR	MR
14	0009	AAA	Borjahaji	MR	MR
15	0081	AAA	Harichal	MR	MR
16	0500	AAA	Peddapacha	MR	MR
17	0632	AAA	GCTCV -119	MR	MR
18	0633	AAA	GCTCV – 215	MR	MR
19	0039	AAA	Tulsimanohar	MR	MR
20	0071	AAA	Leyan	MR	MR/S
21	1621	AAA	Gros Michel	MR	MR/S
22	2339	AAA	Grand Nain (Israel)	MR	MR/S
23	0608	AAA	Williams	MR	S
24	0618	AAA	Shrimanti	MR	S
25	0200	AAA	Robusta	MR	S
26	0498	AAA	Highgate	MR	S
27	2340	AAA	Pachottan	MR	S
28	0165	AAA	Dwarf Cavendish	MR/S	S
29	0166	AAA	Thella Chakarakeli	MR	HS
30	0645	AAA	Williams	S	MR/S
31	0370	AAA	Gandevi selection	S	S
32	0580	AAA	Grand Naine	S	HS
33	0670	AAA	2390-2	S	HS

R – Resistant; MR – Moderately Resistant; S – Susceptible; HS – Highly Susceptible

Regeneration systems in banana

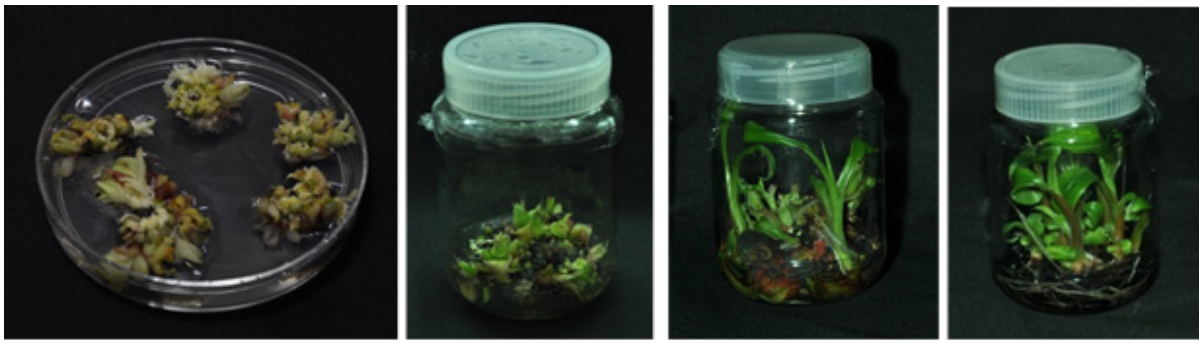
Standardization of *in vitro* regeneration in different banana cultivars

In vitro regeneration protocol has been standardized for varieties like Poovan, Rasthali, Red Banana, Ney Poovan, cv. Rose, Kaveri Kalki etc. The media composition varied with variety, explants and stage of development and are presented in Table 8.

Table 8. Media composition for in vitro regeneration of different banana varieties

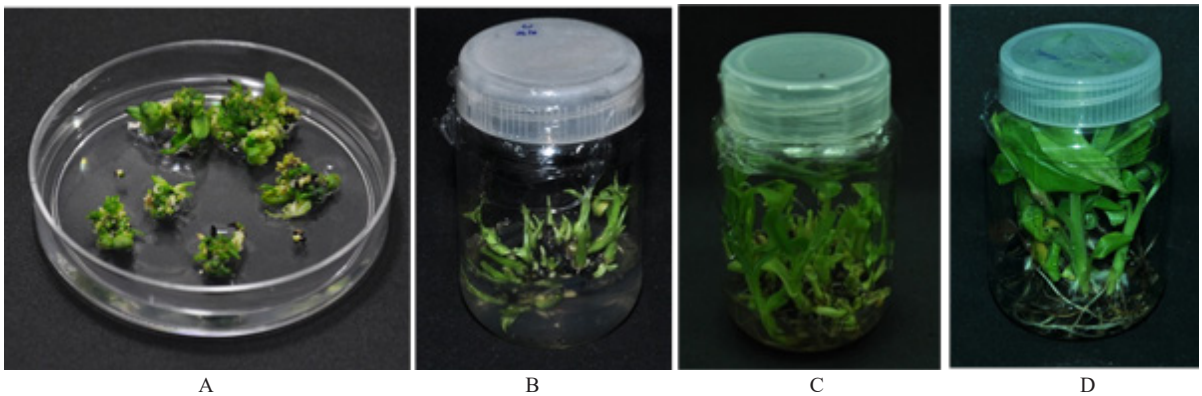
S. No.	Variety	Explant	Stage of multiplication	Gowth regulator requirement
1.	Poovan	Floral hands	Greening and meristematic clump formation	5mg/l BAP + 0.5mg/l Kin+1mg/l IAA.
			Shoot proliferation	3mg/l BAP + 1mg/l IAA.
2.	Rasthali	Floral hands	Meristematic clump formation	4mg/l BAP +1mg/l IAA
			Shoot proliferation	4mg/l BAP+1mg/l IAA
3.	Kaveri Kalki	Floral hands	Meristematic clump formation	5mg/l BAP+0.5 Kin+1mg/l IAA
			Shoot proliferation	4mg/l BAP+1mg/l IAA

4.	Red Banana	Floral hands	Meristematic clump formation	BAP at 9mg/l
			Conversion of floral into shoot meristem	4mg/l BAP + 1mg/l IAA.
			Shoot proliferation	4mg/l BAP + 1mg/l IAA.
5.	cv. Rose	Floral hands	Meristematic clump formation	BAP at 6 mg/l
			Conversion of floral into shoot meristem	4mg/l BAP + 1mg/l IAA.
			Shoot proliferation	4mg/l BAP + 1mg/l IAA.
6.	Williams	Shoot tip	Initial establishment	3mg/l BAP + 1mg/l IAA
			Shoot bud induction	0.4mg/l TDZ
			Shoot proliferation	3mg/l BAP+1mg/l IAA
		Floral hand	Meristematic clump formation	5mg/l BAP+0.5mg/l Kin+1mg/l IAA.
			Conversion of floral into shoot meristem	
			Shoot proliferation	4mg/l BAP+1mg/l IAA.
7.	Ney Poovan	Shoot tip	Initial establishment	4mg/l BAP +1mg/l IAA and 80mg/l adenine sulphate
			Shoot bud induction	TDZ at 0.4mg/l
			Shoot proliferation	4mg/l BAP+1mg/l IAA and 80mg/l adenine sulphate.



A B C D

Fig. 2. Direct regeneration in cv. Red Banana using immature male flower buds



A B C D

Fig. 3. Direct regeneration in cv. Rose using immature male flower buds

A - Meristematic clump formation in MS medium + BAP

B, C - Conversion of floral meristem into shoot meristem and shoot proliferation in MS medium + BAP+ IAA

D - Rooting

Nutritional analysis in banana germplasm accessions

The fresh fruit pulp samples of 450 bunches belonging to 121 commercially cultivated banana cultivars of India were analyzed to quantify nine mineral contents using ICP-OES (Table 9). The ANOVA revealed highly significant cultivar differences for all the minerals with below 10-fold variability for K and Mg to more than 100-fold for Na and Ca; Iron and Zn recorded 35- & 45-fold variability, respectively. Only positively skewed distribution was observed for all the minerals, *i.e.* majority of the banana cultivars have low magnitude for their fruit pulp mineral contents. The descending order of mean fruit pulp mineral content (mg/Kg) was K (626.1) > Ca (548.4) > Mg (321.9) > Na (196.3) > Fe (7.9) > Mn (4.6) > B (3.5) > P (3.2). Therefore, consumption of 100 g of banana pulp is shown to contribute fairly to the daily requirement of Indian adults (men and women with sedentary/moderate/heavy physical activity) in the ascending order of Mn (11.6%) > Ca (9.1%) > Mg (9.5% & 10.4%) > Fe (4.6% & 3.7%) > Zn (2.1%&2.5%) > K (1.7% & 1.9%) > Na (0.9% & 1.0%) and > P (0.1%), according to the revised RDA (Recommended dietary allowances) / AI (Adequate intake) values notified for Indians by the ICMR assuming 100% bioavailability which needs to be studied.

Table 9. Contribution of 100 g of banana pulp to RDA (Recommended dietary allowances)/AI (Adequate intake) requirement of different minerals for Indian adults calculated based on the mean value of Indian commercial cultivars (450 bunches belonging to 121 banana cultivars used in this study)

Minerals	Min.	Max.	Mean	Std. Dev.	RDA or AI (Values given are for sedentary work men; women) (mg/day)	Contribution of banana pulp (100 g) to the % of RDA based on the commercially cultivated bananas		
						Min	Max	Mean
B	0.00	21.63	3.50	3.61	ND	-		
Ca	39.04	3986.00	548.37	542.31	600	0.7	66.4	9.1
Fe	0.00	35.10	7.86	5.61	17:21	0.0	20.7:16.7	4.6:3.7
Mg	123.71	954.86	321.93	118.17	340:310	3.6:4.0	28.1:30.8	9.5:10.4
Mn	0.41	24.14	4.63	2.99	4.0 (AI)	1.0	60.4	11.6
K	209.80	1286.33	626.07	157.41	3750:3225	0.6:0.7	3.4:4.0	1.7:1.9
Zn	0.29	13.29	2.49	1.72	12:10	0.2:0.3	11.1:13.3	2.1:2.5
Na	5.01	556.19	196.33	82.75	2100:1900	0.0	2.6:2.9	0.9:1.0
P	0.51	8.11	3.23	1.50	600	0.0	0.1	0.1

Significant positive correlation was observed for all minerals with highest correlation value of 0.677 between Mg and Zn followed by >0.5 between Mg-Ca, Mg-Fe, Mg-Na and Mg-Mn (Fig.4). Both principal component analysis (Fig.5) and cluster analysis (Fig.6) failed to group the banana cultivars according to their ploidy/genome/subgroups. Further, the association among banana cultivars in close proximity (Biplot) reveals the involvement of only few ancestral species during their evolution with narrow genetic bases followed by uncontrolled spread of suckers through vegetative propagation.

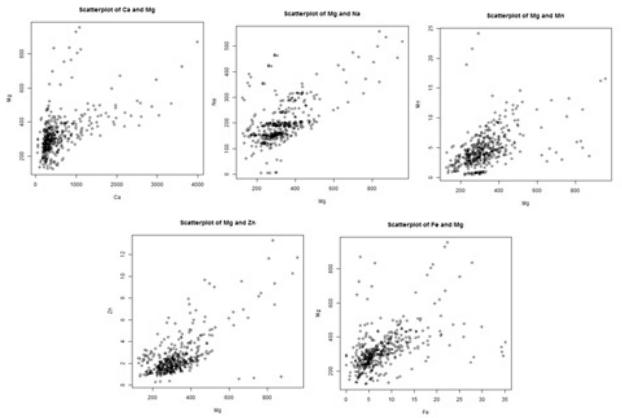


Fig. 4. Significant positive correlations (>0.5) of Zn, Ca, Fe, Na and Mn with Mg calculated based on 450 bunch values belonging to 121 Indian commercial cultivars

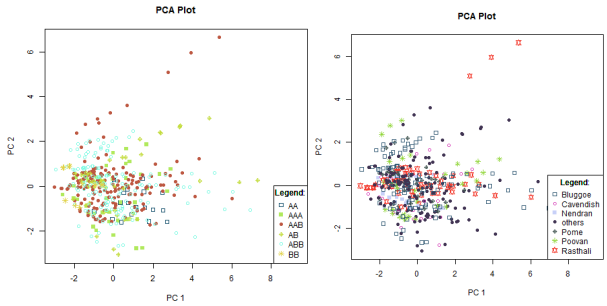


Fig. 5. Principal component analysis (PCA) based on the mean value of Indian commercial cultivars (450 bunches belonging to 121 banana cultivars) for nine fruit pulp mineral contents (K, Ca, Mg, Na, P, B, Mn, Fe and Zn)

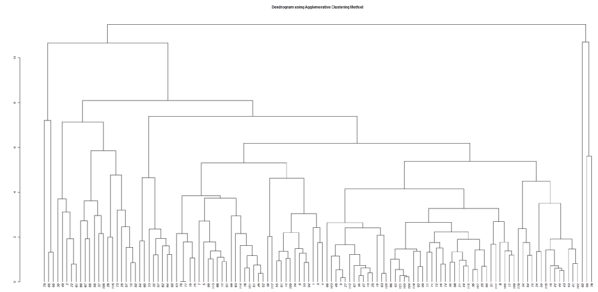


Fig. 6. Cluster analysis (CA) of 121 banana cultivars grown in India using the mean value of 450 bunches based on nine fruit pulp mineral contents (K, Ca, Mg, Na, P, B, Mn, Fe and Zn)

4.1.2 Improvement of banana through conventional breeding

Hybridization program

Efforts were made to develop progenies by hybridizing among various ploidy combinations (2x X 2x, 3x X 2x, 4x X 2x, 4x X 3x, 4x X 4x, 4x X 2x). A total of 72595 fruits were pollinated in 742 cross combinations involving 297 female parents and 44 male parents.

Success of embryo culture

Twelve progenies of three way cross hybrids have been developed from five combinations such as (Matti x cv. Rose) x Pisang Jajee, (Calcutta 4 x Kadali) x Calcatta 4, (Nendran x Pisang Lilin) x IITA 53, Nendan OP x Tani and Karpuravalli x Pisang Jajee. A total of 12 open pollinated progenies were established from commercial cultivars of Karpuravalli (4), Udhayam (1), Poovan (1), Saba (6). One four way cross hybrid [(Karpuravalli x Pisang Jajee) x P-207 (Matti x cv. Rose)] has been established under field conditions. A mapping population with 37 progenies was developed in the cross combination of Calcutta 4 x cv.Rose.

Screening of progenies against banana stem weevil (BSW)

Field screening of progenies against banana stem weevil was done in main crop during two years (2019 and 2021) and no infestation was found in two diploid progenies of cv. Rose x Pisang Lilin (Pro. 0429) and Matti x Anaikomban (Pro.0009). Screening of Pisang Awak based progenies revealed that, three Udhayam x Pisang Lilin (Pro. 0734, 0791, 0820); three Karpuravalli x Calcutta 4 -1 (Pro. 0755, 0783 , 0817); two Bankela x Calcutta 4-1 (Pro. 814 and 816) and one each of Udhayam x Calcutta 4 (Pro 819) and Udhayam x Calcutta 4-1 (Pro. 189); one Bhat Manohar x Udhayam (Pro. 187) and Bankela x Lairawk (Pro. 160) based progenies were found to be resistant. Similarly no BSW infestation was observed in three Saba based progenies namely Pro. 0685 and 0691 (Saba x Pisang Lilin) and one open pollinated progeny (Pro. 0731) of Saba in both the years.

Progenies with multiple resistance

Screening of progenies against biotic stresses revealed that four progenies of various ploidy such as 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 found to be resistant to banana stem weevil and Foc race 1. Being parthenocarpic

and polleniferous progenies (Pro. 429 and 820) are being used as male parent for incorporating multiple resistance in commercial cultivars. Other female and male fertile progenies (Pro. 0009, 819 and 814) having higher ploidy are used as both male and female parents.

Fig. 7. Pro. 819 – Udhayam x Calcutta 4

Evaluation of progenies against Foc race 1

A total of 50 PisangAwak and 10 Saba (Cooking banana) based progenies with various ploidies were evaluated for Foc race 1 under sick plot of Muthalapuram, Theni district, Tamil Nadu. It was observed that three Udhayam x Pisang Lilin (Pro. 820, 0821, 0831), two Udhayam x Calcutta 4 (Pro. 818, 819), three Bhat Manohar x Calcutta 4 -1, two Bankela x Calcutta 4 (Pro. 813, 814), (Pro. 760, 769, 770) and one Chinia x Calcutta 4 -1 (Pro. 777) one Bankela x cv. Rose (Pro.160), one Bankela x Pisang Lilin (Pro. 736), were found to be resistant to Foc race 1. Among the Saba based progenies, a triploid progeny Pro. 684 was found to be resistant to Foc race 1.

Among the six Foc race 1 resistant Udhayam based progenies, progeny Pro. 434 (Udhayam x Chengdawt) produced 14kg bunches with 8 to 10 hands of fruits, parthenocarpic fruits like Peyan with thick fruit skin, orange colored and granular pulp. Another parthenocarpic progeny, Pro. 819 (Udhayam x Calcutta 4) produced an average bunch weight of 16kg with 16 hands and its TSS content of 27°brix. Two diploid progenies (Pro 820 and 821) are found to be highly male and female fertile and being used in breeding program.

Fig. 8. Pro. 434
(Udhayam x Chendawt)

Fig. 9. Pro. 821.
Udhayam x Pisang Lilin

Among the Chinia based progenies, only one medium stature tetraploid, Progeny 777 (Chinia x Calcutta 4-1) was found to be female fertile and being used in breeding program to developed high yielding Foc resistant parthenocarpic triploid progenies.

Three tetraploid progenies of the cross Bhat Manohar x Calcutta 4-1(Pro. 760, 769, 770) were found to be resistant to Foc race 1. Not much variation was observed among these progenies. All are medium statured with 2.6 to 2.7m height and droopy leaves. Though all these progeneis produced an average bunch of 6kg with 5-6 hands, fruits are shorter and seeded in nature and being used as female parents in the Pisang Awak improvement program.

Evaluation of progenies for pro-vitamin A content

Among the Kothia based progenies, a pollen fertile diploid progeny (Pro. 932- OP of Pro. 480 Kothia x Calcutta 4) was found to have high PVA content (109.65µg/g of dry weight) and it is being included in the breeding program to improve the PVA in other commercial cultivars.

Fig. 10. Pro. 932- OP of Pro. 480 Kothia x Calcutta 4

Evaluation of progenies with culinary properties

A total of 28 Saba based progenies were developed of which only 5 progenies (959, 964, 965, 685, 691) produced good bunches weighing more than 20 kg. Evaluation of these high yielding progenies revealed that 959 and 964 as the stable yielders. Among these two, Pro. 959, recorded an average yield of 25.5kg and is highly preferred for its good cooking quality like other Saba based progenies and Monthan.

Evaluation of Nendran based hybrids suitable for chips preparation

Eight Nendran based hybrids were evaluated for their suitability for chips preparation. NCR 2 recorded high chips recovery percentage (41.9%) over cv. Nendran. Other hybrids recorded low percentage of 31.25% (NOP 45) to 38.49 % (NCR 8) than Nendran (40.67%).

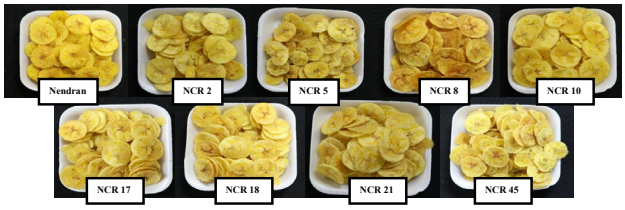


Fig. 15. Chips prepared from fruit pulp of Nendran based hybrids

Table 10. Chips recovery percentage of Nendran based hybrids

Cultivar/ Hybrid	Weight (g)				Chips Recovery %
	Whole fruit	Pulp	Peel	Chips	
Nendran	1020	720	300	415	40.67
NCR 2	865	630	235	363	41.962
NCR 5	962	620	342	339	35.23
NCR 8	852	596	256	328	38.49
NCR 10	819	573	246	300	36.6
NCR 17	915	666	249	320	34.9
NCR 18	902	653	249	343	38.02
NCR 21	967	683	284	329	34.02
NOP 45	960	670	290	300	31.25

Comparison of NCR 17 with Nendran and Grand Nain for biochemical parameters

The biochemical analysis of unripe and ripe fruits of NCR 17, Nendran and Grand Nain pulp was done. The result showed that NCR 17 recorded higher TSS content and less acidity than both the cultivars in the ripe pulp. Higher carotenoid content was recorded in Nendran followed by NCR 17 whereas NCR 17 had high percentage of total protein content than Nendran. Owing to its high carotenoid content, high TSS with less acidity, NCR 17 can be considered as carotenoid rich dessert banana.

Table 11. Biochemical analysis of unripe and ripe NCR 17, Nendran (female parent) and Grand Naine (commercial cultivar) on pulp fresh weight basis

Parameter	Unripe			Ripe		
	Nendran	NCR 17	Grand Nain	Nendran	NCR 17	Grand Nain
Moisture (%)	62.12 ± 1.37	64.17 ± 1.25	60.38 ± 1.02	74.35 ± 1.20	72.9 ± 1.02	70.34 ± 1.36

TSS (°Brix)	3.54 ± 0.29	3.97 ± 0.31	4.37 ± 0.06	25.13 ± 0.98	26.78 ± 1.65	19.40 ± 1.05
Acidity (%)	0.14 ± 0.03	0.12 ± 0.49	0.38 ± 0.04	1.07 ± 0.56	0.87 ± 0.53	0.98 ± 0.034
Total starch (%)	35.23 ± 1.04	33.86 ± 0.66	36.98 ±1.24	1.26 ± 0.49	1.82 ± 0.38	1.24 ± 0.22
Total sugar (%)	1.42 ± 0.28	1.67 ± 0.19	1.18 ± 0.07	18.1 ± 0.23	19.45 ± 0.21	22.18 ± 0.23
Reducing sugar (%)	0.26 ± 0.07	0.93 ± 0.09	0.34 ± 0.07	3.31 ± 0.50	3.38 ± 0.67	3.32 ± 0.36
Total protein (%)	0.36 ± 0.11	0.43 ± 0.08	0.67 ± 0.09	1.38 ± 0.36	1.97 ± 0.42	1.18 ± 0.08
Total fat (%)	0.23 ± 0.02	0.19 ± 0.03	0.36 ± 0.02	0.23 ± 0.06	0.31 ± 0.03	0.65 ± 0.16
Total ash (%)	0.33 ± 0.95	0.44 ± 0.11	0.65 ± 0.04	0.64 ± 0.13	0.64 ± 0.12	1.01 ± 0.10
Total phenol (mg of GA/100g)*	34.21 ± 1.31	37.63 ± 1.33	56.39 ± 0.24	67.5 ± 4.32	65.26 ± 2.45	83.48 ± 1.29
Total flavonoid (mg of QE/100 g)**	20.10 ± 1.12	28.25 ± 0.43	39.48 ± 0.16	58.8 ± 1.20	51.9 ± 1.02	49.26 ± 1.0
Total carotenoid (mg/100g)	389.6 ± 20.87	353.12 ±25.3	68.29 ± 2.19	712.96 ± 15.45	625.2 ±20.08	230.47 ± 1.21
Taste index	0.17 ± 0.04	0.19 ± 0.19	0.05±0.02	1.25 ± 0.12	1.31 ± 0.09	0.97±0.23

*mg of Gallic acid equivalent **mg of Quercetin equivalent

Open pollinated (OP) progenies of Namwa Khom for commercial exploitation in ornamental industry

A number of OP progenies of Namwa Khom (Progeny Nos. 872, 873 and 874) did not produce fruits with edible quality but the architecture of plants could be exploited for its ornamental value. Plants of these progenies (110cm, 130cm and 150cm) are nearly 30-50 % shorter than mother plant (231cm), displayed erect and tight arrangement of leaves, which gives an aesthetic appearance to the plant.

Fig.16. Progeny 872 (Namwa Khom Open Pollinated)

Namwa Khom (Bunch) Namwa Khom (Leaf disposition)

Fig. 17. Namwa Khom mother plant

Fig. 18. Namwa Khom Progenies - Field View

Evaluation of progenies for nutrient deficiency

A total of 132 hybrids progenies have been evaluated for expression of macro and micronutrient deficiency. All the Saba based hybrids (29) showed deficiency symptoms for Iron, calcium and Boron micronutrients. No micro / macro nutrient deficiency was observed in 31% of Pisang Awak hybrids. It was observed that there is no influence of male parent in the symptom development for nutrient deficiency

Deployment of ICT tools for effective management of banana genetic diversity and breeding programme

An effort was made at ICAR- National Research Centre for Banana to digitalize the information which is available with the Crop Improvement Section, so as to have a comprehensive information in a hand held device (A computer tablet/smart phone) to access and retrieve the information on germplasm and breeding material that has been generated using the parental lines. The data would contain the passport information for collected genetic diversity along with the historical evaluation data recorded as per the IPGRI descriptors. The same information module would also provide the researcher in real time, it's physical location in institute's ex situ collection with number of plants that are available for every germplasm accession. This module developed on Microsoft Excel also contains information on progenies that have resulted from an organised breeding efforts at ICAR-NRC for Banana. Any information right from the progeny's physical location to its pedigree, ploidy status and evaluation data could easily be traversed within the module.

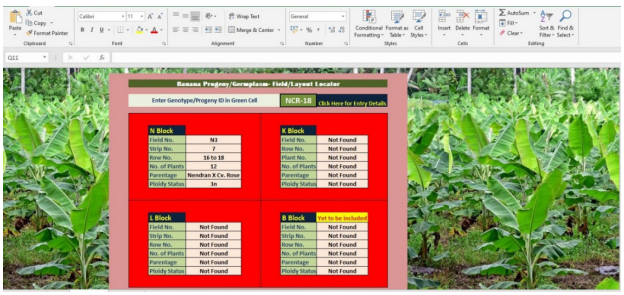


Fig. 19. Use of ICT tools in Banana Breeding Program

Banana Hybridization Information Module (BHIM)

Banana Hybridization Information Module works offline and can be easily accessed through any smart phone, tablet, PC or laptop. The summary/query page automatically gets updated with every entry of the data.

Information is always displayed at the top of the page and is tamper proof:

- Date of last up-dation
- Total no. of different female parents that have been used in crossing programme
- Total no. of different male parents that have been used in crossing programme
- Total no. of unique cross combinations that have been effected till date
- Total no. of pollinations (no. of fingers crossed) that have been performed till date

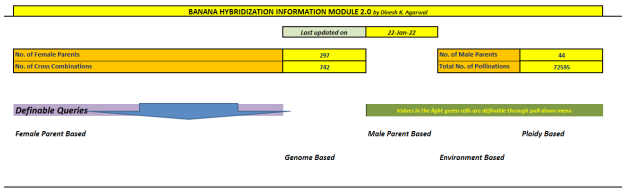


Fig. 20. Banana Hybridization Information Module

Breeding, evaluation and selection of ornamental banana hybrids for potted plants, cut-flowers, cut foliages, colored mini-fruits, edible fruits (seedless), landscaping, *etc.*

Identified twelve unique inter-specific ornamental hybrids (Table 12) after the field evaluation of 362 different ornamental banana hybrids belonging to *Musa rubra* × *M. acuminata* subsp. *zebrina* (37 Nos.), *M. ornata* × *M. rubra* (116 Nos.), *M. ornata* × *M. acuminata* subsp. *zebrina* (119 Nos.), and *M. ornata* × *M. velutina* subsp. *markkuana* (90 Nos.). These elite 12 inter-specific ornamental hybrids for cut-foliages, cut-flowers, pot-culture and landscaping were supplied to different ICAR Institutes, SAUs and NDMC during 2021 with MTA for multi-location evaluation (Table 13). and were approved in the XXIX Annual

Group Meeting of ICAR-AICRP on Floriculture held on December 14-17, 2020. Ten of the following AICRP on Floriculture test Centers were identified for multi-location evaluation of 12 inter-specific ornamental hybrid lines; (i) ICAR-DFR, Pune, Maharashtra, (ii). BCKV, Kalyani, West Bengal, (iii) AAU, Kahikuchi, Assam, (iv) PAU, Ludhiana, Punjab, (v) Dr Y.S.P.U.H & F, Solan, Himachal Pradesh, (vi) KAU, Vellanikkara, Kerala, (vii) ICAR-IIHR, Bengaluru, Karnataka, (viii) ICAR-IARI, New Delhi, Delhi, (ix) ICAR-IARI, New Delhi and (x) OUAT, Bhubaneshwar, Odisha.

Table 12. Number of inter-specific ornamental banana hybrids identified for evaluation under AICRP on Floriculture

S. No.	Crosses	Nos.	Shortlisted for replicated analysis	Identified for evaluation under AICRP on Floriculture
1	*M. rubra* × *M. acuminata* subsp. *zebrina*	37	10	4
2	*M. ornata*× *M. rubra*	116	14	4
3	*M. ornata* × *M. acuminata* subsp. *zebrina*	119	35	2
4	*M. ornata* × *M. velutina* subsp. *markkuana*	90	4	2
Total		362	63	12

Table 13. List of Centres and number of hybrid lines supplied for multi-location evaluation

S. No.	Name of the Centres	No. of hybrid lines supplied including 3 checks
1	ICAR-AICRP on Floriculture test Centres ((i) ICAR-DFR, Pune, Maharashtra, (ii). BCKVV, Kalyani, West Bengal, (iii) AAU, Kahikuchi, Assam, (iv) PAU, Ludhiana, Punjab, (v) Dr Y.S.P.U.H & F, Solan, Himachal Pradesh, (vi) KAU, Vellanikkara, Kerala, (vii) ICAR-IIHR, Bengaluru, Karnataka, (viii) ICAR-IARI, New Delhi, Delhi and (ix) OUAT, Bhubaneshwar, Odisha.	15 lines for each ICAR-AIRCP Centres
2	ICAR-Indian Institute of Oil palm Research, Pedavegi, Andhra Pradesh	15
3	Tamil Nadu Agricultural University (TNAU), Coimbatore	55
4	University of Horticultural Sciences (UHS), Bagalkot	55
5	Agricultural Research Station, College of Agriculture, Anand Agricultural University (AAU),Jabugam - 391155, Gujarat.	43
6	Dr.Y.S.R. Horticultural University, Venkataramannagudem-534101, West Godavari District, Andhra Pradesh	55
7	New Delhi Municipal Council (NDMC) gardens, New Delhi	55

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

A total of 13 core collection accessions representing various genomic groups which showed resistance to Fusarium wilt (Foc) in the earlier pot screening trials were established in pots with five replications each for confirmation. Pot screening results are presented in Table 7. Since the results are not consistent, the pot screening for this set of 13 accessions will be repeated once again and till date the phenotyping for all the 314 accessions have been completed.

Table 14. Screening of core collection accessions for resistance to Fusarium wilt (race 1)

S. No.	Variety	Accession No.	Genome	Fusarium wilt internal score
1	*M. acuminata* ssp. *burmannica*	1631	AA	2.0
2	Imbogo	957	AA	2.0
3	Dwarf Cavendish	165	AAA	2.3
4	Williams	608	AAA	2.5
5	Highgate	498	AAA	2.5
6	K.Kunnan	174	AB	2.0
7	Njalipoovan	188	AB	3.0
8	Ladies Finger	100	AAB	2.6
9	Hoobale	519	AAB	2.5
10	Atrusingan	497	AAB	2.3
11	H-3	735	AAB	3.0
12	Kaliethan	703	AAB	3.0
13	Neokhom	731	AAB	3.5

Genotyping of 153 germplasm accessions which is a mini core representing the major collection has been completed for 15 primers during the reporting period using automated electrophoresis system. Till date, the genotyping has been completed for 153 mini core accessions using 130 markers (100 EST-SSRs and 30 genomic SSRs).

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

Performance of fusarium wilt resistant mutants under sick plot conditions of Theni, Tamil Nadu

Mutants of cv. Grand Naine which showed resistance to race1 / 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 15).

Table 15. Performance of Fusarium wilt resistant mutants under sick plot conditions

S. No.	Grand Nain mutant line no.	Mutagen	Resistant reaction	Plant height (cm)	Psedostem girth (cm)	Bunch weight (kg)	Crop Duration (days)
1.	NRCBGNMG-1	Gamma irradiation	Race 1	225.40	71.50	27.67	345.63
2.	NRCBGNME-2	EMS	Race 1	225.25	80.10	28.67	350.20
3.	NRCBGNME-1	EMS	TR 4	227.50	71.25	29.26	346.75
4.	NRCBGNME-3	EMS	TR 4	221.67	70.40	31.75	340.50
5.	NRCBGNME-13	EMS	TR 4	211.33	70.67	29.16	345.35
6.	NRCBGNME-15	EMS	TR 4	226.55	72.75	26.5	345.15
7.	NRCBGNMD-3	DES	TR 4	223.50	70.50	31.25	345.50

Fig. 21. Fusarium wilt resistant mutants under sick plot conditions in vegetative and shooting stages

NRCBGNME -1	NRCBGNME -3	NRCBGNME -13	NRCBGNME -15

NRCBGNMG -1	NRCBGNME -2	NRCBGNMD -3

Fig. 22. Performance of promising Fusarium wilt resistant mutant lines under sick plot conditions

Field performance of Grand Nain Mutant (NRCBGNMG 1) under hotspot conditions (Theni, Tamil Nadu) for Foc race 1

NRCBGNMG 1, a Grand Nain mutant derived from Gamma irradiated ECS (35 Gy), which was resistant (with a disease score 1.08) in pot culture and found promising in the sick plot conditions was further multiplied and evaluated under hotspot conditions of Theni in three farmers' fields and the growth and yield parameters recorded are furnished in the Table 16.

Table 16. Field performance of Grand Nain Mutant (NRCBGNMG 1) under hotspot conditions

Characteristics	Farmer's field (Gudalur, Theni)		Farmer's field (Erasai, Theni)		Farmer's field (Muthalapuram, Theni)	
	NRCBGN-MG 1	Grand Nain	NRCBGNMG1	Grand Nain	NRCBGN-MG 1	Grand Nain
Pseudostem height (m)	2.28	2.38	2.40	2.53	2.35	2.48
Duration (days)	350.80	366.40	330.40	340.2	355.70	364.80
Bunch weight (kg)	24.30	26.50	30.20	29.00	28.50	26.80
Number of hands	10.90	11.30	12.50	11.80	11.80	11.20
Total number of fruits	188.40	191.20	207.30	198.5	200.40	192.25
TSS (Brix)	25.7	26.2	22.16	23.16	26.2	26.4
Acidity (%)	0.36	0.35	0.69	0.35	0.37	0.36

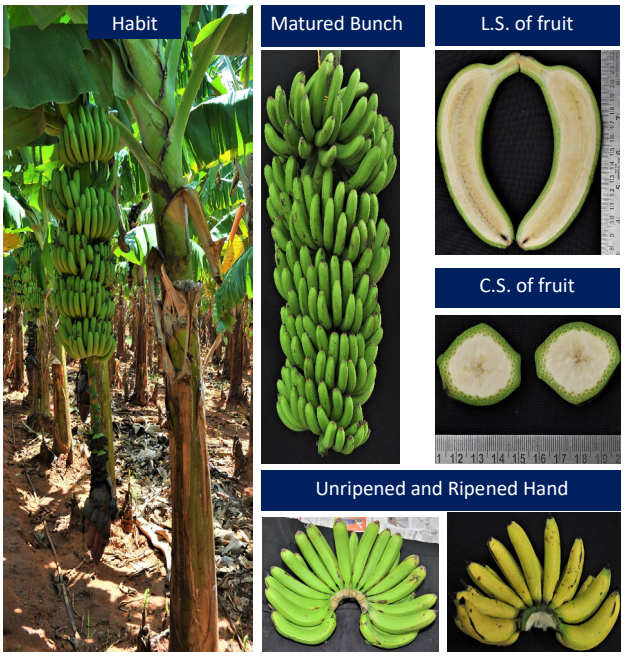


Fig. 23. Grand Nain mutant (NRCBGNMG 1)

Pot culture screening of mutant population of cv. Grand Nain for Fusarium wilt resistance

Totally 346 plants derived from different mutagens and explants have been challenge inoculated with Foc race 1 / TR4 and disease scoring will be done shortly. The details are provided in Table 17.

Fig. 24. Pot culture screening for Fusarium wilt resistance (Race 1 & TR4)

Table 17. Details of mutated population under pot culture screening for Fusarium wilt resistance

S. No.	Mutagen	Explant	No. in screening for race 1	No. in screening for TR4	Total
1.	Gamma irradiation (10 Gy)	Shoot tip	15	10	25
2.	Gamma irradiation (10, 20 and 25 Gy)	ECS	66	72	138
3.	EMS	ECS	26	23	49
4.	SA	ECS	56	68	124
5.	DES	ECS	5	5	10
					346

Status of mutants identified under pot culture conditions

Four mutant lines of cv. Grand Nain derived from the combined treatment of Gamma irradiation and EMS which showed resistance to race 1 in pot culture have been initiated *in vitro* and are under multiplication.

Status of mutagenized population of cv. Grand Nain

Hardening and multiplication stage

ECS derived mutagenized plants of cv. Grand Nain (55 nos.) are in the secondary hardening stage. Immature floral hands have been gamma irradiated once or twice and they are being multiplied *in vitro*.

Cv. Rasthali

Ten potential mutants of cv. Rasthali which were found to be tolerant to race 1 under sick plot conditions were mass multiplied through micro- and macropropagation and planted in the sick plot for confirmation and in the hotspot areas of Trichy and evaluation is in progress.

Fig. 25. Confirmatory trial of race 1 tolerant mutants of cv. Rasthali under sick plot conditions at Theni, Tamil Nadu

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

The initial growth and yield traits of Ney Poovan tetraploids showed that plant height, girth and days taken for flowering were higher than its diploid. However, rachis length, bract scar, no. of hands, no. of fruits per hand, total no. of fruits per bunch were lower than its diploid (Table 18 & Fig. 26). Further, the leaves of tetraploids were more droopier and the leaf drooping angle (Tanθ), ratios of HLT/Hp (height at leaf tip/ height of petiole) and HLT/HPLBJ (height at petiole-leaf blade junction) measured as shown in the Figures 27 & 28 were lower (48.6, 0.76 and 0.68, respectively) than its diploids (79.0, 1.72 and 1.41, respectively). Hence, these morphological traits can very well be used for identification/classification of tetraploids from its diploid Ney Poovan. Male fertility is restored in the tetraploid Ney Poovan because about 650 to 1400 pollen grains were recorded (Fig. 29) with >90% *in vitro* and up to 1% *in vivo* pollen germination (Fig. 30) as compared to its diploid (3 to 7 pollen grains; with no *in vitro* and *in vivo* pollen germination). Unreduced gametes formation was very commonly noticed that's why the pollen diameter of Ney Poovan diploid and tetraploid ranged from 58 to 232 µm & 62 to 292 µm, respectively as shown in the Figure 31 & 32. About 64 percent incidence of corm and pseudostem weevil was recorded in Ney Poovan tetraploids however, no weevil incidence was recorded in Ney Poovan diploid.

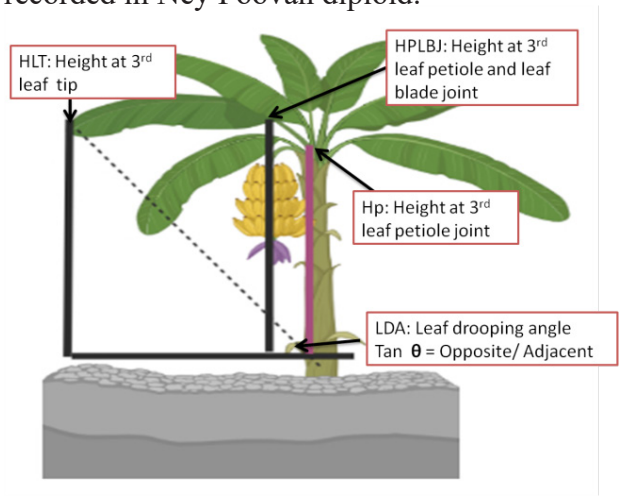


Fig. 27. Schematic diagram used for the measurement of leaf droopiness in Ney poovan

Fig. 26. Growth and yield performance of Ney Poovan tetraploid (Left) and diploid (Right)

Table 18. Growth performance of Ney Poovan diploid and tetraploid

parameters	Height (cm)	Girth (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Rachis length, cm	Days taken for flowering	Rachis length, female phase, cm	Rachis length –male phase	Total no. scars in male phase	No. of hands	No. of fruits per hand	Total no. of fruits per bunch	Avg. no. of fruit per hand	No. of pollen per anther	Pollen fertility (%)
2n	215 to 300	52.3 to 59	192 to 207	52 to 58	43.7 to 63	45 to 84	212 to 315	25 to 50	47 to 60	>100	9 to 12	11 to 16	101 to 153	13.7 to 16	3 to 7	>70
4n	206 to 355	63.5 to 71.0	158 to 220.5	38 to 60.5	38 to 56	35 to 55	370 to >530	14 to 28	35.5 to 39	60-82	5 to 7	4 to 11	30-63	5.8 to 9	650 to 1400	>92

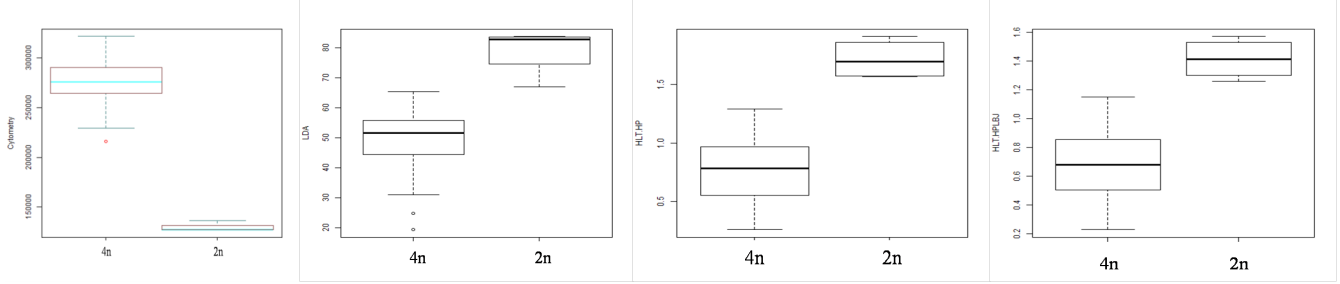


Fig. 28. Comparison of flow-cytometry and quantification of leaf droopiness using leaf dropping angle (LDA), HLT/Hp (height at leaf tip/ height of petiole) and HLT/HPLBJ (height at petiole-leaf blade junction) ratios for classification of tetraploid and diploid in Ney poovan.

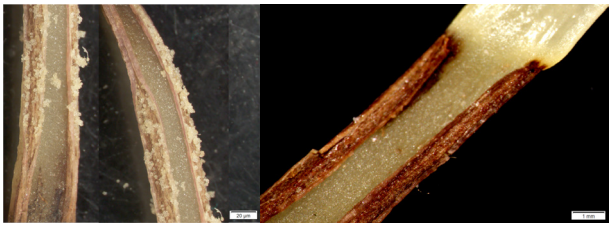


Fig. 29. Anther with abundant pollen grains in Ney poovan tetraploid (Left) and no pollen grains in its diploid (Right)

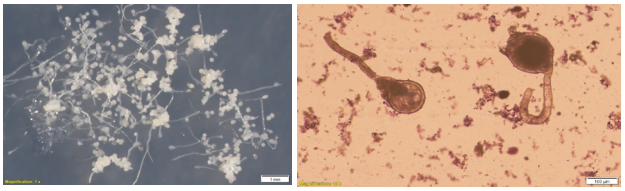


Fig. 30. *In vitro* (Left) and *in vivo* (Right) pollen germination of Ney Poovan tetraploid

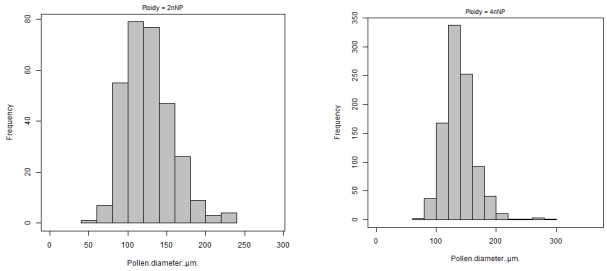


Fig. 31.Histogram showing the variability in pollen diameter of Ney Poovan diploid (2nNP) and tetraploid (4nNP).

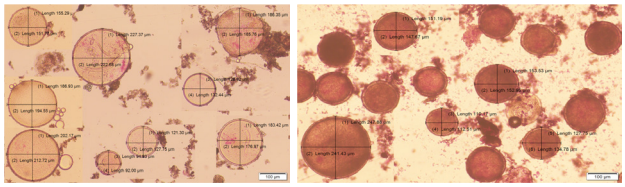


Fig. 32. Variability in pollen diameter of Ney Poovan diploid (Left) and tetraploid (right)

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

The average plant height and leaf length of Grand Nain dwarf clones was 143 cm & 138 cm, respectively which is 30% lesser than the normal Grand Nain's plant height (203 cm) and leaf length (198 cm) nonetheless without compromising the yield traits (Table 19 & Fig. 33). Also, the shooting was about one month earlier in dwarf clones than the high yielding clones. In addition to reduced plant height and leaves length of dwarf clones, the rachis appears with the presence of neutral / male flowers and withered bracts (on the whole stalk) which was bare (without the presence of male flowers/ bracts) in the high yielding normal Grand Nain clones.

Fig. 33. Performance of dwarf Grand Nain clones (left & Middle) with the presence of neutral/ male flowers and withered bracts (on the whole stalk) on the rachis as compared to normal high yielding Grand Nain clone (Right) which recorded bare rachis appearance (without the presence of male flowers/bracts) at ICAR-NRCB's Research Farm

Two surveys were undertaken during the reporting period in Theni and Coimbatore and collected suckers from a virescent red banana (green fruit peel colour; Fig. 34) and a dwarf Grand Nain variant with obvious reduction in plant height (23.4%), petiole (19.2%) and leaf (17.9%) length (Table 20) respectively.

Table 19. Growth and yield performance of Grand Nain somaclones at ICAR-NRCB's Research Farm

Parameters	Height (cm)	Girth (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Days taken for flowering	No. of leaves at shooting	No. of hands	No. of fruits in the 2nd hand	Total no. of fruits per bunch	Avg. no. of fruit per hand
Dawrf (R1-3)	140	58	136	64	23	240	10	8	13	110	13.7
Dwarf (R1-5)	146	61	140	66	23	242	8	10	21	180	18
Average (Dwarf)	143	59.5	138	65	23	241	9	9	17	145	15.9

Dwarf with high yield (R1-9)	160	58	160	63	38	271	9	8	14	106	13.3
Dwarf with high yield (R1-11)	158	54	160	64	34	282	10	7	12	98	14
Avg. (Dwarf with high yield)	159	56	160	63.5	36	276.5	9.5	7.5	13	102	13.7
High yield	185 to 220	61 to 70	192 to 204	69 to 74	24 to 28	242 to 315	8 to 12	10 to 11	13 to 16	135 to 248	13.5 to 15.5
Avg. (High yield)	203	64.7	198.1	71.6	23.8	279	9.2	10.4	15.2	153.8	14.8
% reduction (-) or increase (+) of dwarf clones over high yielding clones	-29.6	-8.0	-30.3	-9.2	-3.4	38 days early flowering (13.6%)	-2.2	-13.5	+11.8	-5.7	+7.4

Table 20. Growth and yield characteristics of a potential dwarf Grand Nain somaclone

Type	Height, cm	Girth, cm	No. of leaves	Petiole length, cm	Leaf length, cm	Leaf width, cm	No. of Hands	No. of fingers in the 2nd hand	Total no. of fruits per bunch
Dwarf	175	76	14	21	124	60	9.5	18	171
Check1	227	79	12	22	142	66	8.5	18	153
Check2	230	84	9	30	160	66	12	20	240
% reduction (-) or increase (+) of dwarf clones over checks (high yielding normal clones)	-23.4	-6.8	+33.3	-19.2	-17.9	-9.1	-7.3	-5.3	-13.0

Fig. 34. Virescent red banana (green fruit peel colour), a somaclonal variant collected from tissue culture raised garden at Theni

Identification and evaluation of superior clones of cv. Grand Nain

Dwarf and high yielding clones of cv. Grand Nain namely 17, 24, 25, 28, 32, 43, 48 and 52 were multiplied using shoot tips and immature male flower buds.

Fig. 35. Secondary hardening of Grand Nain clones

ICAR-NRCB, Trichy, Tamil Nadu

Seepalakottai, Theni, Tamil Nadu

Fig. 36. Field view of Grand Nain clones at different locations

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

Transcriptome analysis was carried out for resistant and susceptible banana roots and corms in response to infection by *Fusarium oxysporum* f.sp. *cubense* race 1 and tropical race 4 at different time intervals post inoculation. Total RNA was isolated, quantified and RNA degradation and contamination were monitored on 1% agarose gels. RNA integrity numbers (RIN) were greater than 7.0 and all the samples passed the primary quality check parameters. Library construction and Illumina sequencing were performed and adapter, ploy-N and low-quality reads from raw reads were removed to obtain filtered and clean reads. The paired-end filtered reads were aligned to the banana reference genome of *Musa acuminata* ssp. *malaccensis* version 4.3 and also with Foc race 1 and Foc TR4 using HiSat2.

A comprehensive genome-wide analysis of PR-1 and R genes from both genomes of banana (A and B) was carried out.Totally 15 and 11 PR-1 genes were identified from A and B genomes of banana, respectively, and the proteins encoded by this gene family are of varying lengths and harbor conserved domains and motifs. PR-1 genes are unevenly dispersed on 11 chromosomes with segmental duplication in both A and B genome, suggesting an important contribution of duplication in the expansion of PR-1 gene family in banana. qRT-PCR analysis of PR-1 gene showed positive correlation with the RNAseq data under various stresses and examination of expression pattern of selected MaPR-1 genes in banana revealed its role in biotic and abiotic stresses in general and fusarium wilt in particular.

Genic SSR marker associated with Foc race 1 and TR4 were validated on reported Foc Race1 and TR4 resistant and susceptible cultivars (Fig. 37-41).

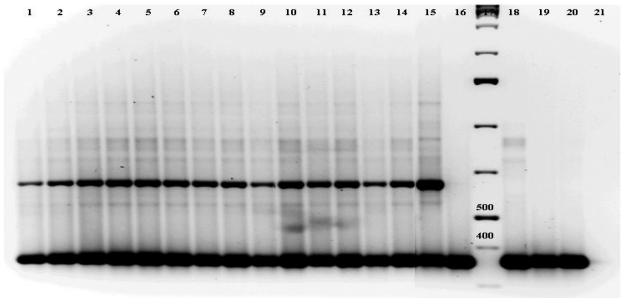


Fig. 37. Validation of genic SSR marker 430 associated with *Foc*race 1. Lane 1 – Jahaji; Lane 2 – Manjahaji; Lane 3 – Borjahaji; Lane 4 – Madhukar; Lane 5 – Lacatan; Lane 6 – Gandevi Selection; Lane 7 – Harichal; Lane 8 – Singapur; Lane 9 – Dwarf Cavendish; Lane 10 – Robusta; Lane 11 – GCTV – 215; Lane 12 – High Gate; Lane 13 – Williams ; Lane 14 – Grand Nain; Lane 15 – *M.ac.zebrina*; Lane 16 – *M.velutina*; Lane 17 – 1 kb plus; Lane 18 – Gros Michel; Lane 19 – Lady finger; Lane 20 – Rasthali; Lane 21 – Negative

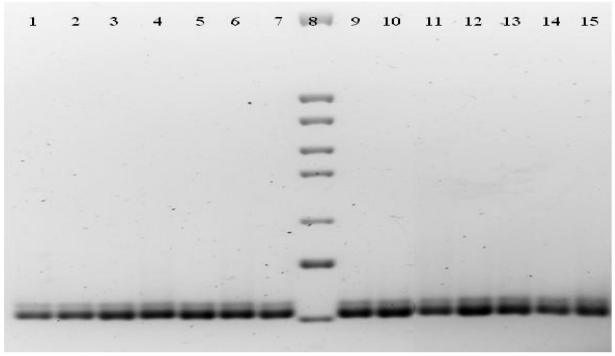


Fig. 38. Validation of genic SSR marker (SSR-R3) associated with ***Foc***-TR4. Lane 1 – Jahaji (AAA); Lane 2 – Manjahaji (AAA); Lane 3 – Borjahaji (AAA);Lane 4 – Madhukar (AAA); Lane 5 – Lacatan (AAA); Lane 6 – Gandevi Selection (AAA); Lane 7 – Harichal (AAA); Lane 8 – Marker 100 bp; Lane 9 – Singapur (AAA); Lane 10 – Dwarf Cavendish (AAA); Lane 11 – Robusta (AAA); Lane 12 – GCTCV – 215 (AAA); Lane 13 – High gate (AAA); Lane 14 – Williams (AAA); Lane 15 – Grand Nain (AAA)

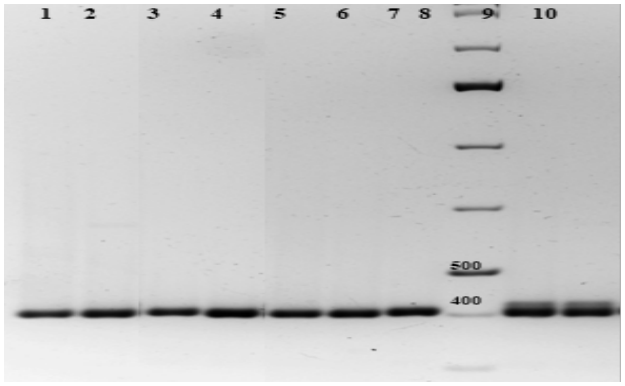


Fig. 39. Validation of genic SSR marker (SSR-R3) associated with *Foc*TR4. Lane 1 - cv.Rose (AA); Lane 2 - SannaChenkadali (AA); Lane 3 - Attikol (BB); Lane 4 - Manoranjitham; Lane 5 - *M.ac.* Assam wild (AA); Lane 6 - *M.ac.* Arunachal Pradesh (AA); Lane 7 - Nendran (AAB); Lane 8 - 1 kb Plus Marker; Lane 9 - Grand Nain (AAA); Lane 10 - Matti (AA)

Genic SSR marker associated with Foc race 1 was validated across ornamental bananas and *M.ac.* ssp. *zebrina* which is reported as a resistant cultivar against Foc race1 showed resistant banding pattern (Fig. 41). SSR marker associated with anthocyanin pigment has been identified to differentiate the red banana (AAA) from its green variant (Pachakappa, AAA) (Fig. 42). The marker was validated on Red banana, Sannachenkadali, Chenkadali, *M. ac.* ssp. *zebrina*, *M. ornata*, *M. rubra* and F1 population of *M. ornata* and *M.ac.* ssp. *zebrina* and found to differentiate the purple from the green bananas.

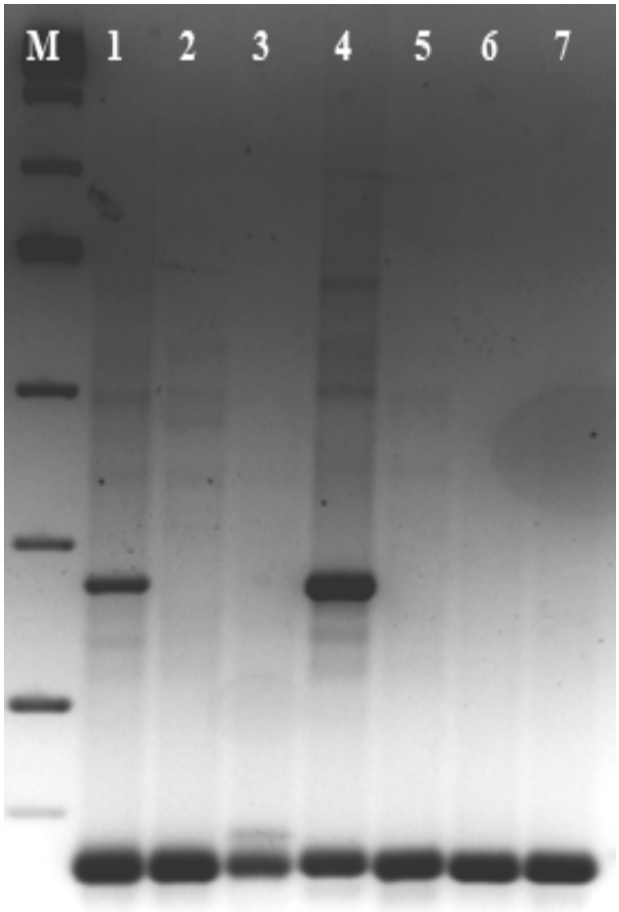


Fig. 40. Validation of genic SSR marker 430 associated with *Foc* race 1. Lane M- 1 Kb Plus Marker; Lane 1- Grand Nain; Lane 2 - Gros Michel; Lane 3 – *M. ornata*; Lane 4 – *M. ac.* ssp. *zebrina*; Lane 5 – *M. rubra*; Lane 6 – *M. velutina*; Lane 7 - *M. ac.* ssp. *marakkuvana*

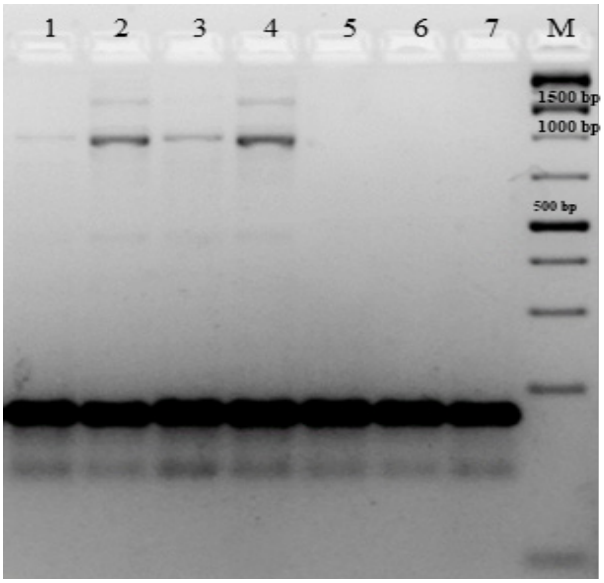


Fig. 41. SSR marker associated with anthocyanin. Lane 1: *M. ac. zebrina;* Lane 2: Red Banana; Lane 3: Sannachenkadali; Lane 4: Chenkadali; Lane 5: Pachakappa; Lane 6: *M. ornata;* Lane 7; *M. rubra;* Lane M: 1kb Plus Marker

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

Crop Production

4.2.1 Studies on nutrient dynamics in banana

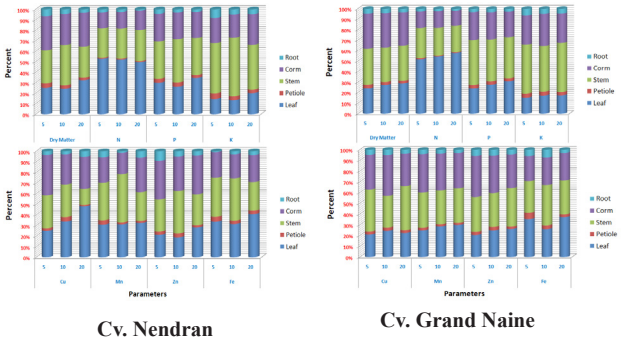
The total dry matter production (DMP in t/ha) increased from 2.31 to 12.86 in cv. Nendran, while it increased from 2.35 to 10.64 in cv. Grand Nain during the growth period from 5-leaf stage to 20-leaf stage (Table 21 and 22). The percent DMP fractions and nutrient accumulations in leaf, petiole, stem, corm and root at different growth stages of Nendran and Grand Nain are given in Fig. 42. The cubic polynomial curves were derived to know the uptake (kg/ha) pattern of macro- and micro-nutrients from 5-leaf stage to 20-leaf stage (Fig. 43). The nutrients uptake (kg/ha) in Nendran, N uptake increased from 22.5 to 233.57 gradually with increasing rate, P uptake from 6.17 to 42.15 at a slow pace and K uptake from 101.01 to 662.68 rapidly with increasing rate. The Cu and Fe uptake increased steadily from 0.85 to 2.62 and 2.44 to 5.13, respectively, while the Mn and Zn uptake increased with decreasing rate from 1.72 to 2.62 and 0.33 to 0.96, respectively. The nutrients uptake (kg/ha) in case of Grand Naine, the N and P uptakes steadily increased from 21.59 to 119.85 and 6.48 to 35.81, respectively, but the K uptake increased rapidly with increasing rate from 106.09 to 593.02. The Fe and Zn uptake increased steadily from 1.84 to 4.9 and 0.34 to 1.35, respectively, while Mn and Cu uptake increased at decreasing rates from 1.9 to 2.61 and 0.34 to 1.35, respectively.

Table 21. Dry matter and nutrient accumulation pattern at different growth stages in cv. Nendran

Parameter	Leaf stage	Accumulation or uptake by					
		Leaf	Petiole	Stem	Corm	Root	Total
Dry Matter (t/ha)	5	0.58	0.10	0.73	0.75	0.15	2.31
	10	1.44	0.19	2.28	1.76	0.26	5.93
	20	4.17	0.31	3.80	4.16	0.42	12.86
N (kg/ha)	5	11.91	0.22	6.28	3.43	0.66	22.50
	10	35.41	0.58	19.41	10.82	1.68	67.90
	20	115.95	2.45	68.94	43.31	2.93	233.57
P (kg/ha)	5	1.85	0.24	2.19	1.63	0.26	6.17
	10	4.80	0.74	7.55	4.66	0.54	18.29
	20	14.57	1.20	14.84	10.51	1.03	42.15
K (kg/ha)	5	14.73	5.48	48.36	24.21	8.22	101.01
	10	36.09	10.02	150.03	59.72	13.33	269.19
	20	134.11	20.91	283.21	194.43	30.01	662.68
Cu (kg/ha)	5	0.21	0.02	0.26	0.32	0.03	0.85
	10	0.57	0.07	0.52	0.48	0.05	1.70
	20	1.26	0.03	0.40	0.79	0.14	2.62
Mn (kg/ha)	5	0.53	0.07	0.61	0.41	0.10	1.72
	10	0.85	0.05	1.24	0.55	0.04	2.74
	20	0.85	0.05	0.71	0.85	0.16	2.62
Zn (kg/ha)	5	0.07	0.01	0.10	0.12	0.03	0.33
	10	0.15	0.03	0.32	0.26	0.04	0.80
	20	0.27	0.02	0.28	0.35	0.04	0.96
Fe (kg/ha)	5	0.82	0.11	0.90	0.59	0.02	2.44
	10	1.18	0.12	1.50	0.85	0.11	3.75
	20	2.08	0.17	1.38	1.30	0.19	5.13

Table 22. Dry matter and nutrient accumulation pattern at different growth stages in cv. Grand Nain

Parameter	Leaf stage	Accumulation or uptake by					
		Leaf	Petiole	Stem	Corm	Root	Total
Dry Matter (t/ha)	5	0.57	0.08	0.81	0.78	0.12	2.35
	10	1.63	0.17	1.95	1.93	0.27	5.95
	20	3.07	0.27	3.56	3.35	0.39	10.64
N (kg/ha)	5	11.18	0.21	6.23	3.40	0.56	21.59
	10	35.84	0.51	17.58	10.52	1.49	65.94
	20	69.21	0.81	30.33	17.29	2.20	119.85
P (kg/ha)	5	1.55	0.22	2.77	1.73	0.21	6.48
	10	4.99	0.56	7.19	4.69	0.62	18.05
	20	11.04	1.03	13.95	8.80	0.99	35.81
K (kg/ha)	5	16.18	4.06	49.47	29.33	7.05	106.09
	10	48.29	10.32	122.09	84.51	14.60	279.81
	20	103.34	18.79	277.52	164.27	29.09	593.02
Cu (kg/ha)	5	0.22	0.03	0.41	0.34	0.05	1.05
	10	0.63	0.08	0.76	0.98	0.13	2.58
	20	0.53	0.06	0.97	0.71	0.09	2.36
Mn (kg/ha)	5	0.47	0.05	0.62	0.68	0.08	1.90
	10	0.69	0.05	0.76	0.83	0.09	2.42
	20	0.78	0.05	0.84	0.86	0.08	2.61
Zn (kg/ha)	5	0.07	0.01	0.11	0.13	0.02	0.34
	10	0.22	0.03	0.28	0.31	0.05	0.89
	20	0.35	0.03	0.48	0.42	0.06	1.35
Fe (kg/ha)	5	0.65	0.11	0.54	0.43	0.11	1.84
	10	0.82	0.11	1.18	0.81	0.23	3.15
	20	1.83	0.13	1.55	1.26	0.15	4.90



Cv. Nendran Cv. Grand Naine

Fig. 42. Dry matter accumulation and nutrient uptake in different parts of Nendran and Grand Nain at different growth stages

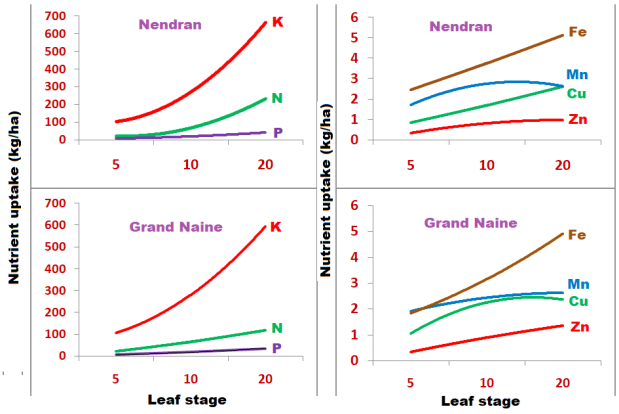


Fig. 43. Cubic polynomial curves representing nutrient uptake pattern at different growth stages in Nendran and Grand Nain

4.2.2 Organic banana farming for sustainable soil health and nutritional security

In organic banana farming studies, the nutrient uptakes (g/plant) were quantified at the 5-leaf stage. The highest nutrient uptakes were recorded in 100% inorganic fertilizer applied plants followed by the organic combination M1 (FYM + neem cake + vermicompost + wood ash) and the lowest values were recorded in the absolute control. The 100% inorganic fertilizer treatment recorded uptakes (g/plant) of N-55.6, P-6.0, K-154.4, Ca-48.2 and Mg-20.7 whereas the treatment M1 recorded uptakes of N-41.8, P-5.3, K-116.2, Ca-42.0 and Mg-18.8. The absolute control recorded the uptake values of N-18.8, P-2.2, K-52.3, Ca-17.5 and Mg-9.2 (Fig. 44).

At 10-leaf stage, the treatment M_2 (*i.e.*, application of poultry manure @ 5 kg/pl + groundnut cake @ 1 kg/pl + rural compost @ 3 kg/pl + wood ash @ 3 kg/pl) overtook M_1 by recording the highest nutrient uptakes (g/plant) of N-64.6, P-7.9, K-179.8, Ca-63.2 and Mg-33.5 among the organic treatments, but the 100% inorganic treatment recorded nutrient uptakes (g/plant) of N-71.7, P-7.8, K-199.2, Ca-62.1 and Mg-26.7. The absolute control recorded the uptake values of N-22.5, P-2.6, K-62.7, Ca-21.0 and Mg-11.0 (Fig. 45).

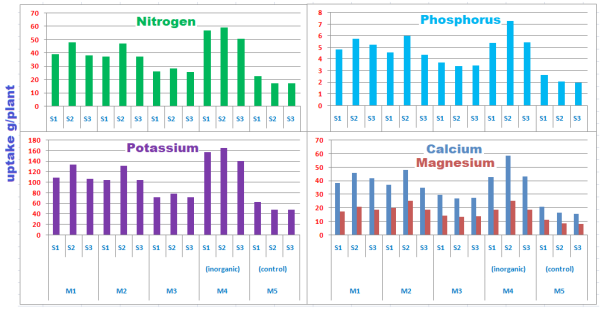


Fig. 44. Nutrient uptake by cv. Ney Poovan at 5-leaf stage

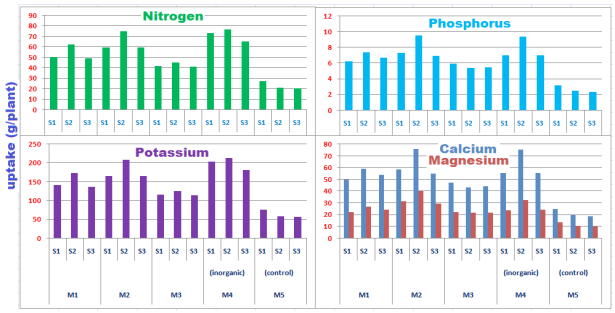


Fig. 45. Nutrient uptake by cv. Ney Poovan at 10-leaf stage

Organic carbon fractions

Soil samples from organic farming field were collected at three different depths *viz.*, 0-15, 15-30 and 30-45 cm and organic C fractions were determined. Irrespective of the treatments and depths, very labile form of carbon is the dominant fraction, which was highest in the treatment M2 (0.65%), followed by M4 and M1 at 0-15 cm depth. The lowest carbon content, irrespective of lability, was recorded in the treatment M5 which is an absolute control without any organic inputs (Fig. 46).

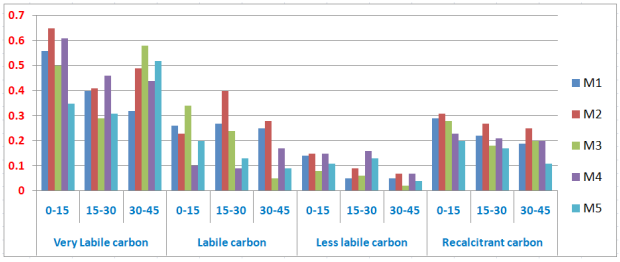


Fig. 46. Different fractions of oxidizable organic carbon (%) at three different depths

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

In cv. Kaveri Saba, irrespective of fertilizer levels (F1: 200:30:300 g NPK and F2: 200:30:400 g NPK per plant), the normal spacing (S1-1.8 x 1.8 m2) recorded lower plant heights at 10-leaf, 15-leaf and 20-leaf stages than that of paired row planting (S2-1.5 X 1.5 X 2 cm2). Irrespective of the planting space, the F1 fertilizer level dominated over F2 in terms of plant height till 15-leaf stage and at the 20-leaf stage, the effects of F1 and F2 were on par in terms of plant height. At F1 level, with normal planting density S1, the pseudostem girth dominated over S2 till the 15-leaf stage and this trend was reversed at 20-leaf stage, but at F2 level, the paired row planting density S2 dominated over S1 till 20-leaf stage. Though the pseudostem girth decreased with increasing planting density, it could be enhanced with increased level of fertilizer from F1 to F2. The phyllochron rate (leaves/week) varied from 0.90 at S1F2 level in 10-leaf stage to 1.1 at S2F2 level in 20-leaf stage. The phyllochron was more in F2 level than in F1 at all the plant densities from

10-leaf stage onwards. The total leaf area (m2) ranged between 0.2 at S2F2 with 5-leaf stage and 1.05 at S2F2 with 20-leaf stage. There was a rapid increase in the total leaf area in all the levels from 5-leaf stage to 10-leaf stage, but it was gradual between 10-leaf stage and 15-leaf stage. There was a rapid increase in the total leaf area from 15 to 20-leaf stage. The total leaf area at F2 level dominated over F1 at all growth stages except the 5-leaf stage (Fig. 47).

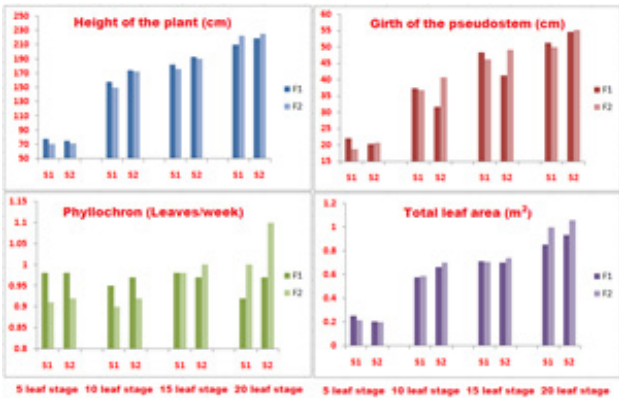


Fig. 47. Effect of spacing and fertiliser levels on plant growth parameters of Kaveri Saba

In cv. Kaveri Harita, the plant height, pseudostem girth and total leaf area increased gradually with duration and the phyllochron varied from 0.9 to 1.1. Irrespective of the fertiliser levels, the plant heights at S2 were more than that of S1 at all the growth stages, except 5-leaf stage. Irrespective of level of plant density, the plant height due to F2 was more than that of F1 at 10-leaf stage and 20-leaf stage and the trend was reversed at 5-leaf stage and 15-leaf stage. Though pseudostem girths were less with S2 density at F1 level up to 15-leaf stage, with S2 density the pseudostem girths at F2 were more than that of F1. This clearly indicated that with increased level of fertiliser, the suppressing effect of increased planting density could be eliminated (Fig. 48). The phyllochron was higher with F1 in S1 density planting than in S2 density till 10-leaf stage and then it was in reverse from 15-leaf stage onwards, which indicated rapid production of leaves for want of sunlight from this stage, at higher planting density. The average total leaf areas in S2 density were higher than that of S1 in all the plant growth stages, except the 5-leaf stage. At both density levels, F2 recorded higher total leaf areas than F1 from 10-leaf stage onwards. Thus, higher level of fertiliser in high density planting was found to reduce the detrimental effects of increased planting density on plant growth parameters (Fig. 48).

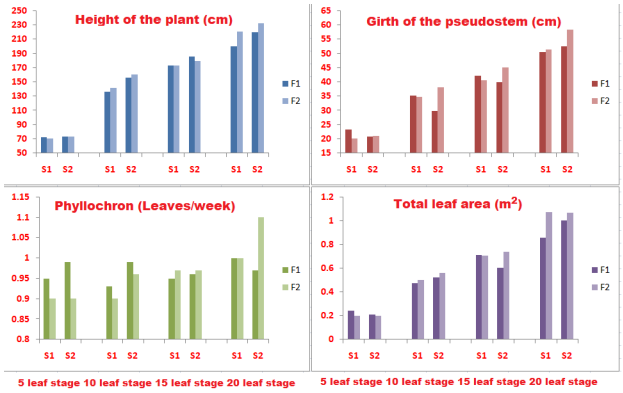


Fig. 48. Effect of spacing and fertiliser levels on plant growth parameters of Kaveri Harita

In case of cv. Popoulu, the average plant heights were more with S2 density when compared to S1 from 10-leaf stage onwards. At 10-leaf stage, F1 recorded higher values of plant height than F2 in S1 and the reverse was the true in S2 planting density. At 15-leaf stage, F2 surpassed F1 at both the densities. Irrespective of the planting densities, F2 recorded more girth than F1 from 5-leaf stage to 15-leaf stage. Irrespective of the fertiliser levels, though the average pseudostem girth in S2 started to remain less than that of S1 density at 15-leaf stage, the S2F2 combination recorded the highest value of pseudostem girth. This indicated the beneficial effect of increased fertiliser levels over the increased density of planting (Fig. 49). The higher the levels of fertilisers, the higher the phyllochron at 5-leaf stage and the reverse was true from 10-leaf stage onwards, irrespective of planting densities. The average phyllochron was always higher in S1 than S2, irrespective of fertiliser levels. At 15-leaf stage, the superiority of S2F2 over S2F1 in phyllochron was not reflected in the total leaf area, which indicated reduced areas of individual leaves at S2F2 suggesting detailed future studies (Fig. 49).

Cv. Kaveri Kalki was studied in three planting densities (S1- 1.8 x 1.8 m^2, S2 - 2.1 x 2.1 m^2 and S3 - 2.4 x 2.4 m^2) with two fertiliser levels (F1 and F2). Though the average plant

heights increased with duration, it started to remain short in wider spacing than in higher density from 10-leaf stage onwards, but a reverse trend was observed in case of pseudostem girths. The average pseudostem girths increased with duration as well as with reduced planting densities. Irrespective of planting densities, F2 always recorded higher pseudostem girths than F1 and F2 recorded higher phyllochrons than F1 during 5-leaf stage to 15-leaf stage, irrespective of planting densities. Though the same trend of phyllochron due to fertiliser levels was observed in 15-leaf stage, it was not reflected in the total leaf area at this growth stage. This indicated reduction in area of individual leaves, even with increased levels of fertilisers, irrespective of planting densities. But the planting densities showed significant influence on average total leaf areas, irrespective of fertiliser levels, *i.e.*, the more the planting density, the less the average total leaf area (Fig. 50).

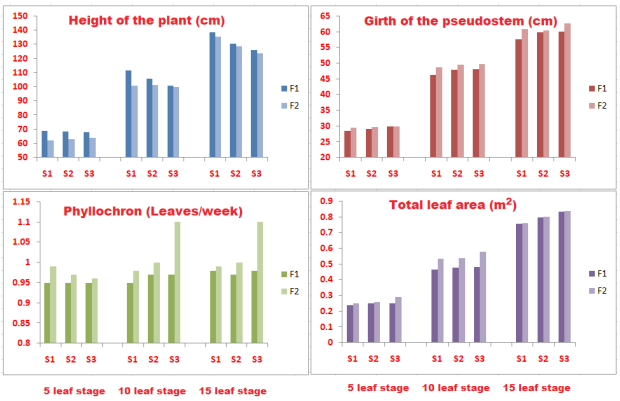


Fig. 49. Effect of spacing and fertiliser levels on plant growth parameters of Popoulu

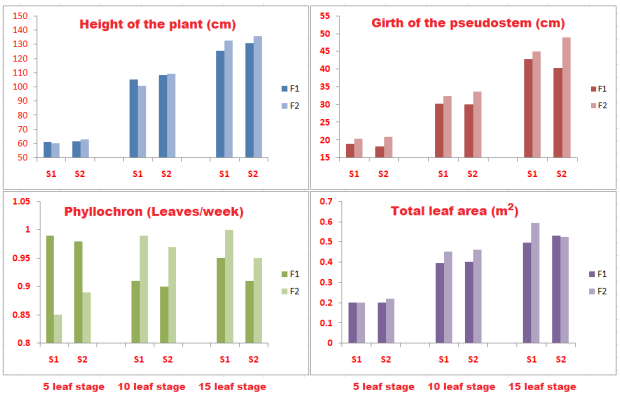


Fig. 50. Effect of spacing and fertiliser levels on plant growth parameters of Kaveri Kalki

Evaluation of ornamental banana hybrids under field and pot culture conditions

Field experiment

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 ($N\text{-}P_2O_5\text{-}K_2O$: 200-30-300 g/plant) as sub-plot treatments. Initial trend showed that S1F2 (3 suckers with 66% RDF) is the best performing treatment combination (Table 23; Fig. 51).

Fig. 51. Field view of ornamental banana hybrids at ICAR-NRCB Research Farm

Table 23. Growth performance of ornamental banana hybrids under field condition

Treatment	Plant Height (cm)	Plant Girth (cm)	Leaf Length (cm)	Leaf Width (cm)	Leaf Area (cm^2)	Petiole Length (cm)	No. of Leaves
S1F1	75.50	13.78	64.28	22.74	1461.72	21.33	7.92
S1F2	98.63	18.06	82.67	29.91	2472.42	27.92	8.08
S1F3	91.13	16.76	79.88	29.24	2335.68	25.08	8.00
S2F1	96.96	17.01	79.25	26.89	2131.16	27.10	9.42
S2F2	73.04	14.93	64.21	23.13	1484.82	24.44	7.92
S2F3	94.13	16.76	79.82	27.12	2164.36	28.29	8.50
S3F1	89.21	12.98	59.18	39.09	2313.58	25.36	13.17
S3F2	88.08	15.50	77.25	27.04	2088.97	26.42	8.00
S3F3	79.63	14.11	66.79	22.83	1524.52	24.85	9.00

Note S1: 3 suckers/ mat, S2: 6 suckers/mat; S3: 9 suckers/mat; F1: 33% of RDF, F2: 66% of RDF; F3: 100% RDF

Pot experiment

Ornamental hybrids 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-P_2O_5-K_2O: 200-30-300 g/plant), applied monthly in 12 equal splits as sub-plot. Plastic pots with bottom diameter of 23 cm were used with two drainage holes at the bottom. Sprouting of suckers was highest under M2 (83.33%) followed by M1 (66.66%) and lowest under M3 (17.77%) condition. Among the three growing environmental conditions, plants under M3 condition could not survive (100% mortality) owing to higher light intensity and building up of temperature in the root zone. Overall the growth performance of ornamental hybrids was better under M2 condition over the M1 (Table 24; Fig. 52). Among the sub-plot treatments, S3 (30% of RDF) recorded higher plant height, girth and number of leaves than S1 and S2 fertilizer levels.

Table 24. Growth performance of three ornamental hybrids under variable light intensity and fertilizer doses

Ornamental Hybrids	Treatments	Plant Height (cm)	Plant Girth (cm)	Leaf Length (cm)	Leaf Width (cm)	Petiole Length (cm)	No of Leaves
Musa rubra x *M. acuminata* ssp. *zebrina*	M1S1	57.75	7.00	54.75	16.25	22.25	3.00
	M1S2	52.00	5.50	49.00	13.50	23.00	3.00
	M1S3	60.00	9.00	58.00	16.00	18.00	4.00
	M2S1	76.20	13.50	75.90	26.70	23.80	6.00
	M2S2	80.80	13.80	80.60	26.60	26.20	5.20
	M2S3	85.67	14.25	80.83	27.50	26.33	6.33
M. ornata x *M. acuminata* ssp. *zebrina*	M1S1	41.50	6.75	38.25	16.00	16.50	3.75
	M1S2	74.00	9.00	62.00	17.00	23.00	6.00
	M1S3	44.50	7.00	40.00	12.88	15.50	6.25

M. ornata x *M. acuminata* ssp. *zebrina*	M2S1	78.50	12.50	77.00	26.00	19.50	6.50
	M2S2	75.20	10.60	70.20	22.80	24.20	6.80
	M2S3	85.40	12.80	76.00	26.20	27.80	6.60
M. ornata x *M. rubra*	M1S1	39.75	6.75	42.00	11.75	15.25	5.50
	M1S2	48.00	7.50	45.50	11.00	15.00	5.50
	M1S3	61.00	8.00	54.00	17.00	22.00	5.00
	M2S1	67.00	12.00	75.00	24.00	28.00	7.00
	M2S2	92.75	12.88	79.63	28.38	27.00	7.67
	M2S3	59.75	9.88	58.75	22.50	19.25	6.00

M1: up to 3000 Lux M2: 3000-6000 Lux M3: 6000 Lux (Intermittent direct sun light)

Fig. 52. Ornamental hybrids under three environmental conditions

4.2.4 Development of clump management technology for enhanced productivity in banana

The experiment on Ney Poovan and Poovan bananas was continued and the results pertaining to the total crop duration, total bunch weight, yield and cost economics are presented. In Ney Poovan, the total clump duration ranged from 463.9 days (S1) to 595.6 days (S4). The difference in duration was more wider (61.8 days) between treatments S3 and S4 where as it was closer between S2 and S3 (32.7 days). In Poovan, the treatment S4 recorded the longest clump duration of 643.6 days that was 160.4 days, 114.6 days and 49.6 days longer than S1, S2 and S3 respectively. No significant differences in total crop duration among three levels of nutrition (Table 25).

Table 25. Effect on total crop duration of entire clump in Ney Poovan and Poovan bananas

	Ney Poovan (AB)				Poovan (AAB)			
Treatments	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
S1	467.3	464.3	460.2	463.93[a]	482.6	485.9	482.9	483.20[a]
S2	504.7	500.1	498.6	501.13[b]	529.4	530.4	527.1	529.00[b]
S3	537	534.6	529.8	533.80[c]	598.3	593.9	589.8	594.00[c]
S4	601.6	593.8	591.4	595.60[d]	651.4	642.9	636.5	643.60[d]
Mean	527.65	523.20	520.00		565.43	563.28	559.08	

In cv. Ney Poovan, among four different sucker population per clump, S4 (MP+4 suckers per clump) recorded the highest bunch weight of 42.1 kg with a total yield of 73.2 t/ha. Among different levels of the nutrition applied, 175% RDF recorded 35.25 kg/clump and was on par with N2 that recorded a total weight of 34.68 kg/clump (Table 26; Fig. 53).

Table 26. Effect on total bunch weight/clump (kg) and total yield (t/ha) in cv. Ney Poovan

	Total bunch weight (kg/clump)				Total yield (t/ha)			
Treatments	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
S1	21.4	22.9	22.9	22.40[d]	37.24	39.85	40.20	39.10[d]
S2	30.9	32.9	32.9	32.23[c]	53.77	57.25	57.77	56.26[c]
S3	38.2	40.3	41.0	39.83[b]	66.47	70.62	71.35	69.31[b]
S4	39.4	42.6	44.2	42.10[a]	68.56	74.89	76.91	73.20[a]
Mean	32.48[c]	34.68[ab]	35.25[a]		56.50[c]	60.65[b]	61.56[a]	

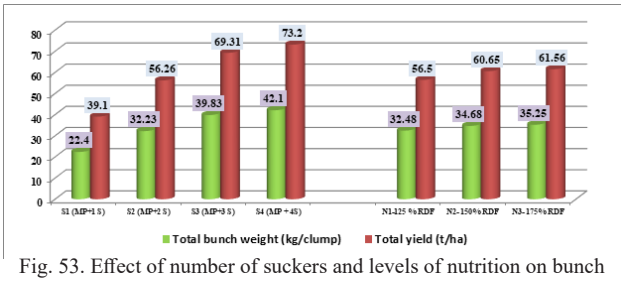


Fig. 53. Effect of number of suckers and levels of nutrition on bunch weight and yield in cv. Ney Poovan

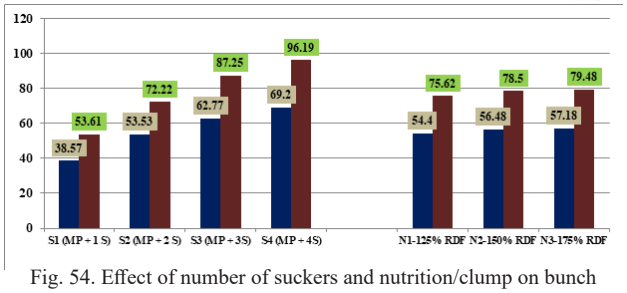


Fig. 54. Effect of number of suckers and nutrition/clump on bunch weight and yield in cv. Poovan

In Poovan banana, S4 recorded the highest bunch weight of 69.2 kg per clump with a total fruit yield of 96.2 t/ha. Among the three levels of the nutrition tried, 175% RDF recorded 57.17 kg/clump and was on par with N2 (56.48 kg per clump). Similarly, the highest yield of 79.5 t/ha was recorded in N3 (175% RDF/clump) that was on par with 150% RD- N2 (78.5 t/ha) (Table 27; Fig. 54).

Table 27. Effect on total bunch weight/clump (kg) and total yield (t/ha) in cv. Poovan

	Total bunch weight (kg/clump)				Total yield (t/ha)			
Treatments	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
S1	37.7	38.7	39.3	38.57^{d}	52.40	53.79	54.63	53.61^{d}
S2	51.3	54.3	55	53.53^{c}	71.31	75.48	69.87	72.22^{c}
S3	61.0	63.1	64.2	62.77^{b}	84.79	87.71	89.24	87.25^{b}
S4	67.6	69.8	70.2	69.20^{a}	93.96	97.02	97.58	96.19^{a}
Mean	54.40^{b}	56.48^{a}	57.18^{a}		75.62^{b}	78.50^{a}	79.48^{a}	

Effect of cost economics

In cv. Ney Poovan, S4 recorded the highest BC Ratio of 3.64 followed by S3 (3.46). Among different levels of the nutrition applied, 175% RDF a BC Ratio of 3.06 closed followed by 150% RDF (3.04). In cv. Poovan, the highest BC Ratio of 2.81 was recorded in S4 followed by S3 (2.48). Among three levels of nutrition, 150% RDF recorded the highest BC Ratio of 2.34 (Table 28).

Table 28. Effect on cost economics (BC Ratio) in Ney Poovan and Poovan bananas

	Ney Poovan (AB)				Poovan (AAB)			
Treatments	**N1**	**N2**	**N3**	**Mean**	**N1**	**N2**	**N3**	**Mean**
S1	1.99	2.09	2.09	2.06	1.66	1.68	1.69	1.68
S2	2.79	2.92	2.90	2.87	2.19	2.28	2.28	2.25
S3	3.38	3.48	3.51	3.46	2.54	2.59	2.61	2.58
S4	3.48	3.68	3.75	3.64	2.78	2.83	2.81	2.81
Mean	2.91	3.04	3.06		2.29	2.34	2.32	

Effect on soil microbial population

Soil microbial studies revealed that the population of fungi, bacteria and actinomycetes varied among four different treatments and increased with increasing number of suckers/ clump. The fungi (5.64-7.84 CFU 10^{-4}), bacteria (10.08-18.44 CFU 10^{-7}) and Actinomycetes (2.30-3.90 10^{-5}) population varied among four different treatments and increased with increasing no. of suckers per clump. Among three levels of nutrition, application of 125% RDF per clump recorded the highest microbial population as compared to the higher doses (Table 29).

Table 29. Effect on soil microbial population at flowering/harvesting stages

Treatments	Flowering stage			Harvesting stage		
	Fungi (CFU 10^{-4})	Bacteria (CFU 10^{-7})	Actinomycetes (CFU 10^{-5})	Fungi (CFU 10^{-4})	Bacteria (CFU 10^{-7})	Actinomy-cetes (CFU 10^{-5})
S: No. of Suckers/Clump						
S1- MP + 1 sucker	4.89	11.00	1.44	5.64	10.08	2.30
S2- MP + 2 suckers	5.44	11.46	1.53	5.86	14.02	2.67
S3- MP + 3 suckers	5.57	14.17	1.89	6.93	17.10	2.97
S4- MP + 4 suckers	7.11	15.88	2.78	7.84	18.44	3.90
N: Levels of Nutrition/clump (% RDF)						
N1- 125% RDF	6.65	14.82	2.08	6.25	16.42	4.25
N2-150% RDF	6.08	12.65	1.50	6.17	13.60	2.41
N3-175% RDF	4.69	11.24	2.00	4.69	12.94	1.96

Based on the results of the previous experiment, a new experiment was laid out with banana cv. Ney Poovan under split plot design with three levels of population per hill *i.e.,* S1- Mother Plant + allowing one sucker each at 4 and 6 MAP (MP + 2 Suckers); S2- MP + a sucker each at 5, 7 and 8 MAP (MP + 3 Suckers) and S3- MP + a sucker each at 5, 6 , 7 and 8 MAP (MP+4 Suckers) and were imposed with three different levels of nutrition i.e., N1- 125% RDF per clump; N2- 150% RDF per clump and N3- 175% RDF per clump and with five replications (Table 30).

Observations recorded in the early vegetative growth stage of the plants revealed that among the three levels of population per clump significant differences were recorded for the parameters of plant height, leaf length and mean leaf area whereas, other parameters were found non-significant. Among the three levels of nutrition tried, the values of the growth parameters were increased with increasing doses of fertilizers. However, the growth performance of the plants applied with 150% RDF and 175% RDF per clump were on par with each other. The plants are in vegetative stage and the differential treatments are being imposed.

Table 30. Effect of number of suckers and levels of nutrition per clump on the growth of banana cv. Ney Poovan

Plant height (cm)				
Treatments	N1 (125% RDF)	N2 (150% RDF)	N3 (175% RDF)	**Mean**
S1 - (MP+ 2 suckers)	145.9	173.1	162.7	160.57^{b}
S2 - (MP+ 3 suckers)	138.7	179.9	198.2	172.30^{ab}
S3 - (MP+ 4 suckers)	156.8	182.1	190.8	176.57^{a}
Mean	147.13^{b}	160.6^{ab}	183.9^{a}	
Pseudostem girth (cm)				
S1 - (MP+ 2 suckers)	47.7	51.9	50.9	50.17
S2 - (MP+ 3 suckers)	50.9	51.8	55.9	52.87
S3 - (MP+ 4 suckers)	49.0	52.3	55.4	52.23
Mean	49.2^{b}	52.0^{ab}	54.07^{a}	
Number of healthy leaves				
S1 - (MP+ 2 suckers)	9.59	10.98	10.66	10.41
S2 - (MP+ 3 suckers)	9.86	10.56	10.94	10.45
S3 - (MP+ 4 suckers)	9.81	10.77	10.94	10.51
Mean	9.75^{c}	10.77^{b}	10.85^{a}	

Petiole length (cm)				
S1 - (MP+ 2 suckers)	33.66	40.68	40.76	38.37
S2 - (MP+ 3 suckers)	35.78	40.62	46.46	40.95
S3 - (MP+ 4 suckers)	35.36	43.10	45.48	41.31
Mean	34.93[b]	41.47[a]	44.23[a]	
Leaf length (cm)				
S1 - (MP+ 2 suckers)	119.9	142.4	135.6	132.6[b]
S2 - (MP+ 3 suckers)	129.7	144.2	160.8	144.9[a]
S3 - (MP+ 4 suckers)	125.6	146.6	158.8	143.7[a]
Mean	125.1[b]	144.4[a]	151.7[a]	
Leaf breadth (cm)				
S1 - (MP+ 2 suckers)	47.4	52.8	50.6	50.3
S2 - (MP+ 3 suckers)	47.2	53.5	57.7	52.8
S3 - (MP+ 4 suckers)	49.6	53.7	56.0	53.1
Mean	48.07[b]	53.0[a]	52.2[a]	
Mean leaf area (m^2)				
S1 - (MP+ 2 suckers)	0.47	0.63	0.57	0.56[b]
S2 - (MP+ 3 suckers)	0.51	0.64	0.77	0.64[a]
S3 - (MP+ 4 suckers)	0.52	0.66	0.74	0.64[a]
Mean	0.50[b]	0.64[a]	0.69[a]	
Total leaf area (m^2)				
S1 - (MP+ 2 suckers)	4.58	6.86	6.15	5.86
S2 - (MP+ 3 suckers)	5.03	6.90	8.52	6.82
S3 - (MP+ 4 suckers)	5.07	7.08	8.12	6.76
Mean	4.89[b]	6.95[a]	7.60[a]	
Leaf area index (LAI)				
S1 - (MP+ 2 suckers)	0.79	1.19	1.07	1.02
S2 - (MP+ 3 suckers)	0.87	1.20	1.48	1.16
S3 - (MP+ 4 suckers)	0.88	1.23	1.41	1.17
Mean	0.85[b]	1.21[a]	1.32[a]	

Post-harvest Technology

4.2.5 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 was recorded during January-December 2021 at monthly intervals. Significant differences (P <0.05) were observed among the varieties, months and their interaction (Varieties x Months). Leaf production varied from 3.88 to 5.00 among the varieties and 3.71 to 4.98 among the months. Karpuravalli produced the maximum number of leaves (5.00), followed by Poovan (4.55), Sakkai (4.43) and Progeny 183 (4.17), while minimum number of leaves were observed in Phirima wild (3.88). Maximum number of leaves were produced during July (4.98), followed by August (4.81), December (4.68), November (4.64), and September (4.56). Minimum leaf production

was seen in June (3.71).

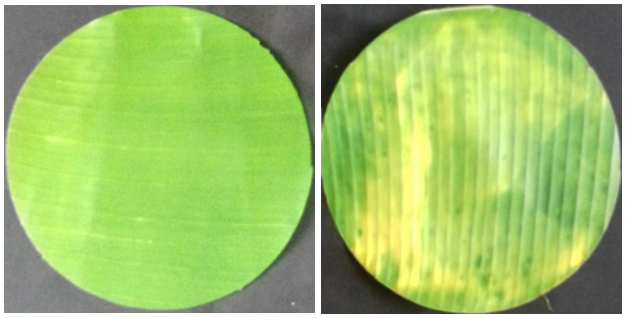
Leaf production associated characters were also recorded for all these varieties. There were no significant differences among the varieties for leaf area, but significant differences were observed for leaf thickness, total chlorophyll content and number of side suckers. Leaf thickness varied from 0.18 to 0.28 mm, the minimum being with Sakkai and maximum being with Phirima wild. Total chlorophyll content varied from 5.40 mg/g (Karpuravalli) to 12.43 mg/g (Progeny 183). Maximum side suckers were produced by Karpuravalli (3.48), followed by Poovan (3.13), Sakkai (2.92) and Phirima wild (2.53), while minimum number of side suckers was produced by Progeny 183 (2.29). 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 in cvs. Naadu, Poovan and Karpuravalli based on the number of suckers was studied in different clumps of mother plant + daughter suckers with combinations like 1+3, 1+4 and 1+5 during January-December, 2021. Significant variations ($P < 0.05$) were observed among the number of suckers, months and interactions between them. In general, 1+5 combination produced the maximum number of leaves irrespective of the variety. In Naadu, maximum number of leaves was obtained in 1+5 combination (13.15), followed by 1+4 combination (11.96) and 1+3 combination (10.86). Production of leaves varied from 10.97 to 13.16 in different months. Maximum leaf production was observed during February (13.16), followed by March (12.72), April (12.49), October (12.11) and September (12.08) and the minimum was during January (10.97).

In Poovan, 1+5 combination produced the maximum number of leaves (12.63), while minimum number of leaves was produced by 1+3 combination (10.59). Leaf production was maximum during August (14.05), followed by September (13.70), December (13.41), October (13.36), November (13.28) and it was minimum during January (9.19). In Karpuravalli, the maximum leaf production was seen in 1+5 combination (13.01), followed by 1+4 (11.49) and the minimum were seen in 1+3 combination. In August, maximum leaf production (13.39) was observed, 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 (0.91 m^2) > Karpuravalli (0.80 m^2). In terms of leaf thickness, Karpuravalli had the lowest (0.19 mm), while Poovan and Karpuravalli recorded 0.27 mm. Cv. Naadu registered the highest total chlorophyll content (10.51 mg/g), followed by Poovan (6.49 mg/g) and it was minimum with Karpuravalli (3.94 mg/g). Colour index ('L', 'a', 'b') of leaves of these varieties showed lightness ('L' value) ranging from 40.29 to 50.15, 'a' value (positive value - redness and negative value - greenness) from-25.10 to -22.06 and 'b' value (positive value - yellowness and negative value - blueness) from 30.74 to 37.88. Positive 'b' value indicates the yellowness in leaves, which is attributed to end of shelf-life of leaves due to degradation of chlorophyll.



Fresh leaf | At the end of shelf-life

Fig. 55. Shelf-life of banana leaf – At beginning and at the end

4.2.6 Developing integrated package of practices for export of selected commercial and GI tagged banana varieties of India

Trial on 'Ney Poovan' banana in the Farmer's field

A trial was initiated in a farmer's field at Kodiyalam village, Tiruchirappalli District on cv. Ney Poovan planted in May 2021 using 260 plants. 'Banana Sakthi' - a micronutrient mixture was sprayed on 3rd and 5th months after planting and the growth characters were recorded and the trial is in progress.

Storage studies on individual and mixed varieties of banana on quality and shelf-life

An experiment was carried out to study the effect of individual and mixed varieties of banana, namely Nendran, Ney Poovan and Red Banana on the quality, sensory parameters and shelf life under cold storage (13.5°C) and room temperature in order to explore the possibilities of exporting mixed varieties in reefer containers to foreign countries without affecting the quality and shelf life. Improved post-harvest handling, pre-treatments, packing (with and without ethylene scrubber), storage (13.5°C and room temperature) and ripening techniques were adopted for all these varieties. Physico-chemical characters were evaluated at harvest stage (fresh banana). The results indicated that fresh Nendran banana had pulp-peel ratio of 1.62, firmness of 26.20 N, 'L', 'a' and 'b' values of 53.44, -20.72 and 26.37, respectively; total soluble sugars of 3.83°Brix, acidity of 0.09%, total sugars of 0.76% and starch content of 26.45%.Similarly, Red Banana registered pulp peel ratio of 2.10, firmness of 25.77 N, 'L', 'a' and 'b' values of 32.39, -15.52 and 12.22, respectively; total soluble sugars of 3.25°Brix, acidity of 0.10%, total sugars of 0.69% and starch content of 24.19%. Compared to Nendran and Red Banana, Ney Poovan recorded with pulp peel ratio of 3.95, firmness of 23.30 N, 'L', 'a' and 'b' values of 47.16, -20.50 and 25.06, respectively; total soluble sugars of 5.61°Brix, acidity of 0.12%, total sugars of 0.85% and starch content of 23.27%.

Significant differences were observed in the shelf-life for the individual as well as mixed varieties of banana. Maximum shelf-life (45.33 days) was recorded with Nendran, followed by Red Banana (35.00 days) and Ney Poovan (31.67 days) when packed with ethylene scrubber in CFB boxes and stored at 13.5 °C, as compared to those packed without ethylene scrubber (Nendran - 16.33 days, Red Banana -15.67 days and Ney Poovan - 13.67 days) and room temperature (control) (Nendran - 8.67 days, Red Banana - 7.67 days and Ney Poovan - 9.67 (packing with ethylene scrubber); Nendran - 5.33 days, Red Banana - 4.67 days and Ney Poovan - 5.67 (packing without ethylene scrubber). However, mixed varieties (Nendran, Red Banana and Ney Poovan) had a maximum shelf-life of 18.67 days when packed with ethylene scrubber in CFB boxes and stored at 13.5 °C, followed by 10.67 days without ethylene packing at 13.5 °C, 8.67 days with ethylene scrubber at room temperature and 4.33 days without ethylene scrubber at room temperature (control). The physico-chemical and sensory parameters did not vary much for the individual varieties and mixed varieties of fruits when packed with/without ethylene scrubber and stored at cold storage and room temperature. In general, mixed varieties exhibited less shelf-life compared to individual varieties both at cold storage and room temperature (control). Increased shelf-life of individual varieties (Nendran, Red Banana and Ney Poovan) is associated with improved quality parameters in accordance with corresponding individual varieties at acceptable levels of sensory evaluation after ripening of fruits when compared to mixed varieties. This indicates that multiple varieties in a single reefer container is not suitable for export through sea protocol.

4.2.7 Functions of resistant starch and designer food development from banana flour

Comparison of starch modification methods

Significant increase in lightness of few modified starch powders were observed when compared with native banana starch. Acid thinning (94.83) and oxidation (98.22) modified starches recorded increase in L values. An important physical property of oxidized starches is the whiteness, characteristic that in many applications is very important. With respect to oxidation modification, certain pigments as well as proteins present in the starch granules are oxidised well before the actual glucose units leading to a whiter starch material.

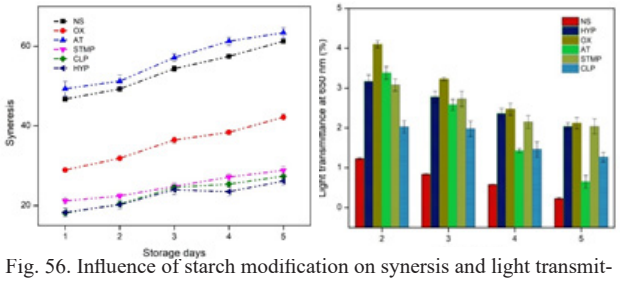


Fig. 56. Influence of starch modification on synersis and light transmittance

Light transmittance was found to decrease for all the modified starches as the storage days increased. Initially, the transmittance was observed to be higher for all the modified starches, but as amylose leached into the solution, the transmittance directly reduced with higher absorbance of light (Fig. 56). The transmittance of hydroxypropylene modified starches was observed to be much higher than the native starches. Hydroxypropylene modification incorporated additional hydrophilic, hydroxypropyl group, which were capable of dissociating the starch molecules that led to the increased light transmittance than the native starch.

Swelling power increased with increase in temperature for all types of modification. Swelling power for oxidised starches at high temperatures was significantly higher than the native starches. Swelling power of STMP modified starches was found to be slightly lesser than the native starches. The solubility of native starch was far higher than modified starches except for acid thinning process. It is seen that starch modified by acid thinning process has the highest solubility of 18.9 at 90 °C when compared to other modifications. Water holding capacity of native starch was higher than the modified starches except for the starch modified by oxidation. The oil holding capacity of the modified starches was found to be higher than the native starch. The highest oil holding capacity is reported by acid thinning followed by cross-linked phosphorylation and oxidation (Fig. 57).

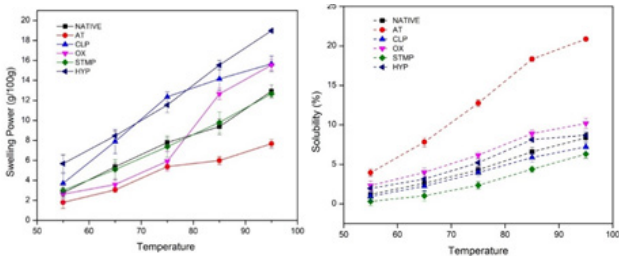


Fig. 57. Gelatinization properties of modified starches

The peak of the native starch at 1647 cm^{-1} appeared sharper whereas the same peak of STMP modified starches was not observed to be sharper as native starch. This clearly indicated the breakage of intra-molecular hydrogen bonds affirming the STMP based modification. Oxidation method of modification led hydroxyl groups to be oxidised to carbonyl and carboxyl groups. This specific enhanced absorption band of carboxyl groups at 1608 cm^{-1} clearly indicated the formation of carboxyl group in oxidised starch. Contradictory to the native starch additional peaks were observed at 1380 cm^{-1} and 1595 cm^{-1}. The results indicate that native starch was oxidized by sodium hypo chloride and hydroxyl groups were changed to carbonyl and/or carboxyl groups (Fig. 58).

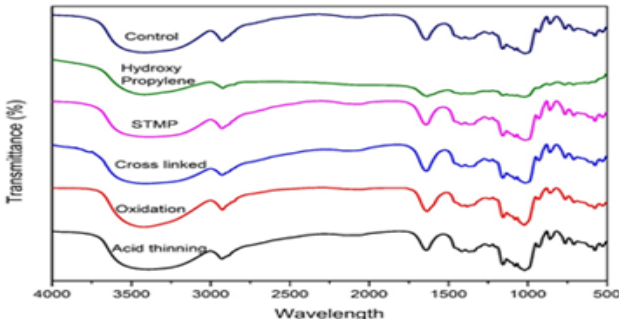


Fig. 58. FTIR peak differences in different starch modification methods

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

Bioplastic films using banana starch

Biofilms are prepared from biological materials that act as a barrier to the external environment, protecting food products and extending their shelf life. The preparation of biofilms involves film-forming agents, solvents, and plasticizers, among other reagents. In general, addition of CMC produced the bio-films with higher thickness than the addition of PVA. Banana starch could be added up to 5% beyond that the film forming capability was severely hampered. Similarly the films made with PVA were comparatively opaque than the addition of CMC. This was corroborated with the higher lightness value of the film when made with CMC. However, higher concentration of CMC led to reduce the lightness of the prepared films. Elongation and tensile strengths of the films increased with the concentration of PVA and CMC. The combination of CMC and PVA did not exert any significant impact on the film characteristics. The biodegradability of the bioplastic film materials was tested using the soil burial method. In terms of decomposition, CMC exerted superiority than the PVA. The progressive reduction in the plasticity was higher up to 15 days. The prepared plastics were decomposed within 25 days of its burial in the soil.

Edible films for food packaging applications

Edible films were developed using starch and additives such as carrageenan gum, CMC, gum Arabica, gum tragacanth. The films were tested by coating in fruits and vegetables. Films prepared with gum Arabica (2%) showed better edible film characteristics than the use of other macromolecules. It reduces the loss of moisture, oxidation and degradation of fruit and increase the film water solubility.

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

Drought or soil moisture deficit stress is one of the major environmental stresses that decrease the plant growth and yield. Once the plants face moisture stress, the plants will exhibit some abnormalities such as reduction in leaf size, pseudostem enlargement, postponement of floral developmental phase and yield reduction. In a field experiment, 53 banana genotypes of different genomes *viz*., AAA (11), AAB (12), ABB (15) and BB (13) were evaluated against soil moisture deficit stress at floral primordial initiation stage (Fig. 59). The plant height and girth were significantly reduced (12.34 to 29.67%) in all the genotypes evaluated. The duration of flowering was also prolonged by 17.50 - 42.05 days. Among the AAB genotypes, cvs. Nendran and Rasthali are found more susceptible as evidenced by bunch weight reduction. Besides, Leyan (AAA) and Lacatan (AAA) are found susceptible to drought stress and evidenced by the significant reduction in bunch weight (Fig. 60) with yield reduction recorded from 3.78 % to 34.78%.

Fig. 59. Field evaluation of banana genotypes against soil moisture deficit stress

Lacatan (AAA) Leyan (AAA)

Fig. 60. Susceptible AAA banana genotypes

The BB genotypes were characterised for biochemicals. There was diversity in free amino acid, proline and chlorophyll pigments. Among 13 BB genotypes evaluated biochemically, the *Musa balbisiana*, Bhimkol, Manohar, Paglapahad Wild-2 recorded better drought tolerance.

The salt stress effect on germination of a few banana genotypes were evaluated under controlled condition. The Grand Nain (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 50mM after producing 1-2 leaves. However, the Kaveri Saba (ABB) and Karpuravalli (ABB) germinated and grown well and produced 4-5 normal leaves and survived.

In a controlled pot experiment, drought alleviation effect of silicon was studied in cv. Grand Nain (Fig. 61). The silicon was given through foliar application as sodium silicate with different concentrations (50, 75 and 100 mM) before imposition of drought. The 50 mM of sodium silicate treated plants recorded higher relative water content, leaf pigments and osmolytes. The higher concentration of sodium silicate (> 50 mM) did not have any positive affect.

4.3.2 Biochemistry

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

Anthocyanin compounds in flower bracts of NE region bananas

Individual anthocyanin compounds in bracts of ten banana cultivars collected from North Eastern area of the country viz., Borkal Baista, Suti Sahaji, Gobin Tulci, Chenichamba, Batheesa Cheriya, Garomoina, Beheula, Vennutmannan, Kaithkullung and Bharatmoni were profiled using RP-HPLC and all the anthocynidin compounds in bracts were identified and quantified. Five to six compounds were identified in various proportions. In bracts of Suti Jahaji, Gobin Tulci and Vennutmannan, cyanidin was predominant compound whereas in Borkal Baista, Bharatmoni and Kaithkullung, pelargonidin was the major compound. The two predominant compounds in the ten banana cultivars collected from North Eastern states are given in Table 31.

Table 31. Anthocyanidins identified in flower bracts of NE Indian bananas

Cultivar	Predominant Compound I	Predominant Compound II
Borkal Baista	Pelargonidin (74%)	Cyanidin (17%)
Suti Jahaji	Cyanidin (81%)	Delphinidin (10%)
Gobin Tulci	Cyanidin (36%)	Peonidin (28%)
Chenichampa	Malvidin (37%)	Pelargonidin (28%)
Batheesa Cheriya	Delphinidin (45%)	Pelargonidin (42%)
Garomoina	Peonidin (37%)	Pelargonidin (32%)
Beheula	Delphinidin (72%)	Cyanidin (20%)
Vennutmannan	Cyanidin (92%)	Delphinidin (5%)
Kaithkullung	Pelargonidin (45%)	Delphinidin (31%)
Bharatmoni	Pelargonidin (49%)	Delphinidin (18%)

Nutraceutical potential of flower bract anthocyanins

Antioxidant activity of anthocyanins of flower bracts of fifteen banana varieties were assessed using TEAC and ORAC assays to ascertain the nutraceutical potential. Anthocyanin pigments were extracted, concentrated and dried to powder and the antioxidant activities were measured. In TEAC assay, Monthan (ABB), Saba

(ABB), Udhayam (ABB) and Popoulu (AAB) exhibited higher antioxidant activity of 86 µmol TE/ g DW and in OROC assay, the same cultivars showed the antioxidant level of 174 µmol TE/ g DW (Fig. 62 & 63). The cultivars Grand Naine (AAA), Namwa Khom (ABB), Pachanadan (AAB), Hill Banana (AAB) and Karpooravalli (ABB) flower bracts anthocyanins showed around 62 and 128 µmol TE/ g DW in TEAC and ORAC assays. The predominant anthocyanidin compound in these banana cultivars is cyanidin and the higher level of nutraceutical potential is attributed to the higher level of cyanidin.

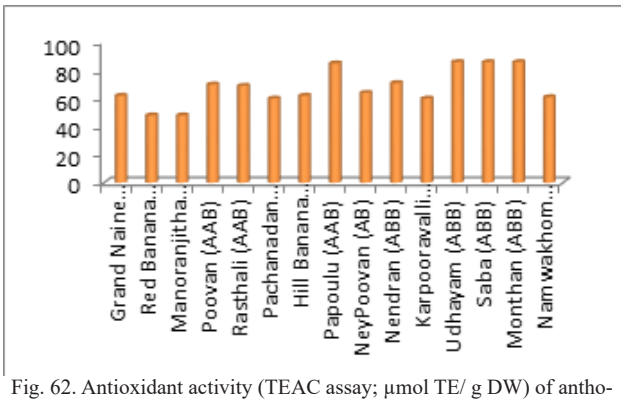


Fig. 62. Antioxidant activity (TEAC assay; µmol TE/ g DW) of anthocyanins extracts of commercial banana flower bracts

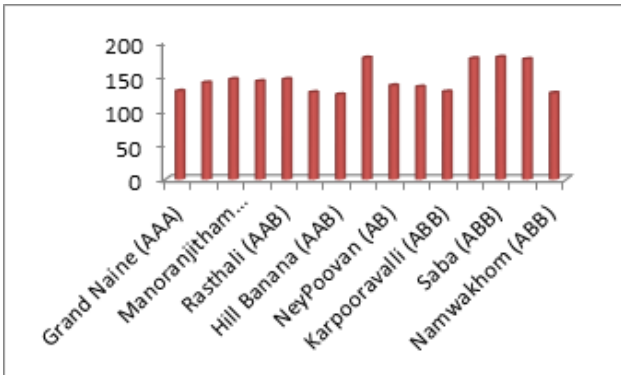


Fig. 63. Antioxidant activity (OROC assay; µmol TE/ g DW) of anthocyanins extracts of commercial banana flower bracts

Flavonoid compounds in fruit pulp of bananas

The contents of three major flavonoid compounds *viz.*, epicatechin, gallocatechin and catechin in pulp of twelve commercial banana cultivars were extracted, profiled and quantified using RP-HPLC. Flavonoid compounds were detected and quantified with R_t of 6.0, 9.1 and 13.8 min, respectively using standards. As in peel, the gallocatechin was the predominant flavonoid compound followed by epicatechin and catechin in pulp of commercial bananas. Monthan (ABB), Karpooravalli (ABB), Udhayam (ABB) and Saba (ABB) contained high amounts of gallocatechin of around 45, 42 and 39 mg/100 g (Fig. 64). The contents of epicatechin, the second flavonoid compound, in fruit pulp of bananas ranged from 28 to 16 mg/100 g with the Monthan, Udhayam (ABB) and Karpooravalli (ABB) containing highest amounts.

Antioxidant / nutraceutical potential of gallocatechin in fruit pulp

Using Trolox Equivalent Antioxidant Capacity (TEAC) and Oxygen Radical Antioxidant Capacity (ORAC) assays, the antioxidant potential of flavonoids purified from fruit pulp of commercial banana varieties were measured. The high gallocatechin containing banana cultivars, Monthan (ABB), Karpooravalli (ABB), Udhayam (ABB) and Saba (ABB), showed higher levels of antioxidant activities of 96.2, 95.6, 95.0 and 94.5 µmol TE / 100 g FW, respectively by TEAC assay. Similar to TEAC test, the Monthan, Udhayam and Karpooravalli showed higher antioxidant potential with 91.3, 89.5 and 88.7 µmol TE / 100 g FW, respectively (Fig. 65).

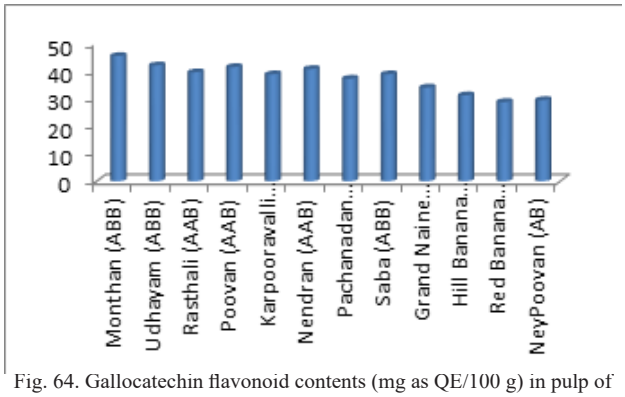


Fig. 64. Gallocatechin flavonoid contents (mg as QE/100 g) in pulp of ripe fruits of commercial banana varieties

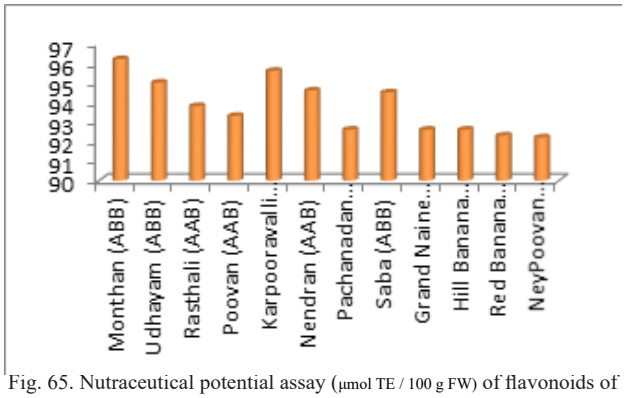


Fig. 65. Nutraceutical potential assay (µmol TE / 100 g FW) of flavonoids of pulp of banana cultivars

Fructans in commercial banana fruits

Total fructans contents in fruit peel and pulp of commercial banana varieties were estimated. Monthan, Nendran and Udhayam possessed higher levels of fructans in both pulp and peel. Fructans in pulp of these varieties was more than 180 µg/g FW and the fructans content was 110 µg/g in pulp of Ney Poovan (AB) and Poovan (AAB) (Fig. 66). The Monthan, Nendran and Udhayam cultivars contained around 70 µg/g fructans in peel and NeyPoovan and Poovan contained around 48 µg/g fructans in peel.

Estimation of alpha-tocopherol (vitamin E) in banana leaf

Estimation of alpha-tocopherol (vitamin E) contents in banana leafs were evaluated in young third leaf and mature leaf of banana variety, Grand Naine. The extraction of total tocopherol was done using acetonitrile: methanol (3:1), concentrated and analysed using RP-HPLC using authenticated standard. The alpha-tocopherol could be detected with retention time of 5.5 min (Fig. 67).

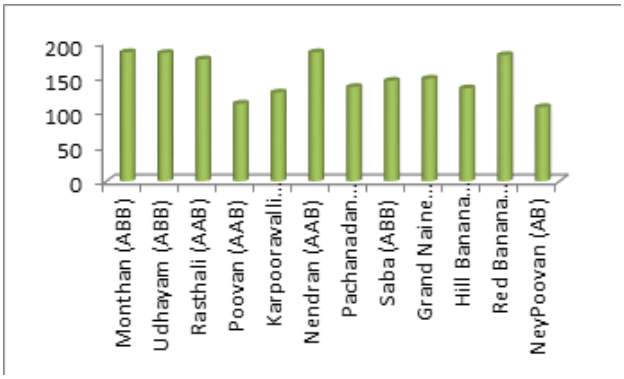


Fig. 67. Chromatogram of alpha-tocopherol from immature leaf of cv. Grand Naine

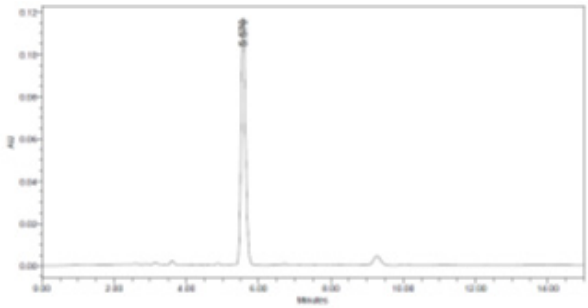


Fig. 66. Fructans contents (mg as QE/100 g) in pulp of ripe fruits of commercial banana varieties

4.4 CROP PROTECTION

4.4.1 Pest mapping in bananas and plantains in India

New pests of banana

Infestation of the Bondar's nesting whitefly, *Paraleyrodes bondari* Peracchi (Hemiptera: Aleyrodidae), a recently reported exotic invasive pest in India, was recorded on banana from Karur and Trichy districts of Tamil Nadu. All the life stages were found on banana and the extent of damage was low. Further monitoring was done on the spread and extent of damage caused by *P. bondari* on banana and the severity was greater on other fruit crops like citrus, mango and custard apple in and around Trichy. The low populations found on banana were eliminated due to heavy rains. Damage by *Spodoptera exigua* was observed for the first time on cv. Ney Poovan (4-5 leaf stage). The damage was limited to a few plants.

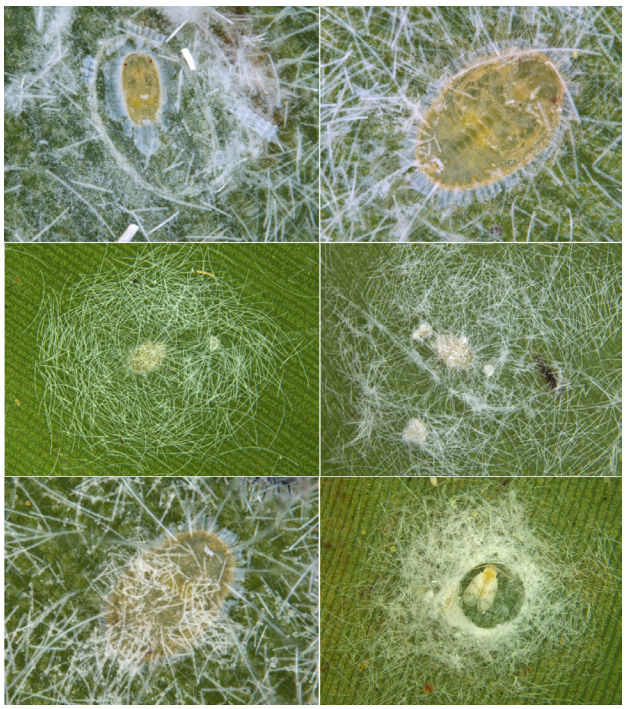


Fig. 68. Bondar's nesting whitefly – Different life stages

Severe foliar damage to young banana plants by the vegetable grasshopper, *Atractomorpha crenulata* (Fabricius) (Pyrgomorphidae) was documented for the first time in the cultivars Ney Poovan and Nendran in farmers' fields in Kuzhumani and nearby

areas and in the research farm of ICAR-NRCB. *Zeugodacus cucurbitae* (Coquillett) was recorded from banana in addition to *Bactrocera dorsalis* and *B. correcta.* The mealybug, *Rastrococcus invadens* (Hemiptera: Pseudococcidae), was recorded as a foliage feeder on banana.

Large numbers of the larvae and pupae of mango looper, *Perixera illepidaria* (Lepidoptera: Geometridae) were collected on the foliage of cv. Karpuravalli. However, feeding on banana was not observed confirming that banana is not a host plant and it was a case of larval migration for pupation.

Natural enemies of banana pests

Regular monitoring of banana insect pests and their natural enemies was done on all germplasm accessions. Five predators (one hemerobiid and four coccinellids) were recorded as natural enemies of banana aphid, *Pentalonia nigronervosa*, in Tamil Nadu. Immature stages and adults of three coccinellids, *Cheilomenes sexmaculata* (F.), *Pseudaspidimeru strinotatus* (Thunberg), and *Scymnus nubilus* Mulsant (Coleoptera: Coccinellidae) and one brown lacewing, *Micromus timidus* Hagen Neuroptera: Hemerobiidae) were found to be active predators in the field during winter months. Samples of banana aphid infected by an unidentified entomofungal pathogen were collected in the field. The pathogen was isolated and cultured for further studies as it was found to be effective in initial laboratory bioassays.

Biology of *Scymnus nubilus* on banana aphid

The biology of *S. nubilus*, the most efficient predator of banana aphid, was studied in the laboratory. The number of eggs laid / day / female was 3–36 (mean 9.86 eggs / day). Egg laying started from the sixth day after adult emergence and continued for up to 46 days. There were four larval instars and the total development from egg to adult emergence took 15–19 days. The egg, larval, prepupal and pupal period lasted 4.5±0.53, 7.88±0.88, 1.50±0.46 and 3.0±0.76 days, respectively. The number of aphids consumed / day by the larvae of *S. nubilus* gradually increased with age and the daily consumption rate was 2–4 aphids in the first instar, 3–5 in the second instar, 4–9 in the third instar and 2–20 in the fourth instar. Total prey consumption during the entire larval period was 36.0–65.0 nymphs. Adult longevity was greater in females (62.13±5.22 days) than males (18.86±6.74 days) and the longest-lived adult female consumed 534 aphids in its lifetime of 71 days and the per day prey consumption by an adult beetle ranged from 7.15 to 11.53 (mean 8.42±1.35).

Biointensive management of major insect pests of banana

Cultures of entomopathogenic fungi contaminated during the covid lockdown period are being revived for further studies. Twenty cultures were resubmitted to ICAR-NBAIM, Mau. Bioasssays of revived cultures of *Beauveria bassiana* and *Metarhizium anisopliae* found to be effective against pseudostem weevil and corm weevil.

4.4.2 Integrated management of Tropical Race 4 of Fusarium wilt disease in banana

Survey for the isolation and characterization of *Foc* isolates in Tamil Nadu

Five major banana growing districts of Tamil Nadu, viz. Kanyakumari, Tirunelveli, Tuticorin, Tiruchirapalli and Namakkal, were surveyed and 39 Fusarium wilt infected samples collected. From these, 39 *Foc* isolates were obtained and subjected to characterization by VCG analyses. The results indicated that the *Foc* isolates from cvs. Ney Poovan, Monthan, Karpuravallli from Tuticorin, Tirunelveli and Kanyakumari districts belonged to VCG 01220 and Foc isolates from cvs. Karpuravalli and Rasthali grown in Namakkal and Karur districts belonged to VCG0125.

Table 32. Characterization of Foc isolates in Tamil Nadu

Districts	Varieties (Genome group)	VCG identified
Kanyakumari	Ney Poovan(AB)	0125
Tuticorin	Ney Poovan(AB), Monthan (ABB)	01220
Tirunelveli	Monthan (ABB)	01220
Namakkal	Karpuravalli(ABB) and Rasthali (AAB)	0125
Karur	Karpuravalli (ABB)	01220

Fig. 69. Characterization of *Foc* isolates in Tamil Nadu

Transformation of *Foc* TR4 with green fluorescent protein

In order to study the spread of Foc in the plant system through transformation of Foc with green fluorescent protein (GFP) which emits green fluorescence when excited by blue light filter, the plasmid harboring sGFP derivative was transformed to *Foc*TR4 using Hygromycin B as a selectable marker. The Foc retained their integrity and pathogenicity. The transformed *Foc*TR4-*gfp* did not differ from wild type *Foc* in growth and morphological characteristics *in vitro*. Fluorescence microscopy studies showed expression of the green fluorescent protein in fungal hyphal structures. Pathogenicity test with tissue culture (Grand Nain) banana plantlets also showed that the transformed *Foc*TR4 did not alter the virulence. Quantitative data on the survival of *Foc* TR4-*gfp* and wild type *Foc*TR4 in banana seedlings was obtained by selective plating on CD agar media supplemented with and without Hygromycin. *Foc* population in whole individuals (leaf, stem and root) significantly increased in *Foc* inoculated plantlets against un-inoculated control.

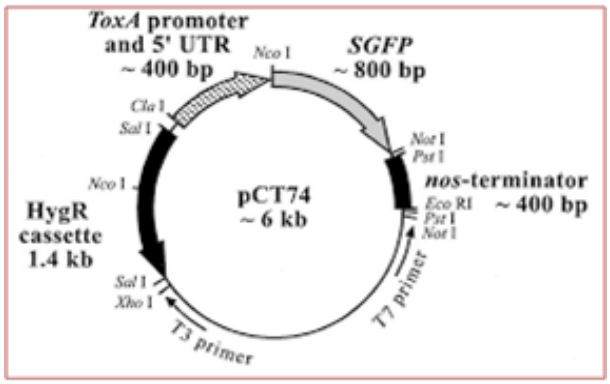


Fig. 70. The pCT74 plasmid construct has hygromycin B resistant gene for transformants selection, sGFP gene and Tox A promoter of *Pyrenophora triticirepentis* for expression of sGFP gene and Tox A promoter of *Pyrenophora triticirepentis* for expression of sGFP gene and nos -terminator is used

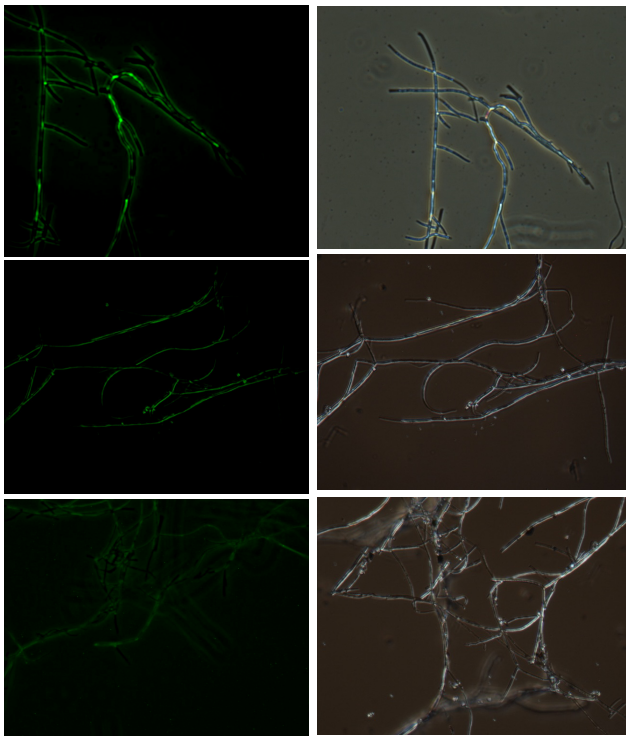


Fig. 71. Fluorescence microscopy images of mycelial fragments of *Foc* TR4. Strong constitutive expression of sGFP occurred and could be visualized in fungal hyphae (Left: fluorescence images; right: bright field images)

Cross reaction of VCGs of *Foc* isolates

A pot culture experiment was conducted to study the cross reaction of VCGs obtained from cultivars on cv. Grand Nain (AAA). The VCG 01220 obtained from cvs. Karpuravalli and Monthan from Karur (Kulithalai), Katihar and Tuticorin districts and VCG 0125 obtained from cv. Ney Poovan from Kanyakumari districts were able to infect the cv. Grand Nain as well.

Fig. 72. Typical corm discoloration in cv. Grand Nain upon inoculation with Foc R1 from cv. Karpuravalli

Fig. 73. Corm discoloration in cv. Grand Nain upon infection with Foc R1 of cv. Ney Poovan

Field evaluation of phosphate nutrient solubilizers in banana

With an aim of increasing the soil and plant health using potential phosphate solubilizing bacteria (PSB), two bacteria, *Enterobacter hormaechii* ssp. *sakuensis* (PSB52) and *Leclerciaa decarboxylata* (PSB54), were identified as effective under glasshouse conditions. These two potential nutrient solubilizers in different combinations with two phosphate sources (single super phosphate and rock phosphate) at 100, 75 and 50% of recommended level are being evaluated under field conditions in cv. Ney Poovan. The preliminary analysis of soil samples indicated that the activity of alkaline phosphatase enzyme (which is involved in the solubilization of insoluble form of phosphorus into soluble form) was 300-500% higher with the combined application of two nutrient solubilizing bacteria along with rock phosphate as compared to control treatment.

Fig. 74. Evaluation of phosphate solubilizers in Ney Poovan, a field view

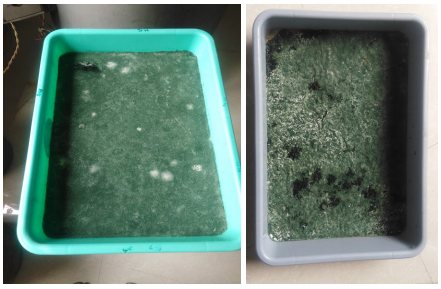


Fig. 75. Mass production of *Trichoderma* spp. using rice gruel medium

Mass production of bioagents for the management of Fusarium wilt Tropical race 4

An economical, rapid method of mass production of *Trichoderma* spp. was developed by using rice gruel medium. By this method, the mass production was achieved in 3-5 days and 50 kg of formulation sufficient to apply for one acre of banana could be produced by incurring a cost as little as Rs.10 (Fig. 75).

Correlation study between symptom expression and toxin production by different Foc isolates

A study to correlate the toxin production and symptom development and its severity was conducted in cv. Grand Nain using 12 *Foc* isolates belonging to race 1 and TR4. The results of the study indicated that the production of Fusaric acid by different isolates ranged from 1155 to 5522 ug/g and that of beauveric acid ranged from 55.90 to 618 ug/g of mycelial tissue. The days taken for symptom expression different *Foc* isolates ranged from 17 to 36 days after inoculation and the severity score of internal symptoms ranged from 2 to 5 on a 0-5 scale of disease rating. In this study no correlation was obtained between toxin production and days taken for symptom expression as well as disease severity.

Table 33. Correlation study between symptom expression and toxin production by different Foc isolates

Foc strain	Race	DAI (symptom development)	External score	Internal score	Fusaric acid (µg/g)	Beauveric acid (µg/g)
TN-1	1	27	3	4	2892.03	383.18
MP6	1	23	3	5	1155.66	122.21
MP- 4	1	27	2	3	5522.76	618.96
Bihar-1	4	17	2	4	2700.52	318.29
Bihar-6	4	36	3	4	2046.61	230.49
Bihar-9	4	17	4	4	1681.14	239.20
Gujarat 1	1	17	1	2	2543.87	171.05
Gujarat 2	1	17	2	3	2563.88	117.14
UP1	4	17	3	5	3746.80	240.17
UP2	4	17	3	5	2044.87	112.99
UP3	4	17	2	5	3165.53	136.59
Untreated control	-	-	0	0	-	-

Management of post-harvest diseases of banana

Post-harvest diseases such as anthracnose and crown rot caused by *Colletotrichum musae* and *Lasiodiplodia theobromae* are important diseases involved in spoilage of quality and shelf life of banana. In order to manage them, fungal and bacterial biocontrol agents of endophytic and rhizhospheric origin, the principal compounds extracted from *Trichoderma* and a botanical (Zimmu) were evaluated under *in vitro* conditions. The results of the study indicated that among the bioagents, the rhizospheric *Trichoderma* sp. (NRCB3) and *T. harzianum* were more effective against *C. musae* and none was effective against *L. theobromae*. However, the principal compound 3 extracted from Zimmu was most effective against both *C. musae* and *L. theobromae*.

4.4.3 Survey, etiology and management of rhizome rot of banana

Molecular characterization of rhizome rot isolates

Three distinct rhizome rot isolates (NPK-3-48, GTC-5 and 1-1B-3) obtained from Ney Poovan, Grand Nain and Thella Chakkarakeli were characterized earlier as *Klebsiella variicola* based on morphology, biochemical and 16s RNA sequencing. For further confirmation PCR amplification of the beta-subunit of RNA polymerase gene (*rpo*B) was done using primers rpoB CM7 and rpoB CM31b and the amplified products were sequenced and confirmed as *K. variicola* (NCBI: MW497572-MW497574). Phylogenetic analysis of *rpoB* also clearly indicated that the isolates belonged to *K. variicola* (Fig. 76).

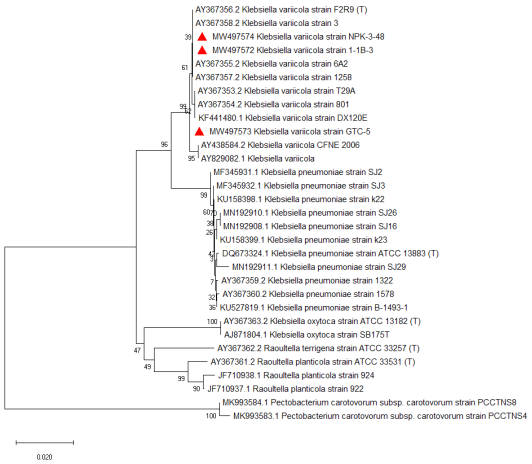


Fig. 76. Phylogenetic neighbor-joining tree based on the partial *rpoB* gene sequences of strains of *Klebsiella variicola, K. pneumoniae, K. oxytoca* and *Raoultella planticola*. The isolates from this study are represented by red triangular blocks, all other strains are reference strains obtained from the GenBank database for phylogenetic analysis. (T) denotes type strain. The tree was generated by MEGA-X software using the NJ and the algorithm of Maximum composite likelihood with 1000 bootstrap re-samplings. Numbers at each branch indicate bootstrap value. Scale bar represents 20 nucleotide substitutions per 1000 nucleotides

Development of PGPR bio-formulations

Bacterial isolates grow at specific temperature and thus PGPR isolates (BCNA 5-3, H6 BC2 H4BC1, H6BC3, H7 BC2, H8BC1 and H8BC2) were checked for their growth at different temperatures (28ºC to 37ºC). Among the isolates, BCNA 5-3 and H6 BC2 showed significantly more colony forming unit (CFU) at 37ºC while H4BC1, H6BC3, H7 BC2, H8BC1and H8BC2 recorded the best growth at 28-30ºC, 30-37ºC, 32-35ºC, 35ºC and 32ºC, respectively. In order to develop bioformulations with low volume and more shelf life, four PGRR isolates (H4BC1, H6BC2, H6BC3 and H7BC2) were multiplied in nutrient broth and the cells were microencapsulated with maltodextrin. Further the formulated cells were subjected to vacuum spray drying by using the facility available at Department of Biotechnology, SASTRA University, Thanjavur. Analysis of the cell viability (CFU) and the effect of growth promotion on banana seedlings indicated that the microencapsulated formulations could maintain the desired CFU but enhanced growth of the seedlings was achieved only with H6BC3 and H7 BC2 treatments.

Development of soilless medium for bio-hardening of tissue culture banana plants

In order to enhance the seedling health through PGPR treatments, the effect of eight PGPR isolates (BCB 2-4, BCNA 5-3, H4BC1, H6BC2, H6BC3, H7BC2, H8BC1 and H8BC2) on the growth of TC banana seedlings (cv. Grand Naine) was tested during primary hardening stage using soilless medium (cocopeat, vermicompost and PGPR cells). Though all isolates except BCB 2-4 could enhance the growth of the seedlings even within a month, H7BC2 and H8BC2 showed significantly enhanced growth than the other PGPR isolates.

Development of microbial decomposer consortium

In order to identify suitable microbes for banana waste decomposition, 28 Actinobacteria were multiplied in broth and applied on sliced pseudostem @10% and observed for decomposition ability based on analysis of percentage of organic carbon and organic matter at different intervals under glasshouse conditions. Among them, two actinobacterial cultures (Act 15 and Act 14) could decompose the material at a faster rate (13 weeks).

4.4.4. Management of post-harvest diseases of banana

Effect of pre-harvest application of chemical pesticides on postharvest diseases and residues

Recommended chemicals, for two major diseases (Fusarium wilt and leaf spot), nematodes and pseudostem / corm borers were applied on banana (cv. Grand Nain) at ICAR-NRCB farm at different intervals with suitable control**.** The fruit samples (cv. Grand Nain) from the markets in Erode, Salem and Theni Districts were collected and analyzed for chemical residues at ICAR-NRCG, Pune and all the samples found to be free from pesticide residues except a sample from Erode District had chlorpyriphos residue but, below MRL level.

Management of post-harvest diseases of banana

In vitro testing of PGPR, Actinobacteria and fungicides recommended for Fusarium wilt and leaf spot was done against two important postharvest pathogens (*Lasiodiplodia theobromae* and *Colletotrichum musae*). All the PGPR and Actinobacteria were able to inhibit both the postharvest pathogens at significant levels, however, two actinobacteria (Act 16 and Act 10) against *C. musae* and PGPR (H8BC1, H7BC2 and H6BC2) against *L. theobromae* showed the maximum inhibition. All the fungicides (Carbendazim 50%, Propiconazole 250 EC, Tebuconazole 50% + Trifloxystrobin 25% and Mancozeb 63% + Carbendazim 12% WP) at 0.05%, 0.1% and 0.2% inhibited *L. theobromae* significantly in a bioassay conducted *in vitro*.

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

Screening of germplasm accessions for resistance against BBTV and BBrMV

Screening of diploid germplasm accessions (26 AA diploids, 36 BB diploids and 23 AB diploids) for resistance against BBTV using viruliferous aphids in an insect proof screen house was continued to confirm the previous results (Fig. 77). Among AA diploids, 18 accessions have expressed BBTV symptom 36-120 days after inoculation. Further, total DNA was extracted from the leaf samples and PCR was carried out to detect the BBTV. Except one accession, all the accessions were PCR positive for the virus, including seven accessions which were not expressing BBTV symptoms. Six AB diploids expressed typical symptoms of bunchy top viral infection 50-140 days after transmission. Except three AB accessions, BBTV CP gene was amplified by PCR from 20 accessions including14 accessions that did not express BBTV symptoms. Among 36 BB diploids, two accessions expressed BBTV symptoms. Totally 11 accessions were positive in PCR. Screening of ornamental banana plants for resistance against BBTV and BBrMV was done using sucker grown ornamental banana plants by transmitting BBTV and BBrMV using viruliferous banana black aphids. Three out of ten plants expressed BBrMV, and one out of 10 plants expressed BBTV. In PCR for BBTV, six plants were found positive.

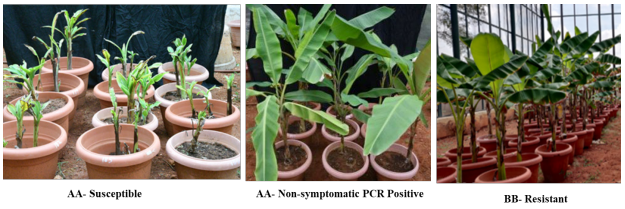


Fig. 77. Screening of diploid banana accessions for resistance against BBTV under screen house conditions

Validation of differential gene expression upon BBTV infection by Quantitative real-time PCR (qRT-PCR)

The differentially expressed genes (DEG) obtained in transcriptome data from BBTV latent and severely infected cv Poovan were identified and 38 sets of primers were designed, and PCR was standardized. Further 15 genes were validated using qRT-PCR.Identified selected genes showing upregulation in BBTV were analyzed using RT-qPCR to confirm the transcriptome data. (Fig. 78).

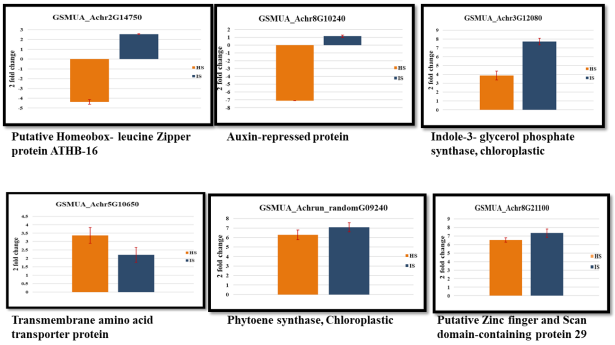


Fig. 78. RT-qPCR-based fold expression profile of selected up-regulated genes showing about and more than two-fold in BBTV infected as compared to healthy banana samples

Identification of potential inhibitor for BBrMV, CMV and BBTV replication by *in-silico* analysis

Structure based virtual screening and docking studies were taken for the replicase protein of BBTV, RNA dependent RNA polymerase protein domain of BBrMV and CMV to identify the potential inhibitors for controlling the viral genome replication. Three-dimensional models were predicted using the structure prediction tool LOMETS (Fig. 12). Several small molecules were derived from ligand databases such as KEGG and Dr. Duck's databases. Hesperidin, (+)-Catechin-7-O-Gallate, Glycosyl-7-O-Luteolin, 13', II8-Biapigenin would be the potential inhibitors of BBTV. Hesperidin forms a maximum of six hydrogen bonds with the Rep (+)-Catechin-7-O-Gallate, Glycosyl-7-O-Luteolin,13', II8-Biapigenin forms five hydrogen bonds. Fenugreekine would be the potential inhibitor against BBrMV forming the maximum of seven

hydrogen bond interactions with binding affinity of -7.2 kcal / mol. Five more ligands also were shortlisted based on the inhibitory action against BBrMV. For CMV, Telliagrandin-I would be the potential inhibitor against the CMVRdRp protein activity in theviral genome replication forming a maximum of 12 hydrogen bonds with binding affinity of -8.9 kcal/mol. Five more ligands were shortlisted based on the inhibitor activity against the CMV. Those are fenugreekine, tannin, echinacoside and myricode with binding energy of -7.2, -7.6, -7.2, -7.6 kcal / mol forming 9, 9, 8, and 8 hydrogen bonds respectively.

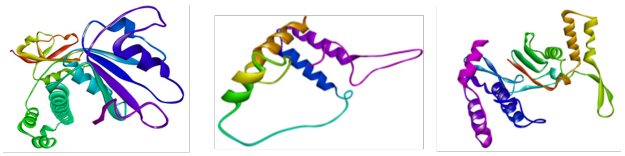


Fig. 79. Prediction of structure based domain model for replication initiation protein of BBTV and RNA dependent RNA polymerase protein of BBrMV and CMV. (a). BBTV M-Rep protein domain model predicted using LOMET server and the model norm z-score is 5.2; (b). BBrMV RdRP Domain model predicted using LOMET server and the model norm z-score is 2.25;(c). CMV RdRP Domain model predicted using phyre2 and the model confidence level is 99.1%

Exogenous application of double-stranded RNA (dsRNA) against Cucumber mosaic virus (CMV)

For this approach, CMV2b gene was amplified from CMV infected banana samples and cloned into a T based vector. Further these clones are subcloned in L4440 and mobilized to HT115 for *in vivo* dsRNA Production.

Phytoplasma association with BBTV infected plants

Banana plants infected with BBTV were suspected ofthe presence of phytoplasma and yielded positive result through PCR analysis. Partial sequencing of the nested PCR products showed that it was not Phytoplasma but the endophytic bacterium, *Bacillus megaterium.*

Long term field study to find expression pattern of BSMYV in cv. Poovan

During 2021, the expression of BSMYV symptom was observed in 28 plants with different levels of severity. The streak virus symptom severity and temperature was correlated and found that the disease severity was lesser at high temperature region and *vice versa* at lower temperature.

Field evaluation of BSMYV free elite TC Poovan banana andECS clones of Hill banana

A field planting was taken up in May, 2021 using suckers derived from the earlier crop under field evaluation on episomal BSMYV free tissue culture derived Poovan banana plants under AICRP-TF. The field was laid out using randomized block design with two treatments and 14 replications with six plants each. New planting was taken up to evaluate the suckers of ECS derived plants, TC along with conventional suckers of cv. Virupakshi.

Mass multiplication of BSMYV free (episomal BSMYV) tissue cultured cv. Poovan

Suckers of cv. Poovan were selected for mass multiplication through tissue culture. Total DNA was extracted from the leaf samples collected from mother plants and tested for banana viruses. All samples were negative against four viruses. These virus free mother plants were sent for mass multiplication to a TC firm recognized by DBT under NCS-TCP.

Virus indexing of TC mother plants

During 2021, 4565 TC banana samples from the TCPUs were tested against four viruses under contract services for virus indexing. Banana germplasm accessions conserved in the field gene bank at different locations (AICRP-TF-Arabhavi, Coimbatore, Gandevi, Jalgaon and Trichy) and mother plants used for ECS development were tested for the presence of viruses. Totally 108 germplasm samples and 76 mother plants used for ECS development were tested for viruses. During 2021, a gross amount of Rs 27,82,159 /- has been generated under contract service for virus indexing. Virus detection kits developed for CMV, BBrMV and BBTV were sold and an amount of Rs 91000 /-

was realized.

4.4.6 Proteomic analysis of host–banana bunchy top virus (BBTV) interaction in banana

Molecular docking was carried out to study the interaction between the BBrMV-VPg and eIF4E from susceptible and candidate resistant gene harboring cultivars. Secondary structure (SOPMA server and SOSUI server) and tertiary structure analyses (phyre server) were built for BBrMV-VPg, eIF4E and validated. For docking studies, the modelled protein structure was submitted in CusproServer and the docked structures were visualized using Biovia Discovery Studio. Observations were made for the presence of H bond in the BBrMV –VPg and eIF4E interacting regions after labeling the amino acids around the H-Bonds. BBrmv-VPg showed no interaction with eIF4E genes from Peyan, Pagalapahad wild and Kungsang wild and these cultivars might be resistant to BBrMV which needs further validation whereas the residues GLN 93, GLN 96, ASN 104, ARG 114, LEU 117, LYS 118, GLU 119 and GLY 120 from BBrMV-VPg interacted with the susceptible cv. Nendran (Fig. 80).

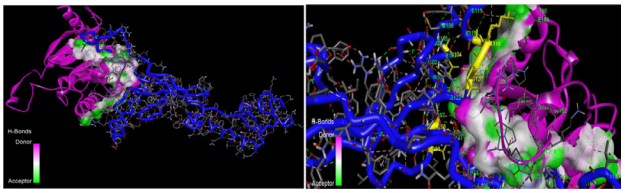


Fig. 80. Molecular docking of eIF4E from Nendran with BBrMV- VPg

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

Effect of application of salicylic acid on root-lesion nematode (*Pratylenchus coffeae*) infecting cultivar Grand Nain

Under pot conditions, foliar application of salicylic acid @ 200 and 500µM concentration at 24hrs prior to inoculation of root-lesion nematode (*Pratylenchus coffeae*) on tissue culture plants of cv. Grand Nain reduced the root population by 72 and 60%, respectively, over control at 3 months post inoculation (Fig. 81).

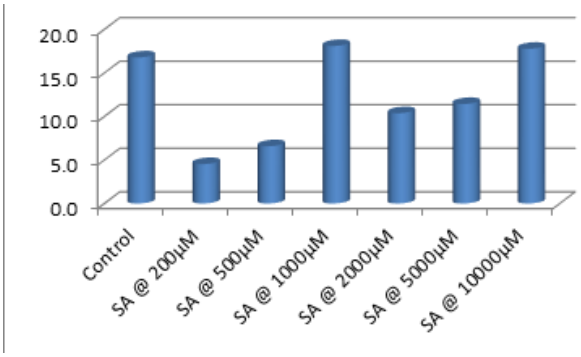


Fig. 81. Effect of application of salicylic acid on root-lesion nematode (*Pratylenchus coffeae*) in cultivar Grand Nain

Evaluation of water extract of zimmu leaf against banana nematodes

In vitro evaluation of zimmu leaf extract on root-lesion (*Pratylenchus coffeae*) and root-knot (*Meloidogyne incognita*) nematodes at different concentrations at different time intervals showed that nematode mortality was more than 90% at or above 50% concentrations at 48hrs and 72hrs of exposure to both the nematode species (Fig. 82).

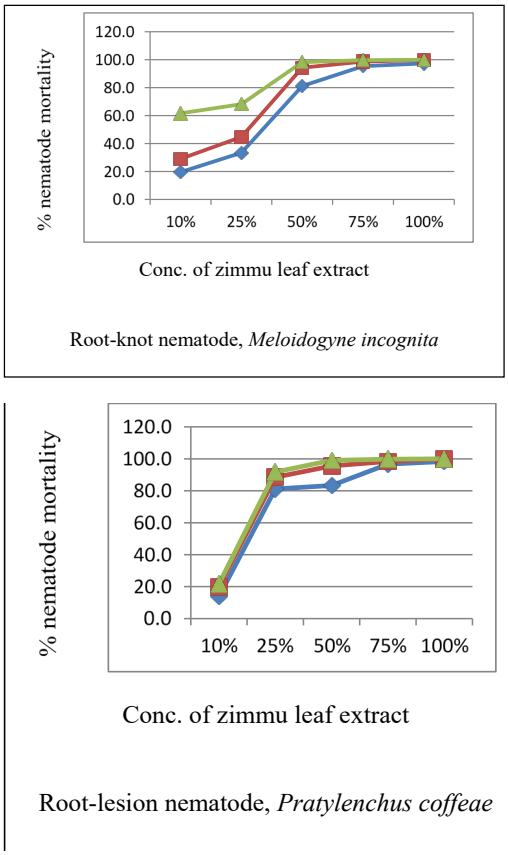


Fig. 82. *In vitro* evaluation of zimmu leaf extract on root- knot and root-lesion nematodes

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

Musa genotypes *viz*., Kunnan (AA), Karthobiumtham (ABB) and *Musa balbisiana* (BB) were evaluated for resistance to root-lesion nematode, *P. coffeae* under rapid screening protocol. Based on dead roots to total roots ratio and root-lesion index, Kunnan, Karthobiumtham and *M. balbisiana* were found resistant.

Reaction of some NRCB selections to Root-knot nematode, *Meloidogyne incognita*

Screening of NRCB released varieties found cvs. Kaveri Saba and Kaveri Kalki as moderately resistant to root-knot nematode, *Meloidogyne incognita* (Fig. 83).

Field sampling of germplasm accessions and NRCB hybrids

Field sampling and nematode damage assessment of different banana germplasm lines found cultivars *viz*., Chakkarakeli (AAB), Krishnavaazhai (AAB), Jungle Kela (BB), Bhimkol (BB), Khungsong wild (BB) and Elavaazhai (BB) as susceptible to root-lesion nematode, *P. coffeae*; Agniswar (AB), Adukkan (AB) and Poovizhachundan (AB) as susceptible to root-knot nematode, *Meloidogyne incognita*. Sampling on NRCB hybrids showed progeny NPL 30 and 115 as resistant to root-lesion nematode, *P. coffeae* (Table 34).

Kaveri Sugantham | Kaveri Saba | Kaveri Kalki | Udhayam | Popoulou

Fig. 83. Response of NRCB selections to root-knot nematode, *Meloidogyne incognita*

Table 34. Reaction of NRCB hybrids to root-lesion nematode, *Pratylenchus coffeae*

Hybrid No.	Average nematode population /g root	Root-lesion Index	Reaction
NPL 28	103	5	Susceptible
NPL 30	6	1	Resistant
NPL 33	152	5	Susceptible
NPL 34	106	5	Susceptible
NPL 36	105	5	Susceptible
NOP 43	111	5	Susceptible
NCR 2	139	5	Susceptible
NCR 5	45	4	Susceptible
NCR 8	114	5	Susceptible
NCR 10	81	5	Susceptible
NCR 18	39	4	Susceptible
NCR 21	38	4	Susceptible
Progeny 115	0	1	Resistant
Progeny 134	23	4	Susceptible
Progeny 429	26	4	Susceptible

Evaluation of ornamental banana species to root-lesion nematode, *P. coffeae* under sick soil conditions found *Musa ornata* and *M. acuminata* ssp. *zebrina* as resistant and *M. rubra* as susceptible.

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)

Out of nine Ney Poovan tetraploids developed through chromosome doubling, two were found to be male and female fertile and these plants are being used in breeding program to improve resistance in Ney Poovan. Four polleniferous (male fertile) Ney Poovan tetraploids are being used as male parent to develop triploids with good fruit quality. Pot culture screening of five IITA hybrids namely IITA1, IITA10, IITA 53, IITA 75 and IITA 146 against Foc race 1 and TR 4 revealed that all these hybrids were resistant to Foc race 1 and except IITA 10, all were moderately resistant to TR4.

Fig. 84. Female and male fertile Tetraploid Ney Poovan

Five each of NARITA hybrids (NARITA 8, 12, 14 21 and 23) and IITA hybrids (IITA1, 10, 53, 75 and 146) were field planted at Falka village, Katihar, Bihar against Foc TR4 during 2021.

A total of 18 hybrids (NARITA – 8 Nos; PITA – 5 Nos and other hybrids – 5 Nos) were obtained from IITA through ICAR-NBPGR during December 2021. These hybrids are being multiplied for field screening against TR4.

DBT-QUT 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 and S. Uma)

Ten transgenic events which were found to be stable for PVA content and yield parameters were multiplied through direct regeneration using suckers and immature male flower buds. Now the plants are ready for conducting event selection trials at TNAU, Tamil Nadu, NABI, Punjab, NAU, Gujarat and AAU, Assam. Fruit analysis for PVA content is being carried out in the fourth ratoon crop of identified events to confirm their stable expression. The backup culture of all the events are also being maintained *in vitro*.

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 Naine events *viz*. NRQIGN68- 20/47, NRQIGN53-19/15, NRQIGN68-20/36, NRQIGN53-19/84 and NRQIGN53-19/74 were multiplied through shoot tip culture using sword suckers. The Grand Nain events were transformed with iron constructs, *p*BMGF-DC-53 and *p*BMGF-DC-68, carrying *Os*NAS1 and 2 genes. A total of 150 plants of the five elites events were generated and around half number of plants are placed under primary hardening and remaining

are maintained in rooting medium (Fig. 85). Besides, plants of 12 more elite events with more than five-times higher iron contents in fruit pulp are being maintained in net houses and sword suckers obtained from the plants are subjected to multiplication through direct regeneration.

The genomic DNA of two top events, NRQIGN68- 20/47 and NRQIGN53-19/15, was isolated, purified, restricted using four different enzymes and their purity was analysed. After ligation of genome walker adapter, nested-PCR (primary PCR and secondary PCR) was performed to obtain specific target gene amplification. The target gene was amplified from secondary PCR using specific primers and then eluted from gel. The DNA sample is sequenced further to know the integration site of the genes.

Fig. 85. Elite iron Grand Nain plantlets in rooting media and under hardening

PPV & FRA project

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

(M.S. Saraswathi and S. Backiyarani)

DUS characterization of reference varieties

During the reporting period, the DUS characters were recorded for six reference accessions including Udhayam, Sabri, Malaikali, Bhar Manohar, Karpuravalli and Poovilachundan.

Varietal Registration

DUS characterization data sheet has been prepared for two farmers' varieties, namely Chingan and Semmatti, along with their respective reference varieties and submitted to PPV&FRA for registration.

4.5.4 DBT-NER Projects

a. Consortium for managing Indian banana genetic resources

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

The molecular mechanism has been hypothesized for natural parthenocarpic fruit formation in *Musa* spp. Based on the differentially expressed genes it is speculated that auxin mediated GA responses and cross talking between the phytohormones (Auxin, GA and Cytokinin), via certain transcription factors (*WUS*, *CLV1*, *AG*) govern the trait parthenocarpy. The expression of *CLF, FIE, EMF2, MSI*-histone modifying enzymes suggested that epigenetic mechanism also plays a vital role in seedless fruit formation. The role of genes related to brassinosteroid signaling pathway (*BZR1*) in seedless fruit formation has also been speculated to *Pnsl5* and *GRF2* act as a bridge between *MaHK2, MaBAM1* and *CLV-WUS* signaling pathway that induces seedless fruit formation.

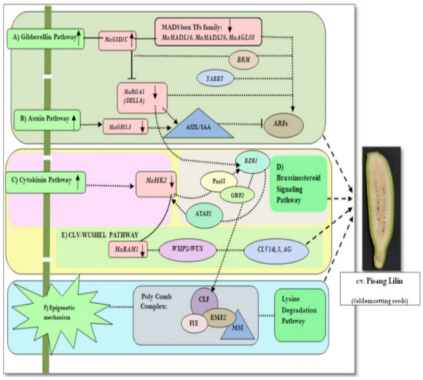


Fig. 86. Molecular mechanism for parthenocarpic fruit formation in *Musa* spp.

b. Genetic resource assessment, *in-situ* on-farm conservation and impact of banana waste as a feed for animals in North East region of India

(M.S. Saraswathi and S. Uma)

Macropropagation and mineral analysis have been completed in leaf, corm and stem samples collected for North Eastern accessions, namely, Athiakol, Attikol, Phirima wild, Manohar, Hatidat, Borkal Baista, Khungsong wild, Pagalapahad wild, Lairawk, Kanaibansi, *Musa acuminata*, Jahaji, Manjahaji, Borjahaji, Tulsi Manohar, Bharat moni, Amrit sagar, Cheeni champa, Jatikol, Malbhog, Deshikadali, Kachkel, Bhat Manohar and *Musa laterita.*

c. Whole genome and transcriptome study of stress-tolerant banana cultivars

(S. Backiyarani, S. Uma and I. Ravi)

A transcriptome-based protein-protein interaction (PPI) network has been constructed from the differentially expressed genes of drought tolerant and drought susceptible cultivars. This study revealed that genes related to drought escape mechanism such as early flowering genes, plant circardian rhythm and hormonal regulation are strongly interconnected and highly expressed in cv. Saba. Further increased expression of genes related to cell wall biogenesis, heat shock proteins, osmoprotectants, and anthocyanin synthesis in cv.Saba clearly depicted drought tolerance mechanism.

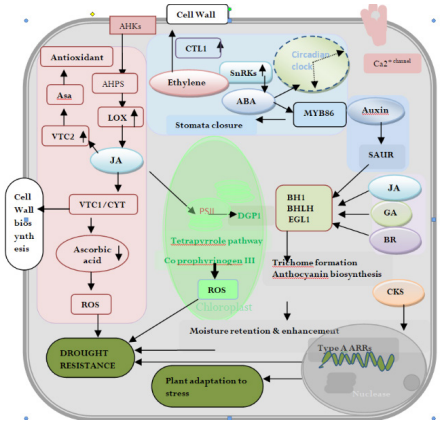


Fig. 87. Transcriptome based protein-protein interaction network for genes involved in drought tolerance

d. Collection, evaluation, documentation and conservation of banana genetic resources from North-eastern region

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

The tissue culture raised plants of Cheeni Champa and Malbhog were hardened and are being evaluated under field conditions.

Mineral analysis has been completed in fruit peel and pulp samples collected at two different phenological stages (unripe and ripe) for North Eastern accessions, namely, Athiakol, Amrit Sagar, Bharat Moni, Hatidat, Musa acuminata type Assam, Lairawk, Ash Monthan, Tulsi Manohar, Desi Kadali, Jahaji, Borjahaji, Bhimkol and Cheeni Champa.

e. *In vitro* mass multiplication of high value hill area bananas of the North Eastern region

(M.S. Saraswathi, R. Thangavelu and I. Ravi)

Micropropagation protocol using shoot tip explants has been standardized for Digjowa (Fig. 88).

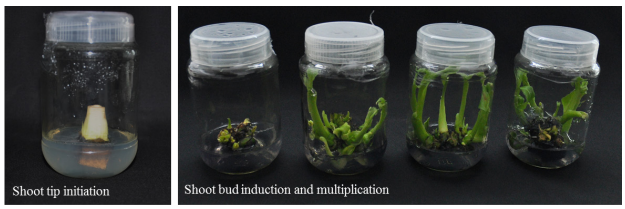


Fig. 88. *In vitro* mass propagation of cv. Digjowa using shoot tip explants

Standardization of micropropagation protocols using male flower buds has been completed for Bharatmoni and it is in progress for Digjowa (Fig. 89).

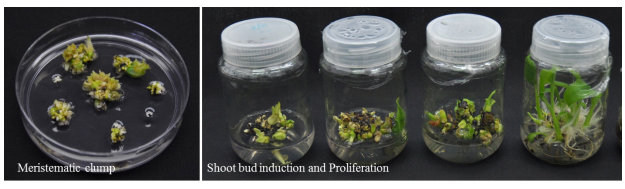


Fig. 89. *In vitro* mass propagation of cv. Bharatmoni using immature flower bud explants

f. Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technologies

(P. Suresh Kumar, V. Kumar and K.N. Shiva)

Extraction of pectin from Nendran banana peel

Pectin from Nendran banana peel was extracted using citric acid and hydrochloric acid (HCl) in wet and dry methods. The dry method along with HCl yielded maximum pectin (47.66 %). However, the dry method along with citric acid has yielded pectin with high AUA content (72.43 %), equivalent weight (1150), methoxyl content (9.72 %) and degree of esterification (74.21 %).

Pasta with type IV banana starch

Pasta formulations were evaluated by replacing 30% of semolina (SF) with green banana flour (GBF) and modified starch (MS). The effect of substitution on its physicochemical quality, *in vitro* starch digestibility and microstructure were evaluated. Addition of MS in the blend decreased the hydrolysis rate and eGI of pasta, as the resistant starch capacity was intact. Sensory evaluation elucidated that the addition of GBF and MS as a desirable ingredient for pasta preparation. It was observed that there was significant improvement in RS (resistant starch), IDF (insoluble dietary fiber), SDF (soluble dietary fiber) and microelement constitute value in ditalini pasta with the addition of GBF and MS. The substitution of SF with GBF significantly improved all the macro and micro elements in uncooked pasta. Most pronounced increment was observed in K and Ca contents with 30% GBF (blend 1) (Table 35).

Table 35. Chemical composition of ditalini pasta with semolina (Control) and composite flour blends (DW g100g^{-1})

Sample*	Control	Blend 1	Blend 2	Blend 3	Blend 4	CP
Digestible starch	67.81±0.94^{a}	57.59±2.51^{b}	51.24±1.99^{c}	46.27±1.31^{d}	40.91±0.33^{e}	66.12±1.00^{a}
Resistant starch	3.24±0.44^{e}	15.00±0.62^{d}	19.27±1.09^{c}	23.69±1.03^{b}	29.20±1.31^{a}	3.83±1.35^{e}
Total dietary fiber	6.36±0.61^{dc}	14.71±2.60^{a}	12.32±0.95^{ab}	10.41±0.12^{bc}	9.10±0.21^{cd}	4.82±0.51^{c}
Soluble dietary fiber	1.57±0.17^{cd}	2.86±0.58^{ab}	3.71±0.46^{a}	2.69±0.44^{abc}	2.23±1.47^{bc}	0.85±0.25^{d}
Insoluble dietary fiber	4.78±0.71^{cd}	11.84±2.15^{a}	8.61±0.57^{b}	7.72±0.46^{b}	6.87±0.74^{bc}	3.97±0.75^{d}

*Blend 1- 70% SF: 30% GBF; Blend 2- 70% SF: 25% GBF: 5% MS; Blend 3- 70% SF: 20% GBF: 10% MS; Blend 4- 70% SF: 15% GBF: 15% MS; CP- Commercial pasta; SF- Semolina flour; GBF- Green banana flour; MS- Modified starch

g. Downstream processing for utilization of banana waste for natural fibre extraction, fibre based products, biomass briquettes and utility compounds

(P. Suresh Kumar and K.N. Shiva)

Characterization of fibre from North Eastern Banana varieties/ germplasm lines

Among the 25 different germplasm lines tested for various physical characteristics including fibre extractable pseudostem, weight of central core stem (CCS) and the rhizome, var. Bhimkhol recorded the highest central core stem weight (11-12 kg) followed by wild kela (10.1 kg) whereas the CCS was very less in Jurmoney (5.5-6.5 kg) and H-201. Cv. Sasrabale recorded the highest rhizome weight (18-20 kg) followed by Bhimkol (15-16 kg). The cellulose content varied between 49.86 - 55.43% and showed not much difference among the cultivars. Chemical analysis showed cellulose is the major fraction in the pseudostem followed by lignin (15-19%) > hemicellulose (11-16%) > pectin (2-5%) and very minor fraction of wax (<0.31%). Middle layers showed higher fibre recovery than the outer and inner layers. The combined fibre recovery was higher in H-201 and seeded

wild type germplasm lines. Popular varieties like Bhimkol, Manohar, Attiakhol, Kunnan, Elavazhai has recorded the fibre recovery of 0.82-1.21%. Textural properties showed the greater variation among the tested genotypes on its elongation strength, young modulus, *etc*.

Process standardization for the extraction of cellulose from banana sheath fibres

Cellulose was isolated from banana sheath fibers using alkaline and acid treatment. This treatment eliminates non-cellulosic components such as pectin, hemicellulose and lignin. The powdered fibers are degummed using ethanol, toluene (1:3) using Soxhlet for 6 hr. It is dried in an oven for 15 min to vaporize the solvent. A Second alkaline treatment with 50 wt% ethanol and 4 g NaOH kept in agitator for 3 hr. Then the solution changed to 25% ethanol, 10 g NAOH, 1 g sodium borax and 1ml hydrogen peroxide. Finally, the insoluble residue was subjected to acid treatment with 70% nitric acid and 80% glacial acetic acid at a temperature 120 °C for 15 min. The residue was submitted to the bleaching process using sodium hypochlorite and glacial acetic acid (1:3) for 10 hr. After filtration, the residue was washed with deionized water and 50% ethanol for several times until the washing liquid turned colourless and neutral. Then it dried in at 50 °C until a constant weight was reached (Fig. 90).

Fig. 90. Cellulose extraction from banana sheath fibers

Utilization of banana fibre for green synthesis of nanoparticles and for making dye degradation materials

Banana fibres were used for the green synthesis of ZnO nanoparticles (ZnO NP). Banana fibres were left to interact with zinc nitrate hexahydrate under constant stirring followed by drying in hot air oven and annealing at high temperatures. The resulted biotemplate of tubular structure ZnO NPs exhibited industrial dye degradation capability. Ag doping of 2% and 8% was also carried out on the ZnO NP to enhance its optical properties to suit its applicability. The structural and morphological properties were studied by FTIR, XRD and FESEM results. Degradation of coloured dyes and waste water industrial effluents could be treated by these NPs produced by green synthesis using banana waste material. This method of green reduction incorporating banana fibres enabled development of economical green photocatalysts for textile dye degradation.

h. Exploring diversity, genomic and transcriptome profiling and phyto-semiochemicals of banana pest complex in North Eastern region

(J. Poorani and S. Backiyarani)

The composition of volatile organic compounds (VOC) released by entomofungal pathogen isolates (*Beauveria bassiana, B. brongniartii, Metarhizium anisopliae, M. robertsii, M. guizhouense* and *M. pinghaense*) utilizing different sources was investigated. Analyses were performed by solid-phase micro extraction (SPME)coupled to gas chromatography (GC) and mass spectrometry (MS).Gas chromatography mass spectrometry (GC-MS) analyses showed that a significantly (X2 = 5.1; p & lt; 0.02) higher number of known insect volatile compounds were present among fungus treated insects compared to the control. Infection by *Beauveria bassiana* and *M. anisopliae* had a significant effect on the extent of release/ concentration of Limonene, Methyl

salicylate, Benzaldehyde, Phenylacetaldehyde, Decan-3-ol, alpha-Terpineol, Benzene, 1,2 -dimethoxy, Methylheptenone, 1-Octadecene, Phthalic acid, Phenylacetaldehyde and 3-Octanone.

Totally 50 volatile compounds were identified when fungus infected banana stem weevil, *Odoiporus longicollis* was analyzed by Headspace Solid-Phase Microextraction (SPME) technique. In a similar analysis, 18 volatile compounds were identified in fruit scarring beetle post infection by fungal pathogens. GC-MS analysis of these volatiles revealed the presence of 42 compounds representing 10 major groups, *viz*. aromatic hydrocarbons, esters, phenols, alkanes, aldehydes, alcohols, hydrocarbons, carboxylic acids, and Iodine-containing compounds.

i. Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system

(R. Selvarajan and C. Anuradha)

Embryogenic cell suspension of cv. Rasthali (AAB group) supplied by the Crop Improvement section were used in co-cultivation with four CRISPR constructs. Totally six separate transformation experiments were carried out, each with a single construct separately and combinations of two constructs like BSV-Ag-Sg159 with BSV-Ag-Sg189 and BSV-Ag-Sg169 with BSV-Ag-Sg202.Three hundred and forty-five virus free Poovan male buds were collected from ICAR-NRCB farm and farmer's fields and were initiated for embryogenic callus induction.

j. Biotechnological interventions through RNAi approach for management of banana bunchy top virus in North Eastern region of India

(R. Selvarajan and C. Anuradha)

Virus free Grand Nain male buds were collected from NRCB farm and farmer's fields and were initiated for embryogenic callus induction. Co-cultivation was done with BBTV RNAi gene construct using Rasthali ECS supplied by the Crop Improvement Section.

DST funded projects

4.5.5 Development of efficient IOT enabled plant disease pest detection system

(R. Selvarajan and R. Thangavelu)

An automatic disease identification system was developed for banana bunchy top disease (BBTD) caused by banana bunchy top virus (BBTV) and banana mosaic caused by cucumber mosaic virus (CMV) using different deep transfer learning models. We have utilized a total of 5,540 images taken using DSLR and mobile cameras and drone images. Several model architectures were trained, with the best performance reaching 96.4 % success rate in identifying the diseases corresponding to BBTD and CMV (Fig. 91). An app has been created for the purpose of acquiring the images of banana diseases and pests from the farmers.

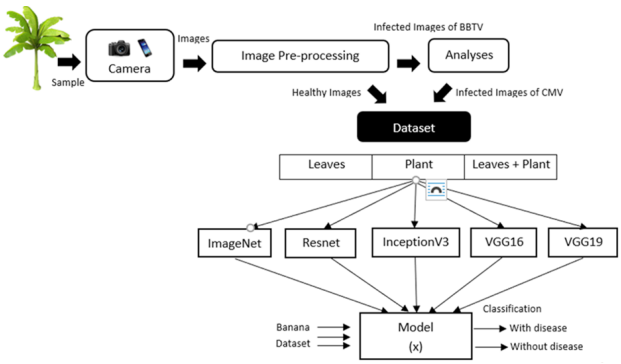


Fig. 91. Schematic representation of best model architecture trained for detection of banana bunchy top disease and banana mosaic disease

4.5.6 Cost effective dot blot TAS-ELISA based diagnostic kit for simultaneous detection of multiple banana viruses in banana plants

(R. Selvarajan)

BBrMV and CMV monoclonal antibodies were supplied to the collaborating partner, PSG College of Technology, Coimbatore, Tamil Nadu. Further, expressed coat proteins of the BBrMV and CMV also were supplied for the development of Dot-TAS ELISA.

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

(C. Anuradha)

A diverse set of phenotyped 200 *Musa* accessions from the germplasm collections of ICAR-NRCB were included in the panel for double digest restriction-site associated DNA (ddRAD) sequencing. HaeIII_MspI, MseI restriction enzyme combination was used to generate fragments within the 200 banana samples. Fragmented DNA (265-290 bp) was then purified and ligated to barcoded adapters. Libraries were sequenced with NovaSeq 6000platformand the length of the reads is 150bp. Sequencing was completed fror 100 samples and they passed the QC.

SSR marker associated with parthenocarpy was identified which has to be further validated in other seeded and parthenocarpic cultivars (Fig. 92).

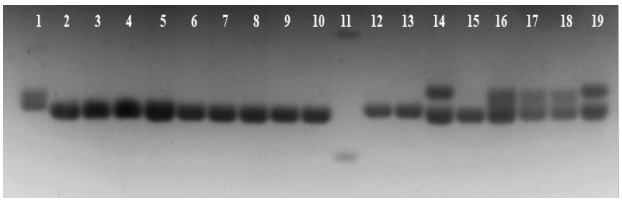


Fig. 92. Validation of SSR marker associated with parthenocarpy. Lane 1: *M. ac.* ssp. *burmannica* (AA); Lane 2:*M. ac.* ssp. *burmanicoides*(AA); Lane 3: *M. ac.* ssp. *zebrina* (AA); Lane 4: *M. ac.* Assam 1715 (AA); Lane 5: *M. ac.* Arunachal Pradesh 1731 (AA); Lane 6: Bhimkol (BB); Lane 7: Athiakol (BB); Lane 8: Attikol (BB); Lane 9: Beejikela (BB); Lane 10: *Musa balbisiana* (BB), (Lane 1-10 seeded cultivars); Lane 11: 1kb Plus Marker (#SM 1331); Lane 12: Pisang Linin (AA); Lane 13: Pisang Mas (AA); Lane 14: Hatidat (AA); Lane 15: PJB (AA); Lane 16: Kunnan (AB); Lane 17: Puttabale (AB); Lane 18: Ney Poovan (AB); Lane 19: Grand Nain (AAA)(Lane 12-19 parthenocarpic cultivars).

4.5.8 Breaking frontiers for the improvement of plants natural defense against pathogens in Banana (*Musa* sp.) through genome mining

(K. Panneerselvam)

Aldo-keto reductase (AKR)-domain (PF00248) containing proteins are NAD(P)(H)-dependent oxidoreductases of a multigene superfamily that mediate versatile functions in plants ranging from detoxification, metal chelation, potassium ion efflux to specialized metabolism. They have also been presumably implicated in the earlier biosynthetic steps of phenylphenalenones production in banana, which represent potential targets for improving the natural defense system of banana against multiple pathogens. Since the AKR nomenclature committee considered only the functionally characterized AKRs for the classification system and that the biological functions of many plant AKRs are yet to be discovered, the actual phylogeny/diversity realm of plant AKRs remains unknown. To decipher the landscape of AKR gene superfamily in plants, all the putative AKRs of 74 diverse plant species (1 rhodophyte, 8 chlorophytes, 1 marchantiophyte, 1 bryophyte, 1 tracheophyte, 3 basal angiosperms, 20 monocots and 39 eudicots) were systematically retrieved and classified using a systematic bioinformatics pipeline using USEARCH, blast+, and synteny network tools (Krishnamurthy *et al*. 2022). This involves a four-step process, whereby genes sharing ≥ 60% protein sequence identity with a ≤ 1E-05 threshold at different sequence lengths (either full-length, ≥ 60% length, or ≥ 150 amino acids) or retaining in the similar synteny blocks are assigned to the same subgroup. Based on this strategy, we proposed an alternative, 14-subgroup classification system for plant AKRs which would provide direct benefit to future gene family characterization studies. This is the first comprehensive study that unveils the complete repertoire of plant AKRs and extends our current understanding of its distinct evolutionary trends. We believe our findings could undoubtedly facilitate future functional studies related to the discovery of hitherto unexplored functions of AKRs in planta. Furthermore, our classification framework can also be readily extended to other (super) families.

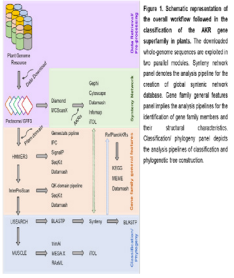


Fig. 93. Schematic representation of the overall workflow followed in the classification of the AKR gene superfamily in plants

4.5.9 MusaTILLING: Construction of a structured high-efficient mutant resource for functional genomics and crop improvement of banana (*Musa* spp.)

(K. Panneerselvam, M.S. Saraswathi, S. Backiyarani and S. Uma)

Though mutagenesis has provided novel genetic materials for crop improvement and facilitated functional genomics of many plant species over the past decades, no mutant libraries have been reported in banana with multifaceted biological insights. The exotic cultivar Yangambi Km5 (YKM5) is internationally recognized as an important source of novel genes for banana improvement that has excellent resistance against multiple pathogens and pests. Mutagenesis generates less chimerism via embryogenic cell suspensions (ECSs) than other explants (e.g., shoot tip), and the chemical mutagen ethyl methane sulfonate (EMS) offers higher mutation frequencies than other mutagen types (e.g. physical ones such as γ-rays and biological ones such as transposons). Taken together, a comprehensive and systematic strategy is thus aimed to construct an efficient MusaTILLING resource for the advancement of functional genomics and crop improvement studies in banana by inducing mutations in the ECS of YKM5 by EMS (Fig. 94). We have successfully established the ECS of YKM5 through male flower bud initiation method for the first time. After ECS propagation, the cells were treated with two different concentrations of EMS (i.e. 0.2% and 0.3%) for two time periods (i.e. 45 min and 90 min). Treatments were performed three times independently. So far, steps 1 – 5 in Figure 1 were completed and further research is underway.

Fig. 94. Musa Tilling – Overall workflow of the project

ICAR Funded Projects

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)

Preparation of unleavened flat bread using Green banana flour made by different methods

Banana flour from unripe banana (var. Kaveri Saba) was prepared using to two different methods, conventional (GBF) and hot water boiling (B-GBF)) to investigate its effect on physicochemical properties and suitability for product preparation. L* value of rice flour was the highest due to polishing and absence of bran or carotenoids. The water activity (a_w) and moisture content of flours were < 0.4 and < 7% respectively, indicating that all these samples are stable to store for longer duration. Carbohydrate, protein, fat and total phenol content of B-GBF was the highest, comparatively (Table 36). Initial works were carried with incorporation of banana flour by both methods at different substitutions (10, 20% and 30%) for the development of unleavened flat bread. Sensory analysis showed that up to 20% B-GBF had acceptable sensory score and higher level of substitution resulted with bitter taste in the final product.

Table 36. Physico-chemical properties of different flour sample

	Wheat flour	Rice flour	GBF	B-GBF
L	86.42±3.94	89.40±2.37	80.45±2.74	78.15±1.69
a	10.96±0.92	12.22±0.82	11.53±0.91	10.25±0.85
b	23.48±0.91	18.74±0.74	20.15±0.55	29.13±0.12
Aw	0.39±0.01	0.36±0.05	0.34±0.01	0.34±0.01
Moisture (%)	4.91±0.07	4.31±0.03	6.52±0.02	5.31±0.08
Carbohydrate (%)	78.42±2.31	83.35±1.68	82.88±1.79	84.63±3.03
Protein (%)	0.35±0.002	0.32±0.003	0.53±0.001	0.60±0.003
Fat (%)	0.34±0.001	0.31±0.002	0.47±0.003	0.58±0.002
Ash (%)	1.43±0.03	1.33±0.01	1.22±0.05	1.34±0.03
Total phenol (mg GAE/ 100g)	47.38±0.85	33.26±0.55	61.43±0.92	63.46±0.91

Optimization of process variables for maximizing the extraction of clarified banana juice and its use in the preparation of banana wine and vinegar

Optimization of enzymatic banana juice extraction using Box-Behnken design using RSM with three numerical factors: 1. incubation temperature (30-50 °C); 2. cellulase concentration (0–6 g/L banana); 3. pectinase concentration (0–6 g/L banana) was carried. Extraction of banana juice at incubation temperature of 50 °C with cellulase and pectinase concentration of 6 g/L yielded with higher nutrient content like total sugar (24.52 g/100 g), reducing sugar (10.11 g/100 g), total protein (2.23 g/100g), total phenol (226.79 mg/100 g) and total flavonoids (53.17 mg/100 g). The banana juice obtained by optimized method was subjected to alcoholic fermentation, (*Saccharomyces cerevisiae* (5% (v/v)) for 7 days at 25 °C. The alcoholic content of developed wine was up to 7.01% (v/v). Alcoholic fermented banana juice (banana wine) was subjected to acetic acid fermentation (*Acetobacter aceti* (3% (v/v)) in laboratory scale fermenter in batch process and was used for vinegar fermentation. Acetic acid fermentation was carried at 28 °C (3 days) with 1.5 l/h airflow rate. The vinegar produced had 4% acidity (Fig. 95).

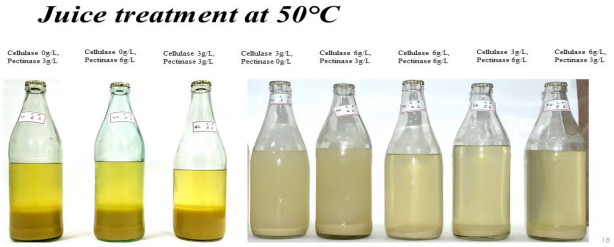


Fig. 95. Vinegar production from clarified banana juice

4.5.11 Development 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

Deciphering ripening dependant glycaemic response and colour development of traditional banana varieties

(P. Suresh kumar)

Although ripening stage dependent colour chart is available for Grand Nain, the traditional varieties such as Rasthali, Poovan, Karpuravalli and Ney Poovan lack ripening stage dependent colour chart (Fig. 96). More than eight distinguishing edible stages were identified for few traditional varieties like Karpuravalli and Ney Poovan. Unlike Grand Nain, in spite of development of brown spots on the skin, the firmness of the fruits of variety Ney Poovan and Karpuravalli was retained making it suitable for consumption even at stages 7 and 8 of ripening. Higher pulp to peel ratio was recorded in Ney Poovan with lower e-GI even in stage 8 (75.2). The estimated GI values of Karpuravalli (71.1%) and Rasthali (73.76 %) were higher at Stage 4 (Table 37).

Table 37. HI and GI indices of different ripening stages

Variety	Stage 2		Stage 4		Stage 6		Stage 8	
	HI	e-GI	HI	e-GI	HI	e-GI	HI	e-GI
Grand Nain	21.60	51.57	48.92	66.57	72.44	79.48	82.25	84.87
Rasthali	41.93	62.73	62.02	73.76	73.60	80.12	86.61	87.26
Poovan	36.13	59.55	52.91	68.76	70.51	78.42	77.35	82.18
Karpooravalli	32.16	57.37	57.17	71.11	79.61	83.42	92.04	90.24
Ney Poovan	27.41	54.76	42.78	63.27	52.22	68.38	64.64	75.27

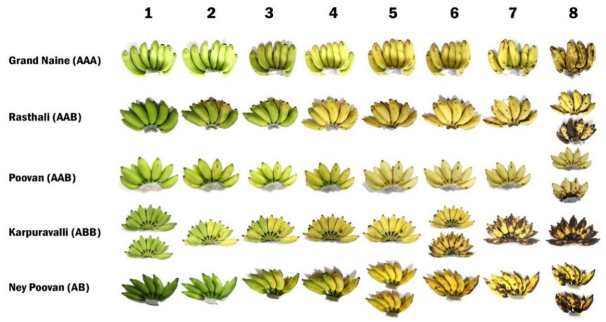
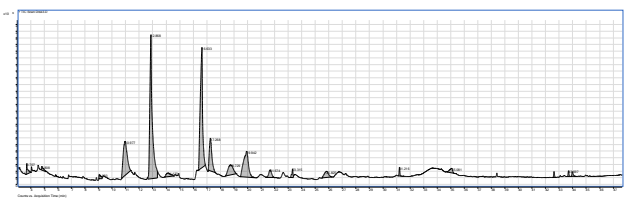


Fig. 96. Ripening colour chart for banana varieties

Influence of ripening methods on the volatiles synthesis and antioxidant profiles of Grand Nain banana fruits

Different commonly used conventional ripening techniques namely ethrel dip, ethrel spray, fumigation, smoke based ripening and calcium carbide chemical based ripening procedures were experimentally analyzed on the commercial variety Grand Nain. Not much variation was observed among the methods tested in terms of acidity, TSS and total sugar. However, expression of phenol and flavonoids varied significantly with the methods used. Ethrel spray and dip has synthesized higher phenol than other methods. The GC-MS profile showed the marked variation in the production of volatiles in fruits ripened using calcium carbide namely, 1-Nitro-2-acetamido-1,2-dideoxy-d-mannitol; 4,5-Diamino-2-hydroxypyrimidine; 6-Acetyl-β-d-mannose; Melibiose; Isopentyl 3-hydroxy-2-methylenebutanoate; 7-Methyl-Z-tetradecen-1-ol acetate (Fig. 97).



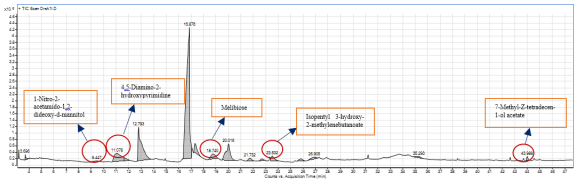


Fig. 97. GC-MS chromatogram of ethylene fumigation based ripened fruits

Non-invasive banana ripeness identification technique during export and bulk handling in processing industries

Grading of banana fruits depending upon the stage of ripening is of paramount importance in export and industrial applications. Bulk handling of banana tiers (hands) and food processing industries require automated non-destructive methods of classification. Tried deep learning based non-destructive method of classification of banana fruits under four categories - unripe, under ripe, ripe and over ripe. A duo of CNN and eXtreme Gradient Boosting (XGboost) algorithm (CNN-XGBoost) is introduced for the effective determination of the ripening stage of banana. CNN acts as the trainable feature extractor of the images and XGboost acts as the identifier of ripening stage. In order to eliminate the need to have data augmentation or huge data set, Linear Discriminate Analysis (LDA) is incorporated. Thus, the proposed deep learning approach possesses capability to perform classification even with a smaller data set where the conventional deep and machine learning techniques fail. The performance accuracy of the proposed duo is found to be satisfactorily higher than the Support Vector Machine (SVM), Gaussian Naive Bayes Classifier (GNB) and k-Nearest Neighbours (KNN) algorithms. While

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. Thus, with or without data augmentation, banana classification using the proposed technique is successfully performed.

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)

One incubatee, Mr. Walter Fernando (Winwal International., Chennai, Tamil Nadu) joined the incubation unit and availed the facilities for making banana flour and banana flour-based weaning food (baby food) and one off-campus incubatee (Mr. Kanthan Nair, Kannur, Kerala) joined for banana nectar fig making. Three products/technologies were developed: (i) Banana rava (*suji*) and Grits (A ready to cook (RTC) breakfast cereal); (ii) Banana rava fortified with millets and quino (fortified banana rava with millets and quinoa for increased nutritive value) and (iii) Flavoured banana chips (in different flavors like tomato, ginger, garlic, capsicum, mint, coriander to increase taste and nutritive value of the banana chips). Eight Entrepreneur Development Programmes (EDPs) and 10 Agri-business Development/Awareness Programmes were organized. About 830 visitors visited ABI and got benefitted. The revenue earned by ICAR-NRCB-ABI activities was Rs. 10,000/-. Two success stories were developed. Two technical bulletins and three training manuals were brought out and popularized through five mass media programmes on TV and AIR.

4.5.13 Integrated management of Fusarium wilt, Tropical Race-4 – A devastating strain on banana

(R. Thangavelu, M. Loganathan, C. Anuradha and S. Uma)

Development of a molecular marker for specific detection of *Fusarium oxysporum* f. sp. *cubense* sub tropical race 4 (STR4)

Fusarium oxysporum f. sp. *cubense,* particularly sub-tropical race 4, is found to infect Cavendish banana in Madhya Pradesh and Gujarat. In order to develop a diagnostic method, whole genome sequences of race STR4 were aligned to identify variable regions in the SIX genes which are important for the disease development in banana. By *in silico* analysis, three specific set of primers were designed and among these, *Foc* STR41/ *Foc* STR42 set specific marker (SIX7-3-F-5' AGGGCTATGCTTTAGCACCA3', SIX7-3-R 5'AGCATCCGGAAGCAAGACTA3') allowed target amplification of 248bp in the characterized highly virulent STR4 *Foc* isolates but did not show any product amplification in other races of Race1 and TR4. Thus, the markers developed in this study are novel and may potentially be useful for early detection and monitoring of virulent strains of *Foc*STR4.

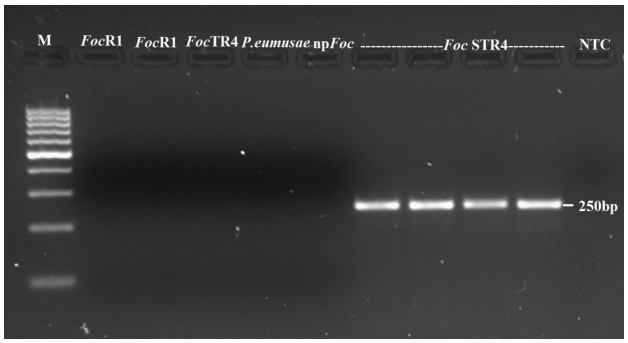


Fig. 98. Development of molecular markers for the specific detection of *Foc* STR4

Field evaluation of biocontrol agents against *Foc* TR4 in Uttar Pradesh

A field experiment was conducted for the management of Fusarium wilt disease tropical race 4 in Siswabazar of Maharajganj district in Uttar Pradesh using three different consortia of bioagents, *viz*. endo. *Trichoderma asperellum* (prr2) + endo. *Penicillium Phinophylum* (BC2), endo. *Bacillus flexus* (TVPr1) + rhi. *Trichoderma* spp. (NRCB3) and *Pseudomonas* sp. + *Raotella* sp. + *Ochrobactrum* sp. on cv. Grand Naine.

Three applications of these bioagents at 2 months interval resulted in an internal score of 1.0-2.0 (0-5 scale) with the lowest score being 0.2 with the combination *Bacillus flexus* (TVPr1)+ rhi. *Trichoderma* spp. (NRCB3) as against 3.8 in the control plants. Besides, this treatment also registered a significant increase in overall plant growth parameters than control.

Table 38. Field evaluation of biocontrol agents against *Foc* TR4 in Uttar Pradesh

Treatments	Disease score (0-5 scale)
Endo. *Trichoderma asperellum* (prr2) + endo *Penicillium Phinophylum* (BC2)	1.00[b]
Endo. *Bacillus flexus* (TVPr1) + rhi. *Trichoderma*spp (NRCB3) and	0.20[a]
Pseudomonas sp. + *Raotella* sp. + *Ochrobactrum* sp. in cv. Grand Naine.	2.00[c]
Carbendazim (0.1%)	3.00[d]
Control	3.80[e]

Control Consortia (T2) treated plants

Fig. 99. Field evaluation of biocontrol agents against *Foc* TR4 in Uttar Pradesh

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

A total of 48 *Foc* isolates collected from Tamil Nadu, Andhra Pradesh, Uttar Pradesh, Gujarat, Madhya Pradesh, Maharashtra and Bihar belonging to different VCGs such as 0124, 0125, 0120, 01218, 01213/16 and 01220 of race 1 and race 4 were screened for the distribution of effector based SIX genes by using SIX genes-specific PCR primers. The result of the study indicated that in *Foc* in *Foc*TR4 (VCG01213/16), the SIX genes SIX 1, 2,8 9 and 13, in VCG 0125 of race 1, the SIX genes SIX1, 4, 6 and SIX 13, in VCG 01220 of race 1, the SIX genes SIX1, 4, 6, 9 and 13 and in VVCG 0120 the SIX genes SIX1, 2, 7, 8, 9 and 13 were present. It was very interesting to note that the SIX genes 4 was absent in Foc TR4 and SIX genes 2 is absent in VCG 125 and 01220 of race 1.

Table 39. Distribution of effector based SIX genes in different VCGs of *Foc* isolates of India

VCGs	SIX1	SIX2	SIX4	SIX6	SIX7	SIX8	SIX9	SIX13
01213/16 (TR4)	Yes	Yes	No	No	No	Yes	Yes	Yes
0120 (STR4)	Yes	Yes	No	No	Yes	Yes	Yes	Yes
0125 (R1)	Yes	No	Yes	Yes	No	No	No	Yes
01220 (R1)	Yes	No	Yes	Yes	No	No	Yes	Yes
Non-pathogenic *Foc*	No	No	No	No	No	No	No	No

Metagenomic insights of corm and rhizospheric microbiome of banana resistant and susceptible to *Fusarium oxysporum* f. sp. *cubense* TR4

Microbial communities from TR4 susceptible and resistant cultivars of banana plants have not been studied until very recently, and their potential role in disease development has not been explored so far. In order to identify potential microbial groups and functional traits correlated with the suppression of *Fusarium oxysporum* f. sp. *cubense* on banana, ITS and 16S RNA gene Microbiome Sequencing and Analysis using Nanopore platform was used to investigate the corm and rhizosphere microbiome of banana cultivars classified as resistant (9) and susceptible (4).It was observed that fungal community abundance and diversity were higher in resistant varieties than in susceptible varieties in both corm and rhizosphere soil of banana, and the abundance of Fusarium species complex and *Aspergillus flavus* increased in the rhizosphere soil of resistant and susceptible varieties, while the abundance of *Coprinopsis udicola* and *Aspergillus flavus* increased in the corm samples of susceptible and resistant varieties. Among bacteria, *Bacillus flexus* (25%), *B. selenatarsenatis* (12.5%), and *Anoxybacillus kestanbolensis* (12.5%) were more abundant in the corm samples of resistant and susceptible varieties, whereas *Anoxybacillus kestanbolensis* (12.0%), *Candidates Portiera aleyrodidarum* (13.0%) and *Propionibacterium acnes* (12.0%) increased in the rhizosphere soil of susceptible and resistant varieties. We also observed that 16srRNA community abundance and diversity were higher in resistant varieties than in susceptible varieties in both corm and rhizosphere soil of banana.

Evaluation of individual application of endophytic and rhizospheric bacterial isolates against *Foc* TR4 under pot-culture conditions

Eight bacterial isolates (one rhizospheric and seven endophytic) were evaluated against *Foc* TR4 in cv. Grand Nain under glasshouse conditions and both negative (*Foc* alone inoculated) and positive control (without application of anything) were maintained. The observations on plant growth parameters and internal wilt disease score (on a disease scale of 0-5) were taken at 3 months after treatment. The results showed that among the biocontrol agents applied, the application of endophytic *Bacillus subtilis* ssp. *spizizenii* (T4) recorded the lowest disease score of 1.2 as against the disease score of 5 in the *Foc* TR4 alone inoculated plants. With regard to growth promotion effect, in general, all the bioagents showed significant increase in the biometric attributes such as plant height, girth, leaf area and root numbers as compared to control plants.

Evaluation of individual application of endophytic and rhizospheric *Trichoderma* isolates against Foc VCG TR4 UNDER in potculture

Seven *Trichoderma* spp. isolates (six rhizospheric and one endophytic) were evaluated against *Foc* TR4 in cv. Grand Nain under glasshouse conditions and both negative (*Foc* alone inoculated) and positive control (without application of anything) controls were maintained. The observations on plant growth parameters and internal wilt disease score (on a disease scale of 0-5) were taken at 3 months after treatment. Among the biocontrol agents applied, rhizospheric *Trichoderma asperellum* (NRCB3) (T3) recorded the lowest disease score of 1.0 as against the disease score of 5 in the plants inoculated with *Foc*TR4 alone. In general, all the bioagents showed significant increase in the biometric attributes such as plant height, girth, leaf area and root numbers as compared to control plants.

Evaluation of combined application of native endophytic and rhizospheric bacterial and fungal isolates against *Foc*TR4 under glasshouse condition

To achieve the maximum disease control, combination of bacterial and fungal isolates of

both endophytic and rhizospheric origin were selected and tested under glasshouse conditions in cv. Grand Nain. The study included different combinations of *Foc* TR4 effective bacterial and fungal isolates based on previous experiments and both negative (*Foc* alone inoculated) and positive control (without application of anything) were maintained. The observation on plant growth parameters and internal wilt disease score (on a disease scale of 0-5) was taken at 3 months after treatment. The results of the study revealed that the treatment (T6) with rhizospheric *T. asperellum* (NRCB3) in combination recorded cent percent suppression of Fusarium wilt disease besides increasing the plant growth parameters such as plant height, girth, leaf area and root numbers significantly compared to both *Foc* alone inoculated and positive controls.

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

(R. Selvarajan and C. Anuradha)

Expression and purification of BSMYV-VAP for raising polyclonal antiserum for developing ELISA based kit for detection of BSMYV

The viral-associated protein (VAP) coded by ORF II of BSMYV (15-kDa) cloned prokaryotic expression vector pCold I was expressed in *Escherichia coli* (Fig. 100). The recombinant protein was purified using Ni-NTA agarose, and the purified protein was used as an immunogen to produce polyclonal antibodies.

Cloning, expression and purification of recombinant BBTVCP for raising polyclonal antiserum for developing ELISA based kit for detection of BBTV

The coat protein (CP) gene of BBTV was amplified from the DNA extracts of a BBTV infected banana sample by PCR using BBTV CP gene specific primers with Nde1 and Xho1 restrictionsites added at the 5' end of

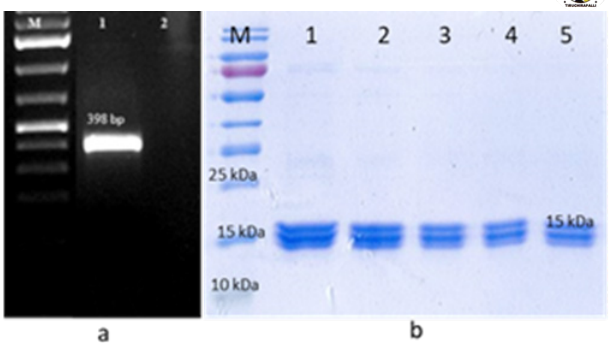


Fig. 100. Cloning and expression of viral-associated protein (VAP) coded by ORF II of BSMYV.a.).Amplification of virion-associated protein (VAP) gene of banana streak Mysore virus (BSMYV) using specific primers, lane M – 1-kb ladder plus (75–20 000 bp; Thermo Fishers Scientific); Lane 1: BSMYV infected leaf sample; Lane 2: healthy; (b) Sodium dodecyl sulphate–polyacrylamide gel electrophoresis (SDS-PAGE) of BSMYV-VAP expressed as His-Tag fusion protein in *E. coli* , lane M – Marker; lane 1-5, soluble form of pCold – BSMYV–VAP fusion protein purified (15 kDa) with His-Tag purification system

Fig. 101. Ready to use TAS-ELISA kits developed for detection of banana bract mosaic virus and cucumber mosaic virus

theforward and reverse primer, respectively. The PCR product was cloned into the pGEMT easy vector and sequenced. The BBTV-CP gene was digested from the recombinant pGEMT plasmid using Nde1 and Xho1 and then subcloned into the 5' terminal 6XHis-tagged pET28a (+) for prokaryotic expression system. The clones were identified by restriction digestion with site-specific enzymes and also confirmed by nucleotide sequencing. Correct clones were mobilized to transform to *Escherichia coli* BL21 (DE3) and expressed *in vitro*.The expressed CP was purified using a Ni–NTA agarose resin column (Fig. 24). The concentration of the purified protein was quantified and used for raising for polyclonal antiserum against the BBTV-CP in rabbits.

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

Bananas and plantains are affected by two RNA viruses namely cucumber mosaic virus and banana bract mosaic virus. Triple antibody sandwich ELISA (TAS-ELISA) has been

standardized and validated using field samples against BBrMV and CMV. TAS-ELISA kit to detect banana bract mosaic virus and cucumber mosaic virus from banana were developed using two antisera. The CMV kit can be used not only for banana but any crop which is known to get infected by CMV. This kit contains high quality recombinant polyclonal and monoclonal antibodies, ELISA plate and buffers, positive and negative control and protocol. This kit is highly sensitive and specific in detecting BBrMV and CMV in banana samples. The kit can test 96 samples and the reagents are stable for up to one year at 4°C.

Nanopore-based detection and characterization of multiple pathogens

To detect and characterize the virus infecting banana and tomato plants, MinION sequencing approach was used and dual infection was recorded in banana. Complete genomes of BBrMV, CMV, and TSWV were detected and characterised. The total RNA samples were isolated from banana and tomato using the RNeasy Plant Mini Kit (Qiagen). MinION sequencing libraries were prepared as recommended by Oxford Nanopore Technologies using a cDNA-PCR Barcoding (SQK-PCS109 with SQK-PBK004) kit and loaded on to an early access minION flow cell FLO-MIN106 R9). Sequence running was performed on the MinION flow cell (FLOMin106 R9 version; Oxford Nanopore Technologies) assembled in the MinION sequencer (MK 1B version; Oxford Nanopore Technologies). Reads were base-called by Guppy_basecaller V3.4.4. EPI2ME barcoding was used to demultiplex the reads with the recommended quality cut-off with Guppy barcoder V3.4.4.

All the pathogens were identified to the species or genius level and ranked in the first five positions of cumulative reads by the WIMP workflow (Fig. 102).

Fig. 102. Results obtained by WIMP workflow following Nanopore sequencing of RNA from diseased plant samples

For BBrMV, a total of 5452 of the MinION reads were further mapped against the BBrMV reference sequences and yielded a consensus sequence covering the entire BBrMV genome, sharing 94.55% pairwise identity with it. A total of 3535423 mapped bases were generated. MinION reads yielded one large contig. BLASTn comparisons between these one contig and all sequences in GenBank indicated that the highest similarity scores were detected with BBrMV (accession number DQ851496, highest percent nucleotide identity=94.55%, query coverage=100%, e-value=0) for contig #1 (9711 bp). For CMV, mapping of the 16748 MinION reads against the CMV reference sequences yielded a consensus sequence covering the entire CMV genome (average contig length-2874, average reads per contig-5582, N50-3045 and N90-2219). Mapped bases for RNA1-1959153, RNA 2-2209878 and RNA 3-313743 were generated. MinION reads yielded three large contigs. BLASTn comparisons between these one contig and all sequences in GenBank indicated that the highest similarity scores were detected with CMV (accession number EU159528, highest percent nucleotide identity=97.75%, query coverage=99%, e-value=0) for contig #1 (3357 bp) and CMV (accession number JN054637, highest percent nucleotide identity=95.60%, query coverage=100%, e-value=0) for contig #2 (3357 bp) and CMV (accession number EF178298, highest percent nucleotide identity=97.43%, query coverage=100%, e-value=0) for contig # 3 (2216 bp). For TSWV, mapping of 17165 MinION reads against the TSWV reference sequences yielded a consensus sequence covering the entire TSWV genome (average contig length-5544, Average reads per

contig-5721, N50-8897, N90-2916). Mapped bases for RNA L-1371018, RNA M-671796 and RNA S-3491886 were generated and MinION reads yielded three large contigs. BLASTn comparisons of contig #1 (8913 bp), contig #2 (4699 bp) and contig # 3 (2968 bp) indicated that the highest similarity scores were detected with TSWV (accession number NC 002052; NC 002050, and NC 002051). These results were validated by RT-PCR using specific primers and Sanger sequencing.

NABARD Funded Project

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)

Bunch traits of different commercial banana cultivars were collected from banana markets to develop non-destructive yield prediction models for the development of online-trading platform. Substantial variation recorded on important bunch traits in four banana cultivars at Kattuputhur Agricultural Regulated Market and Tiruchirappalli Gandhi Market are summarized in the Table 40 and Fig. 103. The bunch weight ranged from 2.9 to 35.0 kg in Rasthali and Poovan, respectively 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 and 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.

Table 40. Variability in bunch traits recorded in four banana cultivars at Kattuputhur Agricultural Regulated Market and Tiruchirappalli Gandhi market

Sl. No.	Cultivars	Variable	No. of observations	Minimum	Maximum	Mean	CV
1	Karpuravalli	Bunch weight (Kg)	132	4	32	11.72	53.9
		No. of hands per bunch	132	4	15	8.21	29.2
		Total no. of fruits per bunch	132	40	306	125.07	41.1
		Peduncle girth (cm)	132	12.5	26	17.58	17.3
		Fruit length (cm)	647	8.0	17.0	12.0	13.9
		Fruit diameter (mm)	647	23.9	47.7	36.2	10.8
	Poovan	Bunch weight (Kg)	144	4.45	35	16.00	39.2
		No. of hands per bunch	144	4	14	9.64	19.2
		Total no. of fruits per bunch	144	40	351	174.73	34.4
		Peduncle girth (cm)	144	12	25	18.27	13.7
		Fruit length (cm)	784	6.0	18.5	11.29	18.8
		Fruit diameter (mm)	784	20.7	55.7	36.2	13.2
	Rasthali	Bunch weight (Kg)	132	2.9	31.5	12.15	52.8

		No. of hands per bunch	132	4	11	6.87	24.1
		Total no. of fruits per bunch	132	36	170	97.2	36.7
		Peduncle girth (cm)	132	11	32.5	17.4	22.2
		Fruit length (cm)	708	6.5	19	12.62	18.2
		Fruit diameter (mm)	708	23.9	49.3	38.4	10.5
	Red banana	Bunch weight (Kg)	100	5	20	12.54	25.2
		No. of hands per bunch	100	3	7	4.8	17.0
		Total no. of fruits per bunch	100	33	126	69.6	26.4
		Peduncle girth (cm)	100	14.5	23.5	19.47	8.8
		Fruit length (cm)	600	13	26	19.96	11.0
		Fruit diameter (mm)	600	39.8	66.8	47.8	7.2

All the correlations between bunch weight with other bunch traits were positive (Table 41). However, peduncle girth recorded highest correlation coefficients (r=0.80 to 0.89 at $p<0.0001$) with bunch weight followed by total number of fruits per bunch (0.74 to 0.80). Both fruit length and girth correlated weakly (≤0.50) with bunch weight.

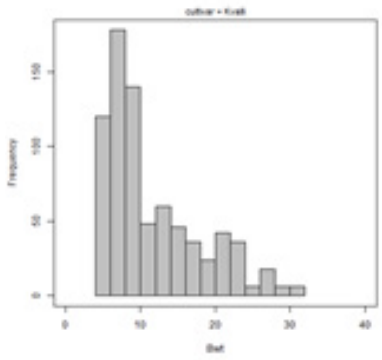
Table 41. Correlation coefficients between bunch weight and other bunch traits for different banana cultivars

Cultivar	No. of hands	No. of fruits	Total no. of fruits	Peduncle girth	Fruit length	Fruit diameter
Karpuravalli	0.7126	0.5694	0.7388	0.8814	0.3569	0.4236
Poovan	0.6722	0.6231	0.7416	0.8857	0.4958	0.4216
Rasthali	0.7731	0.6395	0.8016	0.8815	0.4999	0.4943
Red banana	0.7551	0.6077	0.7837	0.7988	0.4878	0.2851

The regression model was positive for peduncle girth with high determination coefficient for Karpuravalli (77.65), Poovan (78.52) and Rasthali (78.82). Lowest determination coefficient (63.71) was observed for peduncle girth to predict bunch weight in Red banana, hence multiple linear regression model combining peduncle girth and total number of fruits is proposed for better prediction with higher determination coefficient (75.24). Thus owing to ease of measurement and its non-destructive character, the peduncle girth, total number of fruits calculated using no. of hands and no. of fruits in the middle hands, were selected for the prediction of banana bunch weight (Table 42).

Table 42. Prediction model for the banana bunch weight (Bwt) as a function of peduncle girth (PG)

Cultivar	Linear regression equation	Adj R-sq
Karpuravalli	Bwt = -20.57+1.84PG	77.65
Poovan	Bwt = -24.47+2.22PG	78.52
Rasthali	Bwt = -13.51+1.47PG	78.82
Red banana	Bwt = -16.22+1.48PG	63.71
Red banana	Bwt = -10.84+0.92PG+.08TNF	75.24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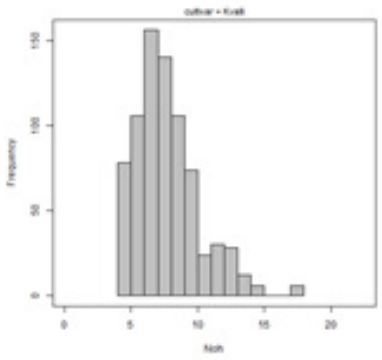
Bwt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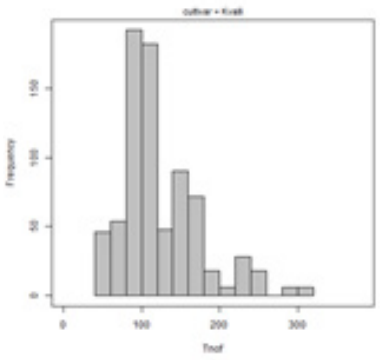
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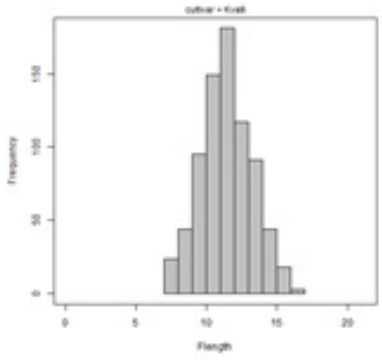
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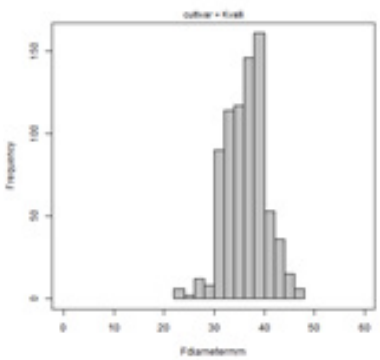
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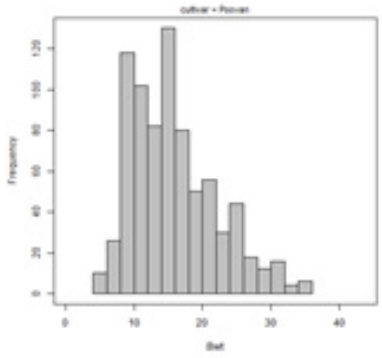
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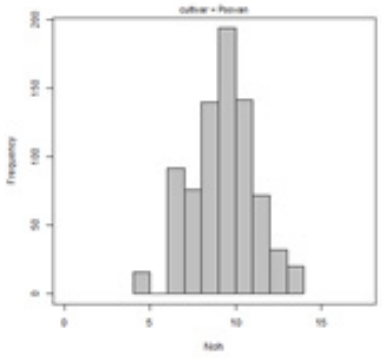
Bwt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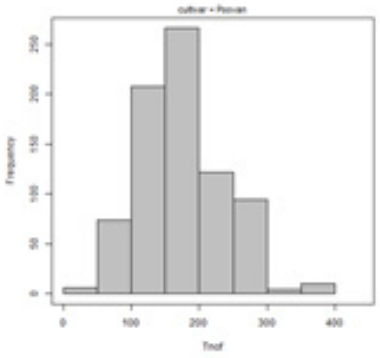
Noh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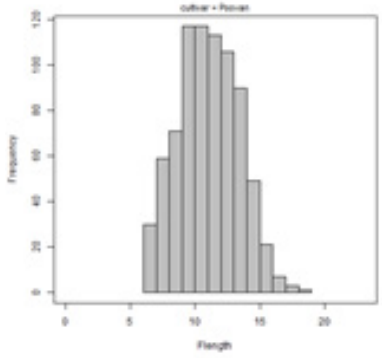
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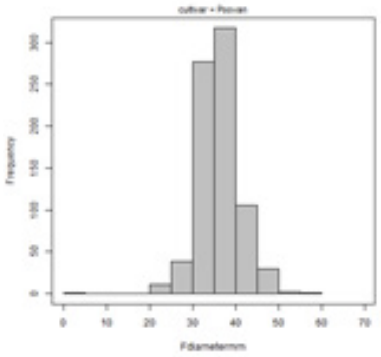
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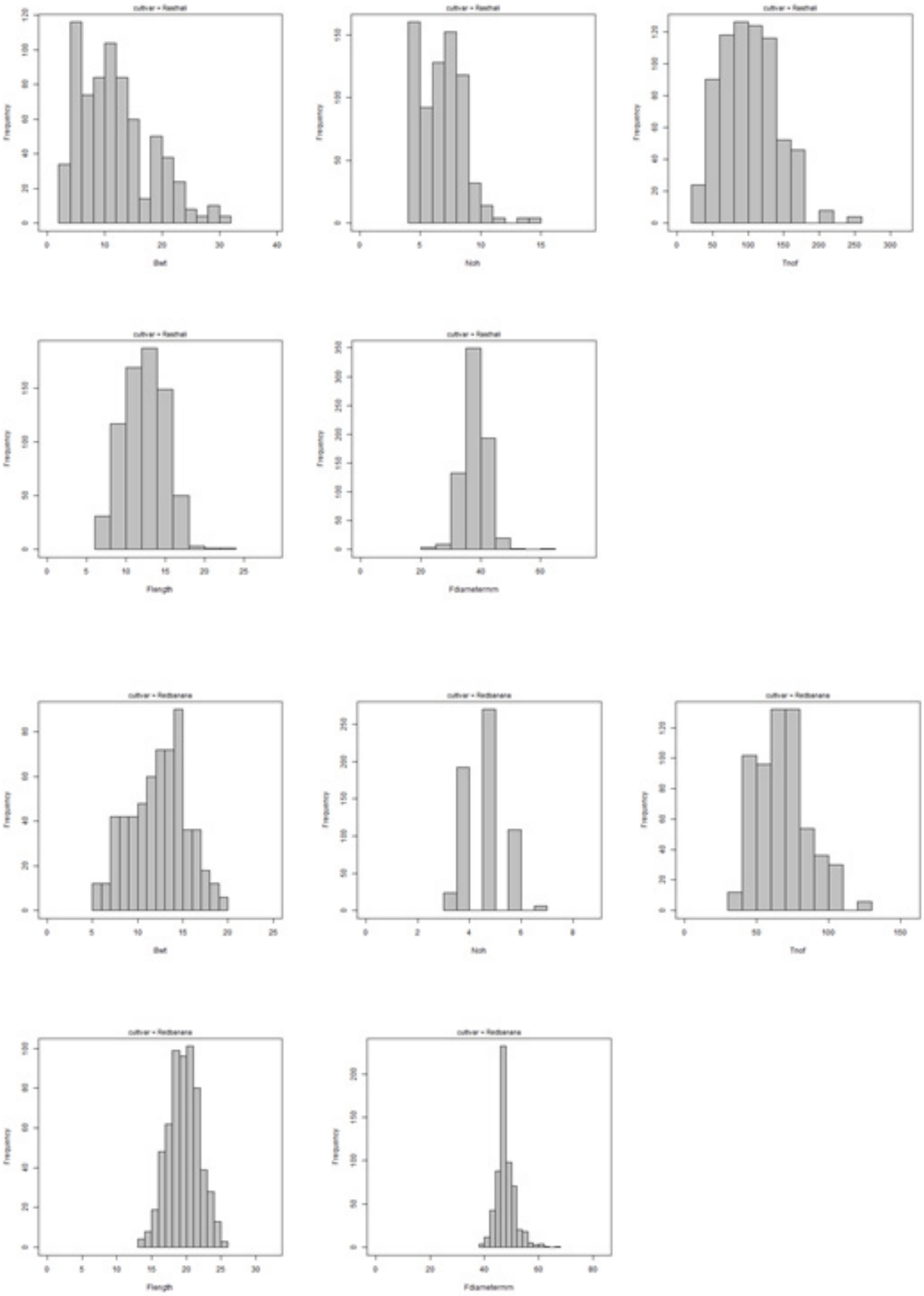

Fig. 103. Histogram showing variability in bunch weight (Bwt), no. of hands per bunch (Noh), total number of fruits (Tnof), fruit length (cm) and fruit diameter (mm) recorded in four banana cultivars at Agricultural Regulated Market, Kattuputhur and Gandhi market, Tiruchirappalli.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Radio talk

Name of the Scientist	Topic	Date of broadcast	Channel
K.J. Jeyabaskaran	Live program on "Soil and Fertiliser Management in Banana Cultivation"	3 February, 2021	All India Radio, Tiruchirappalli
P. Suresh Kumar	Banana fiber: Extraction and utilization	15 March, 2021	
V. Kumar	Sucker selection and planting techniques in Banana	7 April, 2021	
D. Ramajayam	Ornamental banana hybrids	24 April, 2021	Suryan FM
K.J. Jeyabaskaran	Live program on "Integrated Nutrient Management in Banana with special reference to organic recycling"	31 August, 2021	All India Radio, Tiruchirappalli
P. Suresh Kumar	Banana processing and value addition: Entrepreneurial opportunities	13 October, 2021	

5.2 Television talk

Name of the Scientist	Topic	Date of telecast	Channel
V. Kumar	Development of sea protocol for export of Nendran banana to Europe	4 March, 2021	NCTV News, Kerala
D. Ramajayam	Pink coloured ornamental banana hybrids	19 April, 2021	Pasumai Vikatan YouTube Channel
D. Ramajayam	Ornamental banana cultivation	22 April, 2021	Makkal TV
S. Uma	Establishment, importance of ICAR-NRCB	5 May, 2021	Makkal TV under the program "*Malarum Bhoomi*"
	Significant achievements of different disciplines of ICAR-NRCB	6 May, 2021	
	Q&A and the genesis of the program	7 May, 2021	
C. Karpagam S. Backiyarani M.S. Saraswathi D. Ramajeyam	Extension objectives and crop improvement technologies	11 May, 2021	
V. Kumar	Agronomical technological backstopping	12 May, 2021	
K.J. Jeyabaskaran I. Ravi	Soil health, drought management t & Government's Schemes	13 May, 2021	
R. Thangavelu	Technologies for banana wilt disease management	18 May, 2021	
R. Selvarajan	Technologies for banana virus disease management	19 May, 2021	
M. Loganathan J. Poorani P. Giribabu	Technologies for disease and insect pest management in banana	20 May, 2021	

Name of the Scientist	Topic	Date of telecast	Channel
K.N. Shiva	Post harvest technology, export protocols & farmers' success stories	25 May, 2021	Makkal TV under the program "*Malarum Bhoomi*"
P. Suresh Kumar	Post harvest technology, product development and extension strategies in banana	15 June, 2021	
M. Loganathan	Field diagnosis of Fusarium wilt disease of banana	17 November 2021	
M. Loganathan	Field diagnosis of Fusarium wilt disease of banana	17 November 2021	Aaj Thak

The Director and Scientists of NRCB delivering lectures and demonstrating technologies on Makkal TV

5.3 Exhibitions conducted / participated

Name of the event	Organizer & Venue	Date	Name of the participants
National Horticulture Fair 2021	ICAR-IIHR, Bengaluru (Virtual mode)	8-12 February, 2021	S. Uma V. Kumar S. Backiyarani D. Ramajayam P. Giribabu
Workshop cum Expo on "Banana and Jackfruit"	Department of Horticulture, Thiruvarankulam, Pudukkottai District, Tamil Nadu	11-12 February, 2021	V. Kumar
Workshop cum Seminar on "Improved Banana Cultivation and Post Harvest Management"	Ministry of Agriculture, Government of Tripura HRC, Nagicherra, Tripura	17-18 August, 2021	V. Kumar
Banana Cluster-BSM (FPOs & Exporters) Cum Exhibition - Azadi Ka Amrut Mahotsav	APEDA, Chennai – Virtual Exhibition	24 June, 2021	P. Suresh Kumar
India's Rising Export Potential in Global Market – Expo cum Conference	Exporters Conclave, Trichy; APEDA, Chennai &DIC, Trichy, Tamil Nadu	24 September, 2021	V. Kumar P. Suresh Kumar

5.4 Publicity

A total of 88 press notes related to ICAR-NRCB activities / ceremonies / technological information (popular articles) were published in different National and local dailies including digital print, YouTube, Tamil magazines / Journals, All India Radio, Makkal TV *etc*. for the benefit of the banana farmers and other stakeholders.

5.5. Training/ Extension

More than 2500 visitors including farmers, agriculture & horticulture officers, SHG, FPOs, entrepreneurs, students and stakeholders from different parts of India visited the ICAR-NRCB exhibition (for getting firsthand information about technologies developed by ICAR-NRCB on banana) and they were explained about ICAR-NRCB's activities/ technologies. Under the out reach programmes, ICAR-NRCB scientists have trained more than 4000 farmers across the country.

5.6 FLDs and OFTs conducted by ICAR-KVKs with the technical support of ICAR-NRCB

To popularize the ICAR-NRCB's newly released varieties, eight demonstrations (4 FLDs & 4 OFTs) were conducted with the help of five ICAR-KVKs.

List of FLDs and OFTs conducted on ICAR-NRCB released varieties by ICAR-KVKs (Tamil Nadu) with the technical support of ICAR-NRCB

S.No.	Type of Demonstration	Title	Name of the ICAR-KVK
1	Frontline demonstrations (FLDs)	Demonstration of NRCB variety Kaveri Saba with integrated crop management (ICM) practices	ICAR-KVK, Tiruchirappalli
2		Demonstration of new banana variety – Kaveri Saba in saline soils of Trichy District	
3		Evaluation of Kaveri Saba with check variety Monthan in Salem District	ICAR-KVK, Salem
4		Demonstration of Kaveri Saba Variety of Banana for higher yield in Ariyalur District	ICAR-KVK, Ariyalur
5	On farm trials (OFTs)	Assessment of new high yielding cooking type banana (Kaveri Saba and Kaveri Haritha)	ICAR-KVK, Karur
6		Assessment of new high yielding banana varieties for Karur District	
7		Assessment of suitable banana varieties to replace paddy and sugarcane at Thirumanur block of Ariyalur District	ICAR-KVK, Ariyalur
8		Evaluation of suitable banana varieties for Pudukkottai District	ICAR-KVK, Pudukkottai

Visit of banana Farmers to ICAR - NRCB


Visit of banana Farmers to ICAR - NRCB

6.1 Students guided

Student Name	Degree	Project title	Chairperson
K. Arun	Ph.D. (Biotechnology)	Understanding the factors responsible for seed set for enhanced regeneration of hybrids in banana (*Musa* spp.)	S. Uma
R. Maragadavalli	M.Sc. (Biotechnology)	Studies on native endophytic and rhizospheric bacterial and fungal isolates from banana roots, corm and soil for the management of Fusarium wilt pathogen tropical race 4 in banana	R. Thangavelu
K.T. Karthikeyan	M.Sc. (Biotechnology)	Transformation of Green Fluorescent protein (GFP) gene in *Fusarium oxysporum* f. sp. *cubense* TR4, causal agent of Fusarium wilt of banana	
G.K. Sharmila	B. Tech. (Bioinformatics)	Comparison of whole genome sequence of *Fusarium oxysporum* f.sp. *cubense* races 1 and 4 (TR4) infecting Cavendish Banana in India	
G.A. Shivaranjani	M.Sc. (Microbiology)	Investigation on association of phytoplasma with banana bunchy top virus (BBTV) infected banana plants in India	R. Selvarajan
D. Soundarya	M.Sc. (Microbiology)	Exploration of Alpha satellite DNA in Banana Bunchy Top Virus in BBTV infected banana plants in India	
M. Balaadithiyan	M.Sc. (Biotechnology)	Cloning and characterization of cmv 2b geneto produce dsRNA for exogenous application in banana plant confers protection against Cucumber Mosaic Virus	
B. Dhiva Sri	B. Tech. (Biotechnology)	Confirmation of badna viral sequence in chromosome by southern blotting Analysis	
A. Kiruthika	B. Tech. (Bioinformatics)	Identification of potential inhibitor for BBrMV, CMV and BBTV replication by *in silico* analysis	
D. Keshika	B. Tech. (Bioinformatics)	TA cloning of banana bunchy top virus coat protein gene	
G. Vishwa	M. Sc. (Biochemistry)	Biochemical, proteomic and proximate analyses of Grand Nain banana plants genetically transformed with OsNAS1 and 2 genes	M. Mayil Vaganan
S. Vinitha	B. Tech. (Biotechnology)	Molecular confirmation of micropropagated elite Grand Nain banana plants genetically modified with OsNAS genes for iron biofortification	

M.I. Noorjahan	B.Tech. (Bioinformatics)	Development of SSR markers from untranslated regions in *Musa acuminata* (DH Pahang)	S. Backiyarani
S. Nikita	B.Tech. (Biotechnology)	Genetic transformation of banana through CRISPR technology	
G. Hamsini	M.Sc. (Biotechnology)	Confirmation of induced tetraploids of *Musa acuminata* cv. Ney Poovan through SSR markers	
P. Pulamai Dasan	M.Sc. (Biotechnology)	Establishment of *in vitro* aseptic cultures in commercial cultivars of banana and effects of 6-Benzylaminopurine (BAP) and Thidiazuron (TDZ) on *in vitro* shoot multiplication	
B. Vasanth Kumar	M.Sc. (Biotechnology)	Effect of cytokinin in embryo culture of banana	Dinesh Kumar Agarwal
G. Kannan	Ph.D. (Biotechnology)	Development of Fusarium wilt resistance in banana (*Musa* sp.) cv.Rasthali (AAB, Silk) through induced mutagenesis and confirmation through molecular approaches	M.S. Saraswathi
N. Kavitha	Ph.D. (Biotechnology)	Identification of a suitable explant and regeneration pathway for the mass propagation of three recalcitrant varieties of banana	
C.S. Santhana lakshmi	B.Tech. (Bioinformatics)	Expression analysis of R genes in banana germplasm of North Eastern India	
V. Gayathri	B.Tech. (Biotechnology)	Studies on expression of NBS-LRR gene in Sigatoka resistant and susceptible germplasm of North Eastern India	
Rishikesh	B.Tech. (Biotechnology)	Effect of different spectral LED's on direct regeneration of *Musa* spp. cv. Red Banana (AAA) using immature male floral hand as explants	
Ajith kumar	M.Sc. (Biotechnology)	Identification of genes responsible for fusarium wilt resistance in mutant banana cv. Rasthali (AAB, Silk)	
S. Swathi	M.Sc. (Microbiology)	Bio-hardening of banana seedlings with PGPR for enhancing growth and yield associated parameters.	M. Loganathan
S.Yogarani	B.Tech. (Biotechnology)	Embryo culture of inter-specific ornamental banana hybrids	D. Ramajayam
K. Dharani	B.Tech. (Biotechnology)	Identification of polymorphic micro-satellite (SSR) markers for anthocyanin traits in inter-specific ornamental banana hybrids	
P. Nidal Ibrahim	M.Sc. (Food Technology & Quality Assurance)	Influence of methods of preparation on properties of unripe banana flour and the development of unleavened flat bread	P. Suresh Kumar

K. Padma Priya	B. Tech. (Biotechnology)	Molecular diagnostics of economically important nematode pests of banana	P. Giribabu
W. Arun Kumar	M.Sc. (Biotechnology)	Cloning and characterization of eukaryotic translation initiation factor-4E (eIF4E) gene from Pagalapahad wild I and Gros Michel	C. Anuradha
S. Raviraagul	B.Tech. (Biotechnology)	Cloning and characterization of eukaryotic translation initiation factor-4e (eif4e) gene from Khungsang wild and Borkal Baista	
D. Nandhini	B.Tech. (Biotechnology)	Cloning and characterization of eukaryotic translation initiation factor-4E (eIF4E) gene from banana (Peyan and NamwaKhom)	
N. Sivasankara Bharathi	B.Tech. (Bioinformatics)	Genome wide identification and characterization of carotenoid biosynthetic genes in banana	
N. Priyadharshini	B.Tech. (Bioinformatics)	*Insilico* analysis of candidate resistant genes from banana against Banana Bract Mosaic Virus	

6.2 Trainings

6.2.1. On-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Training for Women SHGs from Pudukkottai, Tamil Nadu, organized by Coodu Trust, Dindigul	V. Kumar	50	4 January, 2021
Production of 'Banana Flower Pickle (Thokku)'to entrepreneurs	K.N. Shiva P. Suresh Kumar	1	5-6 January, 2021
Training for Women SHGs from Pathiripatti, Karur, Tamil Nadu, organized by Coodu Trust, Dindigul	V. Kumar	50	20 January, 2021
Exposure visit cum one day training to Lower Coleroon Sub Basin, TNRRI, TNAU, Aduthurai, Tamil Nadu	V. Kumar	50	22 January, 2021
Training on 'Integrated Crop Management in Banana' to farmers of Thiruvarankulam, organized by ATMA- SSEPERS	V. Kumar		23 January, 2021
Training Programme on "Banana based entrepreneurial avenues foreconomic empowerment of Transgenders"	K.N. Shiva S. Backiyarni M.S. Saraswathi D. Ramajeyam P. Suresh Kumar C. Karpagam	8	27-28 January, 2021

Training on 'Macropropagation' to farmers from Paramathiyur, Tamil Nadu	M.S. Saraswathi		9 February, 2021
'Recent Advances in Post-Harvest Management and Value Addition in Banana' to the progressive farmers of Palai, Kottayam Dt., Kerala	K.N. Shiva P. Suresh Kumar	34	9 March, 2021
Production of 'Banana Flour' to entrepreneurs	K.N. Shiva P. Suresh Kumar	3	16-17 March, 2021
Training on'Micropropagation' to one Senior Scientist from RPRC, Odisha	M.S. Saraswathi	1	18 March, 2021
Online training on 'Bacterial diseases of banana and their management' to farmers from Karur District, Tamil Nadu	M. Loganathan	40	24 June, 2021
Capacity Development Program in Banana Cultivation and Academic and Entrepreneurial Opportunities in Banana Sector (Online) to students from UAHS, Shivamogga, Karnataka	S. Backiyarni P. Suresh Kumar C. Karpagam		20 July, 2021
Capacity Development Program for horticulture students from College of Horticulture, Bidar, Karnataka	C. Karpagam P. Ravichamy	300	5 August, 2021
'Banana Flour and Flour based Weaning / Baby Food' to entrepreneur	K.N. Shiva P. Suresh Kumar	1	5-6 August, 2021
Capacity Development Program for horticulture students from College of Agriculture, Kolar, Karnataka	S. Backiyarni C. Karpagam	300	17 August, 2021
Capacity Development Program for students of Govt. High School, Vadaseri, Karur District, Tamil Nadu for the preparation of National Childrens' Science Congress	P. Suresh Kumar C. Karpagam	5	20-28 October, 2021
Capacity Development Program for horticulture students from College of Agriculture, Karekere, Hassan District, Karnataka	C. Karpagam P. Ravichamy	110	29 November, 2021
Capacity Development Program to Diploma students of Agriculture, Institute of Agriculture, Kumulur, TNAU	M.S. Saraswathi C. Karpagam	300	22-24 December, 2021
Capacity Development Program to B.Sc. and M.Sc. students from J. J. College of Arts and Science, Pudukkottai District, Tamil Nadu	C. Karpagam P. Ravichamy	82	29December, 2021
Capacity Development Program for farmers from Periyakulam, Vadukapatti, Tamil Nadu under ATMA-SSEPERS	K.N. Shiva C. Karpagam	50	15-16 September, 2021
"ICM in Banana" to farmers from Chengalpattu District, Tamil Nadu under ATMA-SSEPERS	K.N. Shiva C. Karpagam	40	17-18 December, 2021
'Post-harvest handling, packing, storage and ripening banana for domestic and export markets'	K.N. Shiva P. Suresh Kumar	1	17-18 December, 2021

"ICM in Banana – Recent advances in banana cultivation" to farmers from Valangaiman Block,ThiruvarurDistrict, Tamil Nadu under ATMA-SSEPERS	C. Karpagam P. Ravichamy	40	24 December, 2021
"ICM in Banana – Recent advances in banana cultivation" to farmers fromAthoorBlock, DindigulDistrict, Tamil Nadu under ATMA-SSEPERS	C. Karpagam P. Ravichamy	40	27-28 December, 2021
Capacity Development Program for FPCs *viz*., Lalgudi Thendral Collective Farming Farmer Producer Company Ltd. (LTCFFCL), Trichy &National Agro Foundation, Vellore	C. Karpagam P. Ravichamy	50	28-29 December, 2021
"ICM in Banana – Recent advances in banana cultivation" to farmers fromKaveripakkamBlock,RanipetDistrict, Tamil Nadu under ATMA-SSEPERS	C. Karpagam P. Ravichamy	40	30 December, 2021
Internship Training Programon 'Banana Handling, Processing Technologies and Entrepreneurial Opportunities' to M.Sc. (Food Science and Nutrition) Students of Bishop Heber College, Trichy	P. Suresh Kumar K.N. Shiva M. Mayil Vaganan	25	20 December, 2021 to 20 January, 2022

Transgender trainees at ICAR-NRCB farm

School children getting trained on Post-Harvest technologies at ICAR-NRCB

Farmers' meet organised at the Centre on the occasion of Honourable Prime Minister's interactive session on 'Natural Farming'

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Training on "Pre-harvest Management of Nendran Banana for Export" organized by VFPCK, Kochi at Pudukkad, Thrissur, Kerala	V. Kumar R. Thangavelu	25	16 February, 2021
Training on "Pre-harvest Management of Nendran Banana for Export" organized by VFPCK Kochi at Chalakudy, Kerala		30	17 February, 2021
Training on Banana Plant Health Management	APEDA, Cudappah	50	25 June, 2021
Two Days Workshop cum Training on "Improved Agro-techniques on Banana Cultivation, Macro & Micro Propagation, PHM & Value Addition" in Nagicherra, Agartala, Tripura	V. Kumar	50	17-18 August, 2021
Banana cluster development	V. Kumar	80	27 December, 2021
Hands-on training on banana cultivation to SC beneficiaries held at Kumaramangalam, Karur District, Tamil Nadu	K.J. Jeyabaskaran M. Loganathan C. Karpagam	30	30 September, 2021
Hands-on training on banana cultivation to SC beneficiaries held at KVK, Namakkal District, Tamil Nadu	M. Loganathan C. Karpagam	35	7 October, 2021
Hands-on training on banana cultivation to SC beneficiaries, Keelapalur, Ariyalur District, Tamil Nadu	K.J. Jeyabaskaran M. Loganathan C. Karpagam	60	31 December, 2021
'Production, Value Addition and Trading of Banana'(online), organized by ICAR-CPCRI, Kasaragod, Kerala	K.N. Shiva	52	25 September, 2021

Scientists of ICAR - NRCB with farmers at the Capacity Development Program held at KVK, Namakkal District, Tamil Nadu

Scientists of ICAR - NRCB with farmers at the Capacity Development Programme cum Free Distribution of Farm Inputs held at Karur District, Tamil Nadu

7.1 Awards

ICAR-NRCB bags Sardar Patel Outstanding ICAR Institution Award - 2020

The ICAR-National Research Centre for Banana, Tiruchirappalli, bagged the prestigious Sardar Patel Outstanding ICAR Institution Award - 2020 in the category of small Institutes. The award was given by Shri. Narendra Singh Tomar, Hon'ble. Union Minister of Agriculture and Farmers welfare and President, ICAR, during the Foundation Day ceremony of ICAR held on 16 July, 2021 in virtual mode. The institute has brought a sea change in banana cultivation by introducing improved cultivars and by improved production, protection and post-harvest technologies. Shri. Km. Shobha Karandlaje and Shri. Kailash Choudhary, Honourable Union Ministers of State, Ministry of Agriculture and Farmers Welfare were also present in the ceremony. Shri. Trilochan Mohapatra, Director General, ICAR, DDGs, ADGs and Scientists of different ICAR institutes across the country also participated in the Foundation Day ceremony.

ICAR-NRCB – Recipient of Sardar Patel Outstanding ICAR Institution Award – 2020 (Small Institute)

Name	Award details
S. Uma	'Dr. (Mrs.) Prem Dureja Endowment Award – Biennium 2019-2020' for her outstanding contribution towards overall development of Agriculture at XV Agricultural Science Congress on 'Energy and Agriculture: Challenges in 21st Century' Organized by NAAS & BHU, Varanasi during November 13-16, 2021
R. Thangavelu	'Appreciation Award 2021' from Confederation of Horticultural association of India (CHAI) at the Conference on "Innovative Approaches for Enhancing Water Productivity in Agriculture" held at PJTSAU, Rajendranagar, Hyderabad on 16 September, 2021
	'VD GOOD International Scientists Award on Science-VISA 2021' from VD Good Technology Factory, Vishakhapatnam, on 5 December, 2021
P. Suresh Kumar D. Amelia Keran K.N. Shiva S. Uma	'Best Oral Presentation Award' for research paper titled "Rheological properties of banana starches and its function in development of convenient foods" at -National Conference on Texture & Rheology of Food Materials (TEXRHEO-2021) organized by IIFPT, Thanjavur during 18-19 February, 2021
K.N. Shiva D. Naveen P. Suresh Kumar K. Kamaraju R. Sivasankari S. Uma	'Best Poster Presentation Award for research paper titled "Standardization and evaluation of banana peel powder based cookies" at -National Conference on Texture & Rheology of Food Materials (TEXRHEO-2021) organized by IIFPT, Thanjavur during 18-19 February, 2021

M. Loganathan R. Thangavelu K. Muthubharathi R. Selvarajan S. Uma	'Best Oral Presentation Award' for research paper titled "Rhizome rot of banana in India: Current status and characterization of pathogen" at' Golden Jubilee International Conference on Global Perspectives in Crop Protection for Food Security (GPCP-2021)', organized by and held at TNAU, Coimbatore during 8-10 December, 2021
P. Giribabu C. Anuradha	'Agricultural Scientist Award – 2021' by Dr. B. Vasantharaj David Foundation at National Conference on "Recent Advances in Crop Protection including IPM and Environmental Sciences from GLP Perspective" held at Chennai on 17 October, 2021
P. Giribabu S. Backiyarani P. Durai V. Selvaraj S. Uma	'Best Oral Presentation Award' for research paper titled "Host plant response of diploid hybrids of banana (*Musa* sp.) to root-lesion nematode, *Pratylenchus coffeae*" at 'Golden Jubilee International Conference on Global Perspectives in Crop Protection for Food Security (GPCP-2021)', organized by and held at TNAU, Coimbatore during 8-10 December, 2021
A. Mohanasundaram	'Young Scientist Award' for his outstanding contribution in the field of lac insect bio-diversity, tritropic interaction and effect of climate change on lac cultivation at 'National Web-Symposium on Recent Advances in Beneficial Insects, Natural Resins and Gums' organized by SANRAG, ICAR-IINRG, Ranchi during 25-26 February, 2021
A. Mohanasundaram K.K. Sharma K. Thamilarsi Rashmi Mishra Munna Yadav Naaserah Zeeshan	'Best Oral Presentation Award' for research paper titled "Vegetative propagation of *Flemingia semialata* on root stock of *F. macrophylla* for *kusmi* lac cultivation under water logged condition" at National Web-Symposium on Recent Advances in Beneficial Insects, Natural Resins and Gums organized by SANRAG, ICAR-IINRG during 25-26 February 2021

Dr. S. Uma, Director, ICAR-NRCB – Recipient of 'Dr. (Mrs.) Prem Dureja Endowment Award – Biennium 2019-2020'

7.2 Recognitions

Dr. S. Uma, Director
Panelist- FICCI webinar session on 'Food Startups: Transforming Innovation in Indian Food Processing Industry' on 22 January, 2021(Online)
Valedictory address at International Web Conference on 'Food Technology and Nutrition Prospects for Health' organized Avinashilingam Home Science University, Coimbatore on 29 January, 2021 (Online)
Lead talk on 'Latest varieties of banana suitable for coconut based HDMSCS for East Coast' at Workshop on 'Coconut based High Density Multispecies Cropping System'organized by ICAR-CPCRI, Kasaragod on 29 January, 2021(Online)
Chief Guest - International Day of Women and Girls in Science at Bishop Heber College, Trichy on 11 February, 2021
Panelist at International Women's Day Celebration – 'Role of Women in Agricultural Sciences' organized by NAAS on 8 March, 2021(Online)
Panelist at International Women's Day Celebration –'Role of Women in Agriculture' organized by ICLltd., Gurgaon on 8 March, 2021(Online)
Chairperson - RAC meet of IIFPT, Thanjavur on 25 March, 2021(Online)
Invited talk on 'Banana Industry in India'at International Workshop on Banana organized by Antalya Agriculture Council, Turkey on 5 April, 2021 (Online)
Special Invitee - CII Tamil Nadu's Agri and Food Processing Panel - 1stvideo conference meet on 29 April, 2021 (Online)
Special Address delivered at National Summit on 'Women in Science and Technology' organized by Kerala University of Digital Science, Thiruvananthapuram on 11 May, 2021 (Online)
Presentation in the Scientific session of NAAS for newly elected Fellows on 15 June, 2021 (Online)
Chief Guest at 'APEDA training program on 'banana disease and calendar of operations at Banana clusters' on 25 June, 2021 (Online)
Guest of Honour at ODOP webinar on 'Banana Processing and Value Addition under PMFME', organized by IIFPT, Thanjavur on 1 July, 2021 (Online)
Chief Guest at Webinar Inaugural Program by Association of Plant Tissue Culture companies, Maharashtra on 7 July, 2021 (Online)
Invited speaker at 'Training session on Entrepreneurship Development in Food Processing' organized by FAPCCI on 17 July, 2021 (Online)
Invited lecture on 'Banana Production Technologies and Value Addition for Income Generation' in Zonal Workshop of ATARI, Bengaluru on 30 July, 2021 (Online)
Chief Guest at 'Workshop on Banana Value Addition and Khadya Vaividya' organized by KVK, Uttara Kannada, Sirsi on 11 August, 2021(Online)
Keynote address delivered at 'ODOP–Mysore Banana Webinar', organized by *Mysore Raithodyami Prathishtana* on 16 August, 2021(Online)
Invited speaker at 'Club Speakers Meeting', Rotary Club, Trichy on 7 September, 2021
Panelist at 'Malaysia National Banana Congress (MNBC20210) – Revitalizing the banana industry in Malaysia', organized by University of Malaysia, Kulalumpur on 8 September, 2021 (Online)
Guest of Honour at Kalpa Graduate Readiness Program, organized by ICAR-CPCRI, Kasaragod on 17 September, 2021(Online)

Panelist at brainstorming session on 'Strategy Workshop on Certification of QPM of Clonally Propagated Fruit Crops for Promoting Diversification' organized by NAAS on 20 September, 2021(Online)
Chief Guest at ABI Program, ICAR-CPCRI, Kasaragod on 25 September, 2021(Online)
As Member – CSIR-FTT/FTC Committee (ANB), attended review meeting on 30 September & 1 October, 2021(Online)
Panelist, Technical session on 'Stakeholders Connect – Banana', organized by CFTRI, Mysore on 21 October, 2021(Online)
Delivered invited lecture at Department of Botany, Bharathidasan University, Trichy on 25 October, 2021(Online)
Chairperson, Career Advancement Scheme meet, ICAR-CTRI, Thiruvananthapuram on 2 & 3 November, 2021
Chairperson, Technical Session – Open House in 'National Conference on Fruits and Vegetables for Health and Nutrition (FVHN-2021)' organized by KSTA, Bengaluru 8 November, 2021(Online)
Participated and delivered a Keynote Lecture in the XV Agriculture Science Congress held at BHU, Varanasi during 11-13 November, 2021
Chairperson, Career Advancement Scheme meet, ICAR-IISR, Calicut on 21 December, 2021(Online)
Dr. J. Poorani, Principal Scientist
Invited Lead speaker, Sixth National Conference on Biological Control: Innovative approaches for Green India. Organized by the Society for Biocontrol Advancement, Bangalore, 3-5 March, 2021(Online)
Invited Panelist, Brainstorming Session on 'Classical and Molecular Taxonomy - Standalone or Complementary' organized by ICAR-NBAIR, Bangalore, on 18November, 2021(Online)
Invited Lead speaker, Golden Jubilee International Conference – "Global Perspectives in Crop Protection for Food Security (GPCP 2021)" organized by TNAU, Coimbatore, 8-10 December, 2021(Online)
Invited Panelist, Brainstorming Session on "Invasive whitefly complex on plantation crops: The technical knowledge and the technological interventions for management" organized by ICAR-IIOPR, Pedavegi, on 17 July, 2021(Online)
Reviewer and external examiner for virtual *viva voce* of two Ph.D. students of KAU, Vellayani, on 28 July&23 December, 2021 (Online)
Subject Editor, *Zookeys* (International Journal)
Member, International Union for Conservation of Nature (IUCN) SSC (Coccinellidae)
Dr. R. Thangavelu, Principal Scientist
Recognized as member of Doctoral committee by SRMIST, Chennai
Nominated as member of board of studies, Department of Botany, Srimad Andavar Arts and Science College, Trichy for a period of 3 years from 1 August, 2021
Co-Chairman of one Ph.D. Scholar from UHS, Bagalkot, Karnataka
Reviewer for journals - *Journal of Plant Disease*, *Sugartech*, *Microbial Ecology*, *Frontiers in Agronomy*, *Scientific Reports (Nature)*, *BMC-Plant Biology*, *Plant Pathology*, *Journal of Plant Pathology* and *Indian Phytopathology*
Nominated by DG-ICAR as an expert (Plant Pathology)to ICAR-SBI, Coimbatore for Career Advancement Schemeof ARS Scientists for a period of one year from 7 August, 2021
Nominated by DG-ICAR as an expert (Plant Pathology)to ICAR-IISR, Calicut for Career Advancement Scheme of ARS Scientists for a period of one year

Dr. R. Selvarajan, Principal Scientist
Chairman, Technical Session on "Advances in Detection, Diagnosis and Characterization of Plant Pathogens and Microbes" at IPS-Central Zone Virtual Symposium – 2020 on "Advances in Phytopathology" by Dr.Y.S.R. Horticultural University, Venkataramannagudem, West Godavari, Andhra Pradesh during 6-7January, 2021
Chairperson for selecting Prof. M.J. Narasimhan Academic Merit Award Contest in the 'National e-Conference on Plant Health and Food Security: Challenges and Opportunities' at ICAR-IARI, New Delhi during 25-27March, 2021
Nominated by Indian Phytopathological Society as an expertto evaluate the K.C. Mehta and Manoranjan Mitra Award,Sharda Lele Memorial Award and J.F. Dastur Memorial Award
Convenor, National Symposium on "Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" jointly organized by ICAR-CPCRI and Indian Phytopathological Society (South Zone Chapter) during 1-3 December, 2021
Chairpersonfor selecting Prof. M.J. Narasimhan Academic Merit Award Contest in the National symposium on "Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" jointly organized by ICAR-CPCRI and Indian Phytopathological Society (South Zone Chapter) during 1-3 December 2021
Chairperson for selecting APS travel sponsorship for Ph.D. studentsin the National symposium on "Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" jointly organized by ICAR-CPCRI and Indian Phytopathological Society (South Zone Chapter) during 1-3 December, 2021
Nominated as Expert (Plant Pathology) in the Assessment Committee for CAS for ARS Scientists of ICAR-IISR, Calicut
Nominated as member of the National Network of Plant Health Management Experts, NIHPM, Hyderabad
Member Secretary, RAC, conducted 22ndRAC meet of ICAR-NRCB on 23-24 July, 2021(Online)
Convener - 28thFoundation Day celebration on 21August, 2021(Online)
Convener - Webinar on "Banana Value Chain and Marketing - New Business Horizons" organized by ICAR-NRCB on 21 August, 2021
Convener –Webinar on 'Balanced use of fertilizer in banana cultivation' organized by ICAR-NRCB on 18 June, 2021
Convener - National webinar on 'Sustainable integrated cropping and farming system models with special reference to banana for enhanced income for farmers' organized by ICAR-NRCB on 7 July, 2021
Resource Person - UGC-sponsored online refresher course in Life Sciences (Interdisciplinary), organized by UGC-HRDC, Bharathidasan University and Madurai Kamaraj University
Doctoral committee member, School of Bio Sciences and Technology, Vellore Institute of Technology (VIT), Vellore and Kerala Agricultural University
External examiner and conducted public *viva-voce* for Ph.D. scholars of Department of Plant Pathology, AC&RI, TNAU, Coimbatore
Presented keynote lecture on "Recent developments in plant disease diagnostics using laboratory and artificial intelligence dependent IoT methods" in the Session 5: Genetic variability and diagnostics in National e-Conference on "Plant Health and Food Security: Challenges and Opportunities" at ICAR-IARI, New Delhi during March 25-27, 2021

Presented invited Lecture on 'Onsite real time detection of plant viruses' under a technical session 'Advances in plant disease diagnostics' in National symposium on "Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" jointly organized by ICAR-CPCRI and Indian Phytopathological Society (South Zone Chapter) during 1-3 December, 2021
Presented lead talk on 'Lateral Flow Assays: Application in On Farm Diagnostics of Diseases in Ornamental Crops' in the National webinar 'On farm diagnostics of diseases in ornamental crops' organized by ICAR- DFR, Pune during 30 November, 2021
Delivered a lecture on 'Applied Plant Virology: Diagnosis, Management and Certification of Virus Free Plants' organised by VIT School of Agricultural Innovations and Advanced Learning (VAIAL), VIT, Vellore during 21 May, 2021
Delivered a lecture on "Disease of Banana &Management" in the NAHEP-CAAST training titled "Identification & Management of Insects, Pests & Plant Pathogen Infecting Nutritional Crops", organized by ICAR-IARI and CSAUA&T, Kanpur, U.P. during 20 December, 2021
Presented lead paper on "Gene editing using CRISPR/Cas9 in bananas for viral diseases: Present status and prospects" under the theme of Innovative Breeding strategies International Horticulture Conference "Next generation Horticulture" organized by the TNAU in association with The Society for Promotion of Horticultural Science & Technology during 16-19 September, 2021 held at TNAU, Coimbatore
Delivered invited lecture on "Artificial intelligence for the real time plant disease detection and management" in the IPS Platinum Jubilee Lecture Series organized by Indian Phytopathological Society (IPS), New Delhi during 25November, 2021
Presented invited lead talk on "Novel methods of plant virus detection and their use in certification of quality planting materials" at International Conference on Global Perspectives in Crop Protection for Food Security (GPCP 2021) during 8-10 December, 2021
Dr. I Ravi, Principal Scientist
Nominated by DG-ICAR as an expert (Plant Physiology)to ICAR-IISR, Calicut for Career Advancement Scheme of ARS Scientists for a period of one year
Reviewer for journals - Acta Physiologiae Plantarum, Plant Physiology reports –Springer International, Indian Journal of Agricultural Research , ARCC journals
External expert for Ph.D. thesis of Department of Crop Physiology TNAU, Coimbatore
External expert to recruit a Subject Matter Specialist (Animal Science) Krishi Vigyan Kendra, Saraswathi Foundation for Rural Development and Training, Pulutheri Village,Karur District, Tamil Nadu
Dr. V. Kumar, Principal Scientist
Panelist, National Horticulture Fair – 2021(Zone 10), organized by ICAR-IIHR, Bangalore on 12 February, 2021
Convenor, Webinar on "World Water Day" held at ICAR-NRCB on 22 March, 2021
Consultant – VFPCK, Kerala for the consultancy project on "Development of sea protocol for export of 'Nendran' banana to Europe (U.K.)"
Dr. K. J. Jeyabaskaran, Principal Scientist
Nominated as external evaluator of Ph.D. scholar of TNAU, Coimbatore
Recognised as external examiner for Ph.D. qualification examination, TNAU, Coimbatore
Dr. K.N. Shiva, Principal Scientist
Consultant – VFPCK, Kerala for the consultancy project on "Development of sea protocol for export of 'Nendran' banana to Europe (U.K.)"

External examiner -Evaluated one thesis and conducted final *viva-voce* of one Ph.D. scholar of UHS, Bagalkot on 2August, 2021
Appointed as President, Agricultural Research Service Scientists' Forum, Trichy Unit for a tenure of three years from July, 2021
Co-Chairman, Technical session of webinar on 'Banana Value Chain and Marketing – New Business Horizons", held at ICAR-NRCB on 21August, 2021 (Online)
Member, Organizing committee of Hackathon, 28th Foundation Day of ICAR-NRCB on 21August, 2021
Appreciation memento/letter received from North Malabar Chamber of Commerce and Natural Malabar Fruits Farmers' Producer Company (NMFPC) at the Chamber Hall, Kannur, Kerala for delivering Processing of Banana for Business Development (including ABI), which is evidenced/illustrated by memento/letter for significant presentation in Malayalam
Certificate of Appreciation issued by CEO, Vegetable and Fruit Promotion Council of Kerlam (VFPCK), Government of Kerala on 1st December 2021 in recognition to the services and valuable contribution in providing Technical Consultancy during 2020-21 for successfully developing a Seashipment protocol for export of Nendran banana from Kerala to Europe at APEDA Certified Pack House in Nadukkara, Kerala during September 2020–March/April 2021
Lead Presenter of Post Harvest Technology Projects in the 22nd RAC Meeting held on 23 July, 2021 at ICAR – NRCB
Dr. S. Backiyarani, Principal Scientist
Member of board of studies, Department of Bioinformatics, Bishop Heber College
Dr. M.S. Saraswathi, Principal Scientist
Reviewer - *Journal of Applied and Natural Science*, *Indian Journal of Biotechnology*, *Current Plant Biology*, *Asian Journal of Agricultural and Horticultural Research*, *Plant Cell Biotechnologyand Molecular Biology*
Reviewer of Project titled '*In vitro* mutagenesis of *Stevia* for enhanced production of steviol glycosides' submitted to BRNS, Mumbai
Selection committee member for recruitment of Young Professional I, Post-Doctoral Fellow, Junior Project Assistant, Senior Project Assistant, Junior Research Fellow, Research Associate, *etc*.
Dr. M. Loganathan, Principal Scientist
External member, Committee for scrutinizing applications for Promotion of teaching faculties (CAS) at IIFPT, Thanjavur, Tamil Nadu held on 30 July, 2020
ICAR-NRCB nominee for selection of SMSs in KVK, Perambalur, Tamil Nadu on 18 February, 2021
Co-Chairperson for the session 'Host plant resistance and management strategies for diseases / nematodes' in 'Golden Jubilee International Conference on Global Perspectives in Crop Protection for Food Security (GPCP-2021)', organized by TNAU, Coimbatore during 8-10 December, 2021
Dr. D. Ramajayam, Principal Scientist
'Certificate of Appreciation' as guest speaker in online webinar - 'Production of androgenic haploids and doubled haploids in banana' held on 16 January, 2021 organized by Bioingene.com International webinar series for the promotion of plant science research
'Certificate of Appreciation' as speaker in the online webinar - 'Banana based entrepreneurship opportunities' held on 7 May, 2021 by Kovise Ecoversity, Chennai.

Delivered lecture on 'Detection of aneuploids, haploids and tetraploids in banana and oil palm' in online webinar - 'Industrial application of Flow cytomentry for the determination of ploidy level, genome size and pollen viability in plants' organized by Sysmex India Pvt. Ltd. on 23 July, 2021
Delivered an invited talk on 'Microspore-embryogenesis: A novel way to create variability in sterile commercial banana cultivars and use them in ABBB' in webinar – 'ABBB project seminar series' by IITA on 26 August, 2021
'Certificate of Appreciation' for delivering lectures on 'Technologies for the production of horticulture crops in natural disaster-prone area and Technologies for cultivation of banana in the in natural disaster-prone areas' on 30 November, 2021 in AICTE-sponsored one week Short term training program on 'Disaster Risk Management' Phase-I, organized by University College of Engineering, Anna University, BIT Campus, Trichy
Dr. P. Suresh Kumar, Principal Scientist
'Certificate of Appreciation' from the magazine '*Food and Beverage processing*' for contributing maximum number of articles for the year 2021
'Certificate of Appreciation' for acting as resource person and contributed to the course content on the topic "Banana processing and waste utilization for value addition" in the online certificate course on "Smart Farming Technologies and Secondary Agriculture Key to Making Indian Agriculture Remunerative" held at NAU, Navsari under NAHEP-CAAST sub-project during 8 January – 7 April, 2021
'Appreciation Award- 2021' by VFPCK, Kerala for successful export of Nendran banana to London
Editor - *Pharmacology*, *Toxicology and Pharmaceutics*, *Journal of Agrometeorology*, *Bhartiya Krishi AnusandhanPatrika*
Reviewer - *Indian farming*, *Scientia Horticulturae*, *Journal of Agrometeorology*, *Agricultural Water Management*, *NFS journal*, *Journal of Environmental Biology*, *Journal of Natural Fibers*, *International Journal of Food Science and Technology*, *Indian Journal of Horticulture*, *Chemosphere, Italian Journal of Food Science,Journal of Horticulture Science, Biomass Conversion and Biorefinery, Journal of Applied and Natural Science*, *Proceedings of the National Academy of Sciences*, *Biological Sciences (NASB)*
Delivered keynote lecture (online) on 'Creation of robust circular economy; Utilization of banana pseudostem as textile fibre and innovative products' at '4th European Industry and Research Exchange on Bio-based Fibres and Recycling Materials for Technical Textile Processes and Applications' during 11-12 March, 2021
Management representative - ISO 9001: 2015 certification
Consultant - Development of Sea Protocol for the Trial Shipment for Export of Traditional Variety 'Nendran' banana from Kochi Seaport to London
Associate Editor - Annual Report, ICAR-AICRP(Fruits) – 2020
Convenor for one session and rapporteur for two sessions during 8th Annual Group Discussion of ICAR-AICRP (Fruits)held online during 3-6 March, 2021
Convenor–Online webinar on 'Banana Value Chain &Marketing- New Business Horizons' organized by ICAR-NRCB on 21August, 2021
Nodal Officer–ITMU and Co-Nodal Officer – ICAR-AICRP Fruits (Banana)
Technical Consultant – A.P. food processing society, Andhra Pradesh. Establishment of banana food park

Dr. P. Giribabu, Senior Scientist
Councillor (South Zone), Executive Council, Nematological Society of India, Division of Nematology, ICAR-IARI, New Delhi (2021-23)
Evaluator / Jury to evaluate the posters in Technical Session III at Golden Jubilee International Conference on "Global Perspectives in Crop Protection for Food Security" organized by and at TNAU, Coimbatore during 8 – 10 December, 2021
Rapporteur - Session IV at National Seminar on "The Facets of Innovation and Development of Plant Nematology" organized by Nematological Society of India, New Delhi and held online during 29 – 30 October, 2021
Secretary, Agricultural Research Service Scientists' Forum (ARSSF), New Delhi
Dr. C. Anuradha, Senior Scientist
External expert for selection of Research Associate and Project Fellows in RUSA 2.0 (Biological sciences) for Department of Environmental Biotechnology, Bharathidasan University, Tiruchirappalli on 25 March & 15 September, 2021
Invited talk on "New Strategies of Molecular Breeding in Crop Improvement" at National webinar organised by PG and Research Department of Botany, J.J. College of Arts and Science (Autonomous) on 7 July, 2021
Reviewer- *Journal of Plant Pathology*, *3Biotech*
Dr. A. Mohanasundaram, Scientist
Managing Editor - SANRAG e-Newsletters July, 2020 and January, 2021
Editor - *Agriculture and Food* (e-newsletter)
Rapporteur for two themes at 'National Web-Symposium on Recent Advances in Beneficial Insects, Natural Resins and Gums' organized by SANRAG, ICAR-IINRG during 25-26 February, 2021 (Online)
Delivered invited talk (online) on "Lac cultivation and Entrepreneurship" to students and other faculties of School of Agriculture and Biosciences, Karunya Institute of Technology & Sciences, Coimbatore on 17 February, 2021
Delivered guest lecture (online) on "Cultivation of lac and industries based on lac, forward and backward linkages in marketing of Shellac" to students and other faculties of Department of Entomology, Punjab Agricultural University, Ludhiana, Punjab on 19March, 2021
Delivered lead talk in "Global Perspectives in Crop Protection for Food Security (GPCP-2021)" International conference held during December 8-10, 2021 at TNAU, Coimbatore
Rapporteur in a technical session in "Global Perspectives in Crop Protection for Food Security (GPCP-2021)" International conference held during December 8-10, 2021 at TNAU, Coimbatore
Convener - On farm training cum field day on '*Calliandra calothyrsus* - A good host in Lac Integrated Agro-forestry system' to farmers at Mungadhi, Angara block, Ranchi District, Jharkhand on 20 January, 2021 under ICRAF project
Co-convener - Online HRD Program entitled "ICT driven Interventions in Marketing of Natural Resins and Gums (NRGs)" on 10 March, 2021

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
Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	DAE, Mumbai, Maharastra
Framing crop specific DUS guidelines for banana (*Musa* spp.)	PPV & FRA, New Delhi
Utilization of banana fibre, central core stem, sap, etc. for value addition	National Design & Research Forum, Bangalore; Indian Institute of Information Technology –Design & Manufacturing, Kancheepuram; Gencrest Bioproducts pvt. Ltd., Mumbai
Development of protocol for sea shipment of Nendran banana to European Union	VFPCK, Kerala
Development of protocol for sea shipment of banana to gulf countries	APEDA
Technology demonstration and training to banana farmers	NABARD
Collaborative research	ICAR-IARI, New Delhi; Regional Plant Resource Centre, Bhubaneswar
Research collaboration and student research	ICAR-CPCRI, Kasaragod; Bishop Heber College (Autonomous), Tiruchirappalli; Department of Biotechnology & Microbiology, National College, Tiruchirappalli; Srimad Andavan Arts & Science College, Srirangam
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
Training programme on 'Macropropagation technology'	ICICI foundation, Tiruchirappalli zone SEED Division – DST, New Delhi

Projects sanctioned under DBT-NER banana programme for North Eastern States

Project Title	Collaborating Institute(s)
Consortium for managing Indian banana gentic resources	Mizoram University, Aizwal, Mizoram Assam Agricultural University, Jorhat, Assam Indian Institute of Technology, Guwahati, Assam Tamil Nadu Agricultural University, Coimbatore ICAR-Indian Institute of Horticulture Research, Bengaluru Institute of Advanced Study in Science and Technology (IASST), Guwahati, Assam ICAR Research Complex for NEH region, Umiam, Meghalaya N.V.Patel Collge of Pure and Applied Science, Gujarat Utkal University, Bhuaneshwar, Odisha Tripura University, Suryamaninagar, Tripura National Botanical Research Institute, Lucknow Jawaharlal Nehru Tropical Botanic Garden & Research Institute, Thiruvananthapuram Kohima Science College, Jotsoma, Nagaland Nagaland University, Medziphema, Nagaland Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal Patkai Christian College, Dimapur, Nagaland
Collection, evaluation, documentation and conservation of banana genetic resources from NE region	
Diversity assessment, germplasm conservation and database development on banana resources in NE India	
Whole genome and transcriptome study to stress tolerant banana cultivars	
Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system	
Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	
Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	
Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	
Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	
In vitro mass propagation of high value hill area banana	
Characterization of high value phyto-chemicals of anti-diabetic and immune-modulatory properties in NE banana varieties	

Development of pre & post harvest bunch care management methods for fresh banana	North Eastern Regional Instt. Of Science and Technology, Nirjuli, Arunachal Pradesh Nagaland University, Lumami, Nagaland Gauhati University, Guwahati, Assam TERI School of Advanced Studies, New Delhi The Energy and Resource Institute, New Delhi ICAR – National Bureau of Plant Genetic Resources, New Delhi PSG College of Technology, Coimbatore College of Agriculture, Lembucherra, Tripura Regional Plant Resource Centre, Bhubaneswar, Odisha ICAR- Research Complex for NEH Regional, Nagaland Centre – Dimapur, Nagaland Jawaharlal Nehru University, New Delhi West Bengal State University, Kolkatta ICAR Research Complex for NEH Regional, Manipur Centre, Imphal, Manipur Sikkim University, Gangtok, Sikkim Guru Nanak Dev University, Amritsar, Punjab North East Hill University, Tura Campus, Meghalaya Translational Health Science and Technology Institute, Faridabad Assam down Town University, Guwahati, Assam Institute of Life Science, Bhubaneswar, Odisha Indian Institute of Technology, Kharagpur Tezpur University, Naapam, Assam College of Veterinary Science, Khanapara, Guwahati National Bureau of Plant Genetic Resources – Regional Station, Shillong National Bureau of Plant Genetic Resources – Regional Station - Hyderabad
Genetic resource assessment, *in situ* conservation and impact of banana waste as a feed for animals in NE region of India	
Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	
Management of low temperature and soil moisture deficit stresses in banana growth in NE India	
Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	

9.1 Research Papers

9.1.1 International

Backiyarani, S., Sasikala, R., Sharmiladevi, S. and Uma, S. 2021. Decoding the molecular mechanism of parthenocarpy in *Musa* spp. through protein–protein interaction network. *Scientific Reports.***11**(1), 14592. https://doi.org/10.1038/s41598-021-93661-3

Backiyarani, S., Uma, S., Saranya, S., Durai, P., Eugin, P.S., Selvaraj, V., Saraswathi, M.S., Karthic, R. and Kalpana, S. 2021. Multiple shoot induction in zygotic embryos: A strategy for acceleration of banana breeding. *Plant Cell, Tissue and Organ Culture.* **147**(2), 339–350. https://doi.org/10.1007/s11240-021-02127-x

Jeyabaskaran, K.J., Pitchaimuthu, R., Kumar, V. and Uma, S. 2021. Nutrient uptake and accumulation patterns in banana cv. Rasthali (AAB) with respect to dry matter production at critical growth stages. *Communications in Soil Science and Plant Analysis, DOI : 10.1080/00103624.2024.1956519*

Jeyabaskaran, K.J., Kumar, V. and Uma, S. 2019. Development and validation of soil-test-based fertiliser tailoring equations for banana cv. Grand Naine (AAA). *International Journal of Innovative Horticulture.***8**(2): 135-142.

Kavitha, N., Saraswathi, M.S., Kannan, G., Bathrinath, M., Backiyarani, S. and Uma, S. 2021. Development of direct regeneration protocol for mass multiplication of *Musa* spp. variety Udhayam (Pisang Awak, ABB) using different explants. *Scientia Horticulturae.***290:** 110506. https://doi.org/10.1016/j.scienta.2021.110506

Loganathan, M., Thangavelu, R., Pushpakanth, P., Muthubharathi, K., Ramesh, R., Selvarajan, R. and Uma, S. 2021. First report of rhizome rot of banana caused by *Klebsiella variicola* in India. *Plant Disease.* https://doi.org/10.1094/PDIS-10-20-2316-PDN

Panneerselvam, K., Pothiraj, R., Backiyarani, S., Saraswathi, M.S. and Uma, S. 2022. Phylogenomics classification and synteny network analyses deciphered the evolutionary landscape of an aldo-keto reductase (AKR) gene superfamily in the plant kingdom. *Gene.***816**: 146169. doi: 10.1016/j.gene.2021.146169

Poorani, J., Anuradha, C., Kalleshwaraswamy, C.M. and Thanigairaj, R. 2021. *Manatha albipes* Moore (Lepidoptera: Psychidae), an emerging pest of banana and arecanut in South India, with notes on diagnosis, biology, natural enemies and DNA sequence data. *Phytoparasitica,* 50: 101–115.https://doi.org/10.1007/s12600-021-00942-8

Pothiraj, R., Ravikumar, M.J., Backiyarani, S., Subbaraya, U. and Krishnamurthy, P. 2021. Genome-scale analyses of polyketide synthases in banana: Phylogenetics and expression profiling forecast their candidacy in specialized metabolism. *Gene.***778**: 145472.https://doi.org/10.1016/j.gene.2021.145472

Ramajayam, D., Jeyabaskaran, K.J., Saraswathi, M.S., Sivasankari, R., Pitchaimuthu, R. Kalpana, S. and Uma, S. 2021. Genetic diversity in fresh fruit pulp mineral profile of 100 Indian *Musa* accessions. *Food Chemistry.* 361. doi.org/10.1016/j.foodchem.2021.130080

Suresh Kumar, P., Saravanan, A., Sheeba, N., Shiva, K.N., Ravi, I., Mayil Vaganan, M., Pushpa, R. and Uma, S. 2021. Exploring

differences in the physicochemical, functional, structural, and pasting properties of banana starches from dessert, cooking, and plantain cultivars (*Musa* spp.). *International Journal of Biological Macromolecules*.**191**: 1056-1067. https://doi.org/10.1016/j.ijbiomac.2021.09.172.

Suresh Kumar, P., Amelia, K.D., Saraswathi, M.S., Backiyarani, S., Shiva, K.N. and Uma, S. 2021. Influence of food hydrocolloids on the structural, textural, and chemical characteristics of low-fat banana chips. *Food Science and Technology International*. https://doi.org/10.1177/10820132211003708.

Thangavelu, R., Edwin Raj, E., Muthukathan, G., Loganathan, M., Periyasamy, P., Natesh, M., Manivasakan, P., Kotteeswaran, S., Rajendran, S. and Uma, S. 2021. Comparative whole-genome sequence analyses of Fusarium wilt pathogen (Foc R1, STR4 and TR4) infecting Cavendish (AAA) bananas in India, with a special emphasis on pathogenicity mechanisms. *Journal of Fungi.* **7**(9): 717.

Thangavelu, R., Saraswathi, M.S., Uma, S., Loganathan, M., Backiyarani, S., Durai, P., EdwinRaj, E., Marimuthu, N., Kannan, G. and Swennen, R. 2021. Identification of sources resistant to a virulent Fusarium wilt strain (VCG 0124) infecting Cavendish bananas. *Scientific Reports*. **11**(1), 3183. https://doi.org/10.1038/s41598-021-82666-7

Thangavelu, R., Edwin Raj, E., Pushpakanth, P., Gopi, M., Loganathan, M. and Uma, S. 2021. Draft genome resource of a novel virulent *Fusarium oxysporum* f. sp. *cubense* Race 1 (VCG 0124) strain infecting Cavendish (AAA) group of bananas in India. *Plant Disease.* https://doi.org/10.1094/PDIS-12-20-2737-A

Uma, S., Karthic, R., Kalpana, S., Backiyarani, S. and Saraswathi, M.S. 2021. A novel temporary immersion bioreactor system for large scale multiplication of banana (Rasthali AAB—Silk). *Scientific Reports.* **11**(1): 20371. https://doi.org/10.1038/s41598-021-99923-4

Uma, S., Vel, K., Backiyarani, S., Saraswathi, M.S., Durai, P. and Raju, K. 2021. Somatic embryogenesis as a tool for reproduction of genetically stable plants in banana and confirmatory field trials. *Plant Cell, Tissue and Organ Culture*. **147**. https://doi.org/10.1007/s11240-021-02108-0

Velavan, V., Padmanaban, B., Loganathan, M., Baskar, N.S. and Uma, S. 2021. Entomopathogenic fungi as a promising biological control agent against banana fruit scarring beetle, *Basilepta subcostata* (Jac.) (Chrysomelidae: Coleoptera). *Egyptian Journal of Biological Pest Control*. https://doi.org/10.1186/s41938-021-00382

9.1.2 National

Anuradha, C., Selvarajan, R., Jebasingh, T. and SankaraNaynar, P. 2021. Evidence of viral genome linked protein of banana bract mosaic virus interaction with translational eukaryotic initiation factor 4E of plantain cv. Nendran based on yeast two-hybrid system study. *Virus disease*. **32**(1):123-130.

Anuradha, C. and Selvarajan, R. 2021. Biochemical alterations in banana cultivars infected systemically by banana bract mosaic virus (BBrMV). *Journal of Pharmacognosy and Phytochemistry.* **10**(1): 2619-2627.

Giribabu, P., Anuradha, C., Anitha Sree, T. and Padmanaban, B. 2020. Isolation,

identification, bioassay of native entomopathogenic nematodes, *Steinernemasiamkayai* Stock, Somsook & Reid, 1998 (Rhabditida: Steinernematidae) and *Heterorhabditis indica* Poinar, Karunakar and David, 1992 (Rhabditida: Heterorhabditidae) and their bio-efficacy against banana stem weevil, *Odoiporus longicollis* (Olivier) (Coleoptera:Curculionidae). *Indian Journal of Nematology*. **50**(2): 117-125.

Jeyabaskaran, K.J., Shirgure, P.S., Vikramaditya Pandey, Srivastava, A.K. and Uma, S. 2021. Fertigation in Horticulture: A Guarantee to Economized Quality Production. *Indian Journal of Fertilisers*, **17**(4): 364-383.

9.2 Popular articles

Amelia Keran, D., Suresh Kumar, P., Shiva, K.N. and Uma, S. 2021. Innovative start-up opportunities with banana based processed products. *Food marketing & Technology* (December 2021). 31-33.

Amelia, K.D., Suresh Kumar, P., Shiva, K.N. and Uma, S. 2021. Innovative start-up opportunities with banana based processed products. *Food Marketing & Technology*. December 2021. **12**(12): 31-33.

Amelia, K.D., Suresh Kumar, P., Shiva, K.N. and Uma, S. 2021. Innovative food products from banana and its by-products. *Food & Beverages Processing*. June 2021. **7**(12): 42-44.

Arjun Singh, Agarwal, D.K., Suresh Kumar, P., Shiva, K.N. and Uma, S. 2021. Value Added Products of Banana (Hindi). *Krishi Gyan Ganga.*

Arjun Singh, Jeyabaskaran, K.J., Pitchaimuthu, R., Kumar, V., Agarwal, D.K. and Uma, S. 2021. Micronutrients in Banana: Significance, Deficiency Identification and Management (Hindi). *Phal Phool*.

Agarwal, D.K., Arjun Singh, Suresh Kumar, P., Amelia Keran, D. and Uma, S. 2021. Banana - One Dish Many Fruits and Flowers (Hindi). *Phal Phool*.

Mayil Vaganan, M., Arjun Singh, Ravi, I., Agarwal, D.K. and Uma, S. 2021. Banana: A Nutritious- Medicinal Fruit (Hindi). *Phal Phool*.

Monica Oswal, Divya, P. and Suresh Kumar, P. 2021. Resistant starch: A boon for healthy foods. *Food marketing & Technology*. June 2021. **12**(6): 18-21.

Pushpavalli, S., Amelia, K.D. and Suresh Kumar, P. 2021. Healing renal stones through herbal drugs. *Nuffoods Spectrum*. **8**(7): 41-43.

Pushpavalli, S., Amelia, K.D., Suresh Kumar, P. and Uma, S. 2021. Banana starch and its modification-Boon for low glycemic foods and pharmaceutical industry. *Food and Beverages Processing*. March 2021. 7(9): 42-44.

Saroj Choudhary and Arjun Singh. 2021. Effective use of water and fertilizers through fertigation (Hindi), *Farming*. P. 23.

Selvarajan, R. 2021. Gene editing using CRISPR/Cas9 in bananas for viral diseases: Present status and prospects. In: Compendium of lead and research paper of 'International Horticulture Conference - Next Generation Horticulture' at Horticultural college, TNAU, Coimbatore on 16-19 September 2021, P.12-23. (ISBN:9789384909383)

Selvarajan, R. 2021. Novel methods of plant virus detection and their use in certification of quality planting materials. In: Global Perspectives in Crop Protection for Food Security

(GPCP). Compendium of invited paper. TNAU Golden Jubilee International Conference, December 8-10, 2021. P. 226-234. (ISBN:9789384903718)

Shiva, K.N., Arjun Singh, Dinesh Kumar Agarwal, Suresh Kumar, P. and Uma, S. 2021. Vegetable Banana Based Value Added Products (Hindi). *Unnath Krishi*.

Sivananth, C., Suresh Kumar, P. and Amelia Keran, D. 2021. New found interest in the application of pulsed electric field in food processing: A game changer. *Food and Beverage Processing*. July 2021. 16-17.

9.3 Books / Book chapters

Backiyarani, S., Suresh Kumar, P., Kalpana, S., Mayil Vaganan, M., Jeyabaskaran, P. and Uma, S. 2021. Biofortification of Banana - Methods and Prospects. In: Peter, K.V. (Ed.). *Innovative Techniques for Horticulture Developments*. Brillion Publishing, New Delhi. P. 55-78.

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9.6.1 International

Presentations at International Horticulture Conference - Next Generation Horticulture (NEXTGEN-HORT). Organized by TNAU and The Society for Promotion of Horticultural Science & Technology, held at TNAU, Coimbatore during 16-19 September, 2021

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neural network. P. 199.

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9.6.3 Compilation / documentation / IT based database, software, *etc.*

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9.6.4 Hindi Podcasts (Released on NRCB Foundation Day)

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Arjun Singh, Agarwal, D.K., Jeyabaskaran, K.J., Kumar, V., Ravi, I., Pichaimuthu, R. and Uma, S. 2021. Fertigation and Use of Banana Shakthi in Banana Cultivation (*Kelemein fertigation tatha banana shakti*). ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu.

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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	19 July, 2021	Field evaluation of AgroSpred 200 spray oil along with or without fungicides for the management of leaf spot disease of banana	M/s. Momentive Performance Materials India Pvt., Ltd, B3, SIPCOT Industrial Growth Center, Vaipur Village, Oragadam, Sriperumbadur (TK), Kancheepuram (Dt)-602105.	16.54
2	20 July, 2021	Field evaluation of Paraffinic mineral oil (MAK ADJUVOL) along with or without fungicides for the management of leaf spot disease of banana.	Bharat Petroleum Corporation Limited, 4 & 6 Currimbhoy Road, Ballard Estate, Mumbai - 400 001	16.54
3	21 September, 2021	Field evaluation of Petroleum based mineral oil GOAGBS1A0321 along with or without fungicides for the management of leaf spot disease of banana.	Gulf Oil Lubricants India Limited, IN Centre, 49/50, 12th Road, MIDC, Andheri (East), Mumbai - 400 093	16.54
4	September 2020 to April 2021	"Development of sea protocol for export of 'Nendran' banana to Europe (U.K.) "	Vegetable and Fruit Promotion Council of Keralam (VFPCK), Trivandrum, Kerala	9.91
5	2021	Virus Indexing of tissue culture mother plants		27.82
6	2021	Sale of virus detection kit		0.91
II	**Commercialisation of Technologies**			
1	6 January, 2021	Banana Flower Pickle	Mrs. K. Rajamani, # 17, Sakthi Illam, Meenakshi Nagar, Telungupalayam Post, Coimbatore (Dt) - 641 039	
2	17 January, 2021	Banana Flour	Mr. R.Krishna Mathan 27-47 Chekkala Street, Eraniel, Neyyoor post Kanyakumari (Dt) - 629802	0.15
3	17 January, 2021	Banana Flour	Mr. M. Naresh Kumar 9/168-1-N, Sri Ram Nagar RLY- Kodur Kadapa (Dt) - 516101 Andhra Pradesh	0.15

4	17 January, 2021	Banana Flour	Mr. A.K. Soundararajan 9/65, Velankattu Thottam Anjanur Post Nambiyur Taluk Erode (Dt) - 638 462	0.15
5	15 -17 July, 2021	1. Low glycemic prebiotic extruded snacks like noodles, pasta 2. Banana Flour based weaning food 3. Extraction of banana starch & starch modification 4. Cost effective ripe banana powder 5. Low fat fortified and flavored chips	Mr. Naveen Kumar H.M, M/S. Abhay Natural Food Processing Unit, No.110/1, Rathanapuri village, Aspatrekavel Gram Panchayath, Hunsur, Mysuru, Karnataka - 571189	1.17
6	20 July, 2021	Extraction of cellulose and other utility compounds like pectin and hemicellulose	Mrs. Achamma Thomas, M/S. Trophic Biosystems Pvt Ltd, Kochi, Ernakulam, Kerala - 682028.	0.25
7	5-6 August, 2021	1. Banana Flour 2. Banana flour based weaning / baby food	Mr. Walter Fernando M/S. Winwal International, Banana circles, Dohnavur, Tirunelveli (Dt) - 627102	0.31
8	18 October, 2021	Post harvest handling, packing, storage and ripening of banana for domestic and export markets	Mr. Rajavel Vinayak, M/s Raenco Utilities, 14, Pudhu Thottam, 2nd Sheriff Colony, Tirupur (dt) - 641604	0.25
9	28 October, 2021	Banana Flour Based Extruded Products	Mr. S.P. Sethu Subbiah, M/s Cake Bee Deli Fresh Private Limited, 25/B, 2nd Main Road, Kalyanasundaram Nagar, Karumandapam, Trichy (Dt) - 620001	0.15
10	26 November, 2021	1. Low glycemic prebiotic extruded snacks like noodles, pasta. 2. Low fat fortified and flavored chips	Mr. Mathew P. Kuruvilla, M/S Poabs Agro Industries, Palliambil, Anappara PO, Thuravoor, Ernakulam , Kerala - 683 581	0.53
11		Macro-propagation Technology	Shri Jayeshbhai Nathubhai Patel, JARVI Nursery	0.05

Signing of MoUs / MoCs / MoAs during 2021

Name of the Organization / Company	Purpose	Date
UNIVERSITES / INSTITUTES / COLLEGES		
ICAR - Central Plantation Crops Research Institute, Kasargod, Kerala	Research collaboration and student research	21 January
ICAR- Indian Agricultural research Institute, New Delhi	Collaborative research	27 January
Bishop Heber College (Autonomous), Tiruchirappalli	Research collaboration and student research	4 February
Department of Biotechnology & Microbiology, National College, Tiruchirappalli	Research collaboration and student research	26 April
University of Horticultural Sciences, Bagalkot, Karnataka	Students' training and research	17 June
Regional Plant Resource Center, Bhubaneswar, Odisha	Research collaboration	7 July
Srimad Andavan Arts & Science College, Tiruchirappalli	Research collaboration and student research	8 July
Sastra Deemed University, Thanjavur	Joint exchange of knowledge and research infrastructure	16 November
COMPANIES		
National Design and Research Forum, Bengaluru, India and Indian Institute of Information Technology Design and Manufacturing (IIITDM), Kancheepuram.	Collaborative Research	15 February
Gencrest Bio Products Pvt. Ltd, Mumbai.	Research Collaboration	18 March
Hi-Fi Biotech India Pvt. Ltd., Salem	Mass multiplication of ICAR - NRCB Banana varieties	26 April
Cake bee (Bakery and confectionary chain)	Technology for making banana flour and powder	29 October
OTHERS		
Tripartite agreement signed between ICAR - NRCB, IIFPT and State Agricultural Marketing Department for PMFME Scheme.	PMFME Scheme	15 July
MoA between ICAR-NRCB and NABARD signed for the scheme entitled "Design development and validation of online banana trading platform for farmers of FPOs in Trichy District"	Research Project	19 July
MoU for transfer of technology on "Macropropagation technique of banana" was signed between, ICAR-NRCB as Technology Inventor and ICAR-AICRP (Fruits), ICAR-IIHR, Bengaluru as Technology Facilitator, Fruit Research Station, NAU, Gandevi as Technology Provider	ToT	15 November

ICAR-NRCB signs MoU with Bishop Heber College (Autonomous), Tiruchirappalli for Research collaboration and student research

Patents Filed

Patent	ICAR-NRCB	201941011344	High-throughput Method for production of banana plantlets using Somatic Embryo Regeneration Vessel (SERV)"	22 October, 2021	FER submitted

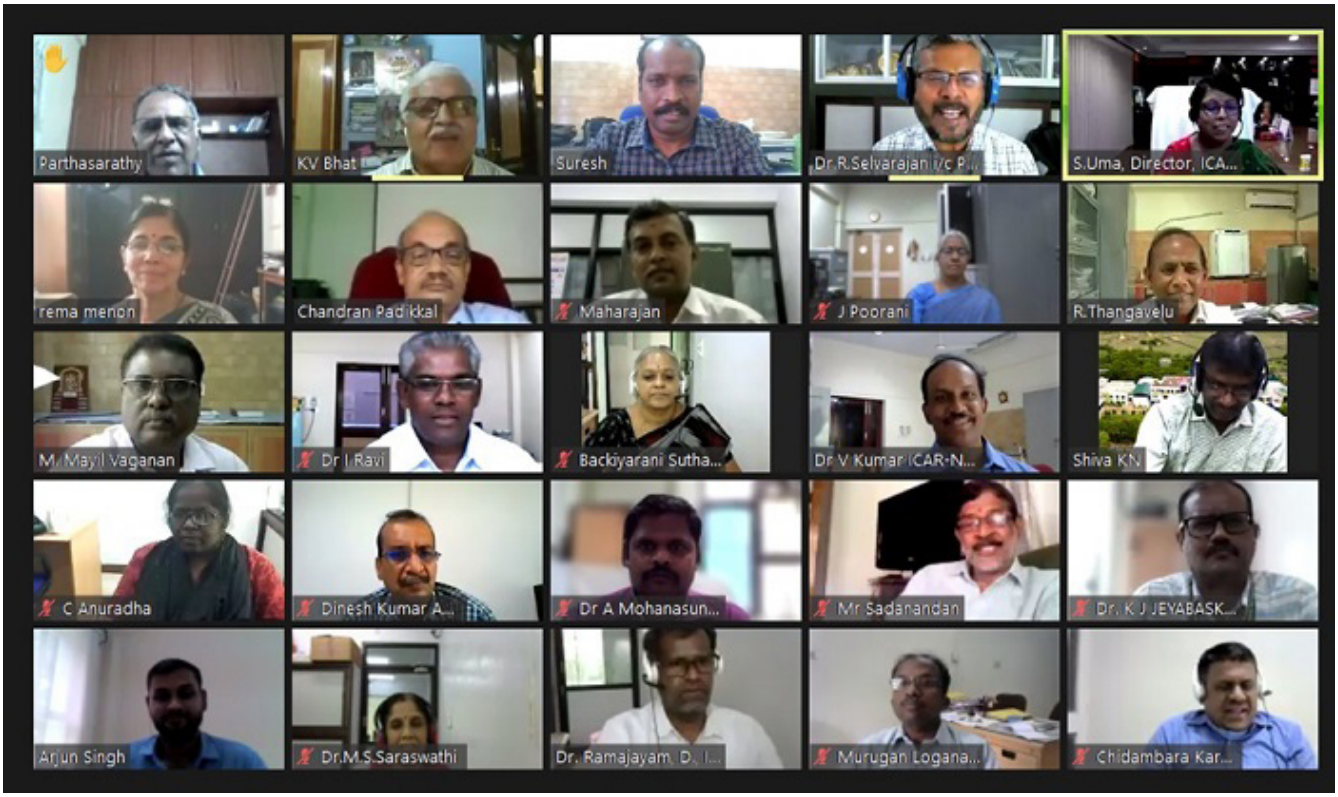
Supply of planting materials

Totally 1127 tissue cultured plants and 5300 suckers of banana varieties have been supplied to banana growers. 431 batches of tissue culture plants of cvs. Grand Naine, Nendran, Karpuravalli, Red Banana, Ney Poovan, etc. were tested for their genetic fidelity using ISSR markers and reports issued generating a revenue of Rs. 12.72 lakhs to the Centre.

11. RAC/ IRC / IMC MEETS

XXII Research Advisory Committee meet

The 22nd RAC meeting of ICAR-NRCB was held in virtual mode on 23 and 24 July, 2021. The meet was held under the Chairmanship of Dr. V.A. Parthasarathy, Retd. Director, ICAR-IISR, Calicut and the members: Dr. K.V. Bhat, Emeritus Scientist, ICAR-NBPGR, New Delhi; Dr. P. Chandran, Principal Scientist & Head, ICAR-NBSS & LUP, Nagpur; Dr. Rema Menon, Retd. Prof. & Head, KAU, Thrissur; and Dr. S.C. Dubey, Head Quarantine, ICAR-NBPGR, New Delhi and Dr. B.K. Pandey, ADG (Hort. Science), ICAR, New Delhi. Dr. S. Uma, Director, ICAR-NRCB presented the salient achievements of the centre during 2019-20. Research work carried out during 2019-20 in Crop Improvement, Crop Production and Post-Harvest Technology, and Crop Protection sections were presented by the selected scientists of the respective section. The recommendations made by the team were prepared and submitted to the SMD for approval.



Scientists of ICAR-NRCB and member of RAC at RAC 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
J. Poorani	Two-day training programme on 'Prevention of Sexual Harassment'(Online)	ISTM, New Delhi	19-20 July, 2021
	Sensitization workshop on 'ARMS and monthly reporting in ICAR-Institutions' (Online)	ICAR-IASRI, New Delhi	18 October, 2021
	Diagnostic Photography Workshop (Online)	USDA / Canadian National Collection of Insects, Arachnids and Nematodes	19 October, 2021
R. Selvarajan S. Backiyarani M.S. Saraswathi P. Suresh Kumar	Management Development Programme (MDP) on 'Biodiversity & Environmental Laws for Agricultural Researchers (BELAR-21)' (Online)	ICAR-NAARM, Hyderabad; IGNFA, Dehradun; NBA, Chennai ; BCIL, New Delhi; UNDP-India & GIZ-India	7-9 June, 2021
R. Selvarajan	Training on 'Implementation and Use of Agricultural Research Management System (ARMS)' (Online)	ICAR-IASRI, New Delhi	8 June, 2021
R. Selvarajan M. Mayil Vaganan S. Backiyarani	Collaborative International Training Program on 'Biofortification: A Key to Nutritional Security'	MANAGE and Harvest Plus India, Hyderabad	12-14 July, 2021
K.J. Jeyabaskaran	Training on 'Right to Information Act' (Online)	National Academy of Human Resource Development, New Delhi.	1-2 July, 2021
	DST Sponsored Training on 'Integrated Nutrient Management and Nutrient Budgeting through Advanced Models to Improve Crop Productivity' (Online)	ICAR-IISWC, Research Centre, Udhagamandalam.	29 November - 3 December, 2021
M. Mayil Vaganan M.S. Saraswathi P. Suresh Kumar	National Accreditation Board for Testing and Calibration Laboratories (NABL) - Laboratory Assessor Training Course (Level 1 & 2) (Online)	NABL, Gurgaon	10-12 March & 21-23 October, 2021
I. Ravi V. Kumar	Collaborative Training Programme on 'Enhancing Agricultural Resilience through Index-based Flood Insurance and Post-flood Management Interventions in India' (Online)	ICAR-IIWM, Bhubaneswar and IWMI, New Delhi	29 to 30 June, 2021

I. Ravi	Training Program on 'Strategies for climate risk management and resilient farming (Collaborative) (Online)	ICAR-CRIDA & National Institute of Agricultural Extension Management, Hyderabad	20-24, September, 2021
	Introduction and basic data analysis using-R	ICAR-NAARM, Hyderabad	28 October to 1 November, 2021
V. Kumar	Online Training on "Role of Technology in Community Level Disaster Management"	Lal Bahadur Shastri National Academy of Administration, Mussoorie	8-12 November, 2021
S. Backiyarani C. Anuradha	SNP Mining, GWAS and Genomic Selection (Online)	ICAR-IASRI, New Delhi	16-21 December, 2021
M.S. Saraswathi	Training on 'Management of Fruit Genetic Resources' (Online)	ICAR-NBPGR, New Delhi, ICAR-AICRP (Fruits) and ICAR-IIHR, Bengaluru	1-2 February, 2021
	Training programme on DUS testing (Online)	PPV&FRA, New Delhi	1 July, 2021
M. Mayil Vaganan M. Loganathan C. Anuradha	Enhancing Research Skills and Refinement of Technology by A Scientist (Online)	ICAR-IIHR, Bengaluru	18-20 January, 2021
M. Loganathan	On-Farm Production of Biocontrol Agents and Microbial Biopesticides	NIPHM, Hyderabad	15-19 March, 2021
C. Anuradha	Application of Bioinformatics in Agricultural Research and Education (Online)	ICAR-NAARM, Hyderabad	20-24 September, 2021
	Transcriptomic Data Analysis (Online)	ICAR-IASRI, New Delhi	28-30 September, 2021
	Training Workshop on 'Analysis of Multi-Location Experiments' (Online)	ICAR-NAARM, Hyderabad	28 October– 1 November, 2021
A. Mohanasundaram	Rodent Management (Online)	ICAR-NCIPM, New Delhi	1 July, 2021
Arjun Singh	Time Series Data Analysis	ICAR- NAARM, Hyderabad	4-9 January, 2021
	Integrated Nutrient Management and Nutrient Budgeting through Advanced Models to Improve Crop Productivity	ICAR-IISWC, Research Centre, Udhagamandalam	18-22 January, 2021
	Geo-informatics in agriculture using open-source data and analysis platforms	ICAR-IARI, New Delhi	1-5 March, 2021
	A Panorama of Affordable Innovative Technologies and Solutions for Rural Development	AARDO, New Delhi and IITM, Chennai	22 March-01 April, 2021

Arjun Singh	Design Thinking in Research Project Formulation and Implementation	ICAR- NAARM, Hyderabad	24-28 August, 2021
C. Sagayam Jacqueline	Advances in web and mobile application development (Online)	ICAR- NAARM, Hyderabad	6-10 December, 2021
	Cyber Forensics Principles	Ministry of Electronics and Information Technology, Government of India	22 June, 2021
R. Pichaimuthu	Appropriate sampling techniques including sample preparation and preservation for soil, water, plant and air samples for various analysis	ICAR-IARI, New Delhi	2-7 August, 2021
R. Mohanraj	Assets Management	Online	6-10 October, 2021

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	National webinar on 'Balanced Use of Fertilizer in Banana Cultivation' organized and held at ICAR-NRCB	18 June, 2021
	Webinar on 'Valuing Water for Everyone's Well-ness' organized and held at ICAR-NRCB	22 March, 2021
	National webinar on 'Integrated Farming System' organized and held at ICAR-NRCB	7 July, 2021
	ICAR Foundation Day and Awarding Sardar Patel Outstanding ICAR Institution Award 2020 to ICAR-NRCB	16 July, 2021
	ICAR-NRCB - 28th Foundation Day & *Kisan Mela*	21 August, 2021
	Webinar on 'Banana Value Chain and Marketing – New Business Horizons'	21 August, 2021
Scientific Staff of ICAR-NRCB	Research Advisory Committee Meeting of ICAR-NRCB	23-24 July, 2021
	Meet on 'Banana fibre extraction and establishment of fibre Industry – Dr. Mylswamy Annadurai, Vice President, TNSCST, TN Govt. and Former Director, ISRO, GoI; ICAR-NRCB; IIIT&DM, Kancheepuram and Industry Gencrest, Mumbai for Banana fiber held at ICAR- NRCB	9-10 February, 2021

S. Uma J. Poorani R. Thangavelu R. Selvarajan I.Ravi V. Kumar S. Backiyarani Dinesh Kumar Agarwal M.S. Saraswathi P. Suresh Kumar P. Giribabu A. Mohanasundaram	Midterm review meeting of ICAR-AICRP (Fruits) - Banana Centres (Online)	12 October, 2021
	VIII Group Discussion of ICAR-AICRP Fruits (Online)	3-6 March, 2021
R. Selvarajan V. Kumar K.N. Shiva M.S. Saraswathi P. Suresh Kumar P. Ravichamy	International Horticulture Conference - Next Generation Horticulture (NEXTGEN-HORT). Organized by TNAU and The Society for Promotion of Horticultural Science & Technology, held at TNAU, Coimbatore	16-19 September, 2021
J. Poorani R. Selvarajan M. Loganathan P. Giribabu C. Anuradha A. Mohanasundaram	Presentations at Golden Jubilee International Conference on "Global Perspectives in Crop Protection for Food Security (GPCP 2021)" organized by and at TNAU, Coimbatore	8 - 10 December, 2021
R. Selvarajan R. Thangavelu	National symposium on "Sustainable Plant Health Management Amidst Covid Pandemic: Challenges and Strategies" jointly organized by ICAR-CPCRI, Kasaragod and Indian Phytopathological Society (South Zone Chapter) (Online)	1-3 December, 2021
M. Mayil Vaganan M.S. Saraswathi C. Anuradha	Second International Agro-forestry Congress – 'Agrobiodiversity for food system transformation' by Alliance Bioversity-CIAT, Rome, Italy (Online)	15-18 November, 2021
V. Kumar K.N. Shiva P. Suresh Kumar	Online meet on 'Cluster Development Programme on Banana' with APEDA Officials	19 April, 2021
S. Uma V. Kumar K.N. Shiva P. Suresh Kumar	Online meeting on "Development of Sea Protocol for Export of Banana' under the Chairmanship of Dr. M. Angamuthu, Chairman, APEDA with APEDA Officials and NRCB Scientists	23 April, 2021
K.N. Shiva P. Suresh Kumar	E-National Conference on 'Food materials TEXRHEO' organized by IIFPT, Thanjavur	18-19 February, 2021
S. Backiyarani M.S. Saraswathi	Virtual workshop on 'Planning and management of CWR and RET species of PGR importance in India' organized by ICAR-NBPGR, New Delhi and BSI, Kolkata	5 July, 2021
M.S. Saraswathi C. Anuradha	'Applications of Gene Editing in Sustainable Agriculture and Food Security in Asia-Pacific Region' organized by BCIL, New Delhi	4 & 18 August, 2021

M.S. Saraswathi P. Suresh Kumar	9th Indian Horticulture Congress - 2021- 'Horticulture for Health, Livelihoods and Economy' organized by CSAUA&T, Kanpur	18-21November, 2021
P. Giribabu C. Anuradha	National Webinar on 'Quarantine procedures for the National and International exchange of plant materials' organized by ICAR-SBI, Kannur centre, Kerala	12 August, 2021
Dr. S. Uma, Director		
Meet on WBF-FAO project proposal on TR-4 (Online)		12 January, 2021
PMFME Meet at IIFPT, Thanjavur (Online)		13 January, 2021
Governing Body Meet, IIFPT, Thanjavur (Online)		22 January, 2021
ICAR Annual General Body Meet (Online)		27 January, 2021
Pre-conference session on agriculture titled 'Kerala's Agriculture: The Need to Raise Productivity' – International Conference on Kerala Looks Ahead (Online)		27 January, 2021
ICAR-IIHR-National Horticulture Fair 2021(Online)		8-12 February, 2021
ICAR-NRCB - IBSC Meet, Tiruchirappalli		26 February, 2021
ICAR-CARI, Portblair – Scientist Assessment Committee Meet – Member (Online)		23 March, 2021
International workshop on Banana by Antalya Agriculture Council, Turkey (Online)		5 April, 2021
ICAR-RCM – No. VIII – Mid Review Meeting		12 April, 2021
Joint meeting of Apex Committee and Project Monitoring and Evaluation Committee under NCS-TCP (Online)		13 April, 2021
MoFPI-IIFPT – PMFME Scheme – ODOP Webinar on 'Millet Processing and Value Addition'		27 April, 2021
Video conference on 'Import of Planting Materials and Creation of PEQ Facilities' organized by AC&FW, GoI, New Delhi		3 May, 2021
Participated in the meeting for development of work plan between ICAR-NRCB, Donald Danforth Plant Science Centre (DDPSC) and BCIL (Online)		18 June, 2021
Inauguration of APEDA - Virtual Buyer-Seller Meet (BSM) cum Exhibition for banana and banana products from the clusters of Trichy, Theni and Pollachi, Tamil Nadu (Online)		24 June, 2021
BIRAC Project Phase-II Progress Review Meet (Online)		24 June, 2021
Board Meeting, TNAU, Coimbatore		28 June, 2021
ODOP webinar on Banana Processing and Value addition under PMFME, organized by IIFPT, Thanjavur		1 July, 2021
ICAR Institutes Directors' Conference (Online)		2 July, 2021
Governing Body Meet, IIFPT, Thanjavur (Online)		6 August, 2021
Meeting on assessment for identifying gaps in infrastructure and processing facilities for development of banana value chain – conducted by Grant Thornton Bharat LLP (Online)		9 August, 2021
NAAS General Body Meet, NAAS (Online)		9 August, 2021
TNAU Board of Management Meet, Chennai		4 September, 2021

ICAR Regional Committee VIII Meet (Online)	14 September, 2021
MusaNet Meet with Bioversity International and Members of Asia & Pacific (Online)	16 September, 2021
Programme on FAO – Scientific Partnership to promote fruits and vegetables production / launch FAO-CIRAD Publication (Online)	20 September, 2021
Global Rice Conference Inaugural programme of TRRI Aduthurai at NIFTEM, Thanjavur	24 September, 2021
CPCRI-ABI Programme, ICAR-CPCRI, Kasaragod (Online)	25 September, 2021
Review Meet, CSIR-FTT/FTC Committee (ANB) (Online)	30 September, 2021
Discussion meet – MoFPI, GoI – Grant Thornton – on Draft Report of Banana (Online)	30 September, 2021
Brainstorming Meet on Export of Banana – Organized by ICAR-NRCB (On-line)	5 October, 2021
NAAS sectional meet organized by ICAR-SBI, Coimbatore (Online)	9-10 October, 2021
ICAR-AICRP (Fruits) - Banana Review Meet (Online)	12 October, 2021
MoS, Agri., GoI – Review Meet on *Swachch Bharat* (Online)	27 October, 2021
DG-ICAR Interaction Meeting with Scientists (Online)	28 October, 2021
TNAU, Coimbatore Convocation / Meeting with Governor of Tamil Nadu (Chancellor of Univ.)	1 November, 2021
National Conference on 'Fruits and Vegetables for Health and Nutrition (FVHN-2021)' organized by KSTA, Bengaluru (Online)	8 November, 2021
APEDA stakeholders meeting at Chennai	15 November, 2021
BIRAC Project- Phase III – 1st Review Meeting with Trial In-charges for conduct of EST of GE Bananas (Online)	16 December, 2021
TANHODA Seminar on 'Banana Cluster Development Programme' at Theni, Tamil Nadu	27 December, 2021
Dr. J. Poorani, Principal Scientist	
Sixth National Conference on Biological Control: Innovative approaches for Green India organized by ICAR-NBAIR, Bangalore (Online)	3-5 March, 2021
First Biannual Subcommittee meeting of 'National Network of Plant Health Experts' organized by NIPHM, Hyderabad	22 July, 2021
Brainstorming session on 'Classical and Molecular Taxonomy - Standalone or Complementary' organized by ICAR-NBAIR, Bangalore (Online)	18 November, 2021
Dr. R. Thangavelu, Principal Scientist	
Global Conference on "Innovative approaches for enhancing water productivity in Agriculture" organised by CHAI and PTJSAU at PJTSAU, Hyderabad	16-19 September, 2021
Dr. R. Selvarajan, Principal Scientist	
IPS- Central Zone Virtual Symposium – 2020 on "Advances in Phytopathology" by Dr.Y.S.R. Horticultural University, Venkataramannagudem, Andhra Pradesh (Online)	6-7 January, 2021

International web-workshop on 'Recent Advances in Design and Emerging Applications in Lateral Flow Assays under IDP-NAHEP' organized by ICAR-NDRI, Karnal (Online)	18-21 May, 2021
National e-Conference on "Plant Health and Food Security: Challenges and Opportunities" at ICAR-IARI, New Delhi (Online)	25-27 March, 2021
International Conference of World Society for Virology on "Tackling Global Viral Epidemics" (Online)	22-26 June, 2021
Institute Biosafety Committee meeting organized by ICAR-CTCRI, Thiruvananthapuram	12 January, 2021
Online meeting for Evaluation of Innovation Excellence Indicators for Public Funded R&D organizations: Webinar for R&D labs organized by CII, India	12 February, 2021
Joint meeting of Apex Committee and Project Monitoring and Evaluation Committee under the NCS-TCP (Online)	13 April, 2021
Work planning on GE banana events organized by Donald Danforth Plant Science Center (Online)	18 June, 2021
Biannual subcommittee meeting of 'National Network of Plant Health Experts' organized by NIPHM, Hyderabad (Online)	22 July, 2021
XXVI meeting of ICAR regional committee No.VII comprises the state of Maharashtra, Madhya Pradesh, Chhattisgarh and Goa hosted by ICAR (Online)	25 August, 2021
Launching of the ICAR-Network Program on Precision Agriculture (NePPA)	8 September, 2021
Review and Sensitization Workshop of ZTMUs/ITMUs/PMEs under NAIF Scheme (Online)	6 October, 2021
Webinar on 'Gene Editing Research in Agriculture: Key Initiatives in India' Organized by Tata Institute for Genetics and Society (TIGS) in partnership with BCIL	17 February, 2021
Webinar on banana diseases and their management	24 June, 2021
Webinar on 'Preventing future zoonotic pandemics: Interventions at the wildlife–livestock–human interface	6 July, 2021
Webinar series on 'Applications of Gene Editing in Sustainable Agriculture and Food Security in Asia-Pacific Region'	21 July, 2021
National Webinar On farm Diagnostics of diseases in ornamental crops organized by ICAR- DFR, Pune	30 November, 2021
Dr. M. Mayil Vaganan, Principal Scientist	
XI Institute Biosafety Committee Meeting, ICAR-NRCB	26 February, 2021
XII Institute Biosafety Committee Meeting, ICAR-NRCB	13 August, 2021
Workshop Cum Hands-on Training program on 'Creating Healthy World through Agriculture-Based Balanced Diet' by Division of Biochemistry, ICAR-IARI, New Delhi	6-8 September, 2021
Dr. I. Ravi, Principal Scientist	
International Plant Physiology Symposium by ICAR-SBI, Coimbatore (Online)	11-12 March, 2021
External expert to recruit a Subject Matter Specialist (Animal Science) at ICAR-KVK, Karur, Tamil Nadu	22 June, 2021
Dr. V. Kumar, Principal Scientist	
Sixth National Review Conference of the '*Pradhan Mantri Fasal Bima Yojana*', organized by Ministry of Agriculture and Farmer's Welfare, New Delhi (Online)	24-25 July, 2021

'Crop Specific Technical Subcommittee meeting' to standardize the term sheets for Banana under RWBCIS (Online)	10 June, 2021
First round table virtual conference on 'Promotion of R&D Services Exports' organized by Dept. of Commerce, FIEO	19 January, 2021
Interface Meeting of Agri Business organized by District Collector, Trichy	29 January, 2021
Interface Meeting on Pre-Kharif 2021 Report	31 July, 2021
Meeting on Agri Export Policy in Kerala organized by Director of Agriculture, Kerala (Online)	
Meeting of National Level Technical Committee Members & CSTSCs- RWB-CIS	6 August, 2021
VC with Banana Cluster in Thrissur organized by APEDA, New Delhi	7 August, 2021
Seminar on Cluster Development for Export of Theni Banana, organized by Directorate of Horticulture & Plantation Crops, Chennai, held at Theni, Tamil Nadu	27 December, 2021
Dr. K.J. Jeyabaskaran, Principal Scientist	
11th Scientific Advisory Committee Meeting of ICAR-KVK, Papparapatti, Dharmapuri District	11 February, 2021
13th Scientific Advisory Committee Meeting of ICAR-KVK, Krishnagiri	12 February, 2021
Dr. K.N. Shiva, Principal Scientist	
Online meeting to discuss the provisions and norms of Enmass Technology Transfer to Micro Food Processing Enterprises under PM-FME Scheme, organized by PM FME Division, MoFPI and IIFPT, Thanjavur	13 January, 2021
Webinar Series Session-I on 'Packaging for Various Food Products by IIP, Chennai	22 January, 2021
Webinar Series Session-II on 'Testing and Evaluation of Packaging Materials by IIP, Chennai	5 February, 2021
Online meeting with VFPCK Officials under Consultancy project on "Development of Sea protocol for export of Nendran bananas to Europe (UK)	9 February, 2021
Webinar on 'New Paradigm in Production and Utilization of Fruits and Vegetables for Health and Livelihood' organized by CHAI, New Delhi	11 February, 2021
E - National Conference on Texture & Rheology of Food Materials (TEX-RHEO-2021) organized by IIFPT, Thanjavur	18-19 February, 2021
Online meeting with VFPCK Officlas under Consultancy project on "Development of sea protocol for export of Nendran bananas to Europe (UK)	19 February, 2021
Online meeting with VFPCK Officials under Consultancy project on "Development of Sea protocol for export of 'Nendran bananas to Europe (UK) (Feedback)"	5 May, 2021
Webshow on 'Enabling Ecosystem for Nurturing Agri Startups' (Online) NAARM a-IDEA's Agri Udaan 4.0, Hyderabad, A.P.	18 June, 2021
Video Conference of 'National Dialogue on Innovative Food for Hospitality Industry' ADG (IPTM), ICAR, New Delhi	22 June, 2021
Virtual Banana Cluster – Buyer - Seller Meet BSM (FPOs & Exporters) cum Exhibition for banana and banana products from the clusters of Trichy, Theni and Pollachi of TN, APEDA, Chennai	24 June, 2021

Webinar on Banana Processing and Value Addition under PM-FME Scheme (One District One Product) - IIFPT, Thanjavur	1 July, 2021
Virtual orientation workshop for ICAR Labs on R & D Exports' hosted by Federation of Indian Export Organizations (FIEO); ICAR, New Delhi along with IP&TM Unit of ICAR, New Delhi	12 & 13 August, 2021
Meeting to discuss and formulate a project proposal on "Establishment of Science Technology and Innovation (STI) Hubs for Development of SC & ST Communities" in four states (Meghalaya, Bihar, Karnataka & Tamil Nadu) by ICAR-NRCB	28 July, 2021
Virtual Techniocal Session on 'Export Procedures and various opportunities of MSMEs DIC, Palakkad, Kerala	23 September, 2021
Focused Group Discussion (FGD) with Stakeholders in the Banana and Honey Ecosystem to seek constructive feedback and suggestions for improvement, The Kerala Agro Industries Corporation Ltd., Trivandrum, Kerala	1 October, 2021
Meeting on "Export of Traditional Banana Varieties" (through Zoom Platform) with stakeholders (Importer, FPO, Packaging unit, shipping liners, logistic provider, APEDA officials and NRCB expert team), ICAR-NRCB	5 October, 2021
Webinar on 'Future of Bananas and Fair trade', AgroFair, Brussels, Belgium	13 October, 2021
Webinar on EDP-15: Entrepreneurship Development Programme on "Business with Agri Waste" Medi-Hub TBI of ICAR-DMAPR, Anand, Gujarat	30 October, 2021
Webinar on "Protection of plant varieties, the key to improved agricultural commerce & growth"	1 December, 2021
Meeting on "Banana Cluster Meeting of Agriculture Export Promotion (AEP) of Kerala" with stakeholders, APEDA and VFPCK, Trivandrum, Kerala	6 December, 2021
Dr. S. Backiyarani, Principal Scientist	
Workshop on 'Coconut based high density multispecies cropping system' organized by ICAR-CPCRI, Kasaragod (Online)	29 January, 2021
National Webinar on 'Brainstorming on Digital Sequence Information (DSI) and Germplasm Sharing' organized by ICAR-NBPGR, New Delhi (Online)	1 March, 2021
Annual meeting of project ABBB (Online)	17-20 May, 2021
Review meeting of DBT-BIRAC (Online)	13 August, 2021
Work plan on genetically engineered crops organized by ICAR, New Delhi and Donald Danforth Plant Science Center (DDPSC)	18 June, 2021
Closing webinar of the 'Genome Harvest Agropolis Foundation flagship project' (Online)	23-24 June, 2021
Dr. M.S. Saraswathi, Principal Scientist	
Gene editing research in agriculture: Key Initiatives in India organized by TIGS, India	18 February, 2021
Exchange of Post PVP Control Measures organized by PPV&FRA, New Delhi in collaboration with DAC & FW, Ministry of Agriculture and Farmers' Welfare, GOI and Federal Ministry of Food, Agriculture (BMEL), Germany under Indo-German Cooperation on Seed Sector Development	8 April, 2021
Translating genomics for next generation crop improvement organized by TIGS, India	11 June, 2021

International webinar on 'Exchange on biochemical and molecular techniques (BMT) – Guidelines and implementation of BMT in DUS' organized by PPV&-FRA, New Delhi in collaboration with Department of Agriculture and Farmers' Welfare, Ministry of Agriculture and Farmers Welfare, Govt. of India and Federal Ministry of Food, Agriculture and Consumer Protection (BMEL), Germany	16 December, 2021
Dr. Dinesh Kumar Agarwal, Principal Scientist	
142nd Meeting of GEAC (Online)	11 May, 2021
143rd Meeting of GEAC (Online)	14 June, 2021
RCGM Central Compliance Committee (CCC) Meet and Field Trial Monitoring organized by Regional Research Station, RRI, Assam	26 November, 2021
Dr. P. Suresh Kumar, Principal Scientist	
Inauguration of APEDA- Chennai & TN marketing Board, Chennai	4 February, 2021
Partnership for exploring potential of Banana as a potential horticulture crop for Hazaribagh district in Jharkhand on a commercial scale (Online)	5 February, 2021
ICAR-AICRP on Fruits Nodal officers meeting (Online)	9 April, 2021
Development of Sea protocol for the export of Banana (Online)	23 April, 2021
National Dialogue on 'Innovative Foods for Hospitality Industry' (Online)	22 June, 2021
Banana cluster-BSM(FPOs & exporters) cum exhibition organized by APEDA, Chennai (Online)	24 June, 2021
Progress of Common Incubation Centres (Online)	16 July, 2021
ABI review meeting Horticulture Division: Guidelines for presentation to PI - ABIs (Online)	27-28 July, 2021
PMFME- ODOP- Execution plan for Trichy at Collecorate office, Trichy	2 September, 2021
Exporters' conclave, India's rising export potential in Global Market. Exhibition and Conference. District collectorate, DGFT	24 September, 2021
Export avenues for traditional banana varieties; ICAR- NRCB	5 October, 2021
Review and sensitization workshop of ZTMUs/ITMUs/PMEs under NAIF Scheme (Online)	6 October, 2021
Ministry of Food Processing Industries - Govt of India: Assessment on gaps in value chain infrastructure for banana in India. Grant Thorton (Online)	11 October, 2021
AEP banana clusters for Kerala (Online)	6 December, 2021
Blending and Regeneration trials of silk with banana fibres and other natural fibres- Meeting with silk board (Online)	16 December, 2021
Dr. C. Karpagam, Principal Scientist	
Scientific Advisory Committee Meeting at KVK, Dharmapuri, Tamil Nadu	11 February, 2021
Scientific Advisory Committee Meeting at KVK, Krishnagiri, Tamil Nadu	12 February, 2021
Scientific Advisory Committee Meeting at KVK, Needamangalam, Tamil Nadu	16 February, 2021
Scientific Advisory Committee Meeting at KVK, Vamban, Tamil Nadu	17 February, 2021
Scientific Advisory Committee Meeting at KVK, Kallakurichi, Tamil Nadu	2 March, 2021
Scientific Advisory Committee Meeting at KVK, Namakkal, Tamil Nadu	3 March, 2021
Scientific Advisory Committee Meeting at KVK, Perambalur, Tamil Nadu	15 March, 2021
International symposium on 'Coastal Agriculture: Transforming coastal zone for sustainable food & income security' organized by ISCAR, West Bengal (On-line)	16-19, March 2021

Scientific Advisory Committee Meeting at KVK, Ariyalur, Tamil Nadu	23 March, 2021
Scientific Advisory Committee Meeting at KVK, Kadayianallur, Tamil Nadu	24 March, 2021
Scientific Advisory Committee Meeting at KVK, Karur, Tamil Nadu	27 October, 2021
Scientific Advisory Committee Meeting at KVK, Kadayianallur, Tamil Nadu	10 December, 2021
Scientific Advisory Committee Meeting at KVK, Sirugamani, Tamil Nadu	22 December, 2021
Dr. P. Giribabu, Senior Scientist	
National webinar on 'Nematodes – A continuing bottleneck in crop production: Available technologies and recent advances' organized by Department of Nematology, Rajasthan College of Agriculture, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan	6 April, 2021
Online National Seminar on 'The Facets of Innovation and Development of Plant Nematology' organized by Nematological Society of India, New Delhi	29 – 30 October, 2021
Dr. C. Anuradha, Senior Scientist	
International Virtual Conference on 'Nanotechnology Application in Plant Disease Management (NAPDM-2021)' organized by Department of Plant Pathology, Annamalai University	19 September, 2021
International Virtual Conference on 'Recent Advances in Crop Disease Management (RACDM-2021)' organized by Department of Plant Pathology, Annamalai University	19 September, 2021
International Symposium on 'Advances in Plant Biotechnology and Genome Editing (APBGE-2021)' & Workshop on 'CRISPR/Cas9 based Genome Editing Technology' organized by ICAR-IIAB, Ranchi	April 8-10, 2021
International webinar on 'Androgenic haploids and double haploids in banana' organized by Bioingene.com	15 January, 2021
International webinar on 'Pan Genomes in Plants: Beyond a single reference genome' organized by Bioingene.com	1 February, 2021
TIGS Science Serving Society Webinar series: Gene editing research in agriculture: Key Initiatives in India organized by TIGS, India	17 February, 2021
International Webinar on 'Cassava Viruses – Global Status and Strategies for Disease Control and Prevention Confirmation' organized by ICAR-CTCRI	10 August, 2021
Dr. A. Mohanasundaram, Scientist	
National Web-Symposium on Recent Advances in Beneficial Insects, Natural Resins and Gums (SANRAG), ICAR-IINRG, Ranchi (Online)	25-26 February, 2021
Webinar on 'Commercial Production of Bio-control agents for crop Pests: A New Opportunities for Entrepreneur Seekers' organized by Central Agricultural University, Imphal (Online)	25-27 October, 2021
Mr. A. Arjun Singh, Scientist	
Virtual National Seminar on 'Advances in sustainable management of natural resources for food and nutritional security' organized by Navsari Agricultural University, Navsari	26-27 August, 2021
9th Indian Horticulture Congress by CSAUAT, Kanpur	18-21 November, 2021
5th International Agronomy Congress organized by PJTSAU , Hyderabad (online)	23-27 November, 2021

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

Moon man of India, Padma Shri Dr. Mylswamy Annadurai joined hands with ICAR-NRCB for efficient utilization of banana waste

A major initiative was launched by ICAR-NRCB, in partnership with Dr. Mylswamy Annadurai, Vice President, Tamil Nadu State Council for Science and Technology (TNSCST), Government of Tamil Nadu and Former Director, Indian Space Research Organization (ISRO). Dr. Mylswamy with staff of IIIT-DM, Kancheepuram and Industry Gencrest, Mumbai joined ICAR-NRCB as partners to utilize banana waste. An MoA was signed to develop pilot scale machinery for extracting more than three tons of banana fiber every day and utilize the sap, central stem and scutcher for producing a variety of products on 10 February, 2021. Dr. S. Uma, Director, ICAR-NRCB, addressed the gathering and emphasized the need for latest technologies for waste utilization to promote a circular economy by converting waste into innovative, high value products. She highlighted the potential use of banana central core stem as a suitable candidate for the development of future food and functional foods. During the occasion, Dr. Ravindra Naik, Principal Scientist from ICAR-CIAE, Coimbatore, demonstrated the high throughput semi-automatic fiber extraction on-farm machine which was developed by ICAR- CIAE (RS), Coimbatore.

Visit of Dr. Mylswamy Annadurai, Vice President, TNSCST to ICAR-NRCB during signing of MoA

ICAR-NRCB and VFPCK, Kerala collaborate project to export Nendran bananas to Europe

Under a joint venture by the ICAR-NRCB and VFPCK, Kerala, a consignment of 10 tons of farm fresh Nendran banana fruits, was shipped to London on 8 March, 2021. An expert team from ICAR-NRCB, comprising Drs. S. Uma, R. Thangavelu, V. Kumar, K.N. Shiva and P. Suresh Kumar provided the technical expertise including developing pack house facility and shipment protocols for Nendran banana to the officials of VFPCK, Kerala. Dr. S. Uma, Director, ICAR-NRCB, opined that successful execution of this project will provide an impetus to quicker and cost-effective sea exports of traditional banana varieties to European markets and fetch higher prices for farmers. ICAR-NRCB also imparted hands-on training to banana farmers from Thrissur district on scientific cultivation of Nendran following Good Agricultural Practices to produce export quality Nendran bananas.

Director and NRCB scientist team flagging Nendran bananas to Europe via Sea

ICAR-NRCB Foundation Day & Kisan Mela

ICAR-NRCB celebrated its 28th Foundation Day in virtual platform. Dr. A. K. Singh, Deputy Director General (Hort. Science), ICAR and Dr. S. K. Malhotra, Agriculture Commissioner, Ministry of Agriculture and Farmers' Welfare, Govt. of India graced the event as Chief Guests. Padma Shri Dr. Mylswamy Annadurai, Former Director, ISRO; Dr. Pawan Kumar Singh, Director, IIM, Tiruchirappalli;

Dr. M. Selvam, Vice Chancellor, Bharathidasan University, Tiruchirappalli and Dr. B. K. Pandey, Assistant Director General (Hort. Science –II), ICAR were Guests of Honor. The event was felicitated by Shri. Ajith Jain, Joint Managing Director, Jain Irrigation Systems Ltd.; Dr. V. Venkatasubramanian, Director, ICAR – ATARI, Bangalore; Dr. T. Janakiram, Vice Chancellor, Dr. YSR Horticultural University; Shri. A. P. Karuppaiah, Chairman, TNBPCL and Shri. G. Ajeethan, Managing Director, TNBPCL.

Shri Dr. Mylswamy Annadurai, Former Director, ISRO, lauded ICAR – NRCB for its contribution to banana cultivation and export and mentioned the potential of banana fibre for value added products and their export. Dr. A. K. Singh, Deputy Director General (Hort. Science), ICAR gave chief guest address. Dr. S. K. Malhotra, Agriculture Commissioner, Ministry of Agriculture and Farmers' Welfare, Govt. of India released ICAR–NRCB publications and gave awards. A webinar titled 'Banana Value Chain and Marketing – New Business Horizons' was organised.

Award	Name of the recipient
Best Banana Farmer Award - 2021	Mr. A.J. Joby, Thrissur, Kerala
	Mr. Santosh Lachheta, Madhya Pradesh
Best FPO Award – 2021	M/s. Tapti Valley Banana Processing & Products Co-op. Society Ltd., Jalgaon, Maharashtra
	M/s. UK-COOFED, Sirsi, Karnataka
Technology Dissemination Award - 2021	*Malarum Boomi*, *Makkal TV*
	Mr. Shree Padre, *Adike Patrike*, Karnataka
Best KVK Award – 2021	ICAR-KVK, Sirsi, Uttara Kannada, Karnataka
	ICAR-KVK, Thirupathisaram, Kanyakumari, Tamil Nadu
	ICAR-KVK, Alappuzha, Kayankulam, Kerala
Best Entrepreneur Award - 2021	M/s. Rise N Shine Bioteck Pvt. Ltd., Pune, Maharashtra
Best Initiative Award - 2021	M/s. Vegetable and Fruit Promotion Council, Keralam (State Nodal Agency for Agricultural Export Promotion), Kerala
Best Employee of the year – 2021 (ICAR-NRCB, Tiruchirappalli, Tamil Nadu)	Dr. P. Durai, Assistant Chief Technical Officer,
	Mr. R. Sridhar, Assistant Administrative Officer
	Mr. V. Ganesan, Skilled Supporting Staff

To invite the fresh ideas in the theme areas of banana production and processing ICAR- NRCB organized a 'Banana Hackathon' for Students, Farmers, Researchers and Self Employed individuals as part of the centres' Foundation Day celebrations. *In toto* 30 proposals were received from 14 States and Union territories under three-theme areas. One award each which comprises of a cash prize of Rs. 2000 and a certificate was being given under the 3 themes to the winners, while a certificate of appreciation was being given in each of these 3 themes to the runners. During the institutes' Foundation Day, the winners and runners were appreciated by issuing certificates and cash reward.

Banana Hackathon Award	Name of the recipient
Theme Area - Banana Production	Mr. Abishek Anand, Sitamarhi, Bihar
	Ms. Suchitra Varakala, Adhilabad, Telangana
Theme Area - Banana Processing	Ms. J. Sivakamavalli, Tiruchirappalli, Tamil Nadu
	Ms. M. Gomathy, Killikulam, Tamil Nadu
Theme Area - Banana Marketing	Mr. Simanta Taid, Nirjuli, Arunachal Pradesh
	Dr. A.D. Ashok, Tiruchirappalli, Tamil Nadu

Commemoration of 75th Year of India's Independence – *Azadi Ka Amrit Mahotsav*

ICAR–NCB organised a series of HRD programs to commemorate 75th Year of India's Independence (*Azadi Ka Amrit Mahotsav*) during 2021. Details are as follows.

Theme of the Campaign	Month & Date	No.of participants	ICAR Institutes / KVK involved
Campaign on water conservation during World Water Day	22 March, 2021	70	ICAR-NRCB
Campaign on reaching and recognizing the grassroot level women achievers with "3-Es" - Entrepreneurship, Equity and Empowerment during International Womens' Day Celebration.	8 April, 2021	100	ICAR-NRCB
Campaign through Makkal TV on Establishment, importance of ICAR-NRCB	5 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on Significant achievements of different disciplines	6 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on Q&A and the genesis of the programme	7 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on Extension objective & Breeding technologies	11 May, 2021	1 Lakh	ICAR-NRCB
Campaignthrough Makkal TV on Agronomical technological backstopping	12 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV Soil health, drought & government's schemes	13 May, 2021	1 Lakh	ICAR-NRCB
Campaignthrough Makkal TV on Technologies for wilt disease management	18 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on Technologies for virus disease management	19 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on Technologies for diseases & Insect management	20 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on PHT, Export protocols & farmers success story	25 May, 2021	1 Lakh	ICAR-NRCB
Campaign through Makkal TV on PHT, Products development & extension strategies	15 June, 2021	1 Lakh	ICAR-NRCB
National Webinar on farmers' participatory campaign on "Balanced Use of Fertilizer in Banana Cultivation"	18 June, 2021	500	ICAR-NRCB & KVK, Karur
National webinar on "Integrated Farming System (IFS)"	7 July, 2021	More than1000	ICAR-NRCB & ICAR-IIFSR
ICAR Foundation Day and Sardar Patel Outstanding ICAR Institution Award 2020 to ICAR-NRCB	16 July, 2021	500	ICAR-NRCB
Capacity development programme for Horticultural Students of College of Horticulture, Bidar	5 August, 2021	300	ICAR-NRCB & COH, Bidar

Capacity development programme for Horticultural Students of College of Horticulture, Kolar	17 August, 2021	300	ICAR-NRCB & COH, Kolar
ICAR-NRCB – Collaborative initiative with Tripura Government for technological backstopping	17 August, 2021	600	ICAR-NRCB & GOT
ICAR-NRCB - 28th Foundation Day	21 August, 2021	200	ICAR-NRCB
ICAR-NRCB – 28th Foundation Day National Webinar	21 August, 2021	500	ICAR-NRCB
Campaign on "Food Nutrition for Farmers" during	26 August, 2021	50	ICAR-NRCB
Nurturing Science- Wonder World of Banana – *Azadi Ka Amrit Mahotsav Lecture Series*	7 September, 2021	100	ICAR-NRCB & Rotary Club
Campaign on *Poshan Vatika Maha Abhiyan* & Tree plantation - "International Year of Millets 2023"	11 September, 2021	100	ICAR-NRCB
Aawareness Campaign on "Climate Resilient Agriculture" on the occasion of PM's Programme	28 September, 2021	240	ICAR-NRCB
Campaign cum free distribution of farm inputs for the banana famers.	30 September, 2021	70	ICAR-NRCB & KVK, Karur
Capacity development programme for students from AD & ACRI, NavalurKuttappattu, Trichy	4 October, 2021	123	ICAR-NRCB
Capacity development programme for students from TNAU & RI, Kudumiyanmalai, Pudukkotai	6 October, 2021	82	ICAR-NRCB
Campaign cum free distribution of farm inputs for the banana famers.	7 October, 2021	35	ICAR-NRCB & KVK, Namakkal
Capacity development programme on Presentation and Public Speaking Skills for students of HC&RI	10 November, 2021	60	ICAR-NRCB & HC&RI (W)
Agriculture and Environment: the Citizen Face:Awareness campaign for school students	26 November, 2021	5	ICAR-NRCB
Capacity development programme for Horticultural Students of COA, Karekere, Hassan, Karnataka	29 November, 2021	110	ICAR-NRCB & COA,
Meeting organised on "Natural Farming" on the occasion of Hon'ble PMs Programme	16 December, 2021	100	ICAR-NRCB
Two days capacity development programme for Chengalpattu farmers under ATMA – SSEPERS	17-18 December, 2021	40	ICAR-NRCB
Capacity development programme on Skill development for banana producers at Trichy	23 December, 2021	100	ICAR-NRCB & FIEO
Capacity development programme for Diploma Agri students from Institute of Agriculture, Kumulur, TNAU, Trichy	22-24 December, 2021	300	ICAR-NRCB & COA, Kumulur

One day capacity development programme for Valangaiman banana farmers under ATMA – SSEPERS	24 December, 2021	40	ICAR-NRCB
Seminar on Formation of Cluster under PMFME, ODOP scheme at Theni	27 December, 2021	50	ICAR-NRCB & NHB
Two days capacity development programme for Dindigul farmers under ATMA – SSEPERS	27-28, December, 2021	40	ICAR-NRCB
Capacity development programme for the UG and PG students from J. J. College of Pudukkottai district	29 December, 2021	80	ICAR-NRCB
Capacity development programme for FPC s of Vellore Trichy district	29 December, 2021	40	ICAR-NRCB
One day capacity development programme for Ranipet banana farmers under ATMA – SSEPERS	30 December, 2021	40	ICAR-NRCB

Farmer's Awareness Campaign on 'Balanced Use of Fertilizer in Banana Cultivation'

ICAR–NRCB in collaboration with ICAR-KVK, Pulutheri, Karur organised a 'Farmers' Awareness Campaign' on 18 June, 2021. Dr. K.J. Jeyabaskaran, Principal Scientist, ICAR-NRCB delivered a lecture on 'Balanced Use of Fertilizer in Banana Cultivation'. The campaign was organized online. Around 500 participants participated in the campaign.

National webinar on 'Integrated Farming System'

National webinar on 'Integrated Farming System' was organised by ICAR-NRCB on 7 July, 2021. Dr. N. Ravisankar, Principal Scientist & Project Coordinator (In-charge), AICRP – IFS, Coordination Unit, ICAR-IIFSR, Modipuram delivered a talk on "Sustainable Integrated Cropping and Farming System Models with Special Reference to Banana for Enhanced Income of Farmers". Around 700 participants' including researchers and students from different SAUs across India, SMS from KVKs of ATARI, Zone XI, Bengaluru and other KVKs also participated the webinar in online mode.

NRCB joins hands with Government of Tripura for promoting new varieties and production and post-harvest technologies

ICAR-NRCB initiated collaboration with Government of Tripura during 'Progressive Farmers' Meet on Horticulture Development with Special Reference to Banana" which was held during 17-18 August, 2021. The meet was inaugurated and graced by Shri. Biplap Kumar Deb, Honourable Chief Minister, Tripura. Around 600 farmers participated.

'*Poshan Vatika Maha Abhiyan*' and Tree Plantation Campaign

NRCB organised a farmers' meet to celebrate '*Poshan Vatika Maha Abhiyan'* and Tree Plantation as part of celebration on 'International Year of Millets-2023' on 17 September, 2021. Dr. S. Uma, Director, ICAR-NRCB delivered a talk on importance of banana and nutri-cereals and their role on human health. All the participants were provided with banana suckers followed by tree plantation campagin was held. Women farmers planted different tree saplings in the institute premises. To create the awareness about millets, pearl millet porridge was provided to all the participants.

Awareness programme on "Climate Resilient Agriculture"

The Centre organised a farmers' meet on 28 September, 2021 for "Mass awareness

campaign for large scale dissemination of climate resilient technologies and methods". In the online campaign, Honourable Prime Minister dedicated 35 crop varieties to the Nation and bestowed the Clean Green Campus Awards to different institutes and addressed the farmers. The programme was attended by around 240 participants.

World Food Day Celebrations

The Centre celebrates World Food Day on 16 October, 2021 with the tag line "Safe food now for a healthy tomorrow". Dr. S. Uma, Director, ICAR-NRCB highlighted the importance of banana in our diet. Around 120 B.Sc. (Agri.) students attended the program. Off-campus & outreach training programmes were also organised. Free distribution of banana planting materials and Banana Sakthi were undertaken. Farmers of Karur and Namakkal Districts attended the program.

Shri. Biplap Kumar Deb, Hon'ble Chief Minister, Tripura Visiting NRCB Stall

Celebration of "Agriculture and Environment: the Citizen Face

ICAR–NRCB organized a training program for school children on the occasion of 'Agriculture and Environment: the Citizen Face' on 26 November, 2021. They were trained for "Edible packaging of fresh fruits using natural products from banana". The students were also exposed to other eco-friendly technologies like banana fiber and napkin production.

Meet on 'Natural Farming'

ICAR–NRCB organised a farmers' meet on 16 December, 2021. Honourable Prime Minister addressed the farmers, students, scientists and other stakeholders on the topic 'Natural Farming' in virtual mode. Around 100 farmers from Viluppuram and Kanyakumari Districts of Tamil Nadu, 50 students and other stakeholders participated in the program.

School children at the Centre during the training program

14. DISTINGUISHED VISITORS

Name	Date
Mr. K. Natarajan, Station Director, All India Radio, Tiruchirappalli	28 January, 2021
Mr. T.K.V. Rajan, Founder–Director, Indian Science Monitor & Indo - Asian Foundation of Archaeological Research, Kumbakonam	
Padma Shri Dr. Mylswamy Annadurai, Vice President for Tamil Nadu State Council for Science and Technology (TNSCST), Govt. of Tamil Nadu & Former Director, ISRO, GoI	10 February, 2021
Dr. (Mrs.) Nandhini Azad, President, Indian Co-operative Network of Women, Chennai	10 March, 2021
Mrs. Kavin Thirumurugan, Director, Sai Kirupa Group of Institutions, Tirupur	
Mrs. D. Nitya, IRS, Joint Commissioner of Income Tax, Tiruchirappalli	
Mr. P. Sridharan, Joint Commissioner of Income Tax, Tiruchirappalli	
Dr. (Mrs.) S. Kowsalya, Registrar, Avinasilingam Institute, Coimbatore	
Dr. B. Elangovan, Joint Director of Agriculture, Irrigation Management Training Institute, Tiruchirappalli	22 March, 2021
Dr. R.Sundhararaman, Principal, National College, Tiruchirappalli	26 April, 2021
Mr. S.Thirunavukkarasar, Member of Parliament, Tiruchirappalli	14 June, 2021
Mr. M. Palaniyandi, Member of Legislative Assembly, Srirangam	
DISTINGUISHED VISITORS (VIRTUAL MODE)	
Name	**Date**
Dr. A.K. Singh, Deputy Director General (Hort. Science), ICAR, New Delhi	21 August, 2021
Dr. B.K. Pandey, Assistant Director General (Hort. Science –II), ICAR, New Delhi	
Dr. S. K. Malhotra, Agriculture Commissioner, Ministry of Agriculture and Farmers' Welfare, Govt. of India	
Dr. Pawan Kumar Singh, Director, IIM, Tiruchirappalli	
Dr. M. Selvam, Vice Chancellor, Bharathidasan University, Tiruchirappalli	
Mr. Ajith Jain, Joint Managing Director, Jain Irrigation Systems Ltd.	
Dr. V. Venkatasubramanian, Director, ICAR – ATARI, Bangalore	
Dr. T. Janakiram, Vice Chancellor, Dr. YSR Horticultural University	
Mr. Karthik Jayaraman, CEO, WayCool Foods, Chennai	
Dr. B. Dayakar Rao, Principal Scientist & CEO, Nutrihub, ICAR – IIMR, Hyderabad	
Dr. P. K. Mandhyan, Principal Scientist, ICAR – CIRCOT, Mumbai	
Dr. Sudha Mysore, CEO, Agriinnovate India Ltd., New Delhi	
Mr. R. Ravindra, Deputy General Manager, APEDA, Mumbai	
Dr. C. Aswath, Principal Scientist, ICAR – IIHR, Bangalore	
Dr. K. Muralidharan, ICAR-CPCRI, Kasaragod	
Dr. Ravindra Naik, ICAR – CIAE (Regional Station), Coimbatore	
Mr. A. P. Karuppaiah, Chairman, TNBPCL	
Mr. G. Ajeethan, Managing Director, TNBPCL	
Mr. D. Anil, Commissioner of Customs	29 September, 2021
Mr. R. Chandramouli, Registrar, Sastra University, Thanjavur	16 November, 2021
Mr.J.Shenbagarajan, Education Officer, DTNBWED, Madurai	27 November, 2021

15. EMPOWERMENT OF WOMEN

International Women's Day celebrations

The ICAR-NRCB celebrated the International Women's Day on 10 March, 2021 with the theme "International Women's Day: Women Leadership in Agriculture: Entrepreneurship, Equality & Empowerment" to acknowledge the role of women in agriculture and allied sectors and honoured women achievers. Dr. (Mrs.) Nandhini Azad, President, Indian Co-operative Network of Women, Chennai was the Chief Guest of the event and Mrs. Kavin Thirumurugan, Director of Sai Kirupa Group of Institutions, Tirupur; Mrs. D. Nitya, IRS, Joint Commissioner of Income Tax, Trichy; Dr. (Mrs.) S. Kowsalya, Registrar, Avinasilingam Institute, Coimbatore; and Mr. P. Sridharan, Joint Commissioner of Income Tax, Trichy were guests of honour. On the occasion, six women achievers were felicitated for their outstanding achievements and significant contribution towards women empowerment and leadership in the society. A team of Covid warriors from the Department of Microbiology, KAPVGMC, was felicitated for its untiring and dedicated service.

Dr. S. Uma, Director, ICAR-NRCB, Chief Guest, Guests of Honour and women achievers at International Women's Day celebrations

Equipping Transgender into Agri -Entrepreneur – A Novel Initiative by ICAR-NRCB

ICAR-NRCB organized a training program titled "Equipping Transgender into Agri - Entrepreneur" with the objective of "Reaching the Un-reached". Two days, hands-on training on "Banana Based Entrepreneurial Avenues for Economic Empowerment of Transgender in Trichy District of Tamil Nadu" on 27 and 28 January, 2021. The program was attended by eight transgender trainees. Chief Guests of the program, Dr. A.K. Singh, Deputy Director General (Hort. Science), ICAR, New Delhi and Dr. B.K. Pandey, Assistant Director General (Hort. Science II), addressed the event through online mode. Drs. S. Backiyarani, D. Ramajayam, P. Suresh Kumar and C. Karpagam, Principal Scientists of the institute gave hands-on training to the participants on macro propagation, banana flower pickle, central stem juice, low-fat banana chips, ornamental banana etc. During the valedictory function, Mr. K. Natarajan, Station Director, All India Radio, Trichy, appreciated the efforts of the institute for upscaling the livelihoods of different spectrum of the society. Shri. T. K.V. Rajan, Founder-Director of Indian Science Monitor & Indo-Asian Foundation of Archaeological Research, also outlined the importance of value addition in banana being the crop selected under ODOP scheme. The program was part of the NABARD funded project of ICAR-NRCB.

Director and staff of ICAR-NRCB with transgender trainees

Mahila Kisan Diwas

ICAR–NRCB organized a women farmers' meet to celebrate "*Mahila Kisan Diwas*". The tag line for the program was "*Sashakat Mahila, Sashakat Bharat*" (Empowered Women, Empowered India). Dr. S. Uma, Director, ICAR-NRCB on her presidential address initiated the importance about the current programme. Post-harvest business opportunities in banana cultivation were explained. The importance of the current programmes and the scope for women Agri-preneurership was discussed. Around 70

women farmers were participated and benefited by the training program. In addition 140 girl students also participated in the meet.

Campaign for the students on “Women empowerment through Agripreneurship

On-campus awareness training program to women farmers

16. PERSONNEL

16.1 Staff News

Name	Event	Date
Dr. C. Karpagam, Senior Scientist	Promoted from the post of Senior Scientist to the post of Principal Scientist	w.e.f. 1 January, 2020
Dr. A. Mohanasundaram, Scientist	Joined ICAR-NRCB on transfer from ICAR - IINRG, Ranchi, Jharkhand	2 April, 2021
Ms. T. Anithasree, Senior 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. R. Sridhar, Personal Assistant	Promoted from the post of Personal Assistant to the post of Assistant Administrative Officer	w.e.f. 6 September, 2021
Mr. M. Bathrinath, Senior Technical Assistant	Promoted from the post of Senior Technical Assistant to the post of Technical Officer	w.e.f. 4 October, 2020
Mr. V. Pandiyan, Skilled Supporting Staff	Voluntary retirement from service	20 March, 2021

16.2 Staff position

Scientific Staff

S. No.	Name	Designation
1	Dr. S. Uma	Director
2	Dr. J. Poorani	Principal Scientist (Entomology)
3	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
4	Dr. R. Selvarajan	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	Scientist (Entomology)
20	Mr. Arjun Singh	Scientist (Agronomy)

Technical Staff

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

Administrative, Audits & Accounts and Supporting Staff

Sl. No.	Name	Designation
1	Mrs. 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	Mr. M. Krishnamoorthy	Private Secretary
6	Mrs. S. Durgavathy	Assistant
7	Mr. R. Neela Mega Shyamala Kannan	Steno Gr. III (on deputation to ICAR-IISR, Calicut as Personal Assistant)
8	Mrs. A.V. Suja	Upper Division Clerk
9	Mr. R. Mohanraj	Lower Division Clerk
10	Mr. V. Thangaraju	Lower Division Clerk
11	Mr. P. Kamaraj	Skilled Supporting Staff
12	Mr. V. Ganesan	Skilled Supporting Staff
13	Mrs. K. Mariammal	Skilled Supporting Staff

17. OTHER INFORMATION

Republic Day celebrations

The 72nd Republic Day was celebrated at ICAR-NRCB on 26 January, 2021 with flag hoisting and distribution of sweets by Dr. S. Uma, Director, ICAR-NRCB. Staff and students of the centre attended the event.

The staff of ICAR-NRCB attending the Republic Day celebration

World Water Day 2021 Celebrations

ICAR-NRCB celebrates World Water Day 2021 on 22 March, 2021 by organizing a lecture on 'Valuing Water for Everyone's Wellness' which was delivered by Dr. B. Elangovan, Joint Director of Agriculture, Irrigation Management Training Institute, Tiruchirappalli. Dr. S. Uma, Director, ICAR-NRCB gave introductory remarks. Welcome address and vote of thanks were delivered by Drs. V. Kumar and I. Ravi, Principal Scientists of the centre.

Independence Day celebrations

India's 75th Independence Day was celebrated on 15 August, 2021 at ICAR-NRCB. Dr. S. Uma, Director, ICAR-NRCB hoisted the National flag and delivered the Independence Day address. She called upon the staff to contribute to the initiatives of the ICAR under the 'AZADI KA AMRUT MAHOTSAV' by organising 75 National and Sector-specific campaigns, 75 lectures and 75,000 success stories of farmers across the country. The programme was attended by around 150 participants including all the staff and farmers from the nearby villages.

Independence Day celebration at ICAR-NRCB

Hindi Pakhwada

The ICAR-NRCB celebrated 'Hindi Pakhwada' during 14-29 September, 2021. As part of the celebration, 'Rajbhasha Pledge' was taken by the staff on 14 September, 2021. Competitions on essay writing, elocution, quiz competition, poem recitation and picture based hindi word competition were held during 22 – 28 September, 2021. The closing ceremony was held on 29 September, 2021. Mr. D. Anil I.R.S., Commissioner, Customs, Tiruchirappalli was the Chief Guest of the event and gave away the prizes to the winners of various competitions and addressed the staff of centre.

Prize distribution to winners of Hindi pakhwada competiions held at the centre

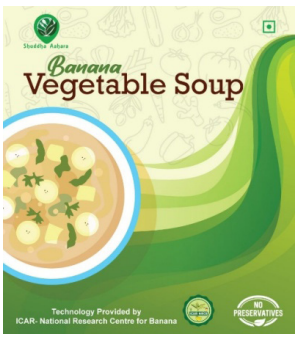
Vigilance Awareness Week celebrations

The ICAR-NRCB observed the Vigilance Awareness Week during 26 October – 1 November, 2021 under the theme "Independent India @ 75: Self Reliance with Integrity". The Director and the staff of the centre took the integrity pledge on 26 October, 2021.

18. SUCCESS STORIES

Mr. Naveen H.M, Abhay Natural Food Processing Unit, Mysore, Karnataka

Mr. Naveen is a weekend natural farmer and project manager with 15+ years of experience in investment research analytics and project management. Hailing from a village Rathanapuri near Hunsur - Mysore district, he is always passionate about Natural food, food processing, and the creation of market opportunities. During the lockdown period, he learnt a lot about Banana processing opportunities and now has become the first PMFME ODOP Banana beneficiary from Karnataka under the scheme. He has taken training and license for the production of value-added products from banana in ICAR - National Research Centre Banana (NRCB) through technology transfer. The new banana-based product line from Abhay Natural Food Processing Unit comes with the brand name "*Shuddha Aahar*".



Mr. Walter Fernando, M/s Winwal International., Chennai, Tamil Nadu

Mr. Walter Fernando is a youngster from Tirunelveli who is actively involved in the export of banana by organizing banana farmers through FPO. He has entered into the banana processing enterprise after learning the market size and volume of the processed banana food market. He has registered an office in the name of Winwal international at Chennai. The processing technology on banana flour and banana flour based weaning food was transferred to him on August, 2021 and they have incubated at ICAR - NRCB, ABI and started their production and test marketing. Mr. Walter Fernando is a youngster from Tirunelveli who is actively involved in the export of banana by organizing banana farmers through FPO. He has entered into the banana processing enterprise after learning the market size and volume of the processed banana food market. He has registered an office in the name of Winwal international at Chennai. The processing technology on banana flour and banana flour based weaning food was transferred to him on August, 2021 and they have incubated at ICAR - NRCB, ABI and started their production and test marketing.

Mrs. Achamma Thomas, M/s Trophic Biosystems, Cochin, Kerala.

M/s Trophic Biosystems is a startup company that explores new avenues in by-product utilization and it approached ICAR – NRCB for solutions on banana peel valorization. They have been trained and received the technology for extraction of cellulose and other utility compounds like pectin and hemicellulose from banana peel and sheath during July, 2021. Now they are conducting laboratory trials and scale up studies.

ANNEXURE – I

I. Institute projects

Name of the Project	Principal Investigator
Crop Improvement	
1. Improvement and management of banana genetic resources in the Indian subcontinent	S. Uma
2. Improvement of banana through conventional breeding	S. Backiyarani
3. Development of trait specific markers for *Fusarium* wilt resistance through association mapping studies in banana (*Musa* spp.)	M.S. Saraswathi
4. Improvement of cv. Grande Nain (Cavendish – AAA) for *Fusarium* wilt resistance through non-conventional breeding	M.S. Saraswathi
5. Production of doubled haploids for improvement of bananas (*Musa* spp.)	D. Ramajayam
6. Identification and evaluation of superior clones of cv. Ney Poovan (AB) and Grand Nain (AAA)	D. Ramajayam
7. 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	
8. Studies on nutrient dynamics in banana	K.J. Jeyabaskaran
9. Organic banana farming for sustainable soil health and nutritional security	K.J. Jeyabaskaran
10. Developing agro-techniques for ICAR-NRCB released varieties and selections	K.J. Jeyabaskaran
11. Development of clump management technology for enhanced productivity in banana	V. Kumar
12. Development of pre- and post-harvest techniques for leaf production in banana	K.N. Shiva
13. Developing integrated package of practices for export of selected commercial and GI tagged varieties of Indian bananas	K.N. Shiva
14. Functions of resistant starch and designer food development from banana flour	P. Suresh Kumar
15. Novel smart delivery systems for developing high value neutraceutical foods using banana and exploring non-food applications	P. Suresh Kumar
Physiology & Biochemistry	
16. 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
17. Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower	M. Mayil Vaganan
Crop Protection	
18. Pest mapping in bananas and plantains of India	J. Poorani
19. Integrated management of Tropical race 4 of *Fusarium* wilt disease in banana	R. Thangavelu
20. Survey, etiology and management of rhizome rot of banana	M. Loganathan

21. Management of postharvest diseases of banana	M. Loganathan
22. Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan
23. 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)
1. 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
2. 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
3. Development 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 \deciphering ripening dependant glycemic response and colour development of traditional banana varieties (ICAR-NASF)	P. Suresh kumar
4. Integrated management of Fusarium wilt, Tropical race 4 – A devastating strain on banana	R. Thangavelu M. Loganathan C. Anuradha S. Uma
5. 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 sponsored project	
1. 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
DBT-QUT sponsored project	
2. 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. Mayil Vaganan
Component - 2: Transfer and evaluation of Indian banana with Iron constructs	M. Mayil Vaganan I. Ravi K.J. Jeyabaskaran
DAE sponsored project	
3. Development of non-chimeral mutants with durable resistance to *Fusarium* wilt in Rasthali through induced mutagenesis	M.S. Saraswathi R. Thangavelu S. Uma S. Backiyarani
PPV & FRA sponsored project	
4. Framing crop specific DUS guidelines for banana (*Musa* spp.)	S. Uma M.S. Saraswathi S. Backiyarani
DBT sponsored consortium projects for North East India (DBT – NER)	
5. Consortium for managing Indian banana genetic resources	S. Uma M.S. Saraswathi S. Backiyarani
6. Genetic resource assessment, *in-situ* conservation and impact of banana waste as a feed for animals in NE region of India	M.S. Saraswathi S. Uma
7. Whole genome and transcriptome study to stress tolerant banana cultivars	S. Backiyarani S. Uma I. Ravi
8. Collection, evaluation, documentation and conservation of banana genetic resources from NE region	M.S. Saraswathi M. Mayil Vaganan S. Uma
9. *In vitro* mass multiplication of high value hill area bananas of the North Eastern region	M.S. Saraswathi R. Thangavelu I. Ravi
10. Diversity assessment, germplasm conservation and database development on banana resources in NE India	M.S. Saraswathi S. Backiyarani
11. Characterization of high value phyto-chemicals of anti-diabetic and immune-modulatory properties in NE banana varieties	M. Mayil Vaganan I. Ravi P. Suresh Kumar

12. Development of pre & postharvest bunch care management methods for fresh banana	P. Suresh Kumar K.N. Shiva
13. Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	P. Suresh Kumar V. Kumar K.N. Shiva
14. Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	P. Suresh Kumar K.N. Shiva
15. Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	J. Poorani S. Backiyarani
16. Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	R. Thangavelu
17. Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	R. Thangavelu M. Loganathan
18. Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system	R. Selvarajan C. Anuradha
19. Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	R. Selvarajan C. Anuradha
DST sponsored projects	
20. A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.) (DST-SERB)	C. Anuradha
21. Development of efficient IOT enabled plant disease pest detection system	R. Selvarajan R. Thangavelu
22. Cost effective dot blot TAS-ELISA based diagnostic kit for simultaneous detection of multiple banana viruses in banana plants	R. Selvarajan
23. Breaking frontiers for the improvement of plants natural defense against pathogens in Banana (*Musa* sp.) through genome mining (DST-INSPIRE)	K. Panneerselvam
24. Musa TILLING: Construction of a structured high-efficient mutant resource for functional genomics and crop improvement of banana (*Musa* spp.)	K. Panneerselvam, M.S. Saraswathi, S. Backiyarani S. Uma
25. Popularization of banana macropropagation technology in the Cauvery delta region of Tiruchirappalli district as an income generation activity for rural women self-help groups	R. Karthic S. Backiyarani M.S. Saraswathi S. Uma
DAC & F W, Govt. of India sponsored project	
26. Co-ordinated horticulture assessment & management using geoinformatics (CHAMAN-Phase-II)	K.J. Jeyabaskaran D. Ramajayam
NABARD sponsored project	
27. 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

IV. Contract research projects

Name of the Project	Funding Source	Principal Investigator
1. Evaluation of petroleum based mineral oil (GOAGBS1A0321) for the management of leaf spot disease of banana	Gulf Oil Lubricants India Limited, Maharashtra	R. Thangavelu
2. Field evaluation of paraffinic mineral oil (MAK ADJUVOL.) for the management of leaf spot *(Eumusae)* disease of banana	Bharat Petroleum Corporation Limited, Mumbai	

ANNEXURE – II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
January, 2021	29.58	22.64	82.5	142.3
February, 2021	32.64	21.75	67.7	_
March, 2021	36.0	24.0	64.8	59.4
April, 2021	38.46	28.93	61.0	4.0
May, 2021	37.87	27.46	62.8	73.5
June, 2021	37.3	27.03	57.2	165.9
July, 2021	35.48	26.22	60.29	81.6
August, 2021	35.03	26.19	63.41	134.4
September, 2021	36.06	25.6	67.46	110.6
October, 2021	32.54	25.93	78.66	273.0
November, 2021	29.33	24.7	86.8	465.6
December, 2021	30.16	22.48	78.96	23.1
Total				1533.4

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