वार्षिक प्रतिवेदन
Annual Report
2019

ICAR - NRCB

भाकृअनुप – राष्ट्रीय केला अनुसंधान केंद्र

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

(ISO 9001:2015 Certified Institute)

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(भारतीय कृषि अनुसंधान परिषद)

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ICAR-NATIONAL RESEARCH CENTRE FOR BANANA

(Indian Council of Agricultural Research)

Thayanur Post, Thogamalai Road, Tiruchirappalli - 620 102, Tamil Nadu, India

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PREFACE

The ICAR-National Research Centre for Banana, Tiruchirappalli, established in 1993, has grown into a nationally and internationally recognized centre of excellence on banana research. I take immense pleasure in presenting the Annual Report of ICAR-NRCB for the year 2019. This year, three elite selections identified and developed by the centre, Kaveri Saba, Kaveri Haritha and Kaveri Kanya, have been recommended for release as central varieties.

Significant research achievements by Crop Improvement section includes collection of 13 species of wild banana (*Musa cheesmani, M. saddlensis, M. itinerans, M.aurantiaca, M. thompsonii, M. velutina, M. flaviflora, M. rosaceae,M. manni*iand *M. nagensium*) from Arunachal Pradesh and 14 germplasm accessions from Kovvur, Coimbatore and Jalgaon; identification of promising hybrids which are resistant to Fusarium wilt race 1 and root-lesion nematode; development of a promising Nendran based hybrid, NCR 17 with stable yield; documentation of the mineral profile of 100 native *Musa* germplasm accessions; NCR-17, a Nendran based hybrid and TBM-9, a dwarf mutant line developed through mutation breeding were recommended for MLT under ICAR-AICRP (Fruits).

Significant research achievements by Crop Production section include working out of nutrient dynamics for cvs. Grand Naine and Nendran; development of clump management technology for cultivars Ney Poovan and Poovan; identification of drought tolerant cultivars suitable for different water stress regimes; development of technologies for reducing finger drop; and profiling of flavonoids and anthocyanins in banana peel and flower etc. Fruits of banana cultivars with better glycemic index were identified. In Post-Harvest management, extension of shelf-life of banana leaf and fruits was standardized. Banana flour and peel powder based products were prepared and characterized. Research on banana starch, peel flour, stem powder and fibre has led to an array of products and technologies.

In Crop Protection section, species complex of banana leaf and fruit scarring beetle was documented from different states of India. Isolates of microbial biocontrol agents effective against stem weevil were identified. Volatile compounds for use as attractants / deterrents against weevils from different banana cultivars were identified. Promising microbial isolates and their effective consortia 4 were identified against Fusarium wilt race 1 and tropical race 4 (TR4). Molecular characterization of various banana viruses was carried out. The centre also developed and validated a lateral flow immunoassay device for on-site detection of Cucumber Mosaic Virus.

During 2019, the centre successfully conducted 17 trainings and two workshops. A total of 27 research articles were published by the centre in various journals of National and International repute and 25 presentations in various National and International conferences / seminars were made by the researchers of the centre. The Centre has signed MoA's with VFPCK, Kerala and provided consultancy services towards 'Sea Shipment Protocol' for Nendran banana to European Union. Various post-harvest value added products were commercialized through training cum sale of technology. The centre has research linkages with international institutes like Alliance Bioversity International-CIAT, France, QUT, Australia, IITA-Nigeria, NARO-Uganda and more than 30 National institutes.

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, Dy. Director General (Hort. Science), ICAR, New Delhi for his inspiring and constant encouragement. Thanks are also due to Drs. W. S. Dhillon; 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 their 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 record my heartfelt thanks to all the scientists, technical, administrative and supporting staff of ICAR-NRCB for having stood by me in various institute activities. Finally, my earnest thanks to the Publication Committee for compiling and shaping this document.

(S. Uma)

2.Introduction

ICAR-National Research Centre for Banana has recently celebrated its silver jubilee year after it was established on 21st August 1993 at Tiruchirappalli, Tamil Nadu, by ICAR, New Delhi, with an aim to increase the production and productivity of bananas and plantains through mission mode basic and strategic research approaches. ICAR-NRCB has contributed immensely for the present production estimate of 30.2MT from an area of 8.47 lakh hectares keeping India in the first place in terms of production for the last three decades. 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 the city. This 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 tissueculture, biotechnology, soil science, water and nutrient management, physiology, biochemistry, entomology, nematology, fungal, bacterial, viral pathology and post-harvest technology research.

Three varieties, Kaveri Saba, Kaveri Haritha and Kaveri Kanya were recommended for release as central varieties. The centre has developed banana hybrids conferring resistance to biotic stresses like Fusarium wilt, nematodes, etc. For the first time in ICAR's history, ICAR-NRCB has successfully developed biofortified bananas with ten times higher pro-vitamin A and five times higher iron contents. For quality planting material, the centre has developed a high throughput technology of mass production using embryogenic cell suspension in bioreactors. Mutation breeding has led to the identification of putative mutants with resistance / tolerance to Fusarium wilt - Race 1 and Tropical Race 4 (TR4). The centre has also documented the mineral profile of 100 *Musa* germplasm accessions. Flavonoids, anthocyanins in banana peel and flower bracts were estimated for different cultivars. Glycemic Index was worked out for commercial banana valuables which are significant in human health point of view. More than 300 accessions have been screened for Fusarium wilt Race 1 and TR4 in hotspots of Theni, Tamil Nadu and Katihar, Bihar respectively, leading to the identification of disease resistant sources. Effective biocontrol agents were isolated, developed and are being evaluated against Fusarium wilt, race 1 and TR4 under glasshouse and hot spot conditions.

In post-harvest management, ICAR-NRCB has developed minimal processing techniques for storing banana slices for day to day marketing. Ready to serve (RTS) juice with suspended basil seeds and more than 40 technologies on value addition have been developed and ten are commercialized.

The Centre has 21in-house research projects and 31 externally funded projects funded by various agencies like ICAR, DBT, PPV& FRA, DAE, DST, Melinda Gates-Bioversity International, etc. Six contract research projects have been completed and MoA was signed with VFPCK, Kerala for export of 'Nendran' banana to Europe. The Centre periodically conducted Institute Research Council meet and Research Advisory Council meet to review the on-going research projects and also monitor the progress made on the RAC and QRT recommendations. The Quinquennial Review Team, under the Chairmanship of Dr. K.V. Peter, Former Vice-Chancellor, KAU reviewed the research activities of the Centre and recommended future research activities for sustained production and productivity of bananas in India. The 4th QRT report (2012-17) was submitted to DG, ICAR.

Vision

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

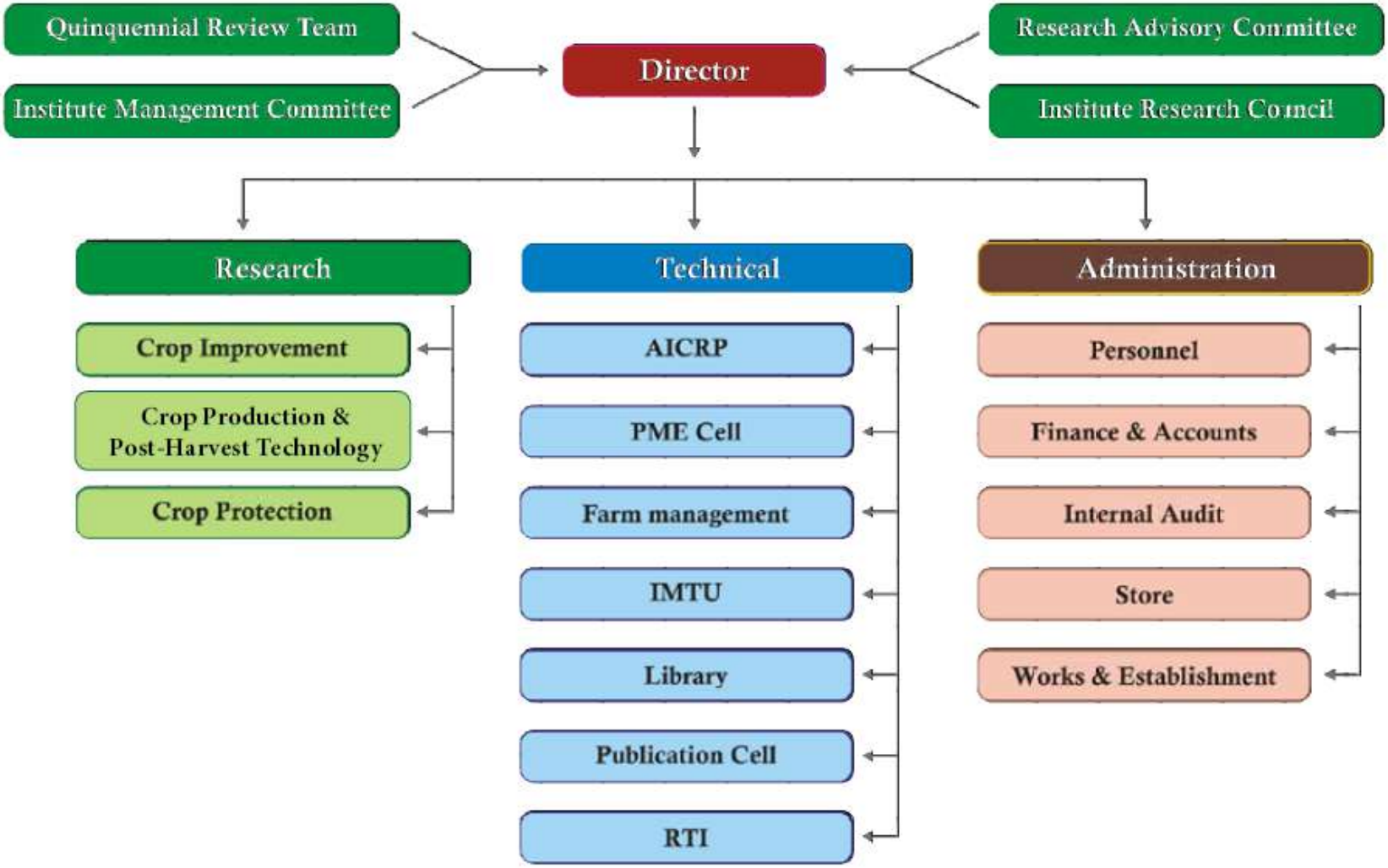
Mandate

* 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 April, 2019 – March, 2020	
Head of account	**Expenditure (Rs. in lakhs)**
Works	96.89
Equipment	39.10
Establishment	715.89
OTA	0.09
TA	13.97
Research Expenses	54.37
Operational Expenses	60.20
Infarastructre	100.85
Communication	8.05
Repir of equipment,Vehicle etc.	15.79
Office building	27.62
Residential building	0.51
Other admin.	18.09
Publicity and Exhibition	0.86
Miscelleneous Expenses	9.96
Pension and Retirement Benefits	2.70
Total	**1164.94**
SCSP-Capital	**0.00**
SCSP-General	**29.46**
Grand Total	**1194.40**

A sum of Rs. 44,27,580/- was generated by the centre during January – December, 2019.

Organizational Setup of ICAR-NRC for Banana



Crop Improvement

Explorations in Arunachal Pradesh twice covering West Kemang, East Kemang, Papumpare, Lower Dabang valley, Namsai and Changlong districts led to the collection of 13 wild *Musa* species. Totally 14 germplasm accessions were collected from secondary sources and added to the field genebank. Two dwarf Grand Naine tissue culture variants, namely GNC18 and GNE18 were identified from farmers' fields in Coimbatore and Erode districts of Tamil Nadu, respectively. Morpho-taxonomic characterization was completed for 10 accessions collected from Tripura and 124 accessions belonging to AICRP centre, Kovvur, Andhra Pradesh, using IPGRI *Musa* descriptor leading to the identification of duplicates and synonyms. DUS characterization has been completed for the dwarf mutant TBM-9 from BARC, Mumbai. Three varieties, namely Kaveri Saba, Kaveri Haritha and Kaveri Kanya were released as central varieties with DNA fingerprints.

Two open pollinated progenies, Progeny 928 and Progeny 940, produced parthernocarpic fruits. Screening of 54 progenies against Cavendish infecting Foc race 1 in the hotspot area at Muthalapuram, Tamil Nadu, resulted in the identification of one immune (progeny no. 778) and two resistant (progeny no. number 754 and 756) progenies. Hotspot and pot culture screening of Nendran based hybrids revealed high resistance to Cavendish infecting *Foc* race 1and four hybrids (NPL 30, NPL34, NPL 36 and NCR 8) were found to be resistant to *P. coffeae*. Multi-location trial on NCR 17 confirms it to be a stable yielder in different agro-climatic conditions. Effect of seed priming on *in vivo* germination of ornamental hybrid seeds revealed no significant effect of the PGR on germination. Greater variability was observed among the 422 inter-specific ornamental hybrids of *Musa* species for both quantitative and qualitative traits. One hundred diverse Indian *Musa* accessions were evaluated for variation in nine elements (Ca, K, Mg, Na, P, B, Fe, Mn, and Zn). The study revealed that Indian *Musa* collections are rich in all the four micronutrients studied besides Ca and Mg, and much lower in K and P contents. Protocol was standardized for developing multiple shoots from single embryo through direct regeneration and decortications of single *in vitro* derived plantlets. None of the 29 accessions screened for Fusarium wilt exhibited resistance, in pot culture. Genotyping of 153 germplasm accessions has been completed for 15 EST-SSRs using automated electrophoresis system.

Five putative mutants of Grand Naine derived from EMS and DES treated ECS showing resistance to Fusarium wilt, Tropical Race 4 (Foc TR4) are ready for sick plot evaluation. Out of nine mutant lines of Giant Cavendish received from BARC, Mumbai, TBM 9 alone was evaluated at three different locations using Grand Naine as local check and found promising in terms of plant height, crop duration and yield, recommended for MLT under ICAR-AICRP (Fruits).

Putative androgenic haploids of cv. Ney Poovan (20 nos.) have been developed. The germination of embryogenic calli for *in vitro* production of androgenic haploids followed by *in vitro* shooting and rooting of putative androgenic haploids were also achieved on the modified MS media. The protocol for the mass multiplication, regeneration and germination of somatic embryos using SERV(expand) has been fine-tuned and found to be highly cost efficient. Two *Bacillus* strains with PGPR activity were tested on tissue culture derived plants of cvs. Red Banana and Grand Naine for their efficacy during hardening and they not only promoted growth but also significantly increased the activity of defense related enzymes. The effect of monochromatic LEDs of different wavelengths on micropropagation of banana (*Musa* spp.) cv. Red Banana indicated that the highest percentage conversion of somatic embryos

and plantlet development were obtained under blue and red light spectrum.

Guide RNA (gRNA) was designed to identify the potential target sites in the LRR-RLP gene for CRISPR/Cas9 knockdown assay. RGA2 gene expression was studied in Foc TR4 resistant and susceptible Indian landraces. Ten SSR primers were designed in R genes present in chromosome 3 and tested in resistant and susceptible cultivars for developing gene specific markers. Out of 10 primers, a single primer 29400 showed polymorphism between resistant and susceptible cultivars.

ICAR-NRCB, Tiruchirappalli, has facilitated the filing of applications for registration of four farmers' varieties and one institute variety Kaveri Sugantham with PPV&FRA, New Delhi. Genetic fidelity testing of tissue cultured bananas of various commercial varieties was done using ISSR markers. Around 1823 tissue culture plants of Udhayam (through M/s.ShaantiAgro-Tech, Bengaluru) and 9156 suckers of other varieties were supplied to banana growers of Tamil Nadu.

Crop Production and Post Harvest Technology

Nutrient dynamics studies showed that the uptake of N increased from 24.7 and 19.1 kg/ha at 5 leaf stage to 408.3 kg/ha 380.5 kg/ha at shooting in cvs. Grand Naine and Nendran with increasing and decreasing rates, respectively. The K uptake showed a steady and sharp increase from 119 to 804 kg/ha in Grand Naine and a sigmoid increase from 93.4 to 934.4 kg/ha in Nendran from 5 leaf to shooting stage. In these cultivars, the order of micronutrient uptakes was Fe > Mn > Cu > Zn at growth stages from 5th leaf stage to shooting. In organically grown Grand Naine, FYM + neem cake + vermicompost + wood ash recorded uptakes of N-85.3, P-13.8, K-151.9, Ca-68.8 and Mg-27.6 at 10-leaf stage, which is lower than 100% inorganic fertilizers, but much higher than absolute control. At 20-leaf and shooting stages, poultry manure + groundnut cake + rural compost + wood ash combination overtook previous organic combination in nutrient uptake.

In development of clump management technology for cv. Ney Poovan, the result revealed that four side suckers per clump significantly reduced the bunch weight of mother plant compared to allowing single sucker. In Poovan, the plants under the control regime showed the earliest flowering at 317.7 days while treatment with four suckers per clump took longest time of 349.1 days.

Among ABB genotypes screened for drought tolerance, Peyan, Sakkai, Bangrier, Saba and Karpuravalli performed better based on NDVI, an indicator of plant health. Based on yield traits,*i.e.*, number of hands and fingers, Bluggoe, Octoman, Kanchikela, Ennabeniyan, Dakshinsagar performed better. Ney Poovan and Kaveri Saba were potential yielders under irrigated conditions. Bluggoe, Peyan, Kostha Bontha and Saba are the ABB genotypes found suitable for growing in water-limited environment as yield reduction was less. Ney Poovan and Kaveri Saba were found suitable for growing with 75% evaporative water demand. Evaluation of leaves for plating purpose showed that the first leaf of Karpuravalli and Kaveri Saba is very thin compared to cv. Poovan and 2nd and 3rd leaves are thicker than cv. Poovan. The NE banana genotypes like Athiakol, Karthobiumtham, Bhimkol, and Kechulepa recorded lesser reduction of chlorophyll content under drought compared to irrigation and the drought stress prolonged the flowering by 21 days in Agni Malbhog and 10 days in Kachkela.

The threshold temperature at and above which the 'green ripening' of Cavendish bananas takes place is 26^{o}C. Biochemical characterization revealed very low activity of pheophorphide *a* oxygenase (PaO) and accumulation of pheophorphides in the peel of green ripe Grand Naine bananas. Treatment of Grand Naine bananas with 6% $CaCl_2$ reduced the finger drop

by 60% and higher concentrations of $CaCl_2$ caused blackening at the pedicel zone and injury to the fruits. Among commercial cultivars, Monthan, Rasthali, Poovan, Karpooravalli and Udhayam possessed about 350 mg of flavonoids in peel. Among cultivars from the North Eastern region, Beejikela, *Musa balbisiana*, Kachkela, Chinali, Nepali Chinia and Batheesa Chiriya belonging to 'B' genome contained high quantity of flavonoids. Peel flavonoids of Monthan, Pachanandan, Nendran and Karpooravalli showed highest anti-oxidant (DPPH scavenging) activity. Profiling of individual anthocyanins in flower bracts of eight cultivars showed six anthocyanin compounds in varying proportions with predominance of one to three compounds.

Five transgenic lines of Grand Naine with 5.5 times higher iron /100 g DW in fruit pulp over the controls have been developed and their large-scale multiplication using IMFB and suckers were initiated. The glycemic index (GI) stage 5 (green at the tips) of North Eastern bananas was 15–30 lower than that of stage 6 (full yellow) and the BB genome bananas like Attikol and Bhimkol had very low GIs compared to other genome bananas. Attikol contained highest quantity of fructans with 558 mg/100 g pulp and the 'B' genome bananas (Attikol, Bhimkol, Beejikela and *M. balbisiana*) contained higher level of fructans than 'A' genome bananas.

Among the banana varieties evaluated for leaf production in Thiruchendur and Srivaigundam areas of Tuticorin dist. of Tamil Nadu, cv. Karpuravalli produced maximum number of leaves (8.87 numbers), cv. Poovan had the highest leaf area (1.12 m^2) and cvs. Sakkai and Phirima wild (0.15 mm) had thin leaves followed by cv. Poovan (0.16 mm). Maximum shelf-life of 11 days was recorded with cv. Sakkai at 13.5°C against 4 days at room temperature. Active packaging studies with Ney Poovan and Red Banana showed placing moisture remover and ethylene absorber extended shelf-life above 90 and 60 days at 13.5°C. Banana flour and peel powder based extruded product, pasta and sweetened and flavored chips were prepared and characterized. The post-harvest losses ranged between 11.03 and 38.77% in various parts of South India.

Starch with high purity of > 90 was obtained from banana varieties and their morphology, size and shape were characterized. Carbendazim and wax dipping treatment enhanced the green life of fruit of cv. Ney Poovan by 55 days over the control at 13.5 °C. Chips coated with 1% hydrocolloid CMC recorded good product quality with lower oil content. A combination of 5% banana flour, 0.6% modified starch, 0.6% peel flour along with 93% refined wheat flour was found to be good for *pizza* base. Flavonoid content was high in central core stem of Manjahaji (165.33 mg) and Kanai Bansi (155.55 QE/100 g) compared to other varieties. The highest cellulose content was found in cv. Karpuravalli (55.84%) followed by cv. Poovan (54.57%) and cv. Popoulu (52.47%). Low sugars, fibre-rich cookies using cv. Nendran center core stem powder, basil seed suspended ready-to-drink banana juice, personal hygienic products from banana fibre, disposable plates form leaf, bio-plates from leaf sheath and biodegradable bio-plastic from fruit peel were developed.

Crop Protection

Basilepta subcostata (Jacoby), *Bhamoina varipes* (Jacoby), and *Sphaeroderma cruenta* Prathapan & Kumari were recorded as leaf and fruit feeders of banana in north and northeastern India and *B. viridipennis* (Motschulsky) was proved to be an erroneous record for banana. *B. subcostata* specimens collected from Karnataka and Deccan were studied, indicating the need for constant surveillance in peninsular India. Populations of *B. subcostata* from Bihar, West Bengal, Assam, Meghalaya, Uttar Pradesh, Odisha and Manipur, belonged to a single morpho-species and were characterized by COI sequencing. *Canna indica*, turmeric, ginger, and taro

were alternate hosts of *B. subcostata* in Assam and Meghalaya. Activity of cuticle degrading enzymes such as chitinase, lipase and protease in promising isolates of *Beauveria bassiana* [0271, 079, 0028(A), 0032, 0086, 0018 and 0043 broths] was tested *in vitro* against stem weevil and the mortality was 81.13–100.0, 76.64–98.35 and 77.68–98.55, respectively. Three isolates of *Akanthomyces lecanii* (0086, 0187, 0297) caused total mortality of *Pentalonia nigronervosa in vitro* on the third day. From 10 cultivars belonging to various genomic groups, 90 volatile compounds including 57 insect attractants and 33 deterrents / anti-microbial compounds were identified.

Surveys in farmers' fields in Tamil Nadu showed root-knot nematode (*Meloidogyne* sp.) was the predominant plant nematode associated with cvs. Red Banana and Nendran whereas, spiral nematode (*Helicotylenchus* sp.) was abundant in root samples of cv. Poovan. Spiral nematode (*Helicotylenchus multicinctus*) and burrowing nematode (*Radopholus similis*) were abundant in root samples of *Musa ornata* and *M. laterita* at ICAR-NRCB farm. Foliar application of salicylic acid at 100 and 200µM concentration in pot culture reduced the reproduction of *M. incognita* as the number of females and juveniles inside the root were reduced by 60-80% over inoculated control.

Rhizome rot incidence on tissue cultured cv. Grand Naine was found to be 2–15% in Madhya Pradesh, Maharashtra, Gujarat, Uttar Pradesh and Bihar. Totally 60 isolates of rhizome rot pathogen were collected and characterized as *Pectobacterium* sp., *Achromobacter* sp., and *Klebsiella* sp. based on cultural characteristics on CVP and 16s rDNA sequencing. A rhizome rot bioassay unit was developed for completing the assay within 10-20 days.

Among 25 microbial isolates evaluated for growth promotion in cv. Grand Naine in glass house conditions, H4 BC1, H6 BC3, H7 BC2 and H8BC1 showed significantly high plant height and girth. Two promising isolates, BCB 2-4 and BCNA5-3, were characterized by 16s rDNA sequencing. Presence of VCGs 01220 and 0125 was detected in 13 Fusarium (Foc) isolates belonging to Foc race-1 in Grand Naine, Monthan and Rasthali and VCG 01213/16 (TR4) was observed in Grand Naine collected from Uttar Pradesh and Bihar. Foc isolates from cv. Grand Naine (Surat) were confirmed as belonging to VCG 01220 and 0125 of Foc race 1 and confirmed by molecular analysis using specific markers. Foc infected samples collected from Kerala (5 nos.) and Tamil Nadu (5 nos.) were identified as Foc race 1 belonging to VCG 0124. Efforts were made to develop a farmer-friendly mass production protocol by solid-state fermentation for *Trichoderma asperellum* (Prr2), identified as most effective in inhibiting *in vitro* mycelial growth of Foc TR4. Farmyard manure was found to be the best organic substrate for colonizing *T. asperellum* (Prr2) and the shelf-life of the formulation was high (11.60 $\log_{10}$ CFU g^{-1}) after two months of storage. Fifty-five potential phosphate solubilizing bacteria (PSB) were isolated from rhizospheric soil of 12 germplasm accessions and studied *in vitro,* of which PSB27 (6.21), PSB39 (5.36), PSB45 (5.36), PSB52 (5.27) and PSB54 (5.37) recorded highest phosphate solubilization index. PSB52 and PSB54 were identified by 16SrRNA analysis as *Enterobacter hormaechei*s sp. *xiangfangensis* and *Leclercia adecarboxylata,* respectively.

Banana bract mosaic virus (BBrMV) was recorded for the first time in Hill banana at Lower Pulney Hills, Tamil Nadu and in Pisang Madu from ITC collections. Cucumber mosaic virus (CMV) incidence was recorded in more than one million NCS-TCP certified TC banana plants and it was upto 16% in Burhanpur (Madhya Pradesh). Totally 43 diploid germplasm accessions (AA and BB) were screened for banana bunchy top virus (BBTV) resistance of which 13 AA diploids expressed typical symptoms but BB diploids were asymptomatic even after three consecutive inoculations. *Musa flaviflora*

and *M. burmannicoides* Type AP also were infected by BBTV. Primers were designed to construct a full-length infectious cDNA clone of BBrMV using Gibson Assembly (GA), using a one-step isothermal *in vitro* recombination reaction. In another approach, primers were designed for amplifying a full-length construct of BBrMV by an overlapping-extension PCR (OE-PCR) to produce infectious cDNA of BBrMV. Nanopore sequencer (MinION device) was used to detect and characterize BBTV from cv. Poovan (AAB) including asymptomatic samples and the copy number could be enriched by RCA method. The whole genome sequences obtained were more accurate with >99 % homology when compared to reference sequences. A field experiment was renewed by replanting suckers of asymptomatic cv. Poovan extracted from a permanent, 13-year-old experimental trial during 2018 and banana streak mysore virus (BSMYV) induced streak symptoms were expressed in 17 plants. Preliminary field evaluation data on endogenous BSMYV free, elite TC derived cv. Poovan plants showed significant differences in the growth and yield parameters compared to sucker grown plants.

Transfer of Technology

Around 7500 visitors including farmers, agriculture and horticulture officers, entrepreneurs, students and other stakeholders visited ICAR-NRCB and were explained about institutes' activities / technologies. Seven radio talks and 35 press notes in various dailies and magazines were published by ICAR-NRCB. The institute participated / organized seven exhibitions at State / National levels and a total of seventeen on-campus and two off-campus trainings were conducted to farmers and entrepreneurs. Two workshops were conducted by the centre. The institute signed MoA with VFPCK, Kerala for export of 'Nendran' fruits to Europe.

Linkages and Collaborations

ICAR–NRCB has research collaborations with International institutes which include IITA, Nigeria; Bioversity International, France; KUL, Belgium; University of Queensland, Australia. The institute has linkages with National institutes, namely, BARC, Mumbai; DST and DBT, New Delhi; APEDA; TNAU, Coimbatore; NIT, Tiruchirapalli and KNCET, Thottiyam, Tamil Nadu. The centre has research collaborations with other ICAR institutes namely, ICAR–NBPGR, New Delhi; ICAR–IIHR, Bengaluru, ICAR–CIAE (RS), Coimbatore. Under DBT-NER, more than 50 institutes located in different parts of the country are being associated with ICAR-NRCB. ICAR–NRCB also coordinates with ICAR-AICRP (Fruits) centers (11 nos.) working on banana. 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 a total of eight training programs were attended by the scientists of the centre. More than 25 seminars / conferences / symposia / workshops / meets were attended by the scientists and technical staff of the center at Regional / National / International levels. The centre has published 27 research papers in various journals of International and National repute and 25 research papers were presented in various conferences / symposia / seminars, etc. held across the country. Twenty students are pursuing B. Tech., M. Tech., M. Sc., Ph. D. and post doctoral research at the centre.

Revenue Generated

A sum of Rs. 44,27,580/- was generated by the centre during January – December, 2019.

कार्यकारी सारांश

फसल सुधार

गत वर्ष दो बार अरुणाचल प्रदेश में पश्चिम केमांग, पूर्वी केमांग, पापम्पारे, लोअर दबाअंग घाटी, नामसाई और चांगलोंग जिलों में भ्रमण करते हुए 13 जंगली मूसा प्रजातियों का संग्रह किया गया। कुल 14 जनन्द्रव्य, द्वितीयक स्रोतों से एकत्र किए गए तथा फील्ड जीनबैंक में जोड़े गए। दो बौने ग्रैंड नाइने टिशू कल्चर प्रकार, GNC18 और GNE18 क्रमशः तमिलनाडु के कोयंबटूर और इरोड जिलों में किसानों के खेतों से चिन्हित किये गए हैं। इपग्री मूसा डिस्क्रिप्टर का उपयोग करते हुए त्रिपुरा से एकत्रित 10 जनन्द्रव्य और अ.भा.समन्वित परियोजना केंद्र कोव्वुर, आंध्र प्रदेश से लिए गए 124 जनन्द्रव्य के लिए मॉर्फो–टैक्सोनोमिक लक्षण वर्णन पूरा किया गया तथा डुप्लिकेटस (प्रतिरूपों) की पहचान की गयी। BARC, मुंबई से प्राप्त बौने उत्परिवर्ती TBM-9 के लिए कै लक्षण वर्णन पूरा किया गया है। तीन किस्मों; कावेरी सबा, कावेरी हरीथा और कावेरी कन्या को डीएनए फिंगरप्रिंट चिन्हीकरण के साथ केंद्रीय किस्मों के रूप में जारी करने की सिफारिश की गई है।

दो खुली परागित संततियों, प्रोजेनी 928 और प्रोजेनी 940 में अनिबेक फलन (पार्थेनोकार्पी) के द्वारा फल विकास पाया गया। तमिलनाडु के मुथलापुरम में हॉटस्पॉट क्षेत्र में 54 संततियों की कैवेंडिश ऍफ ओ सी रेस 1 के खिलाफ स्क्रीनिंग के परिणामस्वरूप एक प्रतिरक्षित (इम्यून) (संतान संख्या 778) और दो प्रतिरोधी (संतान संख्या 754 और 756) संततियों की पहचान की गयी। हॉटस्पॉट और पॉट कल्चर स्क्रीनिंग में नेंद्रण आधारित संकरों की कैवेंडिश ऍफ ओ सी रेस 1 के खिलाफ उच्च प्रतिरोधकता का पता चला है तथा चार संकर (NPL 30, NPL 34, NPL 36 और NCR 8), *P. coffeae* निमेटोड के लिए प्रतिरोधी पाए गये। बहु–स्थानिक परीक्षण के द्वारा एनसीआर 17 के विभिन्न कृषि–जलवायु परिस्थितियों में एक स्थिर जीनरूप होने की पुष्टि की गयी। सजावटी संकर केलों के बीजों पर बीज प्राइमिंग के द्वारा इन–विवो अंकुरण पर पीजीआर का कोई महत्वपूर्ण प्रभाव नहीं पाया गया। मात्रात्मक और गुणात्मक लक्षणों, दोनों के लिए मूसा की प्रजातियों के 422 अंतर–विशिष्ट सजावटी संकरों के बीच बृहद विभिन्नता देखी गई। नौ तत्वों (Ca, K, Mg, Na, P, B, Fe, Mn और Zn) में भिन्नता के लिए भारतीय मूसा के एक सौ विविध परिद्रव्यों का मूल्यांकन किया गया। इस अध्ययन से पता चला कि भारतीय मूसा संग्रह, Ca और Mg के साथ साथ अध्ययन किए गए अन्य सूक्ष्म पोषक तत्वों से समृद्ध है जबकि उनमें K और P की मात्रा बहुत कम पायी गयी। एकल भ्रूण से कई शूट विकसित करने के लिए प्रत्यक्ष पुनर्जनन व एकल इन–विट्रो व्युत्पन्न पौधों में डीकार्टीकेशन विधि के प्रोटोकोल को मानकीकृत किया गया है। फुसैरियम विल्ट के प्रति प्रतिरोधकता गमला परीक्षण में 29 जनन्द्रव्यों में से कोई भी प्रतिरोधी नहीं पाया गया। स्वचालित इलेक्ट्रोफोरेसिस प्रणाली का उपयोग करते हुए 15 ईएसटी–एसएसआर चिन्हकों के लिए 153 जर्मप्लाज्म एक्सेस का जीनोटाइपिंग पूरा किया गया है।

ईएमएस और डीईएस म्युटेंट द्वारा शोधित किए गए ग्रैंड नाइने किस्म के पांच कल्पित (प्यूटेटिव) म्यूटेंट ईसीएस के द्वारा फ्यूसेरियम विल्ट ट्रापिकल रेस 4 के प्रति प्रतिरोधकता का प्रदर्शन किया गया तथा वह सिक–प्लाट प्रक्षेत्र मूल्यांकन के लिए तैयार पाए गए हैं। BARC, मुंबई से प्राप्त जायंट कैवेंडिश की नौ उत्परिवर्ती लाइनों में से, टीबीएम 9 का तीन अलग–अलग स्थानों पर मूल्यांकन किया गया, जिसमें ग्रैंड नाइन का उपयोग स्थानीय जांच (लोकल चेक) के रूप में किया गया। टीबीएम 9 को पौधे की ऊंचाई, फसल की अवधि और उपज के संदर्भ में आशाप्रद पाया गया तथा इसके आईसीएआर–एआईसीआरपी के अंतर्गत बहु–स्थानिक परीक्षण के लिए सिफारिश की गई।

'नेय पोवन'' में प्यूटेटिव एंड्रोजेनिक हैप्लोइड्स (20 नग) विकसित किए गए हैं। एंड्रोजेनिक हैप्लोइड्स के इन विट्रो उत्पादन के लिए भ्रूण जन्य कैलाइ का अंकुरण तथा तत्पश्चात इन प्यूटेटिव एंड्रोजेनिक हैप्लोयड्स में इन विट्रो शूटिंग और रूटिंग को भी संशोधित एमएस मीडिया पर हासिल किया गया। SERV का उपयोग करके दैहिक भ्रूणों के बड़ी संख्या में बहुगुणन, उत्थान और अंकुरण के लिए प्रोटोकॉल को विकसित किया गया है और अत्यधिक लागत कुशल पाया गया है। पीजीपीआर गतिविधि से लैस दो बेसिलस उपभेदों का किस्मों रेड बनाना और ग्रैंड नाइन के टिशू कल्चर व्युत्पन्न पौधों पर उनके सख्तीकरण (हार्डेनिंग) प्रभावकारिता के लिए के लिए परीक्षण किया गया तथा यह पाया गया कि उन्होंने न केवल विकास को बढ़ावा दिया, बल्कि रक्षा संबंधी एंजाइमों की गतिविधि में भी काफी वृद्धि की। मूसा एसपीपी किस्म रेड बनाना के माइक्रोप्रोपागेशन पर विभिन्न तरंग दैर्ध्य के मोनोक्रोमैटिक एलईडी प्रकाश के प्रभाव का अध्ययन किया गया तथा यह पाया गया कि नीले और लाल प्रकाश स्पेक्ट्रम के तहत दैहिक भ्रूण रूपांतरण और पौधों के विकास का उच्चतम प्रतिशत प्राप्त किया गया।

गाइड RNA (gRNA) को LRR-RLP जीन में संभावित लक्ष्य स्थलों की पहचान कर CRISPR / Cas9 नॉकडाउन ऐसे के लिए डिजाइन किया गया। RGA2 जीन अभिव्यक्ति का अध्ययन Foc TR4 प्रतिरोधी और अतिसंवेदनशील भारतीय लैंडरेसेस में किया गया। दस एसएसआर प्राइमरों को क्रोमोसोम 3 में मौजूद R जीन के लिए डिजाइन किया गया और जीन विशिष्ट मार्करों को विकसित करने के लिए प्रतिरोधी और अतिसंवेदनशील किस्मों में इनका परीक्षण किया गया। इन 10 प्राइमरों में से एक एकल प्राइमर 29400 ने प्रतिरोधी और अतिसंवेदनशील जीनरुपों के बीच विभिन्नता प्रदर्शित की।

भा. कृ. अनु. प. – राष्ट्रीय केला अनुसंधान केंद्र, तिरुचिरापल्ली ने चार किसानों की किस्मों और एक संस्थान की किस्म कावेरी सुगन्थम के पंजीकरण के लिए पीपीवी और एफआरए, नई दिल्ली के पास आवेदन करने में सहायता प्रदान की है। ISSR मार्करों का उपयोग करके विभिन्न व्यावसायिक किस्मों के केले के ऊतक संवर्धन की आनुवंशिक निष्ठा का परीक्षण किया गया तथा लगभग 1823 टिशू कल्चर प्लांट्स (मैसर्स शांतीआग्रो–टेक, बेंगलुरु के माध्यम से) और 9156 अन्य किस्मों के सकर्स तमिलनाडु के केले उत्पादकों को दिए गए।

फसल उत्पादन और तुड़ाई उपरांत (पोस्ट हार्वेस्ट) प्रौद्योगिकी

पोषण गतिकीय अध्ययनों से पता चला है कि नत्रजन का अपशोषण 24.7 और 19.1 किलोग्राम / हेक्टेयर से बढ़कर 5 लीफ स्टेज पर

408.3 किलोग्राम / हेक्टेयर 380.5 किलोग्राम / हेक्टेयर तना वृद्धि के दौरान क्रमशः बढ़ती और घटती दरों के साथ केले कि किस्मों ग्रैंड नाइन और नेंड्रान में होता है। K uptake ने किस्म ग्रैंड नाइन में 119 से 804 किग्रा / हेक्टेयर तक स्थिर और तेज वृद्धि दिखाई और किस्म नेंद्रण में 5 पत्ती से शूटिंग चरण तक 93.4 से 934.4 किग्रा / हेक्टेयर की वृद्धि हुई। इन किस्मों में 5 वीं पत्ती अवस्था से लेकर शूटिंग तक सूक्ष्म चरणों में माइक्रोन्यूट्रिएंट अपटेक का घटता हुआ क्रम Fe > Mn > Cu > Zn था। ऑर्गेनिक रूप (FYM, नीम केक, वर्मीकम्पोस्ट, वुड ऐश) में उगाए गए ग्रैंड नाइन, में विभिन्न पोषक तत्वों का अपशोषण जैसे N-85.3, P-13.8, K-151.9, Ca-68.8 और Mg-27-6 आदि 10–लीफ स्टेज पर दर्ज किया गया, जो कि 100% इनआर्गेनिक खेती से कम है लेकिन ''कंट्रोल'' की तुलना में बहुत अधिक है। 20–पत्ती और शूटिंग चरणों में, पोल्ट्री खाद. मूंगफली केक. ग्रामीण खाद. लकड़ी राख संयोजन, पोषक तत्व अपशोषणमें पिछले जैविक संयोजन से आगे पाये गए।

नेय पूवन में क्लंप प्रबंधन प्रौद्योगिकी के विकास के लिए किये अध्ययन के परिणाम से पता चला है कि एकल भूस्तारी की तुलना में चार पार्श्व भूस्तारी प्रति क्लंप ने मात्र पौधे गुच्छे के वजन को काफी कम कर दिया। पूवन में, कंट्रोल के अंतर्गत सबसे पहले 317.7 दिनों में फूल दिखाई दिए, जबकि चार पार्श्व भूस्तारी प्रति क्लंप में 349.1 दिनों का सबसे अधिक समय लगा।

एबीबी जीनोटाइप की सूखा सहिष्णुता के लिए जांच की गई पेयन, सक्काई, बैंगरियर, सबा और कर्पूरवल्ली ने एनडीवीआई के आधार पर, जो कि पौध स्वास्थ्य का एक संकेतक है, बेहतर प्रदर्शन किया। उपज से जुड़े गुणों जैसे उप–गुच्छों एवं केलों की संख्या के आधार पर ब्लग्गो, ऑक्टोमन, कांचीकेला, एनाबेनियन, दक्षिणसागर ने बेहतर प्रदर्शन किया। सिंचित परिस्थितियों में नेय पोवन और कावेरी सबा को बेहतर पाया गया। सीमित–जल वाले वातावरण में ब्लग्गो, पेयन, कोस्टोन्था और सबा जैसे एबीबी जीनोटाइप उपज में हुई कम कमी के कारण उगाने के लिए उपर्युक्त पाए गये। नेय पोवन और कावेरी सबा को 75% बाष्पीकरणीय जल मांग वाले वातावरण में बढ़ने के लिए उपयुक्त पाया गया। रोपण के उद्देश्य के लिए पत्तियों के मूल्यांकन से पता चला कि कर्पूरवल्ली और कावेरी सबा का पहला पत्ता किस्म पूवन की तुलना में बहुत पतला है जबकि दूसरी और तीसरी पत्तियां पूवन से मोटी पायी गयीं। उत्तरी पूर्वी केले के जीनोटाइप्स जैसे अथियाकोल, कार्थोबियमथम, भीमकोल, और केचुलेपा ने सूखे के तहत सिंचाई वाले वातावरण में क्लोरोफिल की मात्रा में कम कमी दर्ज की और सूखे की परिस्थिति में पुष्पन कि अवधि अग्नि मालभोग में 21 दिन और कच्केला में 10 दिन तक बढ़ गई।

कैवेंडिश केले के ''ग्रीन– राइपनिंग' के लिए तापमान कि ऊपरी सीमा रेखा 26ºC पायी गयी। हरे रंग के पके ग्रैंड नाइन केले के छिलके में बायोकेमिकल परीक्षण ने फियोफोरबाइड अल्फा ओक्सीजेनेस (PaO) की बहुत कम सक्रीयता और फियोफोरबाइड के संचय का खुलासा किया। ग्रांड नाइन केले में 6% $CaCl_2$ के उपचार द्वारा ''फिंगर –डॉप'' में 60% की गिरावट दर्ज की गई जबकि $CaCl_2$ की उच्च सांद्रता से फल के पेडिसेल जोन पर काला धब्बा पड़ गया और फलों को क्षति पहुंची। वाणिज्यिक किस्मों जैसे मोंथन, रस्थली, पूवन, कर्पूरवल्ली और उधयम के छिलके में 350 मिलीग्राम फ्लेवोनॉयड्स पाए गये। उत्तर पूर्वी क्षेत्र कि 'बी' जीनोम से संबंधित किस्मों जैसे बीजीकेला, मूसा बालबिसियाना, काचकेला, चिनाली, नेपाली चिनिया और बाथेसा चिरिया फ्लेवोनाइडस की उच्च मात्रा दर्ज की गयी। मोंथन, पचानंदन, नेंड्रान और कर्पूरवल्ली के छिलकों के फ्लेवोनोइड्स में सबसे अधिक एंटी–ऑक्सीडेंट (डीपीपीएच स्केवेंजिंग) गतिविधि देखी गई। आठ किस्मों के फूलों में अलग–अलग एंथोसायनिन के परीक्षण में अलग–अलग अनुपात में छह एंथोसायनिन यौगिक दिखाई दिए जिनमें एक से तीन यौगिकों की प्रबलता देखी गयी।

ग्रैंड नाइन की पांच ट्रांसजेनिक लाइनें विकसित की गई हैं जिनके गूदे में नियंत्रण की तुलना में 5.5 गुना अधिक आयरन / 100 ग्राम डीडब्ल्यू पाया गया और आईएमएफबी तथा भूस्तारी का उपयोग करके बड़े पैमाने पर बहुगुणन शुरू किया गया। उत्तर पूर्वी केले में 5वें चरण (युक्तियों पर हरा) में ग्लाइसेमिक इंडेक्स (जीआई) चरण 6 (पूर्ण पीला) की तुलना में 15–30 बिंदु कम था और बीबी जीनोम के केले जैसे अतीकोल और भीमकोल में अन्य जीनोम के केलों की तुलना में बहुत कम जीआई पाया गया। अतीकोल के गूदे में फ्रुक्टेन की उच्चतम मात्रा 558 mg / 100 g पायी गयी तथा यह देखा गया कि बी जीनोम के केलों (अतिकोल, भीमकोल, बीजीकेला, और मूसा बल्बिसियाना) में ' A 'जीनोम केले की तुलना में फ्रुक्टेन की अधिक मात्रा होती है।

तमिलनाडु के तूतीकोरिन जिले के थिरुचेंदुर और श्रीविगुंडम क्षेत्रों में पत्ता उत्पादन के लिए केले की किस्मों का मूल्यांकन किया गया। किस्म कर्पूरवल्ली ने अधिकतम पत्तियों (8.87 संख्या) का उत्पादन किया। पूवन में सबसे अधिक पत्ती क्षेत्र (1.12 मी 2) और सककाई और फिरिमा जंगली प्रजातियों पतले पत्ते (0.15 मिमी) पाए गये जो कि पूवन (0.16 मिमी) से थोड़े अधिक पतले थे। 13.5ºC तापमान पर 11 दिनों की अधिकतम शैल्फ–लाइफ को किस्म सककाई में रिकॉर्ड किया गया था जो कमरे के सामान्य तापमान पर 4 दिनों कि अवधि के तुलना में अधिक थी। नेय पूवन और रेड बनाना में किये पैकेजिंग अध्ययनों ने नमी हटाने वाले पदार्थ और एथिलीन अवशोषक को 13.5ºC पर शेल्फ–लाइफ को 90– 60 दिनों के ऊपर विस्तारित करते हुए पाया गया। केले का आटा और छिलका पाउडर पर आधारित उत्पाद जैसे पास्ता और मीठे और सुगंधित चिप्स तैयार किए गए और उनके गुणों का अध्ययन किया गया। दक्षिण भारत के विभिन्न हिस्सों में तुड़ाई उपरांत नुकसान 11.03 और 38.77% के बीच दर्ज किया गया।

केले की किस्मों से > 90 की उच्च शुद्धता वाले स्टार्च को प्राप्त किया गया और उनके आकारिकी, आकार और प्रकार की जांच की गयी। कार्बेन्डाजिम और वैक्स डिपिंग उपचार ने सीवी नेय पोवन में फल के ग्रीन लाइफ को 13.5ºC कंट्रोल की तुलना में 55 दिनों तक बढ़ाया। 1% हाइड्रोकार्बन सीएमसी के साथ लेपित चिप्स ने कम तेल अवशेष के साथ उत्पाद की अच्छी गुणवत्ता दर्ज की। पिज्जा बेस के लिए 5% केले का आटा, 0.6% संशोधित स्टार्च, 0.6% छिलके के साथ 93% परिष्कृत गेहूं के आटे का संयोजन अच्छा पाया गया। अन्य किस्मों की तुलना में मंझाजी (165.33 मिलीग्राम) और कनाई बंसी (155.55 क्यू ई / 100 ग्राम) के केंद्रीय कोर स्टेम में फ्लेवोनोइड की अधिक मात्रा दर्ज की गयी। किस्म कर्पूरवल्ली (55.84%) में सेल्यूलोज की उच्चतम मात्रा पायी गयी जो कि पूवन (54.57%) और पॉपुलु (52.47%) से अधिक थी। किस्म नेंद्रण में केंद्र कोर स्टेम पाउडर का उपयोग करके कम शर्करा, फाइबर युक्त कुकीज, तथा तुलसी के बीज युक्त केला जूस, केला फाइबर से व्यक्तिगत स्वच्छता उत्पाद, पत्तों से डिस्पोजेबल प्लेट्स,

लीफ शीथ से बायो–प्लेट्स और फलों के छिलके से बायोडिग्रेडेबल बायो–प्लास्टिक को विकसित किया गया।

फसल सुरक्षा

उत्तर और उत्तरपूर्वी भारत में बेसिलेप्टा सबकोस्टाटा (जैकोबी), भमोइना वार्प्स (जेकोबी), और स्पैरोडर्मा क्रूता प्रतापन और कुमारी को केले के पत्ते और फलों के भक्षक के रूप में दर्ज किया गया था और बी. विरिडिपनिस (मोत्स्कुलस्की) केले के लिए एक भक्षक के रूप में गलत दर्ज पाया गया। कर्नाटक और डेक्कन से एकत्र किए गए बी. सबकोस्टाटा नमूनों का अध्ययन किया गया था, जो प्रायद्वीपीय भारत में निरंतर निगरानी की आवश्यकता को दर्शाता है। बिहार, पश्चिम बंगाल, असम, मेघालय, उत्तर प्रदेश, ओडिशा और मणिपुर से बी. सबकोस्टाटा की आबादी, एक एकल मोर्फो–प्रजाति की थी और सीओआई सीक्वेंसिंग के द्वारा उनकी विशेषता का अध्ययन किया गया। असम और मेघालय में केन्ना इंडिका, हल्दी, अदरक, और तारो बी. सबकोस्टाटा के वैकल्पिक होस्ट के रूप में देखे गये। बेवेरिया बासियाना [0271, 079, 0028 (ए), 0032, 0086, 0018 और 0043 ब्रोथ्स, के संभावनाशील आइसोलेट्स में चिटिनास, लाइपेस और प्रोटीएज जैसे क्यूटिकल अपघर्षक एंजाइमों की गतिविधि का स्टेम वेविल के खिलाफ इन विट्रो परीक्षण किया गया था और मृत्यु दर को क्रमश% 81.13–100.0, 76.64–98.35 और 77. 68–98.55 दर्ज किया गया। अकॉंटोमीस लेकेनी के तीन आइसोलेट्स (0086, 0187, 0297) ने पैंटलोनिया निग्रोनोर्वोसा के विरूद्ध इन विट्रो परीक्षणों में तीसरे दिन पैंटलोनिया निग्रोनोर्वोसा की मृत्यु रिकार्ड की। विभिन्न जीनोमिक समूहों से संबंधित 10 कल्टीवार में, 90 वाष्पशील यौगिकों सहित 57 कीट आकर्षित करने वाले और 33 निवारक (डितेरेंट) / एंटी–माइक्रोबियल यौगिकों की पहचान की गई।

तमिलनाडु में किसानों के खेतों में सर्वेक्षण से पता चला कि रूट–नॉट नेमाटोड (सूत्रकृमी) (*Meloidogyne* sp.) सीवी रेड बनाना और नेंड्रान से जुड़ा प्रमुख पौध नेमाटोड था, जबकि सर्पिल नेमाटोड (हेलिकोटिलीनचस एसपी) सीवी पूवन के जड़ के नमूनों में प्रचुर मात्रा में पाया गया। आईसीएआर–एनआरसीबी फार्म में मूसा ओरनाटा और एम. परिटा के जड़ों के नमूनों में सर्पिल नेमाटोड (हेलिकोटाइलेनसस मल्टिक्टेनस) और बरोइंग नेमाटोड (राडोफोलस सिमिलिस) प्रचुर मात्रा में पाए गये। गमला परीक्षणों में 100 और 200 µM सान्द्रता में सैलिसिलिक एसिड के पर्ण छिड़काव ने एम. इनकाग्निता के प्रजनन को कम कर दिया क्योंकि जड़ के अंदर मादाओं और जुवेनाइल सूत्रक्रिमियों की संख्या में 60–80% तक कमी दर्ज की गयी।

मध्यप्रदेश, महाराष्ट्र, गुजरात, उत्तर प्रदेश और बिहार में ग्रांड नाईन के ऊतक संवर्धित पौधों पर राइजोम सड़न (राईजोम रौट) बीमारी का 2–15% तक प्रकोप पाया गया। कुल 60 अलग–अलग राइजोम सड़न रोगजनकों को एकत्र किया गया और उन्हें सीवीपी और 16 तक्छ। सीक्वेंसिंग के आधार पर पेक्टोबैक्टीरियम एसपी, अक्रोमोबैक्टेर एसपी और क्लेबसिएला एसपी के रूप में चिन्हित किया गया। राइजोम सड़न की भीतरी परख को 10–20 दिनों में पूरा करने के लिए एक जैवपरख इकाई विकसित की गई है।

किस्म ग्रांड नाईन में शारीरिक विकास को बढ़ावा देने के लिए 25 माइक्रोबियल आइसोलेट्स का ग्लास हाउस की स्थितियों में मूल्यांकन किया गया, एच 4 बीसी 1, एच 6 बीसी 3, एच 7 बीसी 2 और एच 8 बी 1 ने पौधे की ऊंचाई और मोटाई में बढ़ोत्तरी प्रदर्शित की। दो होनहार आइसोलेट्स, BCB 2–4 और BCNA5–3, 16 rDNA सीक्वेंसिंग द्वारा चिन्हित किये गये हैं। वनस्पति अनुकूलता समूह (VCGs) 01220 और 0125 की उपस्थिति को ग्रैंड नाइन, मोंथन और रस्तली में Foc रेस –1 से संबंधित 13 फ्यूसेरियम (Foc) आईसोलेट्स में ढूँढा गया और VCG 01213ध16 (TR4) को उत्तर प्रदेश और बिहार से एकत्रित ग्रैंड नाइन में देखा गया। ग्रैंड नाइन (सूरत) से अलग Foc आइसोलेट्स की पहचान Foc रेस 1 के वीसीजी 01220 और 0125 के रूप में की गई और इसकी पुष्टि आणविक विश्लेषण द्वारा अन्य मार्करों का उपयोग करके की गई। केरल (5 नग) और तमिलनाडु (5 नग) से एकत्र किए गए Foc संक्रमित नमूने, वीसीजी 0124 Foc रेस 1 से संबंधित नमूनोंके रूप में पहचाने गए। ट्राइकोडर्मा एस्परेलम (Prr2), जिसे Foc TR4 के इन विट्रो कवक विकास को बाधित करने में सबसे प्रभावी कारक के रूप में पहचाना गया है, के बड़े पैमाने पर कृषक–अनुकूल उत्पादन प्रोटोकॉल विकसित करने का प्रयास किया गया है। टी. एस्परेलम (Prr2) के वृद्धिकरण के लिए फार्मयार्ड खाद को सबसे अच्छा जैविक सब्सट्रेट पाया गया और दो महीने के भंडारण के बाद फॉर्मूलेशन की उच्च शेल्फ–जीवन (11.60 log10 CFU g–1) दर्ज की गयी। पैंसठ संभावनाशील फॉस्फेट सॉल्युबलाइजिंग बैक्टीरिया (PSB) को 12 जर्मप्लाज्म एक्सेस के राइजोस्फेरिक मिट्टी से अलग कर इन विट्रो में अध्ययन किया गया, इनमे से PSB27 (6.21), PSB39 (5.36), PSB 45 (5.36), PSB 52 (5.27) और PSB 54 (5.37) ने उच्चतम फॉस्फेट घुलनशीलता सूचकांक दर्ज किया। PSB 52 और PSB 54 की पहचान 16 एसआरआरएनए विश्लेषण द्वारा क्रमशः एंटरोबैक्टर हॉर्मोशेफ एसपी जिआन्फेन्गेन्सिस और लेक्लेसेरिया एडेकार्बॉक्सील्टा के रूप में की गई।

हिल बनाना में तमिलनाडु के लोअर पलनी हिल्स और पिसंग माडू में ITC कलेक्शन में पहली बार केले के बनाना ब्रक्ट मोजेक वायरस (BBrMV) को रिकॉर्ड किया गया। ककड़ी मोजेक वायरस (सीएमवी) की उपस्थिति एक मिलियन से अधिक एनसीएस–टीसीपी प्रमाणित टीसी केले के पौधों में दर्ज की गई और यह बुरहानपुर (मध्य प्रदेश) में 16% तक थी। केले के बनाना बंची टॉप वायरस (बीबीटीवी) प्रतिरोधकता परीक्षण के लिए कुल 43 द्विगुणित जर्मप्लाज्म एक्सेशंस (एए और बीबी) की जांच की गई, जिसमें से 13 एए द्विगुणितों ने लक्षण व्यक्त किए, लेकिन लगातार तीन बार संक्रमण करवाने के बाद भी बीबी डिप्लॉयड्स लक्षणों से विहीन थे। मूसा फ्लेविफ्लोरा और एम. बर्मननिकाइड्स टाइप एपी भी बीबीटीवी से संक्रमित पाए गये। गिब्सन असेंबली (जीए) का प्रयोग बीबीआरएमवी के एक पूर्ण लंबाई के संक्रामक सीडीएनए क्लोन का निर्माण इन विट्रो पुनर्संयोजन प्रतिक्रिया में एक–चरण आइसोथर्मल का उपयोग करते हुए प्राइमर को डिजाइन करने में किया गया। एक अन्य विधि में, प्राइमरों को बीबीएमएमवी के संक्रामक सीडीएनए का उत्पादन करने के लिए एक ओवर्लेपिंग–एक्सटेंशन पीसीआर (ओई–पीसीआर) द्वारा बीबीआरएमवी की एक पूरी लंबाई के बहुगुणन के लिए प्राइमर को डिजाइन किया गया है। पूवन (AAB) केले तथा कुछ लक्षणविहीन नमूनों में नैनोपोर सीक्वेंसर (मिनियन डिवाइस) का उपयोग बीबीटीवी का पता लगाने और उसकी लक्षण जांच लिए किया गया और प्रतिलिपि संख्या RCA विधि द्वारा बढ़ायी गयी। संदर्भ जीनोम अनुक्रमों की तुलना में प्राप्त किये गये पूरे जीनोम अनुक्रम > 99% होमोलॉजी के साथ अधिक सटीक पाए गये। एक

स्थायी 13 वर्ष पुराने प्रायोगिक परीक्षण से निकाले गये लक्षणविहीन पूवन के भूस्तारी के पुनर्रोपण द्वारा 2018 के दौरान एक क्षेत्र प्रयोग नवीनीकृत किया गया, तथा 17 पौधों में बनाना स्ट्रीक मायसोर वायरस (बीएसएमवाईवी) प्रेरित लकीर लक्षण व्यक्त पाये गए। प्रारंभिक क्षेत्र मूल्यांकन में अंतर्जात BSMYV मुक्त, एलीट टिश्यु कल्चर व्युत्पन्न पोवन पौधों की वृद्धि और उपज मानकों में भूस्तारी जनित पौधों कि तुलना में महत्वपूर्ण अंतर रिकार्ड किया गया।

प्रौद्योगिकी हस्तांतरण

किसानों, कृषि और बागवानी अधिकारियों, उद्यमियों, छात्रों और अन्य हितधारकों सहित लगभग 7500 आगंतुकों ने आईसीएआर–एनआरसीबी का दौरा किया और उन्हें संस्थान की गतिविधियों / प्रौद्योगिकियों के बारे में जानकारी दी गयी। इसके साथ ही सात रेडियो वार्ता और पैंतीस प्रेस नोट विभिन्न दैनिक समाचार पत्रों और पत्रिकाओं में आईसीएआर–एनआरसीबी द्वारा प्रकाशित किए गए हैं। संस्थान ने राज्य / राष्ट्रीय स्तर पर सात प्रदर्शनियों में भाग लिया / आयोजित किया और कुल सत्रह ऑन–कैंपस और दो ऑफ–कैंपस प्रशिक्षण किसानों और उद्यमियों के लिए आयोजित किये। केंद्र द्वारा दो कार्यशालाओं का भी आयोजन किया गया। संस्थान ने नेंद्रण केलों के यूरोप को निर्यात करने के लिए VFPCK, केरल के साथ सहमति पत्र पर हस्ताक्षर किए।

संपर्क और सहयोग

भा. कृ. अनु. प.– राष्ट्रीय केला अनुसंधान संस्थान, तिरुचिरापल्ली ने विभिन्न अंतर्राष्ट्रीय संस्थानों के साथ अनुसंधान सहयोग किया है जिसमें IITA, नाइजीरिया; बायोवार्सिटी इंटरनेशनल, फ्रांस; KUL, बेल्जियम; क्वींसलैंड विश्वविद्याल;, ऑस्ट्रेलिया शामिल हैं। संस्थान का विभिन्न राष्ट्रीय संस्थानों जैसे BARC, मुंबई; डीएसटी और डीबीटी, एपीडा, नई दिल्लीय TNAU, कोयंबटूर; एनआईटी, तिरुचिरापल्ली और केएनसीईटी, थोटियाम, तमिलनाडु के साथ सहयोग और संबंध हैं। इस केंद्र का अन्य आईसीएआर संस्थानों, आईसीएआर–एनबीपीजीआर, नई दिल्ली; ICAR-IIHR, बेंगलुरु, ICAR-CIAE (RS), कोयंबटूर के साथ अनुसंधान सहयोग है। DBT-NER के तहत, देश के विभिन्न हिस्सों में स्थित 50 से अधिक संस्थानों को भा. कृ. अनु. प.– राष्ट्रीय केला अनुसंधान संस्थान, तिरुचिरापल्ली के साथ जोड़ा जा रहा है। यह संस्थान केले पर काम करने वाले ICAR-AICRP (फल) के 11 केंद्रों के साथ भी समन्वय में काम करता है। केले के बड़े पैमाने पर प्रसार, किसान, निर्यातक, राज्य बागवानी और कृषि विभागों और स्वयं सहायता समूहों में शामिल ऊतक संवर्धन उद्योग भी विभिन्न अनुसंधान और विकासात्मक गतिविधियों के लिए इस केंद्र से जुड़े हुए हैं।

मानव संसाधन विकास और शिक्षा

मानव संसाधन विकास के तहत केंद्र के वैज्ञानिकों ने कुल आठ प्रशिक्षण कार्यक्रमों में भाग लिया। केंद्र के वैज्ञानिकों और तकनीकी कर्मचारियों द्वारा क्षेत्रीय / राष्ट्रीय / अंतर्राष्ट्रीय स्तर पर 25 से अधिक सेमिनारों / सम्मेलनों / संगोष्ठियों / कार्यशालाओं / बैठकों में भाग लिया गया। केंद्र ने अंतर्राष्ट्रीय और राष्ट्रीय ख्याति की विभिन्न पत्रिकाओं में 27 शोध पत्र प्रकाशित किए हैं और 25 शोध पत्र देश भर में आयोजित विभिन्न सम्मेलनों / संगोष्ठियों / सेमिनारों आदि में प्रस्तुत किए गए हैं। वर्तमान में भा. कृ. अनु. प.– राष्ट्रीय केला अनुसंधान संस्थान में बीस छात्र B.Tech., M.Tech., M.Sc., Ph.D. और पोस्ट डॉक्टोरल शोध कर रहे हैं।

राजस्व उत्पादन

जनवरी – दिसंबर, 2019 के दौरान केंद्र द्वारा 44,27,580 रुपये की राशि राजस्व के रूप में पैदा की गयी है।

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

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

Collection

During the reporting period, explorations were made in Arunachal Pradesh twice covering West Kemang, East Kemang, Papumpare, Lower Dabang valley, Namsai and Changlong districts of Arunachal Pradesh leading to the collection of 13 wild *Musa* species (Table 1).

Total of 14 germplasm accessions have been collected from the secondary sources BRS, Kovvur, Andhra Pradesh, HC&RI, TNAU, Coimbatore, Tamil Nadu and BRS, Jalgaon, Maharashtra and established at ICAR-NRCB, Tiruchirappalli (Table 2).

Table 1. Details of collections made during the exploration in Arunachal Pradesh

S. No.	Name	Place of collection
1	*Musa cheesmanii*	Mayodia, Roing & Potin
2	*Musa saddlensis*	Mayodia, Roing & Ziro
3	*Musa itinerans*	Kebali, Roing & Yajali
4	*Musa aurantiaca*	Yedhuli, Roing & Yachuli
5	*Musa thompsonii*	Kebali, Roing
6	*Musa velutina*	Yedhuli, Roing & Phasighat
7	*Musa velutina* variant	Yedhuli, Roing &Phasighat
8	*Musa velutina*	Yedhuli, Roing
9	*Musa flaviflora*	Mekha, Roing
10	*Musa thompsonii*	Mekha, Roing
11	*Musa rosaceae*	Ziro
12	*Musa mannii*	Changlong
13	*Musa nagensium*	Changlong

Table 2. Details of germplasm accessions collected from secondary sources

S.No.	Name	Place of collection	Probable genome
1.	Suganthi	BRS, Kovvur	AAB
2.	MC 94-02	BRS, Kovvur	BB
3.	Sonkela	BRS, Kovvur	AAB
4.	H-531	BRS, Kovvur	AAB
5.	Poyo	BRS, Kovvur	AAA
6.	*Musa balbisiana*	BRS, Kovvur	BB
7.	Simla	BRS, Kovvur	BB
8.	Valery	BRS, Kovvur	AAA
9.	MC 93-02	BRS, Kovvur	BB
10.	CO-2	TNAU, CBE	AAB
11.	H-531	TNAU, CBE	Not known
12.	H 97/7-4	TNAU, CBE	Not known
13.	NPH-02-01-5	TNAU, CBE	AAB
14.	Phule Pride	BRS, Jalgaon, Maharashtra	AAA

Characterization

Morpho-taxonomic characterization has been completed for 10 banana accessions collected from Tripura (Table 3) using IPGRI *Musa* descriptor leading to the identification of duplicates and synonyms. The agronomic characters have also been recorded (Table 4).

Table 3. Morpho-taxonomic characterization of Tripura collections

S.No.	Name	Identified genome	Sub group and type
1	Mizocavendish	AAA	Unique –Amritsagar
2	Wild	Wild	Not flowered
3	Kanchikela - I	ABB	Monthan
4	Kanchikela -II	ABB	Monthan –Pacha Bontha Batheesa
5	Kanchikela - III	ABB	Bluggoe - Bangrier
6	Kanai Bansi	AA	Unique
7	Sabri	AAB	Not flowered
8	Gopikela	ABB	Pisang Awak type
9	Wild	Wild	*Musa flaviflora* - type
10	Wild		Not flowered

Table 4. Evaluation of growth and yield parameters under Tripura collections

S. No.	Name	Height (cm)	Girth (cm)	No. of leaves at shooting	Duration	Bunch weight (Kg)	No. of hands	No. of fruits/ hand	Total no. of fruits
1	Mizo Cavendish	230.5	62.5	14.2	368.5	12.5	6.2	16.2	86.8
2	Wild	280.5	68.5	18.5	480.5	15.5	7.3	16.2	129.5
3	Kanchikela – I	265.5	64.5	16.2	362.8	20.3	8.1	16.4	136.2
4	Kanchikela -II	258.5	62.5	15.5	369.5	29.5	22.2	18.2	404.2
5	Kanchikela – III	265.0	64.2	16.5	368.0	15.5	6.2	14.5	88.2
6	Kanai Bansi	165.5	50.2	13.0	240.5	3.5	4.2	16.2	68.5
7	Sabri	263.4	60.5	14.2	398.5	7.5	7.0	15.2	112.5
8	Gopikela	280.6	70-5	15.5	410.0	12.5	9.5	16.0	170.0
9	Wild (*M.flaviflora*)	210.0	52.0	12.0	330.0	4.5	5.0	12.0	64.0
10	Wild	310.0	67.0	15.0	460.5	13.5	9.0	15.0	125.0

Morpho-taxonomic characterization has been completed for 124 banana accessions belonging to different genomes. DUS characterization has been completed for the dwarf mutant TBM-9 from BARC, Mumbai (Table 5).

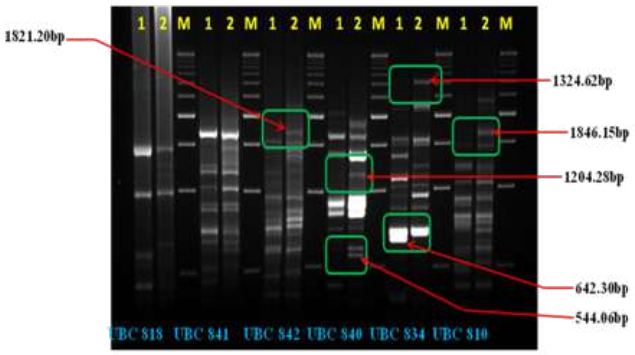
Table 5. DUS characterization of TBM-9, a dwarf mutant of Giant Cavendish from BARC, Mumbai

S.No.	Characters	TBM-9	Grand Naine
1.	Plant height	150 – 160cm	200 - 220cm
2.	Pseudostem blotches	Brown blotches	No blotches
3.	Leaf orientation	Erect	Leaves are spreading
4.	Internodal space	10-12cm	15-20cm
5.	Peduncle nature	Hairy with 40-50cm long	Hairy with 70-80cm long
6.	Bunch shape	Cylindrical	Cylindrical/truncated cone in shape
7.	Bunch size	Medium with 8-9 hands	Big with 10-12 hands
8.	Bract persistence	Completely covered by the persistent male flowers and bracts	Barren just below the bunch and terminal portion is covered by the persistent male flowers and bracts
9.	Fruit color upon ripening	Matured fruits are green and turned yellow upon ripening	Matured fruits are green and turned yellow upon ripening
10.	Fruit taste	Pulp is cream and sweet in taste	Pulp is cream and sweet in taste.

Molecular characterization - DNA fingerprinting of newly released banana varieties

DNA fingerprints have been developed for the newly released varieties Kaveri Saba, Kaveri Haritha and Kaveri Kanya using ISSR markers and the variety specific bands produced by individual primers have been documented. This will facilitate in the registration of new varieties with PPV&FRA, New Delhi and protect our varieties in the context of IPR issues.

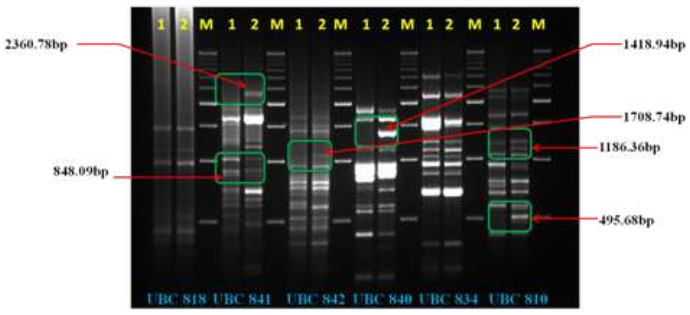
DNA fingerprinting for Kaveri Kanya vs Monthan (ISSR markers)



Lane 1: KaveriKanya; Lane 2: Monthan
M: 500bp marker

Fig.1.DNA fingerprinting of Kaveri Kanya

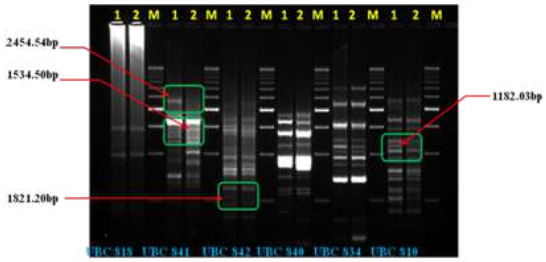
DNA fingerprinting for Kaveri Haritha vs Monthan (ISSR markers)



Lane 1: Kaveri Haritha; Lane 2: Bangrier
M: 500bp marker

Fig.2.DNA fingerprinting of Kaveri Haritha

DNA fingerprinting for Kaveri Saba vs Monthan (ISSR markers)



Lane 1: Kaveri Saba; Lane 2: Monthan
M: 500bp marker

Fig.3.DNA fingerprinting of Kaveri Saba

Registration

ICAR-NRCB, Tiruchirappalli has facilitated in filing the application for registration of four farmers' varieties and one institute variety Kaveri Sugantham with PPV&FRA, New Delhi. IC numbers have been obtained for three ICAR-AICRP (Fruits) centres namely BRS, Kannara (6 nos.), BRS, Kovvur (5 nos.) and TNAU, Coimbatore (1 no.).

Evaluation of TBM-9, a dwarf mutant of Giant Cavendish from BARC, Mumbai

Out of nine mutant lines of Giant Cavendish along with control received from BARC, Mumbai, line nos. 9 and 12 which were found to be promising in the preliminary evaluation. So they were further evaluated at Theni, Tamil Nadu using Grand Naine as check. Results indicated that the average plant height was only 1.55m with a crop duration of 322 days. The average yield recorded was 22.3 as against 26.8 kgs in control. However, the yield could be compensated by accommodating 25% more plants as against local check. This has been recommended for MLT under ICAR-AICRP (Fruits).

Fig.4. Field view of TBM-9 at Theni, Tamil Nadu

Sick plot screening of the 259 germplasm accessions at Theni, Tamil Nadu for Fusarium wilt resistance (race 1) has been completed for the ratoon crop. 124 exotic accessions from ITC have been planted in the sick plot at Muthalapuram, Theni, Tamil Nadu for screening against Fusarium wilt resistance.

Establishment of new field genebank for indigenous and ITC accessions

New field gene bank has been established with 371 accessions of indigenous origin which includes the newly released varieties of ICAR-NRCB, Tiruchirappalli. A separate block has been established with 124 ITC accessions and complete set of growth and yield parameters have been recorded for 65 accessions.

Evaluation of elite cooking bananas

Eight elite lines of ABB cooking bananas were evaluated for the performance of ratoon crop. The plant height was above 3.0m in all the accessions tested. The robust stature with a pseudostem girth of > 75 cm was observed in Ash Monthan, Bainsa, Kothia and Cuba. The bunch weight was found promising (> 25 kgs) in Ashy Batheesa, Pacha Bontha Batheesa and Kothia. The crop duration did not exceed one year in any of the accessions. (Table 6).

Table 6. Evaluation of cooking bananas (ratoon) for growth and yield parameters

Variety	Pseudostem height (cm)	Pseu-dostem girth (cm)	No. of leaves at shooting	Bunch weight (kg)	No. of hands	No. of fingers/ hand	Days for taken shooting	Days taken for fruit matura-tion	Crop duration
Ash Monthan	356.4±0.25	80.6±0.40	18.2±0.20	22.6±0.40	7.6±0.25	13.6±0.25	245.2±0.50	95.4±0.24	340.2±0.58
Ashy Bath-eesa	340.6±0.25	74.4±0.24	18.4±0.24	25.2±0.20	19.4±0.24	17.4±0.24	250.6±0.40	105±0.31	355.6±0.68
Pacha Bontha Batheesa	338.4±0.24	71.4±0.51	17.6±0.25	27.4±0.40	17.6±0.25	17.4±0.25	248.2±0.37	104.6±0.40	352.8±0.37
Bainsa	364.4±0.25	78.2±0.58	17.8±0.50	24.6±0.24	8.8±0.20	14.8±0.20	260.2±0.20	102±0.31	362.2±0.38
Nutepong	321.2±049	73.4±0.24	17.6±0.24	22.4±0.25	7.4±0.24	14.2±0.20	258.2±0.58	104.2±0.37	362.4±0.75
Kachkel	368.2±0.37	73.6±0.24	18.6±0.25	24.6±0.51	8.8±0.20	15.4±0.24	268.2±0.20	105±0.31	373.2±0.20
Kothia	330.2±0.37	77.6±0.24	18.6±0.25	25.4±0.40	10.8±0.20	16.4±0.24	259.2±0.37	102±0.32	361.2±0.58
Cuba	298.4±0.40	76.2±0.20	16.8±0.37	21±0.32	9.6±0.24	15±0.32	268.2±0.58	106±0.63	374.2±0.97
CD(0.05)	1.025	0.937	0.883	0.808	0.631	0.67	1.136	1.111	1.75

Table 7. Evaluation of promising lines for growth and yield parameters at ICAR-NRCB, Tiruchirappalli

Variety	Height(cm)	Girth	No. of leaves at shooting	Days taken for shoot-ing	Days taken for fruit maturation	Duration	Bunch weight	No. of hands	No. of fruits/hand	Total no. of fruits
Popoulu	254.4±3.86	62.8±1.99	14.0±0.31	266.4±0.98	84.4±0.87	350.8±1.77	10.6±1.06	6.2±0.49	11.6±0.51	68.2±4.07
Grand Naine Dwarf	188±3.45	57.6±0.98	10.2±0.37	270.0±0.83	95.2±0.86	365.2±1.39	16.0±0.54	7.8±0.37	15.4±0.40	122.6±3.67
Amrit Sagar	243.8±4.36	60.8±0.58	13.2±0.37	260.6±2.88	92.6±1.12	353.2±2.99	10.4±0.75	5.2±0.20	13.4±0.51	68.8±2.89
FHIA -01	198±3.87	52±1.14	9.4±0.40	269.8±1.80	103.6±1.69	373.4±2.62	11±0.44	7.8±0.20	14.4±0.24	114.6±2.23
Cuba	303.0±7.01	74.0±2.30	12.6±0.40	271.6±2.23	96.0±1.55	367.6±3.06	18.9±0.58	8.2±0.37	15.4±0.24	128.4±6.15
Ash Mon-than	354.8±4.36	70.6±1.29	15.2±0.37	256.2±3.17	109.4±2.23	365.6±3.81	22.2±0.56	7.4±0.24	15.4±0.24	116.2±5.09
Kaveri Kalki	233.8±2.15	89.4±1.21	15.4±0.24	246.8±2.64	117.4±0.87	364.2±2.91	18.3±0.34	13.6±0.24	18.0±0.31	248.2±6.21
CD(0.05)	13.62	3.76	1.07	6.19	4.06	7.29	1.97	0.91	1.12	12.68

Evaluation of promising lines of ICAR-NRCB, Tiruchirappalli

Preliminary evaluation indicated the superior performance of the following 21 accessions which included newly released varieties from the centre, selections, superior ITC accessions, choice varieties of northern eastern India and newly developed Nendran based hybrids. The planting materials of the abovesaid accessions were multiplied and further evaluated to confirm their superior traits like, short duration, dwarf stature, high yield , fragrance of the fruit, unique taste etc. Out of the 21 accessions included in this trial, the main crop has been completed only eight accessions which are presented in the table 7.

The growth and yield parameters especially plant height, crop duration and yield of the eight lines harvested were promising and stable without any significant variations as obtained during the preliminary evaluation trials.

Evaluation of tissue cultured bananas derived from different explants of cv. Ney Poovan

Cv. Ney Poovan derived from different explants namely shoot tip, male flower bud, cormlet, ECS and macropropagation have been planted in the

farmer's field and regular observations on vegetative parameters have been recorded and the crop is in shooting stage.

Cost efficient next generation plant tissue culture system

The protocol for the mass multiplication, regeneration and germination of somatic embryos using Somatic Embryo Regeneration Vessel (SERV) has been fine tuned and its cost efficiency has been worked out. Results indicated that multiplication of shoots in a temporary immersion type bioreactor was significantly higher (2.6-fold) than semisolid culture system. For large scale production of multiple shoots, six aseptic shoot cluster (six numbers) cultured using 250 ml of culture medium produced about 1408 - 1620 shoots per explant at the end of the 6th subculture in 122 days. Chlorophyll a, b, carotenoid content, stomatal index and number of closed stomata were examined to determine the physiology of plants grown in bioreactor and semisolid culture system and both were found to be at par with each other.

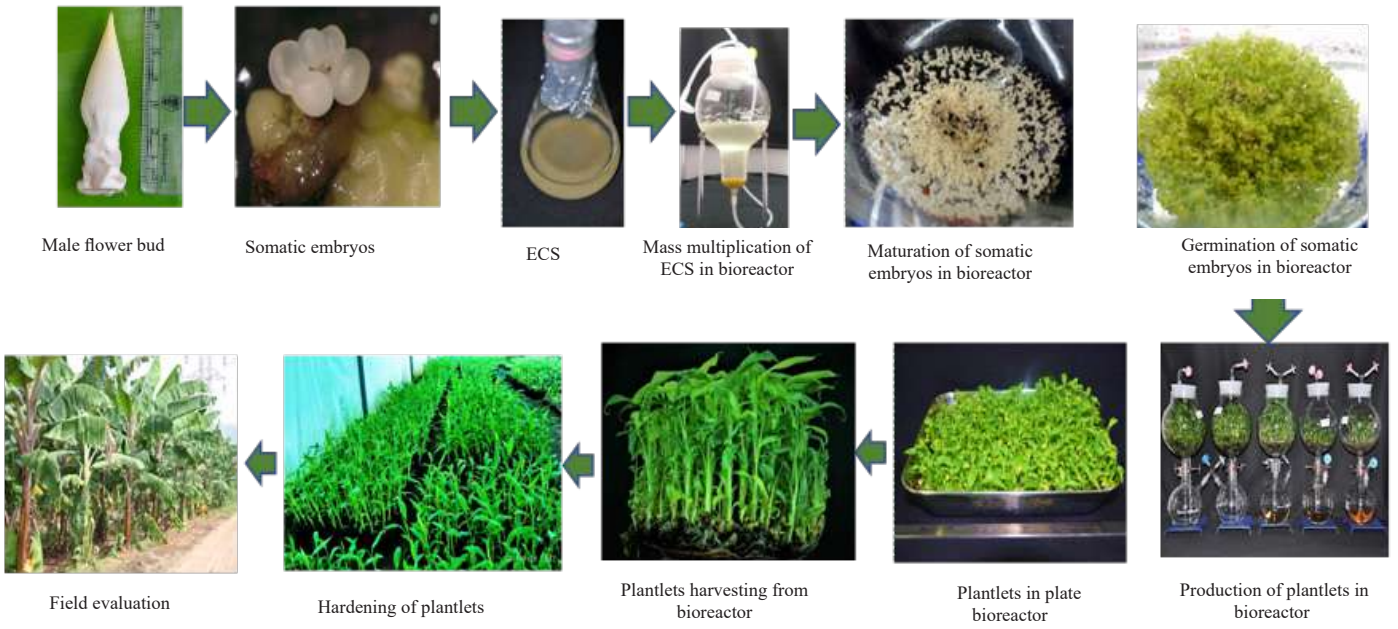


Fig. 5. Next generation tissue culture system in banana

Effect of PGPRs on bio-hardening of tissue cultured bananas of cv. Red Banana and Grand Naine

Two *Bacillus* strains with PGPR activity from Plant Pathology lab were tested for their efficacy in bio-hardening of tissue culture plants of cvs. Red Banana and Grand Naine. In both cultivars, the maximum plant height, girth and number of leaves were obtained in *Bacillus* II (T_2) followed by *Bacillus* I (T_1) and control. While the plants treated with *Bacillus* I showed a larger root complex with more branches and secondary roots than the uninoculated plants. PGPRs also enhanced the chlorophyll, carotenoid and phenol content but the response was better in cv. Grand Naine than Red banana. Increase in the synthesis of catalase, was also one of the significant responses after treatment of tissue cultured plants with *Bacillus* I and II under glass house conditions. This enzyme protects the cell organelles and tissues from oxidative damage by ROS and thereby enhancing disease resistance. PGPR treatment also significantly increased the activity of defense related enzymes like peroxidase and polyphenol oxidase.

Fig. 6. Effect of *Bacillus* spp. on the root growth parameters of cvs. Red Banana and Grand Naine

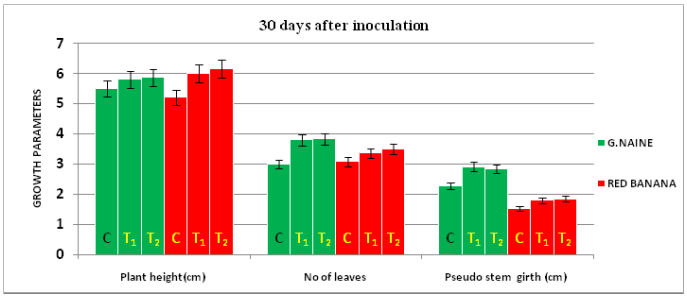


Fig. 7. Effect of *Bacillus* spp. on growth and development of banana cvs. Grand Naine and Red Banana

Studies on the effect of LEDs of different wavelengths on micropropagation of banana (*Musa* spp.)

The effect of monochromatic LEDs of different wavelengths namely white (380–750 nm), red (610–700nm), green (495–570 nm), blue (450–495 nm) and yellow (570-590 nm) on micropropagation of banana (*Musa* spp.) was investigated. The highest percentage conversion of somatic embryos and plantlet development was obtained under blue and red light spectrum. In contrast, green light produced the minimum conversion of somatic embryos compared to white fluorescent light indicating their inhibitory effect on *in vitro* growth and development. Significant differences were observed in number of roots per shoot and their root length grown under different wavelengths of lights.

Table 8. Effect of different wavelengths of light on conversion of somatic embryos, its morphological characteristics, shoot and root length of ECS derived plants in cv. Red Banana

Colour of LEDs	Germination %	Morphological characteristics of somatic embryos	Shoot length (cm)	Root length (cm)
White	45.8±0.73	Green	4.9±0.60	5.7±0.63
Red	58.8±0.97	light green	6.0±0.67	6.8±0.58
Blue	62.0±0.70	Green	4.7±0.30	4.1±0.45
Green	41.4±0.92	White	6.4±0.50	6.2±0.38
Yellow	52.4±0.81	Green	5.4±0.22	5.2±0.47

Fig. 8 Culture rack fitted with LEDs of different wavelengths

Fig. 9 Effect of LEDs of different wavelengths on somatic embryo regeneration and germination

Supply of planting material

Around 1823 plants of Udhayam and 9156 suckers of other varieties have been supplied to banana growers of various districts of Tamil Nadu.

Genetic diversity in fruit pulp mineral profile of Indian *Musa* Collections

Evaluation of 100 diverse Indian *Musa* accessions representing six diverse genomic groups *viz.*, AA (2 genotypes), BB (2), AB (6), AAA (7), AAB (47) and ABB (36), maintained in the Research Farm field plots of the ICAR-NRCB were investigated for variation in nine elemental (Ca, K, Mg, Na, P, B, Fe, Mn, and Zn) concentrations in their fresh fruit pulp using inductively coupled plasma optical emission spectroscopy (ICP-OES). The study revealed substantial genetic variability for all the mineral concentrations with several fold variations ranging from 4.7-fold for K & Mg to 111.1-fold for Ca among genotypes (Fig.10). Among the elements analyzed, calcium showed the largest variation among genotypes from 31.7±3.5 mg kg–1 to 3523±12.5 (mean 529.9±75.8 mg kg–1) followed by Fe, ranging between 0.82±0.1 mg kg–1 and 41.28±0.4 mg kg–1 (mean 8.19±0.99 mg kg–1). The fruit pulp concentration of K (mean 627.0±41.5 mg kg–1) and Mg (309.9±21.5 mg kg–1) showed least variation (range 241.1±32.6-1134.3±153.4 and 158.0±21.1-749.2±112.4 mg kg–1, respectively). The mean content of nine elements in descending order is K>Ca>Na>Mg>Fe>Mn>B>P>Zn, which is fairly low therefore, banana by itself is unlikely to be able to contribute significantly to the recommended dietary allowance (RDA) requirements at the present normal consumption levels. Only either highly or moderately positively skewed distribution was observed for all the minerals, and none of the fruit pulp minerals showed either symmetric or negatively skewed distribution (Fig.11). Thus, the number of genotypes with low mineral contents is more and widely distributed across the genomic groups at a very high frequency. Calcium and Fe showed the largest heritability values (97 and 96%, respectively) while Zn exhibited lowest heritability of 85%. Pearson's Correlation Coefficient test revealed significant positive association for all pulp nutrient concentrations (Table 9). However the correlations between Ca-Mg, Ca-Na, Mg-Na, and Mn-Zn, recorded relatively high correlation coefficients among the analyzed Musa accessions. Path analysis revealed that Mg had maximum direct effect on Fe content followed by Mn, Zn and Na. The principal component analysis (Fig.12 & 13) and cluster analysis (Fig.14) results based on nutritional profile revealed a high variation among the Indian *Musa* accessions and fail to classify them according to their nutrient contents/ genome/ploidy levels. This indicated the involvement of only a few ancestral species (mostly A and B genome) in the evolution of most Indian bananas combined with vegetative propagation and uncontrolled spread of planting material across the country over a long period of time. Interestingly one dozen accessions such as Alpon, Chinia, Dwarf Cavendish, Eathen, Grand Naine, Malbhog, Ney Poovan, Pachanadan, Peyan, Poovan, Rajapuri and Sirumalai which were cultivated commercially in different parts of India are placed in the list of top 10 accessions selected based on their fruit pulp nutrient contents. Also, the comparison between the fruit pulp mineral concentrations obtained in this study and the concentration reported in the literatures revealed that Indian *Musa* collections are highly richer in all the four micronutrients studied besides Ca & Mg, and much lower in K and P contents.

Table 9. Pearson's Correlation Coefficient test for fruit pulp mineral contents in 100 Indian banana accessions

gcv	Boron	Calcium	Iron	Magnesium	Manganese	Potassium	Zink	Sodium
Ca	0.256****							
Fe	-0.070^{NS}	0.211***						
Mg	0.226****	0.774****	0.456****					
Mn	0.011^{NS}	0.340****	0.479****	0.561****				
K	0.125*	0.070^{NS}	0.003^{NS}	0.183***	0.041^{NS}			
Zn	-0.016^{NS}	0.351****	0.336****	0.499****	0.506****	-0.052^{NS}		
Na	0.103^{NS}	0.506****	0.207***	0.568****	0.194***	0.385****	0.168**	
P	-0.088^{NS}	-0.144**	0.067^{NS}	-0.013NS	0.226****	0.233****	0.022^{NS}	0.108^{NS}

Asterisks indicate significance at *P<0.05, **P<0.01, ***P<0.001 and ****P<0.0001.

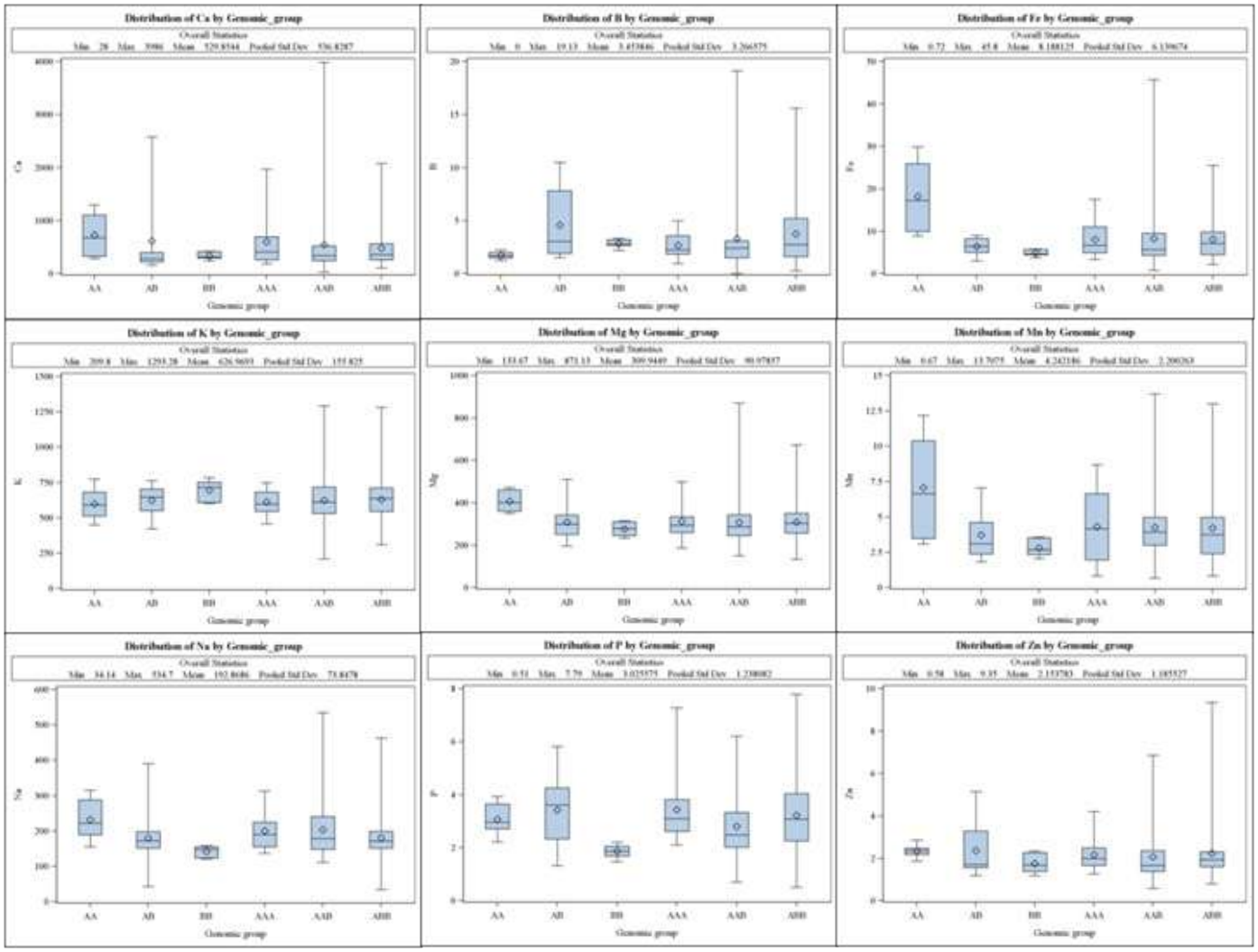


Fig.10. Distribution of nine fruit pulp mineral concentrations for the 100 *Musa* accessions, as a function of their ploidy/genome

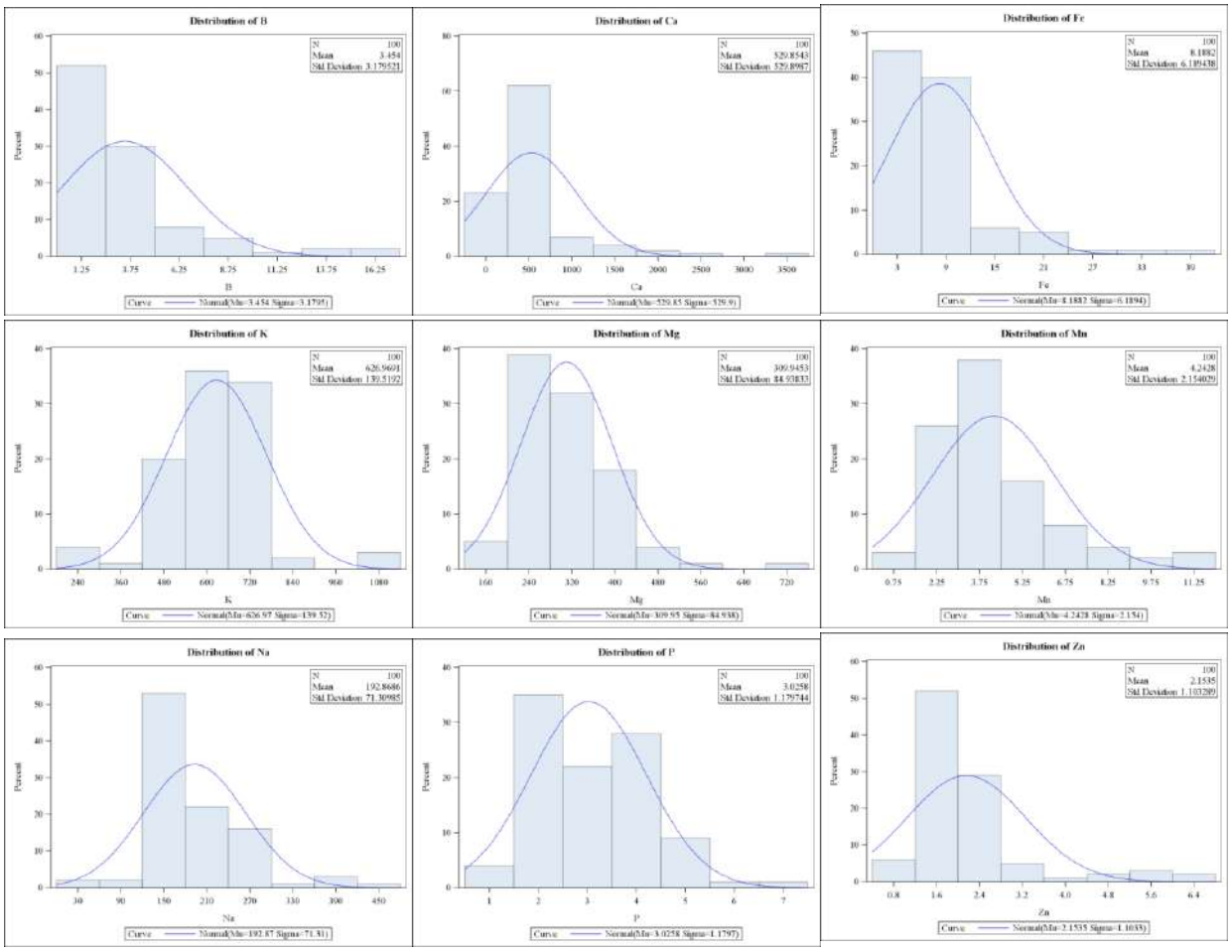


Fig. 11. Univariate frequency distribution pattern of 100 Indian *Musa* accessions for fruit pulp concentrations of the following nutrients: (A) Boron, (B) Calcium, (C) Iron, (D) Potassium, (E) Magnesium, (F) Manganese, (G) Sodium, (H) Phosphorous and (J) Zink. *x-axis* denotes percentage of genotypes, while *y-axis* represents concentrations (ppm).

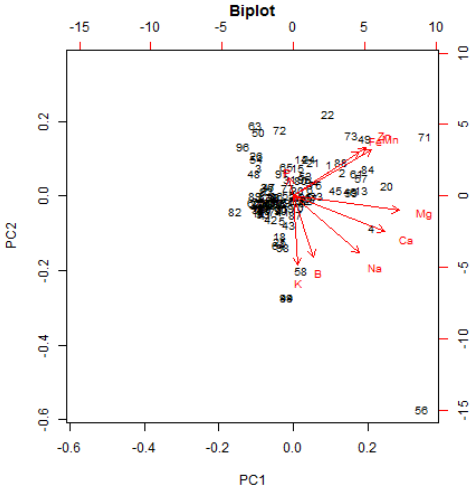


Fig 12. Principal component analysis of nine fruit pulp mineral concentrations recorded on 100 Indian Banana accessions. Biplot vectors are trait factor l

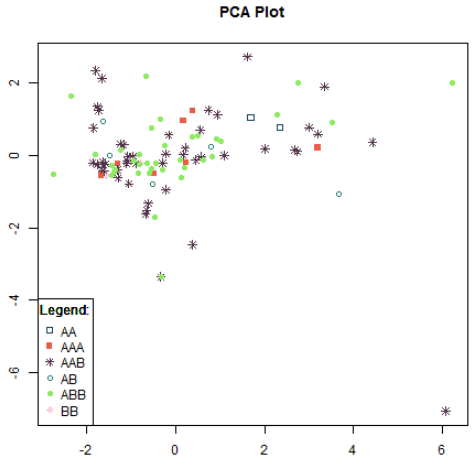


Fig.13. Scatter-plot of first vs second principal component showing six genomic grouping of 100 Indian *Musa* genotypes

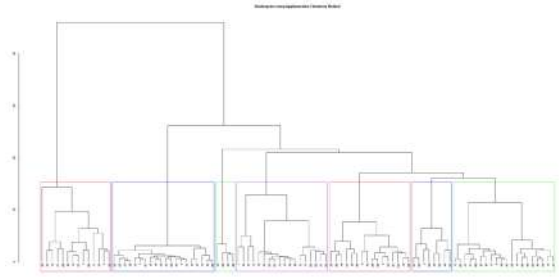


Fig. 14. Dendrogram showing clustering pattern of 100 Indian banana accessions based on their fruit pulp mineral contents

Screening of ITC accessions in Foc race 1 hot spot area

The field evaluation of 19 ITC accessions against Fusarium wilt, race 1 (VCG 0124) at hot spot area indicated that the genotypes such as Pisang Mulik, Akpakpak, Obit Natngu, A-361719, Zebrina and THA 108 showed an immune reaction, Kelong Mekintio, Pisang cici Altas, and *M. balbisiana* showed high resistant reactions and the genotypes Pitu, Chinesh Cavendish, Pisang berangan and Uzhakan exhibited resistant reactions. The remaining genotype showed either moderately resistant or susceptible reaction to Foc race 1.

4.1.2 Improvement of banana through conventional breeding

Validation of multiple shoot formation protocol in controlled and open pollinated seeds of different genomic groups.

The standardized protocol on developing multiple shoots from single embryo through direct regeneration and decortications of single *in vitro* derived plantlets has been implemented and seeds were obtained from 18 controlled and nine open pollinated accessions. This result revealed that combination of these two steps, 88.7-100% of the regenerated embryo produced multiple shoots in various genomic accessions of both controlled and open pollinated seeds. As this technique enhances the regeneration of hybrid seeds and allows simultaneous evaluation for multiple traits banana breeder can accelerate the breeding program by reducing the time span taken (7-9 months) for the release of potential banana hybrids.

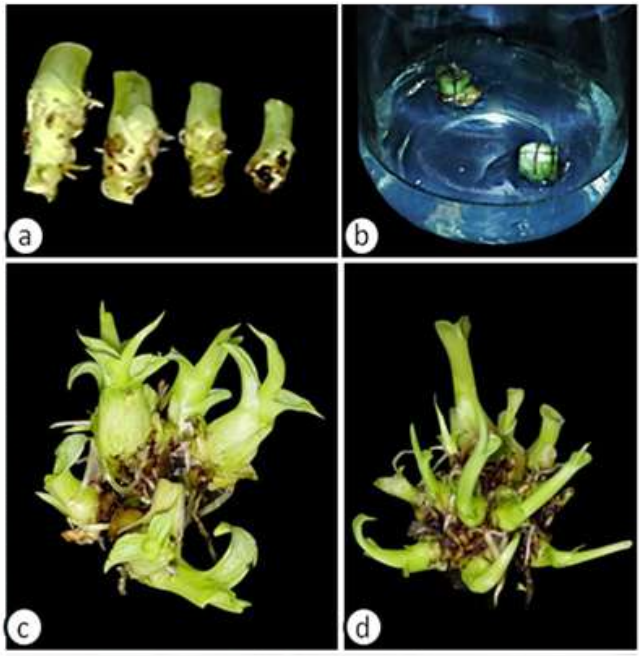


Fig. 15. Multiple shoot induction through decapitation of *in vitro* plantlets and sub-cultured in modified MS media .a- Explants selection based on girth size, b- Decapitated plantlets, c- Multiple shoots observed in 3rd subculture, d- Maximum multiple shoots obtained after 5th subculture.

Field establishment of controlled and open pollinated progenies

A total of 81 progenies were established under field, of which 31 were established in triploid

x diploid cross combinations which consists of four- Nendran, 12- Poovan, 2- Karpuravalli, 4 -Chinia and 1-Kothia based progenies. A total of 13 three way cross hybrid progenies were established by crossing the hybrid progenies of P4 and P-441 with Pisang Jajee, and P-793 and P834 with Pisang Lilin. Nine and 22 open pollinated progenies were established from six germplasm accessions and 12 hybrid progenies respectively.

Evaluation of progenies

Among the 20 progenies evaluated, Progeny No. 9 (Matti x Annaikomban) was found to be parthenocarpic and produced a bunch of 20kg with a maximum of nine hands and 16 fruits per hand. Single fruit weight was 132g with an average fruit length of 17.5 cm and recorded 19.6^{0} brix TSS content and 0.96% acidity. Evalaution go this progeny under Foc

race 1 hot spot area of Muthalapuram revealed that it is resistant to Cavendish infecting Foc race 1.

Development of parthenocarpic fruits from open pollinated progenies

Two open pollinated (OP) progenies namely Progeny 928 (OP progeny 213- Matti x cv.Rose) and Progeny 940 (OP of Enna Benian) produced parthernocarpic fruits (Fig. 16).

Progeny 928 [OP of progeny of P 213 (Matti x cv. Rose)] Progeny 940 (OP of Enna Benian)

Fig. 16. Parthenocarpic fruits of open pollinated progenies

Screening of progenies against Cavendish infecting Foc race 1 under hot spot area

A total of 54 progenies belonging to different cross combinations were screened against Cavendish infecting Foc race 1 in the hot spot area at Muthalapuram, Theni, Tamil Nadu. The result revealed that Progeny Number 778 (Chinia x Pisang Jajee) is immune and progeny number 754 and 756 (Karpuravalli x Pisang Jajee) are highly resistant whereas both the female parents are susceptible to Foc race 1. Screening of 18 Nendran based hybrids under hot spot area of Cavendish infecting Foc race 1 at Muthalapuram, Theni, Tamil Nadu revealed that all are highly resistant to Cavendish infecting Foc race 1.

Evaluation of Nendran based hybrids

Screening of Nendran based progenies against root-lesion nematode (*Pratylenchus coffeae*)

Out of five Nendran x Pisang Lilin progenies, three (NPL 30, NPL34 and NPL 36) were found to be resistant to root-lesion nematode, *Pratylenchus coffeae* whereas out of eight Nendran x cv. Rose progenies, only one (NCR 8) progeny showed resistance. Interestingly all the five open pollinated Nendran based progenies are highly susceptible. The result of the occurrence of resistance in four controlled pollinated progenies revealed that the resistance trait might be heritable from *P. coffeae* resistant male parents (Pisang Lilin and cv. Rose).

Relative susceptibility of Nendran progeny against banana stem weevil, *Odoiporus longicollis* under field conditions

Among the Nendran progeny, Nendran x cv.Rose-18 and Nendran x Pisang lilin-28 were identified as resistant to banana stem weevil and no infestation was recorded.

Evaluation of Nendran based progenies for pro vitamin A content

Among the Nendran based progenies NCR 17 (103.23) and NCR 21 (79.08) had high pro-vitamin A content (µg/g of dry weight) than the better parent, cv. Nendran (66.70). And the variation for PVA content of NCR 17 was statistically non significant over three years. All the open pollinated Nendran progenies were found to be on par with the female parent cv. Nendran for PVA content. All the Nendran x Pisang Lilin progenies exhibited low PVA content (9.92--31.81 µg/g of dry weight) than the better parent cv. Nendran. But in variably all the Nendran based progenies recorded higher lutein content than the female parent Nendran.

a) NCR 17 b) cv. Nendran

Fig. 17. Longitudinal section of fruits of NCR 17 & cv. Nendran

Multilocation trial for NCR 17

Evaluation of 18 Nendran based progenies revealed that five progenies namely NCR-2, NCR-8, NCR-17, NCR-21 and NOP-45 were found to be high yielders than the female parent, Nendran Observations on the organoleptic parameters also indicated that, NCR-17 had the best consumer acceptability than other progenies, followed by NCR-2, NCR-21, NCR-8 and NOP-45. Thus NCR-17 has been tested in two different locations (Nachikuruchi, Tiruchirappalli and Muthalpuram, Theni, Tamil Nadu) and the result revealed that it is a stable yielder with an average yield of 26.0, 27.3 and 25.6 kg/bunch (Fig. 18) which produce 59.5%, 39.2% and 50.58 % higher yield than Nendran in the respective places. Except plant girth and days taken for flowering all the traits namely plant height, days taken for maturity, duration, bunch weight, number of hands, number of fruits per hand, fruit weight, fruit length, pulp- peel ratio were significantly different from that of cv. Nendran. NCR-17 recorded less number of days for maturity and less fruit circumference than cv. Nendran

Fig. 18. Number of fruits per hand in NCR-17 (with lengthy fruit)

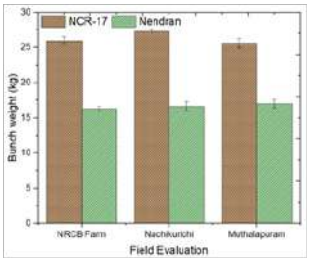


Fig. 19. Yield performance of NCR-17 and Nendran at different location

Effect of seed priming on *in vivo* germination of different ornamental hybrid seeds

The number of seeds per fruits varied highly within the hand (Fig. 5a) and within the cross (Fig. 5b) as revealed by the box-plot analysis. Irrespective of the cross combinations, the seed-set was more in the fruits situated at 4th (83 nos.) or 5th (74 nos.) hands and less (31 nos.) in 1st and 2nd hands. The number of seeds per fruit was highest (61) for the crosses of RV which was on par for VMO (*Musa velutina* ssp. *markkuana* X *M. ornata*) (61), OZ (*M. ornata* X *M. acuminata* **ssp.** *zebrina)* (57) and VOP (Naturally pollinated *M. velutina)* (46). The seed-set was lowest for the cross of OR (*M. ornata* X *M. rubra)* (31).

The percent seed germination at the end of 8th week after sowing in the pro-trays (Fig. 19) kept under glasshouse varied significantly from 10 to 90% with respect to different ornamental banana hybrid crosses. The seed germination was 64% for the cross of OV (*M. ornata* X *M. velutina*) which was on par for the crosses of RZ (*M. rubra* X *M. acuminata* **ssp.** *zebrina*) (61%), 57% with OPL (*M. ornata* X Pisang Lilin), and 56% with VMO. The lowest germination of 33% was recorded for the VOP (Fig.19a). Similar trend was observed for mean germination time (MGT) and seed germination index (SGI). However, the seed germination results in priming treatments with water or with different PGRs were not significantly different from that obtained for the control (unsoaked) treatment. Fruit pulp weight is highly correlated with number of sunken seeds (0.93) and not with number of floating seeds (0.11).

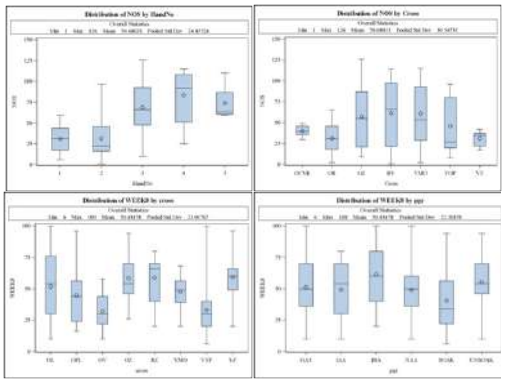


Fig. 19. OPL: *Musa ornata* X Pisang Lilin; OCVR: *M. ornata* X 'Cultivar Rose'; OR: *M. ornata* X *M. rubra*; OV: *M. ornata* X *M. velutina*; RV: *M. rubra* X *M. velutina*; OZ: *M. ornata* X *M. acuminata* ssp. *zebrina*; RZ: *M. rubra* X *M. acuminata* ssp. *zebrina*; VMO: *M. velutina* ssp. *markkuana* X *M. ornata*; VZ: *M. velutina* X *M. acuminata* ssp. *zebrina*; VOP: Naturally pollinated *M. velutina*

Fig. 20. In vivo germination of ornamental banana hybrid seeds in pro-trays under glasshouse

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

Great variability was observed among the progenies for all the qualitative characteristics evaluated (Fig. 21, 22 & 23), mainly the colour (leaves, fruits, rachis, and heart), peduncle orientation, fruit position and bract opening as shown in the Table 10.

Greater variability was also observed for quantitative traits like plant height (52 to 170 cm), and girth (10 to 29 cm), days taken for flowering (70-189), peduncle length (15 to 50 cm), flower size (length: 13-38 cm & circumference: 5-20 cm) and no. of hands (0 to 5) & fruits (0-85).

Fig. 21. Ornamental hybrids with coloured bracts between *M. ornata* x *M. rubra* (first line) *M. rubra* x *M. ornata* (second line) *M. ornata* × *M. velutina* ssp. *markkuana* (Third line)

Fig. 22. Ornamental hybrids with coloured fruits in (a&b) *M. rubra* x *M. acuminata* ssp. *zebrina* and (c&d) M. ornata× M. acuminata ssp. zebrina

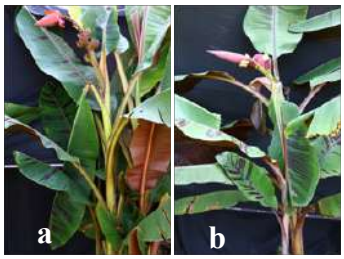


Fig. 23. Ornamental hybrids with coloured foliage in (a) *M. rubra* × *M. acuminata* ssp. *zebrina* and (b) *M. ornata* x *M. acuminata* ssp. *zebrina*

Table 10. Qualitative characteristics of ornamental hybrids

Cross	Leaf colour (%)				Peduncle colour (%)		Fruit colour (%)		Position of fruits on the crown (%)			Bract curling (%)		Position of bunch (%)	
	Adaxial		Abaxial				Uni- seriate	Bi-seriate	Both	Non-revolute	Revo-lute	Erect	Angled		
	Green	Purple	Green	Purple	Green	Purple	Green	Purple							
OR	100	-	100	-	100	-	100	-	86	9	5	81	19	100	-
OZ	52	48	52	48	53	47	72	28	73	5	22	43	57	51	49
RZ	44	56	67	33	10	90	19	81	11	76	13	5	95	5	95
O	100	-	100	-	100	-	100	-	100	-	-	100	-	100	-
R	100	-	100	-	100	-	100	-	-	100	-	100	-	100	-
Z	-	100	-	100	-	100	-	100	-	100	-	-	100	-	100

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

A total of 55 core collection accessions representing various genomic groups namely AAB (5), ABB (36), AA (2), AAA (2), ABBB (8) and *Rhodochlamys* (2) were established in pots with five replications each for pot screening against fusarium wilt. Out of 29 accessions screened for Fusarium wilt resistance under pot culture conditions, none were found to be resistant. Genotyping of 153 germplasm accessions has been completed for 15 primers using automated electrophoresis system. Further they will be genotyped using banana microsatellite markers for which the run method has been standardized in automated electrophoresis system.

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

Cv. Grand Naine

NRCBGNM (P) 1 derived from gamma irradiated ECS showing resistance to race 1 is under *in vitro* multiplication for large scale field evaluation in hot spot areas. NRCBGNM (E) 1, 3, 13 and 15 derived from EMS treated ECS and NRCBGNM (D) 3 derived from DES treated ECS showing resistance to race 4 are under various stages of multiplication and some are under secondary hardening stage ready for sick plot evaluation.

Sodium azide treated ECS derived plants are in the primary hardening (50) and spore inoculation (57) stages respectively.

Cv. Rasthali

All the Fusarium wilt resistant mutants of cv. Rasthali identified from the pot culture and sick plot conditions have been raised in a separate block for sucker multiplication purpose. *In vitro* multiplication of Fusarium wilt tolerant mutants of cv. Rasthali (RM 217 and RM 100) are in progress. The optimal dose of Beauvericin to be used for *in vitro* screening of mutated Rasthali has been determined as 7 µM.

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

Achieved the production of 20 numbers of secondary hardened putative androgenic haploids (Fig. 24.) from cv. Ney Poovan through callus induction of anthers containing highly vacuolated uninucleate stage located with in bract No. 22 to 24 on the modified MS media containing PGRs of 2,4-D (3.5 ppm), IAA (1 ppm) and NAA (1 ppm). Later the germination of embryogenic calli for *in vitro* production of androgenic haploids followed by *in vitro* shooting and rooting of putative androgenic haploids were achieved on the modified MS media containing PGRs of IAA (1.5 ppm), BAP (0.5 ppm) and GA3 (0.5 ppm).

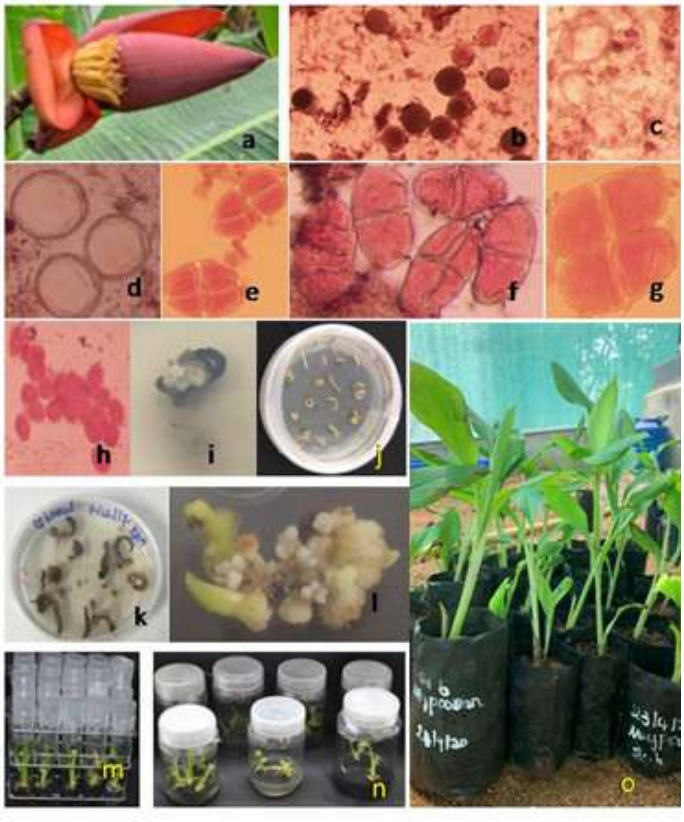


Fig. 24. Androgenic callus induction and somatic embryogenesis followed by germination, shooting and rooting of somatic embryos in cv. Ney Poovan.

(a). Flower bud, (b). matured pollen grain, (c). Vacuolated microspores, (d). Highly vacuolated uninucleate microspores with a nucleus in a periphery , (e). tetrad, (f). Dyads, triads and tetrads, (g). Dyads, (h) Pollen mother cells, (i). Immature anthers containing highly vacuolated uninucleate microspores, (j). Callus induction, (k). Embryogenic calli, (l). Germination of somatic embryos, (m). Shooting, (n). Rooting and (o). Hardened putative Hs/DHs.

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

Identified two dwarfs Grand Naine tissue culture variants namely GNC18 and GNE18 from farmers' fields situated in Coimbatore (Mr. Thangavelu, Kalapatti, Valiyampalayam) and Erode (Mr.N.Nagaraj, Baguthampalayam, Bhavani) districts of Tamil Nadu, respectively. The GNC18 had plant height of 1.5 m with 13 hands and 20 Kg bunch weight. Another variant GNE18 had plant height of 1.6 m with 10 hands and 15 to 18 fingers in each hand.

Evaluation of these two variants at ICAR-NRCB farm recorded reduced plant heights (30 to 32 %) and bunch weights (9 to 22%) than the normal Grand Naine as shown in the table 11 and Fig. 25.

Table 11. Growth and yield characteristics of two Grand Naine dwarf clones at ICAR-NRCB Research Farm

Clone	Height (cm)	Girth (cm)	Leaf length x Girth (cm)	Petiole length (cm)	No. of hands	No. of fruits in 2nd hand	Bunch weight (Kg)	Days taken for harvesting
GNC18	125	52	110 x 60	7.0	8	17	12.0	321
GNE18	130	53	119 X 60	10.0	8	20	14.0	334
Normal Grande Naine	185	55	180 x 72	31	14	19	15.3	385

Fig. 25. Performance of dwarf Grand Naine clones (GNC18 and GNE18, respectively) at ICAR-NRCB's Research Farm

The extent of somaclonal variants observed in the farmers' fields who are growing tissue culture bananas are shown in the Table 12 and Fig. 26.

Table 12. Type of somaclonal variants recorded in farmers' fields

S.No.	Name of the somaclonal variants	Cultivars	Extend of somaclonal variants (%)	Area covered
1.	Dwarfness	Grand Naine	0.4 to 0.7 %	Tamil Nadu (Bhavani-Erode, Kalapatti-Coimbatore), Karnataka (Tumkur)
2.	Green pseudostem	Nendran	1.0 to 2.0 %	Tamil Nadu (Kalapatti and siruvani-Coimbatore)
3.	No side suckers	Ney Poovan	0.5 to 1.5%	Tamil Nadu (Kalapatti-Coimbatore), Karnataka (Tumkur, Chitradurga)
4.	Shy suckering (=1 number)	Ney Poovan	1.0 to 2.0%	Tamil Nadu (Kalapatti-Coimbatore), Karnataka (Tumkur, Chitradurga)

Fig. 26. Somaclonal variants in farmers' field (a). Dwarf Grand Naine, (b). Nendran with green pseudostem, (c). Ney Poovan without side sucker and (d). Ney Poovan with single sucker (shy suckering)

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)

Confirmation of LRR-RLP gene for Foc race1 resistance through CRISPR knockdown study

Guide RNA (gRNA) was designed using CRISPR-P V2, CRISPOR and WU-CRISPR target prediction server to identify the potential target sites in the LRR-RLP gene for CRISPR/Cas9 knockdown assay. Based on knockout potency and off target score two effective gRNAs were selected for CRISPR knockdown studies. Knockout potency and off target score for Target 1 is 100 and 0.85 were as Target 2 had a score of 98 and 0.79 suggesting that both the gRNA likely to be more effective.

Confirmation and cloning of RGA2 gene against Foc tropical race 4 (TR4) in Indian land races

RGA2, the only reported gene showing resistance when overexpressed against *Foc* TR4

(Dale, 2017) was analysed in Foc TR4 resistant and susceptible Indian land races. Realtime-PCR analysis revealed higher basal expression of *RGA2* in roots samples of hardened and *in-vitro* plants of resistant cultivars (Matti and cv. Rose) than susceptible cultivars (Namarai and Grand Naine). Thus, full length of RGA2 (3.78 kb) has been cloned and sequenced. The multiple sequence alignment revealed sequential difference at amino acid level among all the cultivars. Motifs and domain analysis revealed that *RGA2* is typical CC-NBS-LRR gene.

Identification and expression analysis of R genes from chromosome 3 in roots of *in-vitro* and hardened plants against Foc TR4

Based on genetic resistance studies by Aitken *et al*., 2018, resistant genes from chromosome 3 were selected for expression studies. A total of 36 resistant genes were identified from chr3 through *in-silico* analysis from banana genome hub and based on expression of these genes from Cavendish and Pahang transcriptomic data we narrowed down to 12 genes which showed higher expression in TR4 inoculated than un-inoculated. Semi-quantitative PCR analysis of all the selected genes showed no particular expression pattern among the TR4 resistant and susceptible cultivar from roots samples of hardened and *in-vitro* plants except for RGA2 gene.

Identification of SSR markers associated with R genes against Foc TR4

Ten SSR primers were designed in R genes present in chromosome 3 and tested in resistant and susceptible cultivars for developing gene specific markers. Out of 10 primers, a single primer 29400 showed polymorphism between resistant and susceptible cultivars.

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

Crop Production

4.2.1 Studies on nutrient dynamics in banana

Under nutrient dynamics studies, banana cvs. Grand Naine and Nendran were planted in randomized block design, with imposing of treatments like 50%, 75%, 100%, 125% and 150% of recommended dose of fertilizer (RDF – 200gN:30gP:400gK per plant) with an absolute control. The initial soil NPK contents were 112.1, 6.2 and 122.4 kg N, P_2O_5 and K_2O per ha. At planting, the average N-P-K concentrations (%) of pseudostem were 1.29-0.34-6.51 and 1.41-0.20-5.29 and that of corm were 0.51-0.19-3.51 and 0.69-0.14-4.09 in cvs. Grand Naine and Nendran, respectively. The total dry matter production (DMP in g/plant) total nutrient uptake (g/plant) by cvs. Grand Naine and Nendran were given in the Tables 13 and 14.

Table 13. The total dry matter production and nutrient uptake (g/plant) by cv. Grand Naine at different growth stages

Growth Stage	DMP	N	P	K	Cu	Mn	Zn	Fe
5 leaf	846	8.23	2.48	39.65	0.42	0.73	0.13	0.74
10 leaf	1771	17.36	5.77	81.65	0.85	0.87	0.3	1.19
20 leaf	3619	44.36	13.44	219.26	0.89	1.05	0.51	1.79
shooting	6420	136.11	19.96	268.24	0.98	1.22	0.76	1.89

Table 14. The total dry matter production and nutrient uptake (g/plant) by cv. Nendran at different growth stages

Growth stage	DMP	N	P	K	Cu	Mn	Zn	Fe
5 leaf	687	6.37	1.78	31.14	0.27	0.55	0.11	0.8
10 leaf	1765	17.89	5.83	78.55	0.56	0.98	0.27	1.41
20 leaf	4222	85.4	15.77	239.65	1.01	1.03	0.37	1.93
shooting	6024	126.84	20.86	311.48	1.17	1.38	1.51	2.29

The nutrient uptake pattern in 2nd order polynomial graphs were worked out in kg/ha at different growth stages of cvs. Grand Naine and Nendran were given the Fig.27 In cv. Grand Naine, the N uptake increased from 24.7 kg/ha at 5 leaf stage to 408.3 kg/ha at shooting with increasing rate and that of cv. Nendran increased from 19.1 kg/ha at 5 leaf stage to 380.5 kg/ha at shooting with decreasing rate. A gradual increase in P uptake of cv. Grand Naine (from 7.4 to 59.9 kg/ha) and of cv. Nendran (5.3 to 62.6 kg/ha) from 5 leaf stage to shooting was observed. In case of K uptake, cv. Grand Naine showed a steady and sharp increase (from 119 to 804 kg/ha) and cv. Nendran showed a sigmoid increase (from 93.4 to 934.4 kg/ha) from 5 leaf to shooting stage. In both cvs. Grand Naine and Nendran, the order of micronutrient uptakes were Fe > Mn > Cu > Zn at growth stages from 5 leaf stage to shooting. In both the bananas, the Fe, Cu and Mn uptakes showed increasing trend with decreasing rate but the Zn uptake showed increasing trend with increasing rate, which shows increasing demand of Zn in the later growth stage of the crop.

At 10-leaf stage, the average root length densities (RLD in mm/cm^3) were 2.02 and 1.47 and the specific root length (SRL in cm/g) were 4.23 and 3.03 in cvs. Grand Naine and Nendran, respectively. At 20-leaf stage the RLD were 3.11 and 2.89 and SRL were 2.56 and 2.27 in cvs. Grand Naine and Nendran, respectively while at shooting stage RLD were 7.26 and 6.32 and SRL were 1.37 and 1.29 in cvs. Grand Naine and Nendran, respectively.

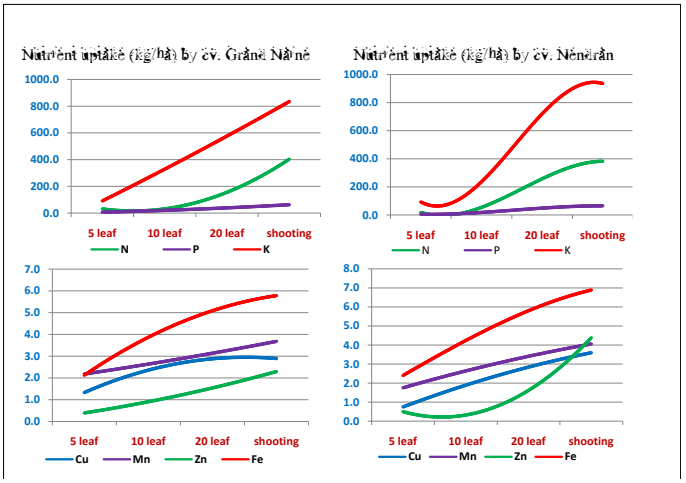


Fig. 27. The 2nd order polynomial graphs representing the nutrient uptake patterns at different growth stages on banana.

The soil Q/I parameters of potassium were estimated at different growth stages of banana. At 10-leaf stage, the soil recorded DK (cmol kg^{-1}) of 0.37 and at 20-leaf stage, it was 0.28 while at shooting it was 0.23. At 10-leaf stage, the soil recorded AR_e^K ((M/L)$^{0.5}$) of 16.06 and at 20-leaf stage, it was 15.19 while at shooting it was 13.18. The potential buffering capacity of soil for potassium (cmol.kg^{-1}.(M/L)$^{-0.5}$) at 10-leaf stage was 24.03 and at 20-leaf stage it was 18.92 while at shooting it was 17.36.

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 10 leaf stage. The highest nutrient uptakes were recorded in 100% inorganic fertilizer applied plants followed by the organic combination M_1 (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-113.4, P-15.9, K-158.2, Ca-79.0 and Mg-30.4 where as the treatment M1 recorded uptakes of N-85.3, P-13.8, K-151.9, Ca-68.8 and Mg-27.6. The absolute control recorded the uptake values of N-38.4, P-5.8, K-69.7, Ca-28.7 and Mg-13.5.

At 20 leaf stage, the treatment M_2 (ie., application of poultry manure @ 5kg/pl + groundnut cake @ 1kg/pl + rural compost @ 3kg/pl + wood ash @ 3kg/pl) overtook the M_1 by recording highest nutrient uptakes (g/plant) of N-93.7, P-13.8, K-202.9, Ca-74.4 and Mg-31.1 among the organic treatments but the 100% inorganic treatment recorded nutrient uptakes (g/plant) N-101.0, P-13.9, K-222.6, Ca-72.7 and Mg-24.9. The absolute control recorded the uptake values of N-44.4, P-6.9, K-95.6, Ca-32.0 and Mg-15.5.

At shooting stage, the M_2 recorded the highest nutrient uptakes (g/plant) N-156.7, P-24.7, K-284.8, Ca-122.9 and Mg-58.4 while the 100% inorganic treatment recorded nutrient uptakes (g/plant) of N-177.6, P-24.9, K-322.5, Ca-123.7 and Mg-47.6. The absolute control recorded the uptake values of N-63.4, P-9.5, K-115.2, Ca-47.4 and Mg-23.3. The nutrient uptake pattern of Grand Naine at different treatment combinations at different growth stages are depicted in the Fig. 28.

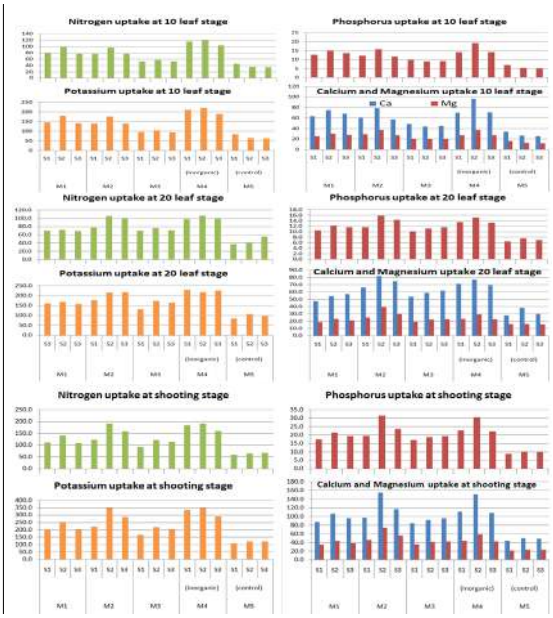


Fig. 28. Nutrient uptake pattern by cv. Grand Naine at different growth stages

The 'r' values pertaining to the treatment M_2 for Soil Available Nutrients (SAN) at 5 leaf stage Vs. Nutrient Uptakes (NU) at 10 leaf stage were N=0.47*, P=0.86**, K=0.74*, Ca=0.64*, Mg=0.71*, while that of SAN at 10 leaf stage Vs. NU at 20 leaf stage were N=0.76**, P=0.55*, K=0.63*, Ca=0.76**, Mg=0.58*. The SAN at 20 leaf stage Vs. NU at shooting stage were N=0.64*, P=0.47*, K=0.48*, Ca=0.65*, Mg=0.53*. The correlation coefficients between soil nutrient contents versus overall nutrient uptakes at different growth stages (Table. 15) indicate significant matching of nutrient releasing and uptake patterns in organic banana farming.

Table 15. Correlation coefficients (r values) between soil nutrient contents vs. overall nutrient uptakes at different growth stages

Soil Nutrient contents	Overall Nutrient uptakes			
	5-leaf stage	10-leaf stage	20-leaf stage	shooting
5-leaf stage	0.42*	0.68**	0.52*	0.33
10-leaf stage		0.46*	0.65**	0.55*
20-leaf stage			0.34	0.65**
Shooting				0.30

4.2.3 Development of clump management technology for enhanced productivity in banana

The experiment was continued with banana cvs. Ney Poovan (AB) and Poovan (AAB) by imposing the treatments of allowing the daughter suckers in a staggered manner at various months after planting as per the treatment schedule and three different levels of nutrition *viz.*, 125% , 150% and 175% RDF per clump.

In Ney Poovan, the time taken for flowering of mother plant as well as and first daughter suckers were recorded and the plants under the treatment of T3-S1N3 took least number of days (311.3 days) whereas the flowering of mother plant was delayed to 338.5 days in T10-S4N1 in which 4 suckers per clump allowed and applied with 125% RDF (Fig. 29). Among the four different numbers of suckers per clump, the earliest flowering (314.3 days) was noticed in the treatment of allowing one sucker per clump at 4th month after planting. The plants with the highest number of suckers per clump took the longest time of 334.5 days for flowering of the mother plant.

Similarly, the time taken for flowering of first suckers ranged from 366.0 days (T3-S1N3) to 388.0 days, which was recorded with more number of suckers and the least dose of 125% RDF per clump (T10- S4N1) (Fig. 29).

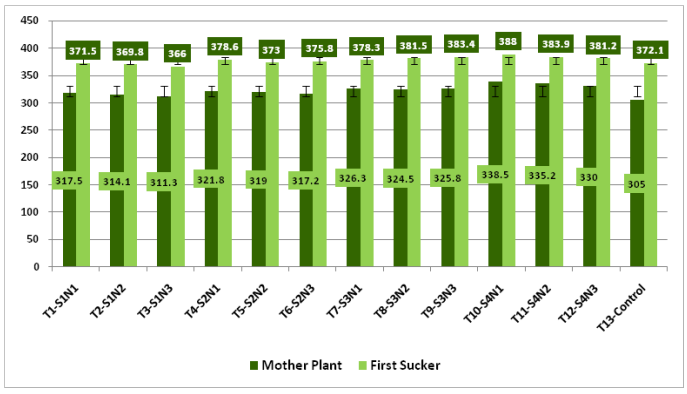


Fig. 29. Effect of no. of suckers and levels of nutrition on flowering in banana cv. Ney Poovan

Data on bunch weight and other yield parameters revealed that allowing more number of side suckers *i.e.*, four suckers per clump significantly reduced the bunch weight of mother plant to as low as 9.47 kg as against the highest bunch weight of 11.13 kg recorded in S1 (mother plant + 1 sucker) (Fig. 30). Among three levels of nutrition, the highest bunch weight (10.68 kg) was recorded in N2- 150% RDF followed by N3- 175% RDF (10.45 kg) while lowest bunch weight of 9.72 kg was recorded in plants with 125% RDF per clump.

Fig. 30. Effect of number of suckers and levels of nutrition on bunch weight in banana cv. Ney Poovan

The total number hands per bunch and fingers per bunch showed significant differences among treatments. The lowest number of hands/bunch (11.0 hands) as well as fingers/bunch (166.3 fingers) was recorded in T10-S4N1 as against the highest values of 13.6 hands and 188.4 fingers per bunch that was recorded in T2-S1N2. The varied population per clump and levels of nutrition per clump significantly influenced the TSS of the fruits and the highest fruit TSS of 26.8 (^{o}B) was recorded in T9 (S3N3) while the fruits from the T13 (control) recorded the lowest TSS of 24.6 ^{o}B. (Fig. 31).

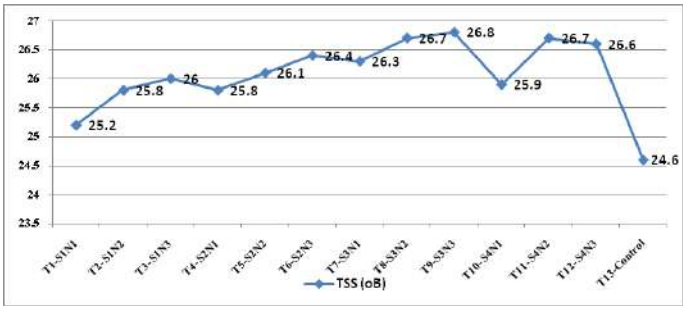


Fig. 31. Effect of number of suckers and levels of nutrition on fruit TSS (^{O}B) in cv. Ney Poovan

In banana cv. Poovan, the plant growth parameters in terms of plants height, pseudostem circumference, leaf characteristics of leaf length, leaf breadth and leaf area differed significantly among the treatments of four different plant population per clump and three levels of nutrition.

Among all the treatments, the tallest mother plant (206.1 cm) was found in the most dense population of mother plant + 4 suckers per clump while the shortest plant of 170.5 cm was recorded in the control (T13). (Fig. 32)

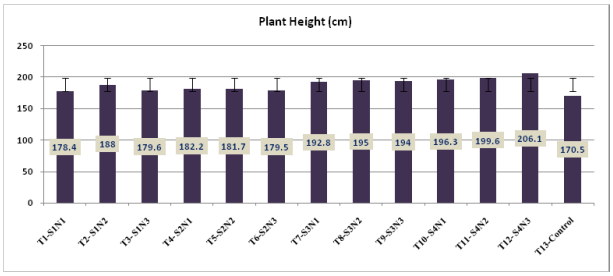


Fig. 32. Effect of no. of suckers and levels of nutrition on plant height of cv. Poovan (mother plant)

Data on leaf characteristics revealed that the larger leaf length was recorded in T7 (S3N1) and the leaf breadth was more in T8 (S3N2) as compared to other treatments (Fig. 33).

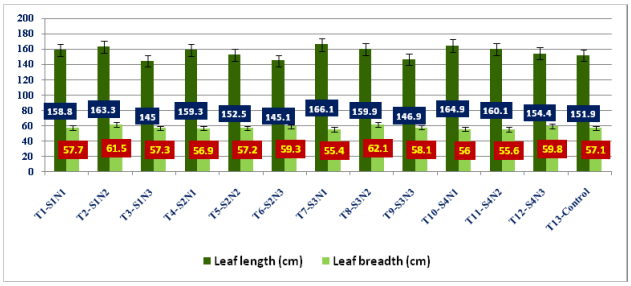


Fig. 33. Effect of no. of suckers and levels of nutrition on leaf characteristics in cv. Poovan

With regard to the effect on flowering of mother plant of cv. Poovan, the plants under the T13 (control) showed the earliest flowering in 317.7 days while treatment T10 took longest time of 349.1 days for flowering (Fig. 34).

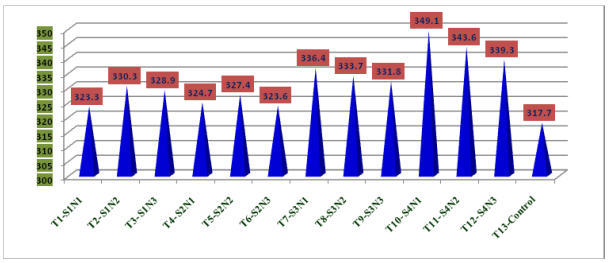


Fig. 34. Effect on days taken for flowering of mother plant in cv. Poovan

Post Harvest Technology

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

Survey on leaf production

A survey was undertaken in Thiruchendur and Srivaigundam areas of Tuticorin Dt., Tamil Nadu, one of the major banana growing tracts for leaf purpose. In these areas, the varieties cultivated mainly for leaf purpose are Sakkai and Naadu. A population of 600 to 700 plants/acre is maintained with wider spacing. Minimum of three to maximum of five suckers are maintained per plant. Fifteen to twenty leaves per hill per month at 3/4th stage from the seventh month onwards daily. Bundle of leaves leaf tied with coarse fiber is made to prevent opening of leaf and to protect from wind damage. Whole leaf is harvested and bundled to 200 nos. Cost of cultivation: Rs. 80,000/- to 1,00,000/- per acre with a net Profit of Rs. 80,000/- to 1,00,000/- per acre (farmer as producer).

A market survey was also undertaken in Tuticorin wholesale/assembly market for leaf. The leaf bundles are received from surrounding areas of Tuticorin Dt., mainly from Thiruchendur, Srivaigundam and Aathur areas. As soon as the bundles are received, the bundles opened up to remove the field heat, bundled again and despatched to Aruppukottai, Salem and Madurai mainly. During peak season, 1500 to 2000 bundles (200 full leaves/ bundle) per day are received in the market, while 900 to 1200 bundles are received during off-season. The bundle is sold at the rate of Rs. 900/- to 1500/- during off-season and Rs. 2000 to 2500/- during peak season.

Leaf production of banana

A trial was laid out to study the leaf production as influenced by five selected varieties namely, Poovan, Karpuravalli, Sakkai, Phirima wild and Progeny 183. Observations were taken after five months of planting, i.e., September to December (monthly interval) on leaf

production (marketable leaf size) from main and side suckers. Significant differences were recorded for the varieties and months and its interaction. Among the varieties, 'Karpuravalli' produced maximum number of leaves (8.87), followed by 'Poovan' (6.35), Sakkai (5.60), 'Phirima wild' (5.20) and minimum was recorded with 'Progeny 183' (4.80). With respect to the months, maximum number of leaves was produced during October (7.26), followed by November (6.70), September (6.00) and minimum number of leaves during December month. Leaf area varied among the varieties, the highest being with 'Poovan' (1.21 m^2). The next maximum size of leaf was obtained with 'Progeny 183' (1.15 m^2), followed by 'Sakkai' (1.13 m^2) and 'Poovan' (1.10 m^2) and the lowest being with 'Phirima wild' (0.85 m^2). The minimum leaf thickness is a preferred character for leaf purpose, which was measured with Sakkai and Phirima wild (0.15 mm each), followed by Poovan (0.16 mm), Karpuravalli (0.18 mm). Regarding the side suckers, the maximum side suckers of 2.55 was produced by Karpuravalli, followed by Poovan with 2.16, Sakkai with 2.11, and Progeny 183 with 2.00. The total chlorophyll content was estimated in the leaves of all the five varieties, which ranged from 6.71 mg/g (Karpuravalli) to 12.77 mg/g (Progeny 183) on fresh weight (FW) basis, the lowest being with 'Karpuravalli', 'Poovan' and 'Sakkai'. Color index was measured in the leaves of all the five varieties in terms of 'L', 'a' and 'b'. 'L' value varied from 34 to 43, while 'a' value from -24 to 17 and 'b' value from 20.21 to 38.28.

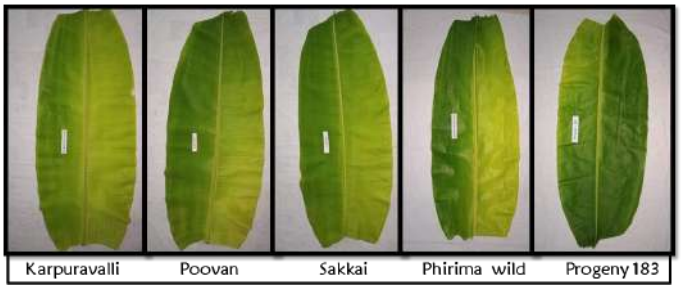


Fig. 35. View of harvested leaf of banana varieties

Shelf-life of banana leaves

Shelf-life of banana leaves was studied in five varieties both in room temperature and at 13.5 °C. Maximum shelf-life of 11 days was recorded with 'Sakkai' at 13.5 °C against 4 days in at room temperature. Similarly, nine days of shelf-life was observed with Phirima wild at 13.5 °C against 4 days at room temperature, eight days of shelf-life with Karpuravalli and Poovan at 13.5 °C against four and three days, respectively at room temperature. There was four days increase in shelf-life in Phirima wild at 13.5 °C (7 days) compared to control (3 days).

In a storage trial to extend the shelf-life of leaves stored in of three varieties, maximum shelf-life of 17 days for Poovan leaves (6'', 8'' and 10'' bio-plates), 11 days each for Karpuravalli and Naadu was observed at 13.5 °C in thermo-coal box with gel-pack. Shelf-life of five days each in Poovan, Naadu and Karpuravalli was recorded at 20 °C compared to control of two days each.

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

Extraction of starch

Starch was extracted from five banana varieties. Consumer acceptance and quality of the starch and its products is primarily assessed with colour of the product. The results (Table 16) showed that L, which reflects the relative lightness or darkness of the products varied significantly ($p < 0.05$) from 92.55 to 95.71. The commercial corn starch recorded higher value (98.02) than banana starches. The higher starch purity (>90) of all the banana varieties implies its use in various food applications.

Fig. 36. Starch extraction method

Table 16. Colour properties and chemical composition of banana and corn starches (dry weight basis)

Properties	Varieties					
	Grand Naine	Monthan	Saba	Nendran	Popoulu	Corn
Colour properties						
L	92.55 ± 0.24^{f}	93.30 ± 0.12^{e}	94.00 ± 0.18^{d}	94.55 ± 0.44^{c}	95.71 ± 0.14^{b}	98.02 ± 0.12^{a}
a*	-11.55 ± 0.01^{b}	-10.75 ± 0.64^{a}	-11.78 ± 0.4^{b}	-11.79 ± 0.03^{b}	-11.89 ± 0.03^{b}	-13.04 ± 0.06^{c}
b*	6.26 ± 0.04^{b}	5.47 ± 0.38^{d}	5.82 ± 0.02^{c}	6.24 ± 0.09^{b}	5.42 ± 0.06^{d}	7.33 ± 0.04^{a}
WI	86.58 ± 0.02^{b}	87.66 ± 0.70^{a}	86.64 ± 0.03^{b}	86.45 ± 0.03^{b}	86.77± 0.03^{b}	84.97 ± 0.03^{c}
YI	9.67 ± 0.09^{b}	8.39 ± 0.57^{d}	8.84 ± 0.02^{c}	9.43 ± 0.18^{b}	8.09 ± 0.10^{d}	20.41 ± 0.07^{a}

The changes in morphology of starch granule at various temperatures provide lucid information about the structural changes during gelatinization. From the Fig. 37, it is evident that the granules at temperature range of 55-65°C were stable and intact. Grand Naine, Nendran, Popoulu and corn starches were partially gelatinized at 75 °C and fully disintegrated at 85 °C whereas the starch from Saba and Monthan had intact granules till 85 °C and started to lose its structure after 95 °C.

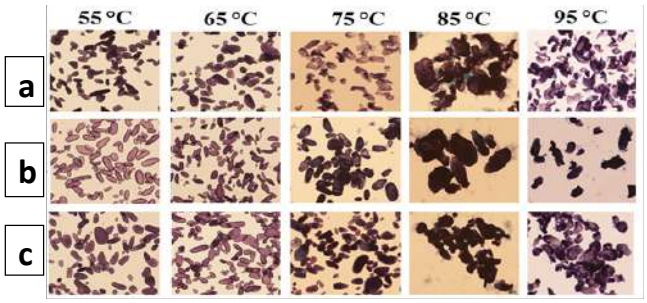


Fig. 37. Light microscopic images (40 x magnification) of gelatinized starch granules at various temperatures. (a) Grand Naine, (b) Monthan, (c) Saba

Starch granules of different bananas have exhibited extensive array of shape like elongated, oval and irregular shapes and different sizes. Smaller starch granules mostly appeared in circular form and some starch granules with smooth surface without any grooves were noticed. Starch granules from cvs. Monthan and Saba appeared more elongated than other starch granules whereas starch granules from cv. Grand Naine were irregular in shape and smaller in size. Starch granules from cv. Nendran were elongated and had flattened surface while larger starch granules perceived from cooking bananas like Monthan, Saba and Popoulu with more elongated granules and few were found to be circular smaller granules. The starch granules from cv. Monthan exhibited multimodal distribution with higher particle size of 40.19 ± 5.57 µm whereas bimodal dispersion with mean particle size of 23.01 ± 5.65 µm and 29.60 ± 6.19 µm was exhibited with the cvs. Saba and Popoulu starch granules respectively. Grand Naine and Nendran starches exhibited unimodal with lower mean particle size of 13.59 ± 6.90 µm and 8.56 ± 2.31 µm respectively.

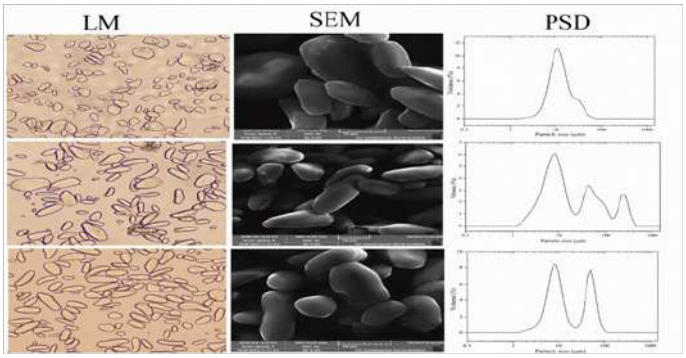


Fig. 38. Light microscope (LM) (40 x magnifications), scanning electron microscope (SEM) images (50 µm) and particle size distribution (PSD) of banana starch

The diffractogram of different starches showed several peaks (2θ) ranging from 14° to 34°. In our studies, the highest peak was located between 17-18° for all banana starches, while other minor peaks (2θ) were obtained approximately at 14-15° (Shorter), 22-23° (broader), which were typical of a B- type and C- type (combination of A and B). The additional

peak (2θ) at 31° (Grand Naine, Popoulu) and 34° (Nendran) indicated the differences in the crystalline structure of these starches. It is inferred that Monthan, Saba and Popoulu exhibited B-type polymorph and Grand Naine displayed C-type polymorph indicating combination of A and B type.

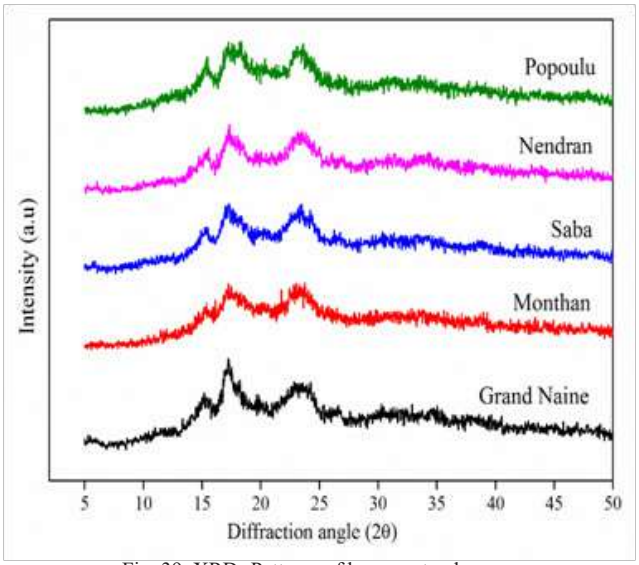


Fig. 39. XRD- Patterns of banana starch.

4.3 PHYSIOLOGY AND BIOCHEMISTRY

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

In a field experiment conducted at ICAR-NRCB farm to evaluate the ABB banana genotypes against drought tolerance at flowering stages. The ratoon crop has been allowed to evaluate these genotypes against drought stress. Out of 48 genotypes evaluate for a few ABB genotypes observed and recorded good fruit development and bunch development. Consistently, the drought tolerant check "Kaveri Saba" has recorded higher yield than many of the banana genotypes.

The NDVI of traits of ABB genotypes were recorded. There is diversity in NDVI among the ABB genotypes (Fig. 40). The Manjavazhai recorded lowest among all and Peyan, Sakkai, Bangrier, Saba and Karpuravalli are recorded highest NDVI. It is an indicator for plant healthiness based on reflectance of leaf canopy. It captures reflectance signals and provide the status of the plant based on the leaf chlorophyll content and water.

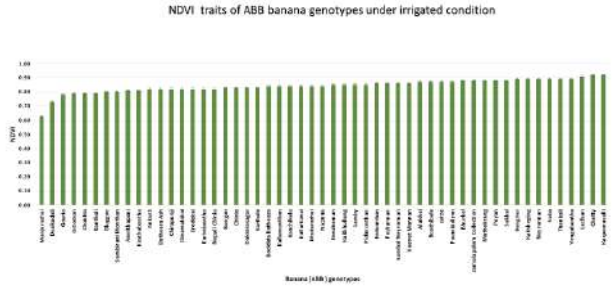


Fig. 40. NDVI traits of ABB banana genotypes under irrigated conditions

The Fv/Fm is a physiological parameter for assessing the function of photosystem II (PS II), which is functioning during light reaction and its efficiency of light harvesting ability and converting this light energy into chemical energy and utilize them in manufacturing of photosynthate under dark cycle. The full potential of light harvesting functioning of PSII is known under fully opened state after dark adoption of leaves. This FV/Fm parameter was assessed in fully grown ABB genotypes under irrigated condition and observed diversity in PS II functions (Fig. 41). The genotypes like, Kanthali, Bangrier and Enna Benian recorded highest value. The Ankur 1 and Peyan genotypes recorded lower Fv / Fm values. There is varied response of ABB genotypes on light harvesting potential as evidenced in Fv/Fm ratio.

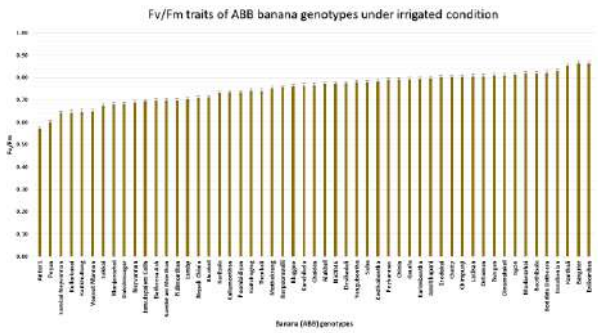


Fig. 41. The Fv/Fm of ABB banana genotypes under irrigated condition

There is a diversity among ABB banana genotypes for their yield and yield traits. The number of hands

and fingers are the major determinants of yield traits in banana. In this regard the number of hands were recorded higher in Bluggoe, Octoman, Kanchikela, Enna Benian, Dakshin Sagar (Fig.42). The similar trend was observed more or less similar in total number of fingers per bunch (Fig.43). It is appeared that, the ABB genotypes are potential yielder under irrigated condition, under optimal management, till harvest.

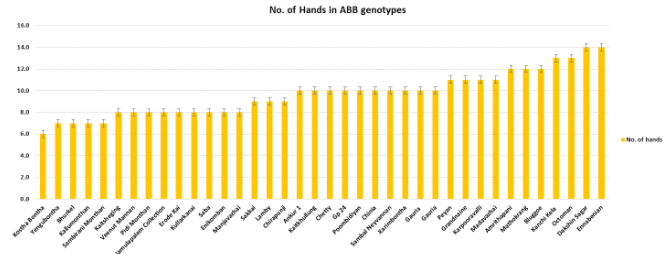


Fig. 42. Diversity of number of hands in ABB genotypes under irrgiated condition

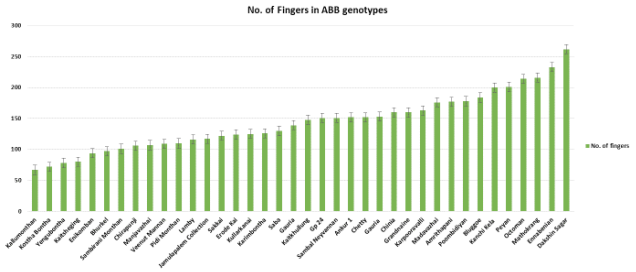


Fig. 43. Diversity of number of fingers (fruits) per bunch in ABB genotypes under irrgiated condition

ABB genotypes against drought reduced the yield compared to irrigated. However, the yield reduction was lesser in Bluggoe, Peyan, Kostha Bontha and Saba. The percentage reduction in bunch yield and yield traits showed a similar trend. The number of hands, fingers and bunch weight reduction was less than 20 % in these ABB genotypes (Fig. 44). These ABB genotypes are suitable to grow in water limited environment. The present experiment revealed that not genotypes with B rich genomes (ABB) are soil moisture deficit stress tolerant.

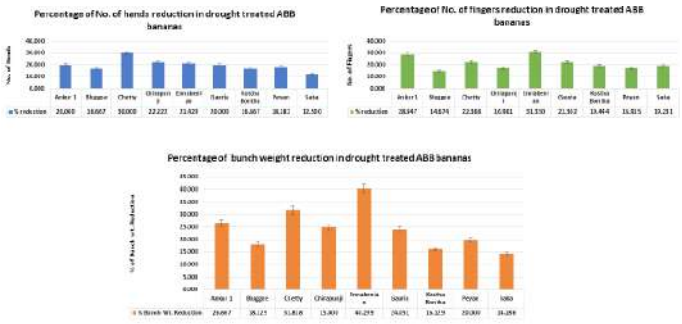


Fig. 44. Impact of drought on ABB genotypes on bunch weight and its yield components reduction at flowering

In a pot study five different popular banana cultivars were grown for three months and treated them with three different levels of irrigation to check the tolerance level in the cultivars (Fig. 45). The levels of irrigation (100%, 75% and 50%) was determined based on evaporative demand of plants. Physiological and biochemical assays were performed to determine the stress tolerance level in cultivars and to identify water use efficient banana cultivars with less water consumption. On basis of results, the studies revealed that cultivars like Ney Poovan (AB) and Kaveri Saba (ABB) were more tolerant deficit irrigation condition compared to the other cultivars like Rasthali (AAB) and Grand Naine (AAA). The cv. Grand Naine is more susceptible to the drought conditions and also they cannot survive in the water deficit condition. While irrigating the plants at the level of 50% and 75% evaporative water demand, irrigating the plants with 75% water demand were able to grow and better plant development during the earlier vegetation phase compared to irrigating 50 % evaporative water demand plants. Plants that were irrigated in 50% were not able to withstand to the higher temperature and water deficit condition and their dry matter yield was minimized and the growth of the plants were decreased. Thus it is surmised that, based on dry matter production and growth parameters, 75% of evaporation of water demand may be given as irrigation to banana cultivars like Ney Poovan (AB) and Kaveri Saba (ABB) to give normal yield.

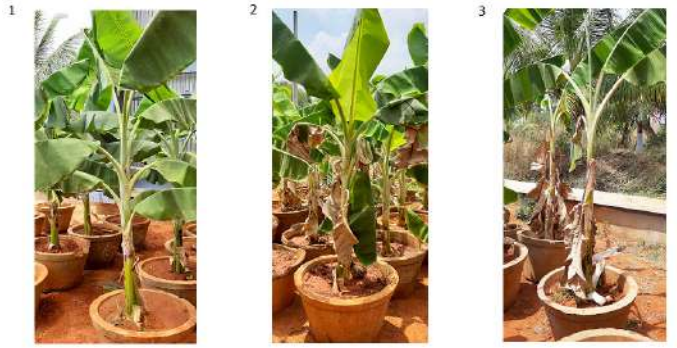


Fig. 45. Effects of level of irrigation; 1: Plants under irrigation to full level (100%) remaining healthy; 2: Plants under75% irrigation with most of the leaflet remaining healthy but with drooping and withering of some leaves; 3: Plants under 50% irrigation with plants becoming weak and most of the leaves are fragile and drying.

In an experiment to evaluate the banana cultivars for high temperature tolerance, the plants were grown in pot for three months and exposed to low light and higher temperature and assessed function of photosynthetic function. The high temperature (unshaded plants) reduces PS II yield to the level of 39.6% in cvs. Grand Naine banana. The higher light and temperature affected the photosynthetic pigment and reduced the PS II yield.

In an experiment to evaluate the banana leaf traits which are suitable for leaf plate purpose, the specific leaf area (SLA) was recorded from first three leaves from apical region, i.e. top to down in five month old plants of cvs. Poovan, Karpuravalli and Kaveri Saba. In case of Karpuravalli and Kaveri Saba, the first leaf is very thin compared to cv. Poovan and 2nd and 3rd leaves are thicker than cv. Poovan. These traits may be genetically governed. The most popular and acceptable banana cultivar for leaf plate purpose is Poovan. The optimum value of SLA may be in the range of 1.0 - 1.3 (mm^2 / mg) (Fig. 46). Sometimes people are also using cv. Karpuravalli leaves and the SLA values also indicates that its values are near to values of cv. Poovan.

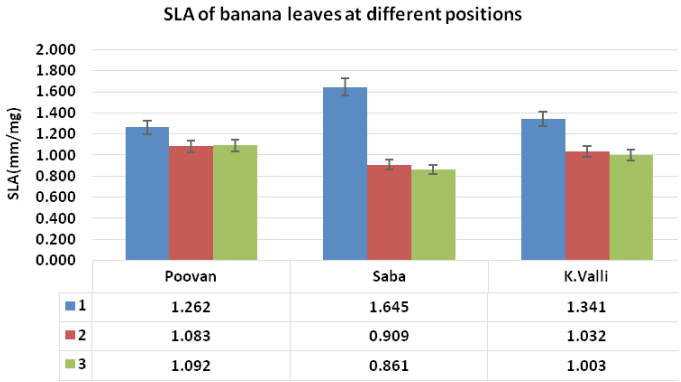


Fig. 46. Banana cultivar difference on leaf traits of Specific Leaf Area of top three leaves

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

Threshold temperature of 'green ripening' of Cavendish (Grand Naine) bananas

In order to find out the threshold temperature at and above which the green ripening of Cavendish bananas occurs, full (95%) mature Grand Naine bananas were subjected to ripening from 21 to 31°C with RH of 94% in ripening chambers. From 21 to 25°C, the bananas exhibited normal ripening behaviour including yellowing of peel of the fruit. The bananas ripened at 26°C exhibited a tinge of green colour in the peel and at 27°C and above temperatures, the peel hue remained green and at 30°C, the colour of the peel was full green. From the results, it is found that 26°C is the threshold temperature at and above which the 'green ripening' of Cavendish bananas take place (Fig. 47).

Fig. 47. Ripening behavior of Cavendish banana (Grand Naine) at different temperatures; (From left to right) 24, 25, 26, 28 and 30°C

The physiological, biochemical and quality parameters analyses of the Grand Naine fingers ripened at 24 and 30°C showed similar profile of ripening except low Mg-dechelatase and very low pheophorphide *a* oxygenase (PaO) activities (Fig. 48). Mg-dechelatase and PaO are the second and third enzymes in the catabolic pathway whereby the degreening of fruit rinds occurs. Profiling of chlorophyll catabolites by RP-HPLC showed high accumulation of pheophorphides, the substrates of PaO in the peel of the fruits ripened at 30°C (green ripe) (Fig. 49). This clearly corroborates that impairment of PaO enzyme activity at temperatures above 26°C that disrupts chlorophyll catabolic pathway and partial degradation of chlorophyll leading to green peel of bananas.

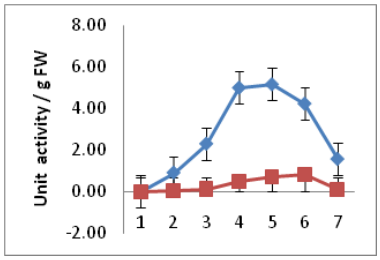


Fig. 48. Activity of pheophorphide a oxygenase activity in peel of Grand Naine ripened at 24 oC (blue line) and 30oC (red line)

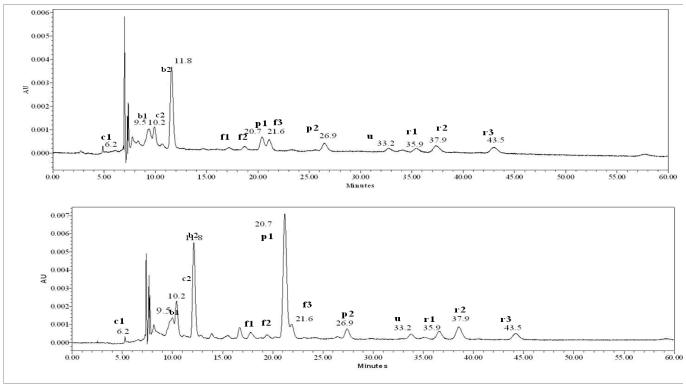


Fig. 49. Chromatogram of chlorophylls and their catabolites in Grand Naine bananas ripened at 24 ^{O}C (top) and 30 ^{O}C; Peak P1 with Rt of 20.7 min is for pheophorphide a which is highly accumulated at 30 ^{O}C

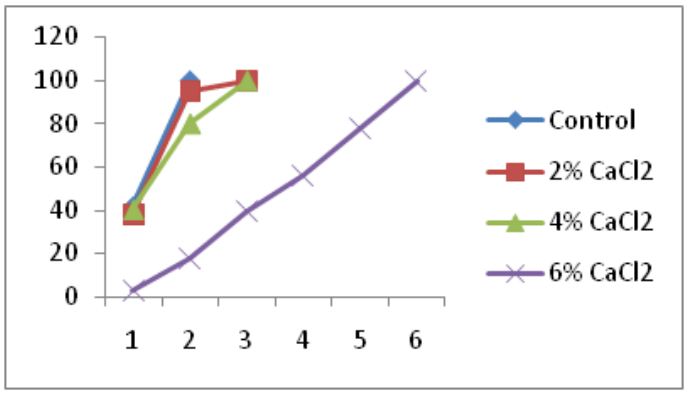


Fig. 50. Effect of various concentrations of CaCl2 on finger drop in Grand Naine bananas

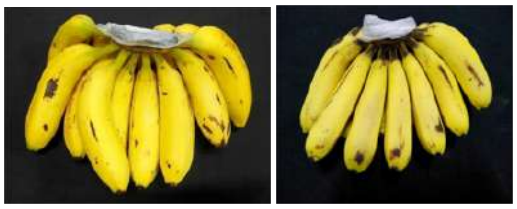


Fig. 51. Hands of Grand Naine treated with 6% (left) and 8% (right) CaCl2 for management of finger drop

Management of finger drop in bananas

Grand Naine (AAA) is the cultivar highly susceptible to finger drop phenomenon. For management of the phenomenon, full (95%) mature Grand Naine fingers were first fumigated with 500 ppm of ethylene for uniform ripening, then the hands were sprayed with 2, 4, 6, 8, 10% of hydrated calcium chloride ($CaCl_2$) at the rupture developing pedicel region of fingers as target-treatment and stored at controlled conditions of 22^{O}C and 94% RH for ripening. The results showed that the 6% $CaCl_2$ treatments delayed the onset of finger drop i.e., initiation of pedicel region rupturing by two and three days after ripening. Complete finger drops occurred on fourth day in control and on fifth day in 2% and 4% $CaCl_2$ treatment. Only 40% drops occurred in the 6% $CaCl_2$ treatment thus reducing finger drop by 60% and 100% droppings occurred on eighth day after ripening extending the shelf life of fingers (Fig. 50). Higher concentrations (8% and 10%) $CaCl_2$ caused blackening at the pedicel zone and injury to the fruits (Fig. 51). Enzymatic analysis of the pedicel peel tissues of control and 6% calcium chloride treated bananas showed reduced activity of polygalacturanase and pectin lyase, the enzymes involved in the depolymerisation of pectins during ripening of fruits. The polygalacturanase activity was 4.35 Unit activity/ g fresh peel tissue against the 2.42 Unit activity in 6% $CaCl_2$ treated fingers.

Evaluation of commercial banana cultivars for flavonoids content

Flavonoids contents in peel and pulp of and unripe and ripe fruits of 12 commercial cultivars were determined as mg quercetin equivalent per 100 g DW. Among the cultivars, unripe peel of Monthan (ABB) contained highest amount of flavonoids with 392 mg followed closely by Rasthali (AAB), Poovan (AAB), Karpooravalli (ABB) and Udhayam (ABB), which possessed about 380 mg. In unripe pulp, again Kaveri Saba (ABB) and Nendran (AAB) contained highest quantity of 162 and 161 mg followed by Monthan with 144 mg. In ripe fruit peel, again Monthan contained highest quantity of flavonoids with 384 mg followed by Udhayam, Rasthali, Karpooravalli (ABB) and Poovan which contained above 350 mg. Kaveri Saba topped in flavonoids contents in ripe pulp with 146 mg and Nendran, Monthan and Pachanadan (AAB) containing more than 100 mg of flavonoids in ripe pulp.

The flavonoids contents in unripe fingers of 14 cultivars and ripe fruits of 21 banana cultivars collected from North Eastern region were also estimated. Peel of unripe Beejikela (BB), *Musa*

balbisiana (BB) and Kachkela (ABB) possessed more than 350 mg of total flavonoids and pulp of unripe fingers of *Musa balbisiana* contained highest quantity of flavonoids with 271 mg and Chinali (AAB), Nepali Chinia (ABB), Beejikela and Batheesa Chiriya (ABB) contained more than 200 mg of flavonoids (Fig. 52). Among the 21 cultivars used for analysing the flavonoids contents in ripe peel and pulp, again the Beejikela, *Musa balbisiana* and Kachkela contained high quantity with more than 350 mg around 320 mg/100 g DW in peel and *Musa balbisiana*, Chinali and Nepali Chinia contained more than 200 mg flavonoids (Fig. 53). Generally, the 'B' genome cultivars possessed higher quantity of flavonoids than 'A' genome bananas; between peel and pulp, the peel contained higher quantity of flavonoids and compared to ripe peel and pulp, the unripe peel and pulp contained higher levels of total flavonoids.

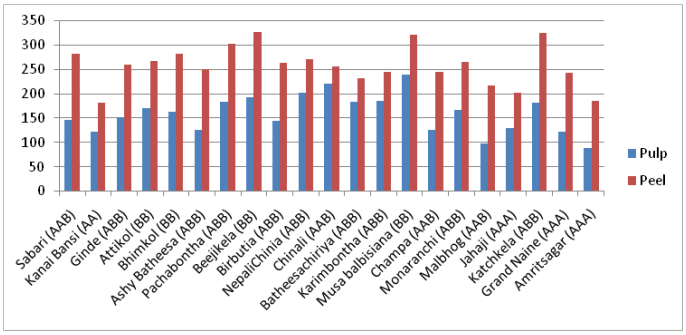


Fig. 52. Total flavonoids contents (mg quercetin equivalent / 100 g DW) in ripe bananas of North Eastern region

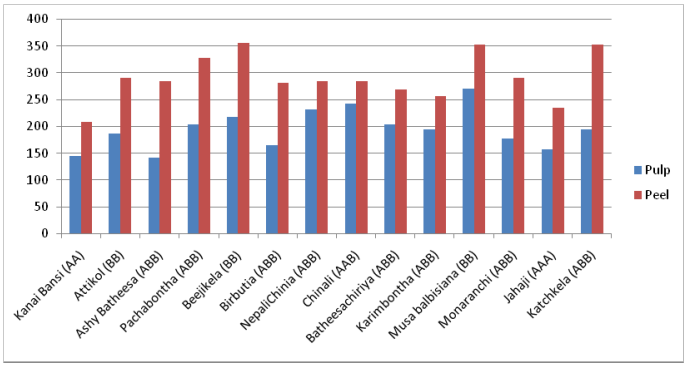


Fig. 53. Total flavonoids contents (mg quercetin equivalent / 100 g DW) in unripe bananas of North Eastern region

Antioxidant potentials of flavonoids

Antioxidant (DPPH scavenging) activity of flavonoids (methanolic extract) from ripe peel and pulp of commercial banana varieties were determined. The peel extracts showed 86-94% activity with Monthan and Udhayam showing highest activity and similarly, pulp extracts of Monthan, Pachanandan, Nendran and Karpooravalli exhibited higher activity with Monthan of 88%. The FRAP (Ferric Reducing Ability in Plasma) assay of these varieties showed 3450-6950 mg Trolox Equivalent/100 g with Monthan showing highest ability. The antioxidant activity and FRAP assay of methanolic peel and pulp extracts of North Eastern banana cultivars were also worked out and *Musa balbisiana* and Beejikela showed greatest activity.

Anthocyanin compounds in banana flower bracts

Individual anthocyanin compounds in flower bracts of eight commercial banana cultivars *viz*., Grand Naine (AAA), Red Banana (AAA), Ney Poovan (AB), Poovan (AAB), Nendran (AAB), Rasthali (AAB), Karpooravalli (AAB) and Monthan (ABB) were profiled by RP-HPLC. The commercial cultivars contained six anthocyanin compounds in varying proportions with predominance of one to three compounds. The predominant compound in Grand Naine flower bracts was cyanidin-3-rutinosides with 72% (Fig. 54) while Red Banana contained two major compounds of cyanidin-3-rutinosides and malvidin-3-rutinosides with 28 and 35% respectively. The composition of anthocyanin compounds in Ney Poovan and Poovan were similar with predominance of cyanidin-3-rutinosides, peonidin-3-rutinosides and malvidin-3-rutinosides (Fig. 55). Nendran and Rasthali contained cyanidin-3-rutinosides and malvidin-3-rutinosides as the major compounds with about 22 and 40% respectively while Karpooravalli possessed around 50% cyanidin-3-rutinosides and two compounds, cyanidin-3-rutinosides and cyanidin 3 rhamnosides-7-glucosides, constituted 91% of anthocyanin pigments of Monthan flower bracts.

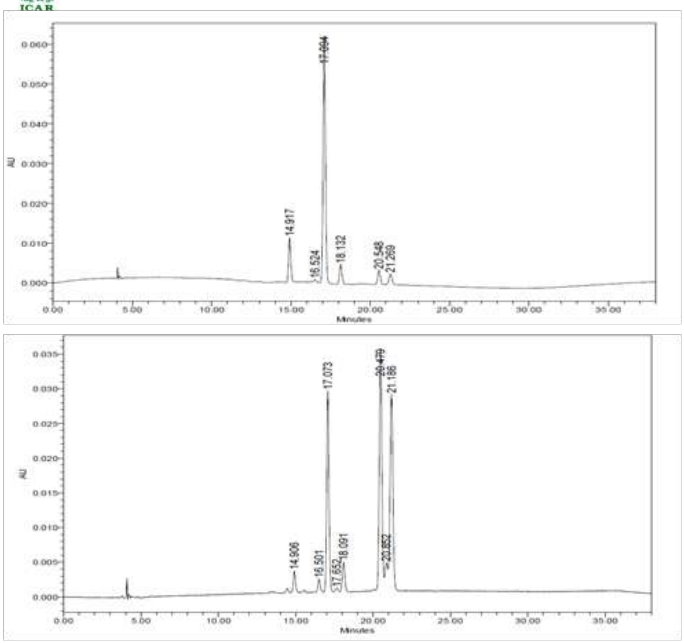


Fig. 54 & 55. Chromatograms of anthocyanin compounds of flower bracts of Grand Naine (top) and Ney Poovan (bottom)

4.4 CROP PROTECTION

4.4.1 Management of banana weevils

In vitro screening of entomopathogenic fungi against banana aphid

Fifteen isolates of the entomopathogenic fungus *Akanthomyces lecanii* (=*Lecanicillium lecanii*) were screened *in vitro* against the banana aphid, *Pentalonia nigronervosa*. Three isolates (0086, 0187, 0297) were found to cause total aphid mortality on the third day.

Cuticle degrading enzymes of entomopathogenic fungi

Promising isolates of *Beauveria bassiana* (0271, 079, 0028, (A), 0032, 0086, 0018 and 0043 broths) were tested *in vitro* for activity of cuticle degrading enzymes such as chitinase, lipase and protease against banana stem weevil, *Odoiporus longicollis*. The weevil mortality was recorded from 6th to 10th day after treatment. The maximum and minimum activity of chitinase, lipase and protease causing weevil mortality was 81.13-100.0, 76.64-98.35 and 77.68-98.55, respectively.

Predatory spiders recorded from banana ecosytem

Six spider species (*Argiope anasuja*, *Plexippus paykulli*, *Heteropoda venatoria*, *Leucaugetes sellata*, *Neoscona* sp. and *Cyrtophora* sp.) were collected from the banana ecosystem as predators of insect pests such as lacewing bug, mites, aphids, *etc*. (Fig. 56).

Cyrtophora sp. *Neoscona* sp. *Leucage tesselata*

Fig. 56. Natural enemies (spiders) associated with banana ecosystem

GC-MS analysis of volatiles of live banana plants by air entrainment method

90 volatile compounds were identified from ten cultivars, Grand Naine (AAA-Dwarf Cavendish), Karpuravalli (ABB-Pisang Awak), Monthan (ABB-Bluggoe), Rasthali (AAB-Silk), Red Banana (AAA-Red Banana), Nendran (AAB-Plantain), Pachaladan (AAB-Pome), Poovan (AAB-Mysore), Ney Poovan (AB-Pome) and Manoranjitham (AAB-Pome). Of these, 57 compounds were insect attractants and 33 were deterrent and anti-microbial compounds. (Table 17 & Fig. 57).

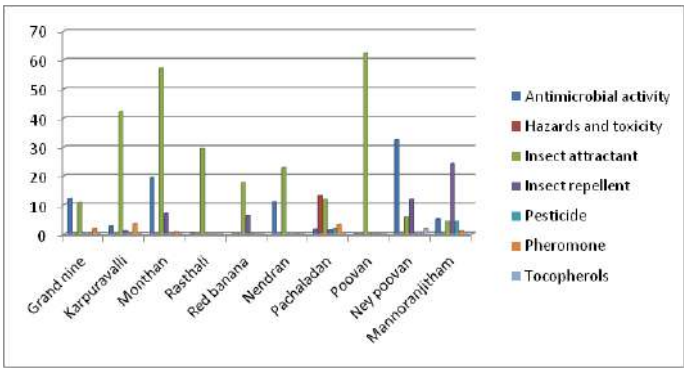


Fig. 57. Histogram indicating the per cent of compounds having different biological activity among the ten banana cultivars

Table 17. Comparative table indicating the per cent of compounds having different biological activity among the ten banana cultivars

Biological activity	Grand Naine	Karpu ravalli	Mon-than	Rasth-ali	Red-Ba-nana	Nen-dran	Pacha-ladan	Poovan	Ney poovan	Manoran-jitham
Antimicrobial activity	12.25	2.69	19.46	0.46	0	11.05	1.75	0.24	32.44	5.23
Hazards and toxicity	0	0	0	0	0	0	13.28	0	0	0
Insect attrac-tant	10.94	42.18	57.25	29.46	17.73	22.96	11.91	62.35	6.07	4.33
Insect repellent	0	1.08	7.06	0	6.39	0	1.58	0	12.03	24.37
Pesticide	0	0	0	0	0	0	1.88	0	0	4.33
Pheromone	1.95	3.56	0.70	0	0	0.18	3.34	0.16	0	1.06
Tocopherols	0	0	0	0	0	0	0	0	1.95	0

4.4.2 Pest mapping in bananas and plantains in India

Surveys were carried out for banana leaf and fruit scarring beetles in Assam and Meghalaya in October 2019. The beetle population was generally low and only in some pockets, incidence was high. Alternate hosts of *B. subcostata* were recorded based on presence of beetles and damage symptoms. *Canna indica* L. (Cannaceae, Zingiberales), turmeric (*Curcuma longa* L., Zingiberaceae), ginger (*Zingiber officinale* Roscoe; Zingiberaceae, Zingiberales) and taro (*Colocasia* sp., Araceae, Arales), were recorded as host plants of *B. subcostata* besides banana and the beetle population on these plants was low (2-3 / leaf) but characteristic damage symptoms were observed on the leaves. Observations were recorded on the natural enemies of *B. subcostata.* In Uttar Pradesh, North India, adults of the predatory beetle, *Paederus fuscipes* Curtis (Coleoptera, Staphylinidae), were found to be commonly associated with *B. subcostata.* Natural epizootics of entomofungal pathogens, such as *Beauveria bassiana*, were commonly recorded on *B. subcostata* in the northeastern region of India and found to exert some control in the post-monsoon months.

Based on extensive surveys in north and northeastern states, three species of banana-feeding chrysomelids, namely, *Basilepta subcostata* (Eumolpinae), *Bhamoina varipes* (Jacoby), and a new species, *Sphaeroderma cruenta* Prathapan & Kumari (Galerucinae, Alticini), were documented from India. Of these, *B. varipes* and *Sphaeroderma cruentata* were recorded for the first time from Meghalaya, India. An illustrated diagnostic account of these three species was prepared to facilitate their identification by economic entomologists.

Studies were carried out on the male and female genitalia of all the common polymorphic forms of *B. subcostata* from Bihar, West Bengal, Assam, Meghalaya, Uttar Pradesh, Odisha and Manipur, and no differences were found in the morphology, including genitalia, of these populations indicating that they belonged to a single morphospecies. In total 10 COI sequences of *B. subcostata* (six from Assam and four from Uttar Pradesh) were deposited in GenBank and accession numbers obtained (KY908365.1, MK414475.1, MK414474.1, MK414473.1, MK414472.1, K414470.1, MK414469.1, MK414468.1, MK414467.1 and MK414466.1). The pairwise nucleotide sequence identity of COI sequences of *B. subcostata* from Assam and Uttar Pradesh ranged from 98 to 100%, indicating that they were conspecific. The phylogenetic tree constructed by the maximum likelihood method based on COI

gene sequence alignments revealed two clusters, with *B. subcostata* from Assam and UP forming one cluster (Group I), and the sequences from the outgroup taxa falling in another cluster (Group II). COI sequences of populations of *B. subcostata* from Assam and Uttar Pradesh showed 98–100% homology, indicating that these populations are conspecific and that COI sequences can be used for rapid species determination.

Records of *Basilepta viridipennis* (Motschulsky), a species frequently reported in the literature as a pest of banana in the Indian Subcontinent (India and Bangladesh), were found to be erroneous based on the examination of the type specimen of *Nodostoma occipitale* Jacoby at the Natural History Museum, London, a synonym of *B. viridipennis*. Specimens of *B. subcostata* collected from Vittal, Karnataka, and Deccan were examined at the Natural History Museum, London, indicating that *B. subcostata*, a pest hitherto unknown from peninsular India, is present here and it needs to be kept under constant surveillance.

Incidence of *Erionota* spp. in Assam and Meghalaya during October 2019 was low. Incidence of rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin, was found to be very heavy on banana intercropped with coconut in Guwahati, Assam. Parasitization of the whitefly by the exotic parasitoid, *Encarsia guadeloupae,* was also observed. *Asprothrips navsariensis* Tyagi was recorded in large numbers on Cv. Grande Naine and ornamental banana (*Musa ornata*) during February-March 2020 at NRCB research farm. New natural enemies of *Olene mendosa,* a common pest of banana, were documented. A web-based identification aid to about 50 insect and mite pests of bananas and plantains in different parts of India hosted in NRCB's website (URL: nrcb.res.in/album) was further updated.

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

Survey and distribution of VCGs in India

Thirteen Fusarium (Foc) isolates were collected from Bihar and Uttar Pradesh during the period under report and the analyses indicated the presence of VCGs 01220 and 0125 belonging to Foc race-1 in Grand Naine, Monthan and Rasthali cultivars from Uttar Pradesh and Bihar. Besides VCG 01213/16 (TR4) was also observed in Grand Naine collected from Uttar Pradesh and Bihar. PCR amplification using molecular marker also confirmed the same. Analysis of Foc isolates collected from cv Grand Naine of Surat confirmed that the cultures belonged to VCG 01220 and 0125 of Foc race 1 and it was further confirmed by molecular analysis using specific markers. In 2018-19 VCG 120 was found in Gujarat and Burhanpur only. Sequencing of Translation Elongation Factor 1α (TEF) gene also confirmed the same. Foc infected samples collected from Kerala (5 nos) and Tamil Nadu (5 nos) from different varieties were identified as Foc race 1 belonging to VCG 0124.

Field evaluation of consortia of bioagents for the management of Fusarium wilt disease Tropical Race 4/ R1 VCG 0124 in cv. Grand Naine

Field evaluation of biocontrol agents against Foc TR4 in Surat

For the development of sustainable Fusarium wilt control in Surat, a consortium of different treatments including a combination of bacteria and fungi was evaluated in randomized block design and consisted of six treatments (each with 150 plants) with three replications. The treatments were: T1: Endophytic *Trichoderma asperellum* (Prr2) + Endophytic *Penicillium pinophilum* (BC2); T2: Endophytic *Bacillus flexus* (Tvpr1) + Rhizospheric *Trichoderma asperellum* (NRCB3); T3: Endophytic

Pseudomonas extremorientalis (B1) + *Ochrobactrum anthropi* (B5) + Endophytic bacteria (B3); T4: Endophytic *Trichoderma asperellum* (Prr2) + *Trichoderma* sp. (NRCB New) + Rhizospheric *Trichoderma* sp. (Assam); T5: Carbendazim (0.3 %); and T6: Control. The results indicated that the experimental plot that received T2 recorded the lower percentage of wilt incidence (i.e. 6%) than the control in the fourth month of observation. Similarly, T2 resulted in maximum plant height (195.5 cm), plant girth (70.5 cm), total number of leaves (10.8 nos/ plant) and leaf area (7129 cm^2). The experiment is in progress.

Table 18. Field evaluation of biocontrol agents against Foc TR4

Treatments	No. of plants infected	Plant height (cm)	Plant girth (cm)	Total no. of leaves	Leaf area (cm^2)
T1	14 (9.3%)	191.6 (17.25)	63.9 (16.81)	10.4 (15.55)	5736.25 (31.27)
T2	9 (6%)	195.5 (19.64)	70.5 (28.88)	10.8 (20.0)	7129.13 (63.14)
T3	26 (17.3%)	196.3 (20.13)	68.7 (25.59)	10.4 (15.55)	6852.51 (56.81)
T4	15 (10%)	189.3 (15.85)	65.6 (19.92)	10.6 (17.77)	6721.76 (53.82)
T5	27 (18%)	180.6 (10.52)	60.9 (11.33)	8.7 (3.33)	5474.02 (25.27)
T6	37 (24.6%)	163.4	54.7	9.0	4369.70

T1: Endophytic *Trichoderma asperellum* (Prr2) + Endophytic *Penicillium pinophilum* (BC2); T2: Endophytic *Bacillus flexus* (Tvpr1) + Rhizospheric *Trichoderma asperellum* (NRCB3); T3: Endophytic *Pseudomonas extremorientalis* (B1) + *Ochrobactrum anthropi* (B5) + Endophytic bacteria (B3); T4: Endophytic *Trichoderma asperellum* (Prr2) + *Trichoderma* sp. (NRCB New) + Rhizospheric *Trichoderma* sp. (Assam); T5: Carbendazim (0.3 %); and T6: Control. Values in parentheses are percentage of increase over control, except the number of plants infected.

Studies on mass production of *Trichoderma asperellum* on low cost organic materials for the control of *Fusarium oxysporum* f. sp. *cubense*, Tropical Race 4 (Foc TR4)

Trichoderma asperellum (Prr2), was found to be the most effective biocontrol agent inhibiting the*in vitro* mycelial growth of Foc TR4. This study investigated the mass production of antagonistic fungi using easily available, cost-effective organic sources (rice chaffy grain, farmyard manure and wood ash) through solid-state fermentation besides checking their shelf-life. Among the different organic substrates tested, farmyard manure was found suitable for colonizing *T. asperellum* (Prr2). Moreover, other ingredients added into FYM further enhanced the mass multiplication of *T. asperellum* (Prr2) at 30 DAI based on high-density propagules (10.26 $\log_{10}$ CFU g^{-1}). The shelf-life of the formulation was tested periodically (0-60 days) to ensure viable CFU and thus suitability of field application. The population of *T. asperellum*Prr2 was higher in FYM used substrate and found to be 11.60 $\log_{10}$ CFU g^{-1} even after two months of storage. The study showed that mixture of FYM with other cost-effective organic constituents

resulted in high-density propagules of *T. asperellum* with extended shelf-life, therefore, this farmer-friendly technology can be used for the management of Foc TR4 in banana.

Fig. 58. Mass multiplication of *Trichoderma asperellum* (Prr2) in the bamboo basket using FYM formulation

Isolation and evaluation of nutrient solubilizer (Phosphorus) for increasing the soil and plant health in Fusarium wilt management

To increase the soil and plant health for combating fusarium wilt disease of banana by increasing the root vigor and growth, potential phosphate solubilizing bacteria (PSB) were isolated from rhizospheric soil of 12 different banana germplasm and the population of PSB ranged from 5.46 to 6.32 log CFU/g of soil. Based on colony morphology, 55 bacterial isolates were obtained and studied for *in vitro* phosphate solubilization efficiency. Among the isolates, PSB27 (6.21), PSB39 (5.36), PSB45 (5.36), PSB52 (5.27) and PSB54 (5.37) recorded highest phosphate solubilization index. Based on the quantification of available phosphorus in culture supernatant through Inductively Coupled Plasma (ICP) analysis, the isolates PSB52 and PSB54 recorded the highest available P content(24.12 and 32.0 µg mL^{-1}, respectively) and were found to have potential for further evaluation. Molecular identification by 16S rRNA analysis revealed that the selected isolates are *Enterobacter hormaechei* ssp. *xiangfangensis* (PSB52) and *Leclercia adecarboxylata* (PSB54) and the sequences were deposited in NCBI database under the accession numbers MN515096 and MN515095, respectively.

To check *in vitro* phosphate solubilization efficiency of the strains, a pot culture experiment was conducted with 12 treatments in three different soil types (Black, Alluvial and Red soil) and inorganic phosphate sources. Among these treatments, T5 (PSB52 + tricalcium phosphate) and T6 (PSB54 + tricalcium phosphate) recorded the highest plant growth attributes (plant height, leaf area, number of leaves, root length and root biomass), maximum available phosphorus (3.50 µg/mL) and phosphatase enzyme activity in tested soil types (61.9%), particularly red soil.

Fig. 59. Effect of phosphate solubilizing bacteria on total plant biomass in cv. Grand Naine

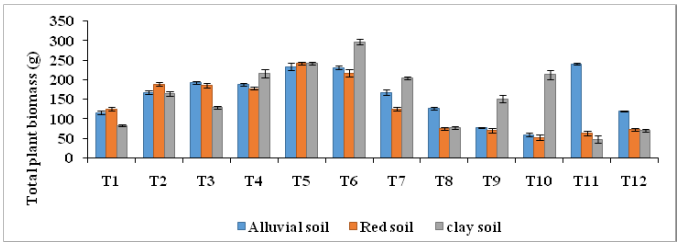


Fig. 60.Effect of phosphate solubilizing bacteria on total plant biomass in cv. Grand Naine

4.4.4 Survey, etiology and management of rhizome rot of banana

Survey and characterization of rhizome rot of banana

Survey on rhizome rot of banana was conducted in Madhya Pradesh (Virodha, Nachankheda, Dapora and Khamni, Burhanpur District), Maharashtra (Muktainagar, Jalgaon District), Gujarat (Kholeshwar and Kurjan, Kamrej Taluk, Surat District), Uttar

Pradesh (Lucknow and Siswabhajar-Maharajganj) and Bihar (Falka, Katihar) during 2019-20. Rhizome rot incidence on tissue culture banana (cv. Grand Naine) grown in these regions was 2-15%. In all, 60 different isolates of rhizome rot pathogen were collected and based on cultural characteristics on CVP and sequencing with 16s rDNA primers, the majority of isolates were characterized as *Pectobacterium* sp., *Achromobacter* sp., and *Klebsiella* sp. These isolates produced characteristic rhizome rot on cv. Grand Naine after 30-45 days of inoculation.

Development of rhizome rot bioassay unit

A soil heating unit was developed using locally available materials such as heater, sensor, conductor, specialized motor, etc. Using this unit,the specific soil temperature required for pathogenicity of rhizome rot bacterial isolates was standardized. Through this method the rhizome rot assay could be completed with 10-20 days. Validation of the technique with repeated assays is in progress.

Isolation and characterization of biocontrol agents

In total, 25 isolates of microbes were evaluated for growth promotion on banana (cv. Grand Naine) under glasshouse conditions. Among them, four isolates *viz*., H4 BC1, H6 BC3, H7 BC2 and H8BC1 showed high plant height and girth at significant level. Additionally, 12 Actinobacteria were isolated and are being evaluated for plant growth promotion, rhizome rot control and decomposition ability of banana waste. Two other isolates, BCB 2-4 and BCNA5-3, which showed enhanced plant growth promotion earlier were characterized at species level based on sequencing of 16s rDNA.

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

Survey for viral diseases

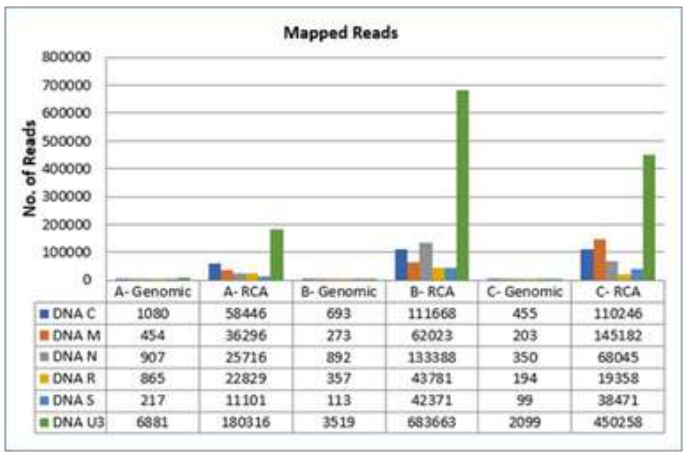
Surveys were undertaken in Theni, Dindigul and Thanjavur districts of Tamil Nadu and Jalgaon district of Maharashtra for banana viral diseases. In Theni, the incidence of banana bunchy top disease (BBTD) (1-60%) and banana bract mosaic disease (BBrMD) (0.5 to 11 %) was recorded in cv. Grand Naine and Red Banana and the incidence of cucumber mosaic virus (CMV) was 5.06 %. In lower Palani Hills, the incidence of BBTD ranged from 1 to 28% and 1-15% of BBrMD was observed in cv. Virupakshi. High incidence of BBTD (6–42%) and BBrMD (5–20%) was recorded in cv. Poovan (AAB) in Thirukattupalli and Thanjavur areas of Tamil Nadu where the banana leaf industry is prominent. In Jalgaon district, BBTV incidence ranged from1 to 10%. Orchards with tissue culture (TC) banana (cv. Grand Naine) had up to 95% of cucumber mosaic virus (CMV) incidence in Jalgaon district of Maharashtra. More than one million NCS-TCP certified TC banana plants in 2019 showed the incidence of CMV. CMV incidence upto 16% was also recorded in Burhanpur of Madhya Pradesh. Banana bract mosaic virus (BBrMV) incidence was recorded in BRS, Jalgaon.

Molecular characterization of banana viruses

Banana bract mosaic virus (BBrMV) in Hill banana at Lower Pulney Hills and Pisang Madu from ITC collections was recorded for the first time. This was confirmed by cloning and sequencing of partial genome of the virus. For complete genome characterization of CMV-Banana isolate, full length fragments of RNA-1, RNA-2 and RNA-3 of CMV infecting three banana isolates were amplified and cloned. For developing RNA silencing suppressor construct, HC-Pro gene of BBrMV and 2b gene of CMV were amplified and cloned in pMD20-T vector.

Characterization of banana bunchy top virus, single stranded DNA virus infecting banana using Oxford nanopore MinION sequencing

Nanopore sequencer (MinION device) was used to detect and characterize BBTV from cv. Poovan (AAB). A total of 4,431,681 reads were obtained of which 3,366,283 reads were above Q7. Local base calling and trimming of reads were done. Target BBTV sequences were extracted by mapping the reads (Fig. 61). The mapped sequences were assembled. The sequences of six genomic DNA components of BBTV from the latent (apparently healthy) and the symptomatic (infected) plants were obtained from the total genomic DNA and RCA products of two distinct samples. The results showed that BBTV could be detected in asymptomatic samples and the copy number could be enriched by RCA method. The whole genomes obtained were more accurate and the sequences showed above 99 % homology when compared to reference sequences.



	A- Genomic	A- RCA	B- Genomic	B- RCA	C- Genomic	C- RCA
DNA C	1080	58446	693	111668	455	110246
DNA M	454	36296	273	62023	203	145182
DNA N	907	25716	892	133388	350	68045
DNA R	865	22829	357	43781	194	19358
DNA S	217	11101	113	42371	99	38471
DNA U3	6881	180316	3519	683663	2099	450258

Fig. 61. Characterization of BBTV infecting banana cv. Poovan using Oxford nanopore MinION sequencing

Development of constructs of partial dimers for different genomic components of BBTV for testing infectivity

Primers were designed to construct a modified binary vector by inserting a newly designed MCS for developing infectious clone for BBTV and BSMYV. Initially a modified MCS was cloned in pJET vector.

Development of infectious clones of Banana Streak Mysore Virus (BSMYV) and BBrMV

Full length genome of BSMYV was cloned into binary vector pBin19 in kpn RE site and then a little more than half of the length genome was recloned to obtain partial dimer (Fig. 62). This clone was immobilized in *Agrobacterium tumefaciens* strain for infectivity assay. Primers were designed to construct a full-length infectious cDNA clone of BBrMV using Gibson Assembly (GA), using a one-step isothermal *in vitro* recombination reaction. In another approach, primers were designed for amplifying a full-length construct of BBrMV by an overlapping-extension PCR (OE-PCR) to produce infectious cDNA of BBrMV.

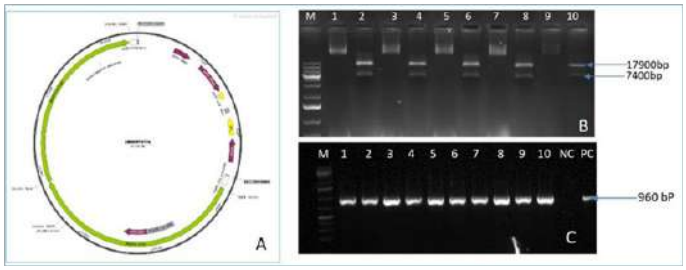


Fig. 62. (A) Infectious clone construct of BSMYV-TRY (B). Agarose gel electrophoresis showing the restriction enzyme digestion of plasmid DNA with EcoRI analysis for confirmation of BSMYV infectious clones in E.Coli. M- 1kb DNA ladder Plus (thermo); Lanes1,3,5,7,9- unrestricted plasmid DNA; Lanes 2,4,6,8,10-Restricted plasmid DNA with EcoRI. (C). Colony PCR analysis for confirmation of BSMYV infectious clones in Agrobacterium strain EHA105 using internal primer. M- 1kb DNA ladder Plus (thermo); Lanes1-10-recombinant clones

Screening of banana germplasm against BBTV

In all, 43 diploid banana germplasm accessions (AA and BB) were screened for resistance against BBTV using viruliferous aphids in an insect proof screen house. Thirteen AA diploids expressed typical symptoms of bunchy top viral infection but none of the BB diploids showed symptoms even after three consecutive inoculations with viruliferous aphids. The time taken to express the symptoms varied between 30 and 120 days. The control (susceptible triploid) varieties, *viz*. Virupakshi (Hill banana) and Grand Naine, expressed BBTV symptoms within 30 days of inoculation. Some of the *Musa* species like *M. flaviflora* and *M. burmannicoides* Type AP also got infected by BBTV (Fig. 63).

Fig. 63.A) A view of diploid banana accessions showing the reaction to BBTV inoculation. (Left: BBgenotypes and Right: AA diploids expressing typical bunchy top symptoms)

Analysis of yield, expression of Banana Streak Virus (BSV) symptoms, symptom severity in the permanent field trial on cv. Poovan

A field experiment was renewed by re-plantingsuckers of asymptomatic Poovanbanana extracted from a permanent,13-year-old experimental trial during 2018. This year the expression of BSMYV induced streak symptoms were observed in 17 plants. All growth and yield parameters were recorded.

Field evaluation of BSMYV free TC banana of cv. Poovan

Preliminary field evaluation data on endogenous BSMYV free elite tissue culture derived Poovan banana plants showed significant differences in the growth and yield parameters compared to sucker grown plants.

Out of six eIF4E genes studied, eIF4E1 was found to interact with BBrMV-VPg in yeast two-hybrid assay. Hence, for the identification of resistant source, eIF4E gene was cloned and sequenced from 50 germplasm accessions and compared with resistant genes from other crops for identification of SNPs in the VPg-eIF4E interacting domain. Out of 50, eight cultivars had SNPs in their VPg interacting domain. *In silico* analysis was carried out to study the changes corresponding to non-conservative amino acid substitution in the cap binding pocket and at the surface of the protein in 3D structure of eIF4E.

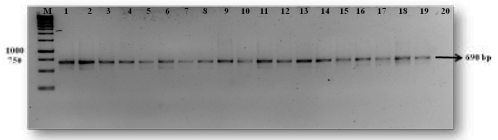


Fig. 64. PCR amplification of eIF4E gene from different germplasm accessions

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

28 differentially expressed spots (>2.5 fold) during BBTV time course study were analyzed and proteins were identified. Primers were designed for RT-PCR analysis for further validating the proteomic results.

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

Effect of foliar application of salicylic acid on root-knot nematodes (*Meloidogyne incognita*) infecting cv. Grand Naine

Salicylic acid was evaluated against root-knot nematode (*Meloidogyne incognita*) at three concentrations (50, 100 and 200µM) under pot conditions by foliar spray at 24hrs prior to nematode inoculation. Foliar application at 100 and 200µM concentration reduced the reproduction as the number of females and juveniles inside the root were reduced by 60-80% over inoculated control.

Survey and sampling of banana for nematodes

Nematode sampling from farmers' fields at Gudalur, Theni Dist., Tamil Nadu, showed root-knot nematode (*Meloidogyne* sp.) was the predominant plant nematode associated with cvs. Red Banana and Nendran. Spiral nematode (*Helicotylenchus* sp.) was found abundant in root samples of cv. Poovan obtained from farmers' fields at Kodumudi, Erode Dist., Tamil Nadu. Root sampling of ornamental banana at ICAR-NRCB farm showed that spiral nematode (*Helicotylenchus multicinctus*) was abundant in root samples of *Musa ornata*, whereas burrowing nematode (*Radopholus similis*) was abundant in root samples of *M. laterita*.

4.5 EXTERNALLY FUNDED PROJECTS

IITA – Collaborative Project

4.5.1 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 Small holder

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)

A total of 21 accessions were introduced from IITA diploids, of which seven were found to be polleniferous in nature and are being used as male parents. Ten chromosome doubled plantlets (4x) (Fig. 65) have been obtained through oryzalin treated Ney Poovan ECS and field planted for evaluating the commercial traits.

Approximately 10000 fruit hands were crossed and 1972 seeds were extracted of which 375 seeds were embryo cultured. From this, 32 hybrid progenies were regenerated and field planted. Three mapping populations (Calcutta 4 x Kadali, Calcutta 4 x Cv. Rose and Calcutta 4 x Matti) have been developed with the population of 67, 60 and 30 progenies, respectively for developing *Foc* resistant markers. A banana breeding tracker has been developed with QR code and is being utilized in NRCB breeding program for on the spot and quick update on breeding status.

Fig. 65. Comparison of 4x and 2x of cv. Ney Poovan

Validation of SSR markers associated with R genes against Foc TR 4

The putative SSR marker developed in R gene located in chromosome 9 was validated in five susceptible and 12 Foc race 4 resistant cultivars. A clear variation in banding pattern was observed between resistant and susceptible cultivars. Monomorphic bands were observed in all the susceptible cultivars tested whereas polymorphic banding pattern was observed among the resistant cultivars (Fig. 66).

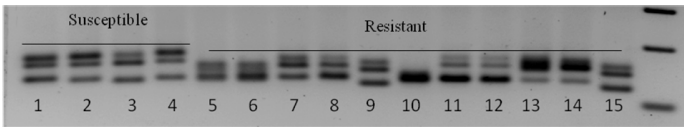


Fig. 66.SSR marker distinquising the susceptible and resistant accessions of Foc TR 4

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)

The top ten PVA enriched transgenic events were compared with the commercial cultivars namely Grand Naine, Rasthali, Red banana and Nendran. Maximum of 27.91, 19.14, 6.96 and 1.25 fold PVA content was recorded in NRQP34-`19/01 compared with Rasthali, Grand Naine, Red Banana and Nendran. Three events NRQP34-`19/01, NRQP34-`19/02 and NRQP34-`19/03 had high PVA content with (more than 10 fold) than Nendran which is rich in PVA among the commercial cultivars.

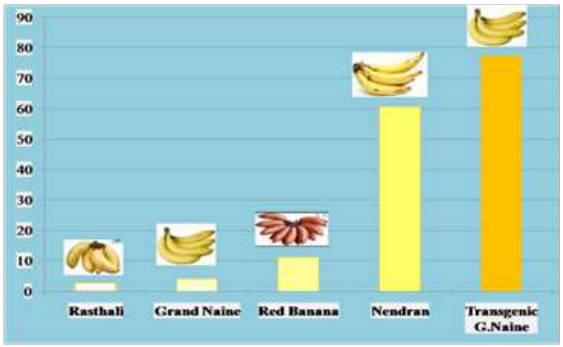


Fig. 67. Comparison of transgenic event with other commercial cultivars with respect to PVA content

DUS characterization of Bio-fortified banana plants at NABI, Mohali, Punjab

A total of 258 transgenic events of cv. Grand Naine using *Phytoene synthase* gene developed by NABI, Mohali have been tested for DUS characterization. Of 71 plants were found to be off types as they are having unusual long peduncle (90-95cm long)/short peduncle (10-15cm long), erect and fan shaped leaf arrangements, droopy leaves, leathery leaf texture, persistent male flowers and bracts on whole male axis, clustering of fruit hands and irregular fruit orientation. Similarly 208 transgenic events of cv. Rasthali were characterized and most of the plants were found to produce small bunches.

Component-II: Transfer and evaluation of Indian bananas with iron gene constructs (M. Mayil Vaganan, I. Ravi and K.J. Jeyabaskaran)

Mother crops and their ratoon 1 of one hundred eighty eight Grand Naine transgenic lines transformed with iron constructs *viz.*, *p*BMGF-DC-53 and -68 carrying *Os*NAS1 & 2 genes were analyzed for iron content in ripe fruit pulps. Out of 188, 20 lines showed 4.5 times greater iron content in pulp over the control plants of which five lines showed around 5.5 times higher iron /100 g against control (0.937 mg dry weight) (Fig. 68). The bunch weight of elite lines ranged between 22 and 38 kg while the mean bunch weight of 20 control plants was around 31 kg. Similarly, 85 Rasthali transgenic lines transformed with same iron constructs were analyzed for iron mineral contents in ripe fruit pulp and only four lines performed well with 2.5-3 times greater iron content against the controls (0.818 mg).

The DUS characteristics of promising lines were found to be 100% true to type. The plant and bunch characteristics of all transgenic and control plants are recorded and maintained. The Southern analysis of three elite Grand Naine lines showed two lines with single copy number and third line with two copy numbers. Immature male flower buds for direct regeneration and suckers of five elite Grand Naine transgenic lines were initiated for large scale multiplication of the lines (Fig. 69).

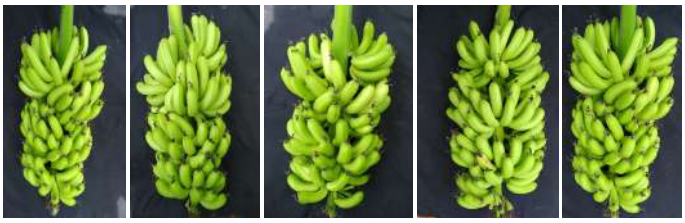


Fig. 68. Bunches of elite lines of Grand Naine transformed with iron constructs

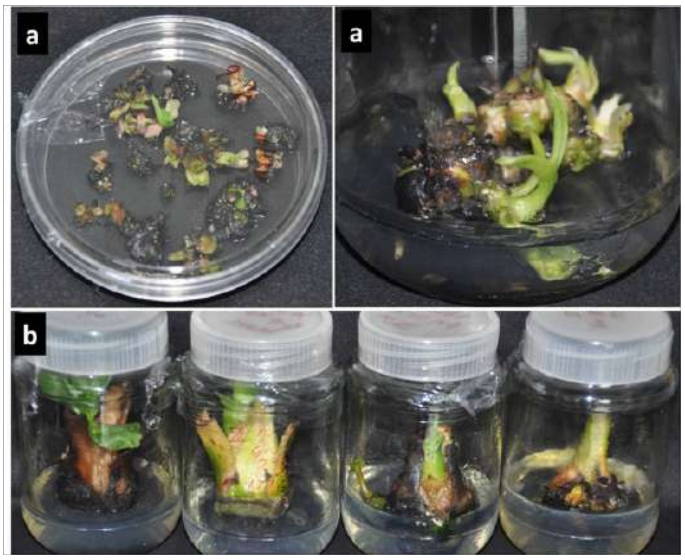


Fig. 69. Initiation of immature male flower buds and suckers of elite Grand Naine lines for mass multiplication

DAE Project

4.5.3 Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis

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

Comparison of global root proteomes between RM15 and control Rasthali plants in response to Foc race 1

To understand the molecular mechanisms behind Fusarium wilt resistance, global root proteomes of the Rasthali mutant (RM15) and parental control were profiled in response to *Foc* race 1 and compared. The protein profile was

highly reproducible among the respective biological replicates with 37 consistent spots. Twenty of the 37 protein spots exhibited varying abundance (at least 2.9-fold changes) with a statistical significance of $p < 0.05$ compared with control. Eighteen spots (2, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 20, 21, 22, 26, 27), were up-regulated in RM15 whereas two spots (spots 36 and 37) were up-regulated in control. Of these 20 spots, expression of four spots (spots 2, 7, 13 and 26) was detected only in RM15. These 20 protein spots were analyzed by MALDI-TOF-MS.

Validation of the gene expression of differentially regulated proteins in RM15 and control

Differentially regulated proteins which showed significant Mascot Score (n=9) were validated for their corresponding gene expression by quantitative real time PCR (qRT-PCR) analysis. The qRT-PCR analysis was carried out using cDNAs that was carried out to find out whether the differentially regulated proteins show different transcript levels and determine the time point at which the differential regulation occurred. Compared to the control, in RM15 the expression of Actin 2 and 3, Rboh protein, and ATP synthase subunit alpha was maximum at 48h; enolase and UTP-glucose-1-phosphate uridylyltransferase showed maximum expression at 12h; IST1 homolog showed maximum expression at 72h. Similar to proteomic analysis, the V-type proton ATPase catalytic subunit A and annexin like protein were up-regulated in control than in RM15, especially after 48h and 72h post *Foc* race 1 inoculation. These results indicated that all the differentially regulated proteins were correlated with their transcript levels and showed that the results obtained in 2-DE analysis were highly promising (Fig. 70).

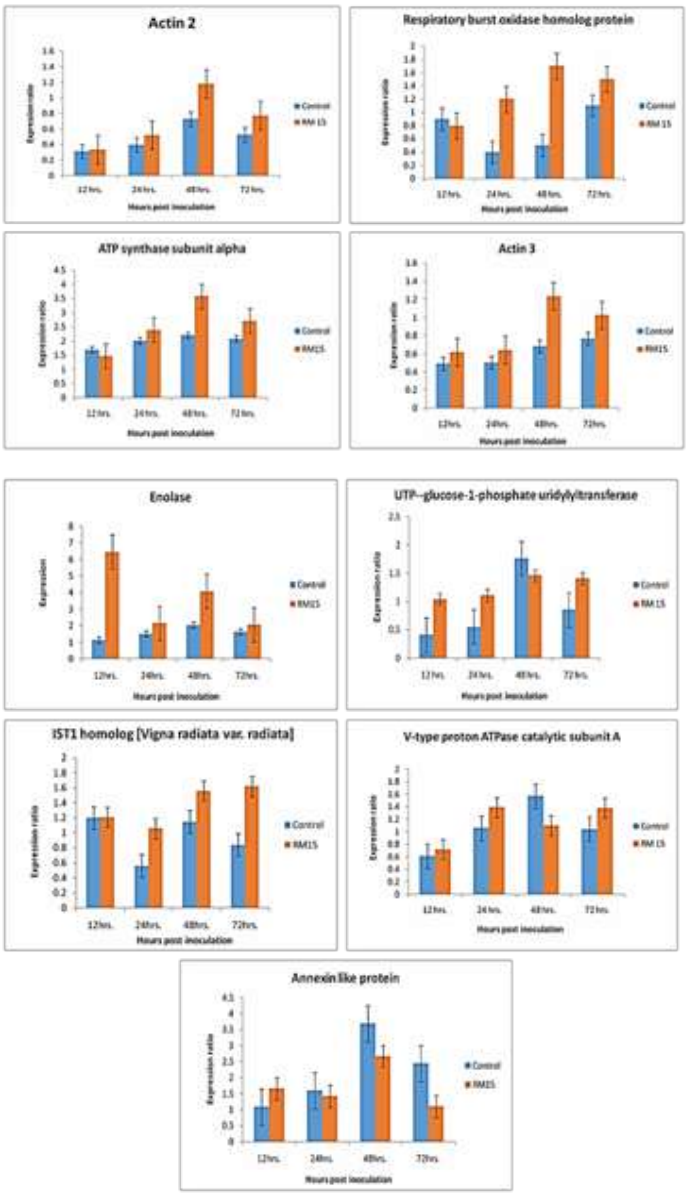


Fig. 70. Expression of nine differentially regulated genes at different time points

Real time PCR analysis of nine selected genes in Rasthali mutant RM15 and control. Rasthali Relative quantification was carried out to measure fold changes in selected gene expression at 12h, 24h, 48h and 72 h among control and RM15 relative to internal reference gene. RPS2 was used as a reference gene. Data (technical replicates of three biological experiments) are reported as means ± standard error

The unique proteins in RM15 displayed functional specificity and were involved in diverse functions such as electron carrier, response to wounding, binding proteins, cytoskeleton organization, extracellular region, structural molecule, biological regulation and pigmentation.

PPV & FRA project

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

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

DUS characterization of reference varieties

During the reporting period, the DUS characters were recorded for 10 reference accessions which included accessions of *Musa balbisiana* (BB), Suganthi (AAB), Nendrapadathi (AAB), Popolou (AAB) and Peyan, Saba, Bainsa, Bangrier, Nutepong (ABB), Red banana (AAA). In addition, the agronomic traits like Plant Height (cm), Plant Girth (cm), No. of hands, No. of fruits/hand, Fruit length (cm), Fruit circumference (cm)] and yield parameters like Bunch wt (kg), Fruit wt (g), Pulp wt (g), Peel wt (g), Pulp: Peel ratio, TSS and Acidity (%)] were also recorded for the aforesaid cultivars. The maximum bunch weight (23.0kgs) was recorded in Cv. Suganthi (AAB) whereas the minimum (12.2kgs) was observed in Cv. Nendrapadathi (AAB). Likewise, TSS was less (20.1) in Popoulu (AAB) and more (25.4) in Peyan (ABB). The maximum fruit length was recorded in Nutepong (26cm) among ABB group.

Fig. 71. *Musa* genotype Suganthi

Description of Suganthi

It's a collection from BRS, Kannara, Kerala, belongs to Silk subgroup. Plant stature is robust; and pulp consistency is very poor.

Varietal Registration

Application for the registration of four farmers' varieties namely Sematti, Chingan, Kuthiraival Chingan & Thottuchingan and one Institute variety Kaveri Sugantham has been submitted to PPV&FRA, New Delhi.

Table 19. Details of varieties submitted to PPV&FRA

S.No.	Name	Location	Remarks
1.	Sematti	Erumbukadu, Nagercoil	Individual farmer's variety
2.	Chingan	Erumbukadu, Nagercoil	Farmers' community
3.	Kuthiraival Chingan	Erumbukadu, Nagercoil	Farmers' community
4.	Thottuchingan	Erumbukadu, Nagercoil	Farmers' community
5.	Kaveri Sugantham	ICAR-NRCB, Tiruchirappalli	ICAR-NRCB variety

4.5.5 DBT-NER Projects

a. Consortium for managing Indian banana genetic resources (S. Uma, M. S. Saraswathi and S. Backiyarani)

Based on the protein-protein interaction network analysis 14 genes were shortlisted as candidate genes for parthenocarpy. And based on qRTPCR analysis it was confirmed that AGL8 followed by MADS were found to play major role for the trait parthenocarpy. A marker for parthenocarphic trait has been developed in the candidate gene Mitochaondiral di/tri carboxylate (MDC) upon validation in seeded (3) and seedless accessions (21). SNPs have been identified between seeded and seedless accessions in the full length parthenocarpic candidate genes of pentacotri peptide repeats (9 SNPs) and MDC (2SNPs).

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 trials have been completed for 10 north-eastern varieties, *viz.,* Bhimkol, Cheeni champa, Malbhog, Jahaji, Pisang Jari Buaya, Tani, Khungsong wild, Jatikol, Desikadali and Manohar using saw dust as substrate under bed method in two (summer and rainy) seasons. All varieties performed better in terms of bud production in rainy season compared to summer season sowing. The duration of priming has been determined based on the water uptake% for each of the wild species and it ranged from 2.5 to 3 days for most of the wild species collected from North-eastern India. Seed storage studies are in progress for north eastern wild species. Standardization of low cost protocol for *in vivo* seed propagation was completed for North Eastern wild varieties using different media and sowing depths. Most of the species showed good germination of 80-90% if seeds are sown at 1.5 cm depth in coco-peat: vermicompost media.

GA3 priming @ 10 ppm for two days followed by *in vitro* germination of seeds in MS medium with BAP + IAA resulted in better germination.

c. Whole genome and transcriptome study of stress-tolerant banana cultivars (S. Backiyarani, S. Uma and I. Ravi)

Functional characterization of genes from the preexisting transcriptome data of drought tolerant (Saba) vs drought sensitive (Grand Naine) cultivars were carried out using different bioinformatics tools. Approximately ~85% of the total uncharacterized genes was characterized. With increased characterized genes, candidate genes for drought tolerant were taken through the construction of PPI network. Genes such as *NRT*, codeine-o-demethylase, *Hsp, WRKY, DREB2A*, peroxidase, *LOX1, ETR1* were taken as gene of interest and validated using qRT-PCR.

d. Collection, evaluation, documentation and conservation of banana genetic resources from North Eastern region (M. S. Saraswathi, M. Mayil Vaganan and S. Uma)

Tissue culture initiation and shoot multiplication have been standardized for traditional varieties of North Eastern region – Cheeni Champa and Malbhog using different combination of growth regulators. The nutrient analysis for fruit-peel and fruit-pulp at unripe and ripe stages of nine accessions *viz.,* Attikol, Bhat Manohar, Borkal Baista, Kanai Bansi, Manjahaji, Phirima wild, Pagalapahad Wild I and Pagalapahad Wild II have been completed and statistical analysis was done. Maximum Ca content among peel samples was observed in Phirima wild (unripe-341.28) while Borkal Baista recorded highest Fe content of 9.99 ppm in unripe peel sample. All the cultivars possessed higher K content when compared with other minerals and it was highest in peel sample (ripe-1315.73 ppm) of Manohar. Pearson's correlation

analysis revealed significant positive correlation between Na and Zn and highly significant positive correlation between Ca and Mg in fruit-peel and fruit-pulp samples. Biochemical analyses of the peel and pulp of unripe bananas of seven accessions, namely Attikol, Bhat Manohar, Kanai Bansi, Manjahaji, Phirima Wild, Pagalapahad I and Pagalapahad II have been completed. Among the accessions, carbohydrate was maximum in Manjahaji (2.01 g/100), which also depicted maximum phenols (100.55 m/100g) and flavonoids (34.2 m/100g). Maximum protein content was present in Attikol (15.05 m/100g), while Kanai Bansi recorded highest carotenoid content of 1194.79 µg/100g.

e. *In vitro* mass multiplication of high value hill area bananas of the North Eastern region (M. S. Saraswathi, R. Thangavelu and I. Ravi)

Molecular characterization (genetic diversity) of 26 less exploited *Musa* species of North Eastern India was completed using 14 ISSR markers, 10 IRAP combinations and 10 SCoT markers. Different marker attributes like polymorphic information content (PIC) effective multiplex ratio (EMR), marker index (MI) and resolving power (Rp) were also calculated. All the marker parameters were higher in ISSR markers, except PIC which is less than IRAP and SCoT markers. The highest PIC (0.320) was produced by SCoT marker than IRAP (0.314) and ISSR (0.300). Cluster analysis was also done for ISSR and IRAP markers which grouped the 26 NE wild varieties into two main clusters with minor variations. Twenty one wild accessions have been screened under pot culture conditions for identification of *Fusarium* wilt resistant varieties in North Eastern region. The wild accessions have shown different phenotypic scoring. The disease score ranged from 0 to 5, with plants showing no internal symptoms scoring as 0 and plants showing 100% vascular discoloration scoring as 5. Micropropagation protocol using shoot tip explants has been standardized for the test variety, Amritsagar (AAA- Cavendish) and for Sabri (AAB-silk) it is in progress. Similarly,direct regeneration using immature male flower buds for both varieties, is in progress where the floral meristems have been converted into shoot meristem. Bio and chemical priming studies have been initiated in cv. Amritsagar under pot culture conditions towards the improvement of growth and vigor of plantlets.

f. Diversity assessment, germplasm conservation and database development on banana resources of North Eastern India (M. S. Saraswathi and S. Backiyarani)

Genetic variation in the population of North Eastern cultivated varieties has been analysed using three different marker systems namely ISSR, IRAP and SCoT markers. All the three markers showed high level of polymorphism and discriminating efficacy. It has been observed that ISSRs generated highest (91.59 %) number of polymorphic bands per primer, and higher PIC, EMR, MI and Rp (0.340, 20.62, 7.03 and 12.52 respectively) compared to IRAP and SCoT markers. The dendrograms for all the three marker systems separated the seventeen populations into two distinct clusters with only very slight variations and proven their genetic makeup. MS medium with different hormonal concentrations like BAP + IAA + TDZ produced the highest number of multiple shoots in *Musa laterita* for use in transcriptomic studies against Fusarium wilt resistance. Multi-shoots were formed after 150 days indicating that they are highly recalcitrant for tissue culture multiplication. The cultures are in sixth subculture stage and the single plantlets are being separated for rooting. Cloning and sequencing of Foc resistant gene namely Putative RPM1-interacting protein 4 from *Musa acuminata* Assam, Bhimkol, and *M. ac.* Arunachal Pradesh, Attikol, *M. cheesmanii* and Athiakol showed 21 nucleotide variations among them. *In vitro* screening

of North Eastern varieties were done using juglone to identify Sigatoka resistant and susceptible varieties for further cloning processes.

Fig. 72. Field screening of North Eastern varieties against Sigatoka resistance

g. Characterization of high value phytochemicals of anti-diabetic and immune-modulatory properties in North Eastern bananas varieties

(M. Mayil Vaganan, I. Ravi and P. Suresh Kumar)

The glycemic index (GI) of three stages 1 (full green), 5 (green at the tips) and 6 (full yellow) of 20 cultivars including Cavendish banana, Grand Naine (AAA) were worked out and presented. The bananas were collected from North Eastern states of Assam and West Garo Hills district of Meghalaya after extensive surveys in green stage and ripened at controlled temperatures and humidity using ripening chambers. The GI of three stages of these 20 varieties was estimated using the above method. The GI of full green stage was estimated to compare the GIs of stage 5 (green at the tips) and stage 6 (full yellow). In general, the GI of green stages ranged between 15 and 35 and BB genome cultivars like Attikol, Bhimkol and *M. balbisiana* had low glycemic index except Beeji kela. The stage 5 GI ranged between lowest of 25.8 for *M. balbisiana* and highest of 56.4 for Birbutia. The glycemic index of stage 5 in general was 15 to 30 points lower than stage 6, which is full yellow edible stage. The glycemic index of stage 6 varied between 40.2 for *M. balbisiana* to the highest of 80.8 for Birbutia. Grand Naine had the GI of 30.6, 50.0 and 60.0 in three stages of ripening, which is well above the BB genome bananas Bhimkol and Attikol and equivalent to Sabari, Kanai Bansi and Ginde in full yellow stage of ripening. The BB genome bananas (Attikol and Bhimkol) had very low GIs compared to other genome bananas.

The fructans content in peel and pulp of ripe banana fruits of 20 banana cultivars including Grand Naine (AAA) was estimated using fructans assay kit. In pulp, Attikol contained highest quantity of 558 mg/100 g pulp and Kach kela contained lowest amount of fructans with 35 mg/100 pulp. The 'B' genome bananas (Attikol, Bhimkol, Beejikela and *M. balbisiana*) contained higher level of fructans and equally ABB genome bananas like Nepali Chinia and Ashy Batheesa contained more fructans compared to cultivars belonging to 'A' genome. The fructans content ranged between 9 mg/100 g of peel in Malbhog to 294 mg/100 in *M. balbisiana* with B genome banana containing higher levels of fructans in peel. Generally, the pulp contained higher quantity of fructans than peel of the fruits.

h. Management of low temperature and soil moisture deficit stresses in banana growth in North Eastern India (I. Ravi, M. Mayil Vaganan and M. S. Saraswathi)

In a field experiment at ICAR-NRCB farm, 13 North Eastern Indian Region (NER) banana genotypes were evaluated for soil moisture deficit stress (drought stress). These genotypes were collected through our collaborating partners from Assam Agriculture University, Jorhat. There was differential response among NER bananas under soil moisture situation compared to irrigate on chlorophyll content, NDVI (Normalised Difference Vegetation Index), Fv/ Fm (Ratio of variable to maximal chlorophyll fluorescence). The chlorophyll content recorded lesser in all drought stress treatment compared to irrigated control. However, the genotypes like Athiakol, Karthobiumtham, Bhimkol, and Kechulepa recorded lesser reduction compared to its irrigated control. The NDVI reveals the state of plant health. The NER banana genotypes recorded higher values of NDVI

in irrigated control than drought-imposed plants, however, observed similar trend in reduction of NDVI in drought stress treatment. The lesser reduction of NDVI in stress treatment observed in Agni Malbhog, Nutepong, Kechulepa and Bhimkol. The Fv/Fm values reflect the maximum potential of quantum efficiency of photosystem II under dark adopted condition. In the present study recorded significantly lesser Fv/Fm values compared to irrigated control. However, Jahaji, Borjahaji, Nutepong, and Honda did not affect the PS II in the first week of soil moisture stress deficit treatment. The drought stress prolonged the duration for flowering compared to irrigated control and it is varied from 10 to 21 days. The most delay (21 days) in flowering was recorded in Agni Malbhog and least delay was recorded in Kachkela (10 days). The number of hands and fingers and bunch weights were recorded significantly lesser in all soil moisture deficit stressed genotypes than irrigated control (Fig. 73). However, the percentage of reduction in bunch weight was lesser in Nutepong, Kachkel and Honda. These are some of the promising NER bananas can be grown under water limited environment.

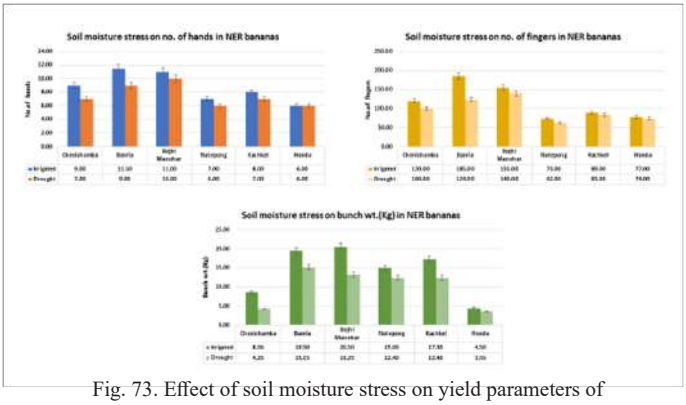


Fig. 73. Effect of soil moisture stress on yield parameters of NER banana cultivars

i. Development of pre and post- harvest bunch care management of fresh banana (P. Suresh Kumar and K. N. Shiva)

Different combinations of preharvest sprays including bunch cover was tested for var. Ney Poovan. Increase in bunch weight was noticed with K_2SO_4 (2 %) spray + Banana Shakthi+ Bunch coverTreatment with Salicylic acid (100mg/litre) + Bunch cover has showed the gain in fruit weight and caliper among the treatments (Table). New molecules like Hexanol and ICAR- NRCB formulations were also tested to study the influence of chemicals on the shelf life of Ney Poovan. Among the newly tested chemicals NF-2 and Hexanol (66 and 70 days) recorded the shelf life which was comparable to the application of carbendazim (84). Using ethylene absorber alone did not enhance the shelf life beyond 17 days. Var. Grand Naine coated with wax after infusing ethylene for ripening showed significant effect on the extension of yellow life and prevention of crown rot and black spot for 8 days after ripening, when compared to control upto 3 days.

Fig. 75. Popoulu chips treated with different hydrocolloids

j. 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)

Different value added, functional products were tried. In the attempt to prepare the low fat chips, 1% carboxy methyl cellulose (CMC) recorded higher yield recovery cvs. Popoulu (77.6%) and Nendran (76.53%). Lowest peroxide value (4.94±0.31) was observed with 1% pectin whereas, the lowest free fatty acid value (0.95±0.07) and higher crispiness were observed with 1% CMC.

Pizza base enriched with modified starch and dietary fibre was prepared with 5% banana flour, 0.6 % modified starch, 0.6% peel flour along with 93% refined wheat flour. North eastern germplasm were characterized for nutritional properties of center core stem powder.The total phenol content of Kanai Bansi (395.82 mg GA/100 g) and Popoulu (380.69

mg GA/100 g) center core stem powder was higher than other varieties. Flavonoid content was high in Manjahaji (165.33 mg QE/100 g) and Kanai Bansi (155.55 QE/100 g).Nendran banana center core stem powder (10%) and all-purpose flour (90%) provided the superior cookies in terms of taste, colour, physical appearance, stickiness, oiliness andflavor. Considering the healing properties of Basil seed, Banana RTS with seed suspension was standardized for colloidal agents, suspension ratio, weight of the seed, RPM and centrifuge time.

k.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)

Personal hygienic products (napkin) were tried with different combinations of banana fibre and other cellulosic materials like wood pulp and cotton. Use of 100% banana fibre and 75% banana fibre led to swelling when compressed though good in absorption. It is to be tested more to come out with concrete results. The yield recovery of cellulose from chemical treatments showed higher extraction of cellulose fibres in Karupuravalli (68.33%) followed by Red banana (54%) and less recovery in Popoulu (51.6%). SEM exhibited a compact structure, composed by several microfibrils with diameter in the range of 8-12 µm (Fig. 76).

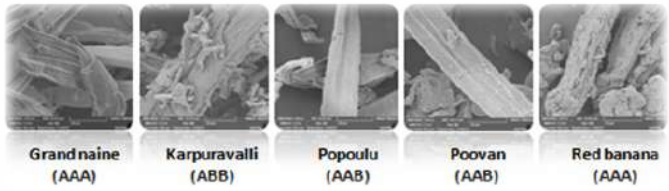


Fig. 76. SEM Image of cellulose from pseudostem sheath

Fig. 77. Film produced from banana peel

In addition, different treatments were executed to extend the shelf of banana leaves. Single corrugated sheets were used as base material for making disposable plates. Dry blanching, wet blaching, chemical dip, and freeze drying were tried to retain the green colour of the leaves. Dry blanching resulted in color retention of the leaf and needs to be standardized further for making the leaf more pliable and to make disposable plates. The process for enhancing the pliability of the pseudostem sheath for making handicrafts were identified. The bioplastic prepared with peel+ sheath filtrate had more plastic characteristics compared to bioplastic prepared from peel paste. Tensile strength ranged from 0.85MPa to 9.94MPa and elongation at break ranged from 15.53% to 63.33%. The percentage of water absorption ranged from 22.06% to 120.08%. The biodegradability test showed major decrease in the mass of bioplastic within three days followed gradual decrease.

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

(B. Padmanaban, S. Backiyarani and J. Poorani)

Surveyed and collected healthy and infected insects North and North-eastern region in India, Surveys were conducted for collection of entomofungal pathogens of banana fruit scarring beetle, *Basilepta subcostata.* Natural infection of entomopathogenic fungi was observed on banana insect pests including *B. subcostata, Odoiporus longicollis* and *Cosmopolites sordidus*. Totally 30 fungi were isolated and identified as *Beauveria* sp. (12) and *Metarhizium* sp. (18). The collected fungi were identified morphologically and by molecular characterization through the partial gene sequences of parsimony informative genes ITS4-ITS5 region (for *Beauveria*) and ITS1-ITS2 gene sequencing (for *Metarhizium* sp.)

These 30 sequences were BLASTed with the NCBI Databank sequences of *B. bassiana* and *M. anisopliae* and aligned by CAP3 and BLASTn software. Phylogenetic hypotheses were developed with Neighbour-joining based on genetic distances calculated by the Maximum Composite Likelihood (MCL) and Jukes-Cantor model MEGA-X software and compared with the isolates of *Beauveria bassiana, B. brongniartii, M. anisopliae, M. robertsii, M. quizhousense* and *M. pinghaense* available in the GenBank/NCBI database.

Bioassay was conducted with conidiospores of these fungal isolates against *B. subcostata* adults and significant mortality was observed. Among the 30 isolates tested, 5 isolates showed significantly >90% mortality at 105conidia/mL concentration and 21 isolates caused <90% mortality. Four isolates [*M. anisopliae* (NRCBEPF-18; NRCBEPF-34) and *B. bassiana* (NRCBEPF-28; NRCBEPF-27)] were observed to cause total mortality within 8 days.

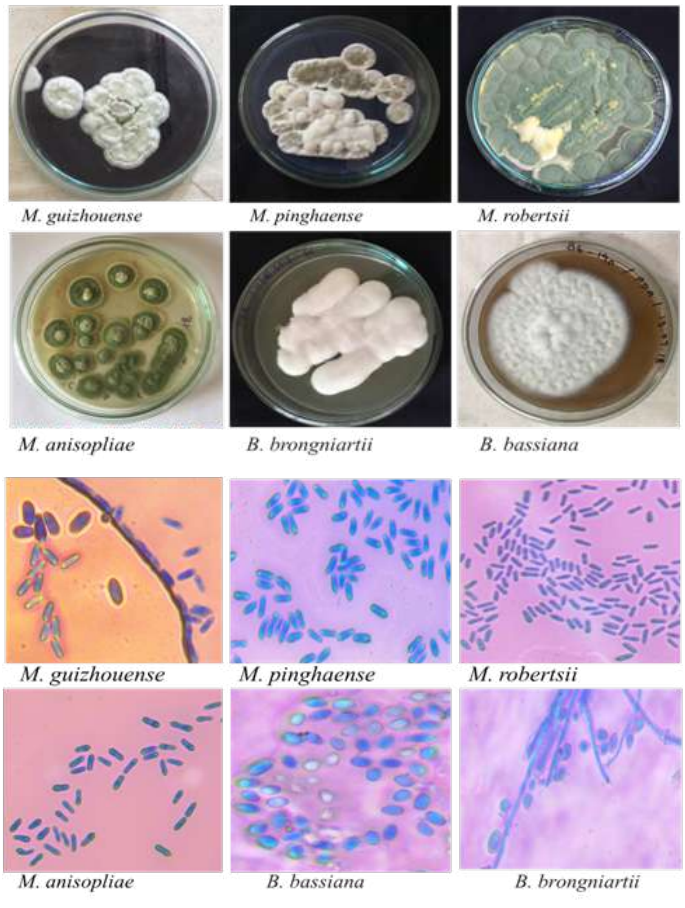


Fig. 78. Morphology of colony and conidia of entomopathogenic fungi tested against B. subcostata

m. Molecular dissection of defense against Sigatoka infection in banana: Exploitation of *Musa* germplasm of North Eastern region for development of Sigatoka resistant hybrid

(R. Thangavelu)

Isolation and identification of leaf spot pathogen from different banana growing regions of India

A survey was conducted under different agro climatic regions of India *viz*., Assam, Meghalaya, Manipur and Nagaland to study and document the symptomatology and etiology of the pathogen inciting leaf spot disease of banana occurring in different banana growing regions of India. For this, a total of 65 leaf spot samples were collected, isolated and detected for the presence of *Pseudocercospora emusae* by both microscopic and molecular analysis using PCR specific markers. The result of microscopic analysis revealed that majority of samples (40) showed were high resemblance to *P. emusae* by the presence of flask shaped telomorphic fruiting bodies called perithecia bearing asci and ascospores. The presence of the pathogen was further confirmed by amplification of PCR specific markers which yielded amplicons of 490 bp size. The remaining 25 samples subjected to microscopic analysis revealed the presence of other minor leaf spot pathogens Hence, the pathogen inciting leaf spot diseases on banana in Assam, Meghalaya and Nagaland was identified and confirmed as *P. eumusae*.

n. 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)

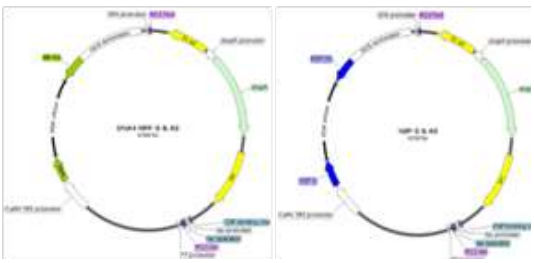
The integration patterns of endogenous BSMYV were identified in DH Pahang and *Musa balbisiana* (PKW) genomes. Conserved sequence of endogenous BSMYV integrated in PKW was shared with IIHR. sg RNAs were designed and four

CRISPR/Cas9 constructs were received from IIHR. In order to develop embryogenic cell suspension of cv. Chinichampa (Syn: Poovan) totally 380 virus free Poovan banana male buds (total 6060 inflorescence ex-plants) were initiated for callus formation in three different media composition. After two to three months on M1 (MS basal medium and supplemented with 4mg/l 2,4-D, 1mg/l BAP and 1mg/l NAA) medium, yellow nodular callus formed, most frequently on flower rows 5 to 10. Six ECS lines of banana cv. Poovan were initiated.

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

(R. Selvarajan and C. Anuradha)

Primers were designed for developing RNAi gene constructs targeting three important gene/s (DNA-R (Master Rep), DNA-M (movement protein) and DNA-N (nuclear shuttle protein) of BBTV (Assam isolate) and developed two strategies, one in cloning using pHannibal vector and the other to clone in pGreen vector. A PCR product length of 247bp - DNA-M (movement protein) and 256bp - DNA-N (nuclear shuttle protein) were cloned in both sense and anti-sense orientation in pHannibal vector (provided by AAU) further, these were sub-cloned in pCambia2301 and named as ihpRNA-MP and ihpRNA-NSP respectively (Fig. 79). All the six components of the BBTV Assam isolate were amplified by RCA (Rolling Circle Amplification) and partial dimers of two components viz DNA-U and DNA-M were cloned in pBluescript vector and DNA-R cloned in pTZ57R/T. Both Poovan and Grande Nain male flower buds have been initiated and the embryogenic calli has been obtained.



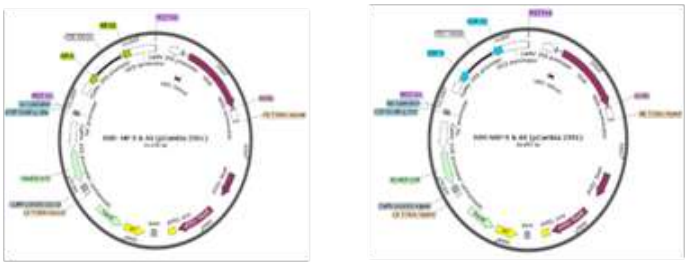


Fig. 79. Preparation of intron hairpin constructs with BBTV Movement protein gene (ihpRNA-MP) and Nuclear shuttle protein gene (ihpRNA-NSP) in the pCAMBIA vector background. Initially the sense and antisense genes of two genes were cloned into pHannibal vector having PDK intron and subsequently they were released and subcloned into pCAMBIA2301 which has Kanamycin as selection marker

DAC & F W, Govt. of India funded project

4.5.6 Coordinated Horticulture Assessment and Management using Geoinformatics (CHAMAN-Phase-II) Project

(K. J. Jeyabaskaran and D. Ramajayam)

Using the survey data collected from 10 selective districts of Tamil Nadu, different linear regression equations for different varieties of banana were developed. The data on plant height, pseudostem girth, number of functional leaves, number of hands per bunch, number of fingers per bunch and bunch weight at the bunch harvesting stage of representative samples from different banana varieties were collected from different districts of Tamil Nadu like Theni, Thirunelveli, Kaanyakumari, Thoothukudi, Tiruchirappalli, Tanjavur, Thiruvannamalai, Vellore, Erode and Coimbatore. Using these data, the following yield prediction equations for different varieties were developed.

Table 20. Y ield prediction equations developed for different varieties of banana

S.No.	Banana variety	Equations
1.	Grand Naine	$Y = 0.024\ X_1 + 0.098\ X_2 + 0.346\ X_3 + 0.592\ X_4 + 0.424\ X_5 - 3.50$
2.	Karupuravalli	$Y = 0.004\ X_1 + 0.028\ X_2 + 0.220\ X_3 + 0.456\ X_4 + 0.388\ X_5 + 2.172$
3.	Monthan	$Y = 0.002\ X_1 + 0.036\ X_2 - 0.016\ X_3 + 0.114\ X_4 + 0.006\ X_5 + 10.492$
4.	Nendran	$Y = 0.004\ X_1 + 0.026\ X_2 + 0.024\ X_3 + 0.466\ X_4 + 0.024\ X_5 + 5.83$
5.	Quintal Nendran	$Y = 0.074\ X_1 + 0.036\ X_2 - 0.004\ X_3 + 0.280\ X_4 + 0.022\ X_5 + 5.934$
6.	Ney Poovan	$Y = - 0.036\ X_1 + 0.036\ X_2 - 0.038\ X_3 + 0.192\ X_4 + 0.008\ X_5 + 9.202$
7.	Poovan	$Y = 0.006\ X_1 + 0.014\ X_2 + 0.076\ X_3 + 0.168\ X_4 + 0.01\ X_5 + 8.204$
8.	Rasthali	$Y = 0.016\ X_1 + 0.028\ X_2 - 0.342\ X_3 + 0.244\ X_4 + 0.018\ X_5 + 7.384$
9.	Red Banana	$Y = - 0.002\ X_1 + 0.004\ X_2 + 0.082\ X_3 + 0.714\ X_4 + 0.003\ X_5 + 10.156$

Y – bunch weight in kg, X1- plant height in cm, X2 – pseudostem girth in cm, X3 – number of functional leaves, X4 – number of hands per bunch, X5 – number of fingers per bunch.

DST funded projects

4.5.7 Development of efficient IOT enabled plant disease pest detection system

(R. Selvarajan, R. Thangavelu and B. Padmanaban)

In collaboration with SSN College of Engineering, Chennai an IoT project is implemented at ICAR - NRC Banana and around 16000 images of healthy and pest and disease affected banana plants and their parts such as leaves, pseudostem, fruit bunch, cut fruits and corm were taken from banana orchards in Thanjavur, Theni and lower Palani Hills of Tamil Nadu. These images are used for machine learning for developing a decision support system for pest and disease diagnosis and management. Validation of banana bunchy top and leaf spot diseases were done using machine learning tools. Drones were used to identify the wilt affected plants in the large orchards in Theni, Tamil Nadu.

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

(R. Selvarajan)

In collaboration with PSG college of technology, Coimbatore, Tamil Nadu a cost-effective dot blot based TAS-ELISA kit is being developed. In this direction, The E. coli BL21(DE3) strain containing the pET28a-BBTV-CP, pET28a-BBrMV-CP and pCold-CMV-CP constructs developed previously were retrieved from glycerol stock. Polyclonal antisera were raised against the Ni-NTA column-purified recombinant BBrMV-CP and CMV-CP in rabbits as per the custom-made injection schedule and standard protocolFurther, a polyclonal antiserum is being raised against BBTV using the Ni-NTA column-purified recombinant BBTV-CP in rabbits. Standardized Direct antigen coating ELISA and Dot blot ELISA for detection of CMV and BBrMV. The polyclonal antisera raised against BBrMV and CMV were supplied to the collaborating partner for multiplex TAS-ELISA / Dot blot kit development. In addition, a monoclonal antiserum was raised for BBrMV which has successfully detected the virus in ELISA and supplied to the collaborating partner for TAS-ELISA.

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

(K. Panneerselvam)

Banana plants synthesize an array of phenylphenalenone-type phytoalexins (PPs) in response to various pathogens, including fungi,

nematodes, and insect herbivores. Though PPs represent potential target for improving banana defense systems against multiple pathogens, no genes involved in the PPs biosynthetic pathway has been functionally characterized. Members of at least four multigene families namely type III polyketide synthase (type III PKS), aldo-keto reductase (AKR), cytochrome P450 monooxygenase (CYP450) and polyketide cyclase (PKC) have been assumed to involve in the earlier biosynthetic steps of PPs production in banana. In order to reveal the genes of PPs biosynthetic pathway, members of the above four gene families have been mined from banana genome through comparative genome-wide analyses and their structural characteristics, phylogenetic relationship, and evolutionary characteristics have been examined. A total of 21 type III PKS, 34 AKR, 273 CYP450 and 3 PKC genes were retrieved, of which 19, 18, 214 and 3 genes were selected based on their authentic domains to represent the respective gene families for banana. Candidate genes from each gene families for PPs biosynthesis have been selected using the phylogenetic relationship and sequence homology which resulted in short listing of 10 type III PKS genes, 12 AKR genes and three PKC genes for PPs biosynthesis. Functional characterization of selected candidate genes is in progress.

4.5.10 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 and M. S. Saraswathi)

The conventional propagation by side suckers (5-10 suckers/plant) is insufficient to meet the requirements. Bananas are being propagated aseptically in the laboratory through tissue culture techniques. However, tissue culture plants are relatively expensive and not readily accessed in resource-poor regions. The demand for indigenous cultivars is increasing year by year to fulfill the domestic and international market requirements. Thus, a simple, inexpensive and easily accessible technique has been standardized for multiplication of banana plantlets and the technology has been disseminated to rural people for the improvement of livelihood opportunities. About 760 farmers and women SHG members from all over India are trained through different State Horti. & Agri. Dept., KVKs, and NGOs. Farmers' federations in Tiruchirappalli, Namakkal and Thanjavur District started their own enterprises and successfully propagating banana for their needs.

Fig. 80. (A) Transfer of technology (B) Hands on training for farmers (C) Establishments in villages for macropropagation of banana. (D) People preparing the suckers. (E) Planting of suckers in grow bed. (F) Primary shoots

ICAR Funded Projects

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

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

Survey on the Fusarium wilt, Tropical Race 4 (Foc TR4) in Madhya Pradesh, Maharashtra and Gujarat

In 2019, roving surveys were made in Gujarat, Maharashtra, Madhya Pradesh, Uttar Pradesh and West Bengal. The incidence of Fusarium wilt disease

in cv. Grand Naine was observed in different states (Uttar Pradesh 30-45%, West Bengal 25 to 30%, Madhya Pradesh 5-40% and Gujarat 5-15%). For the first time, the incidence of Fusarium wilt was observed on cv. Grand Naine in Muktainagar, Besalvadi taluk, Jalgaon district, Maharashtra. The incidence observed was up to 5%. In addition, meetings were conducted involving progressive farmers, extension officials from the research institutes and KVKs, plant protection scientists, officers from the state agricultural departments and representatives from banana growers associations and tissue culture industries etc. to create awareness about the importance and impact of the disease, prevention of further spread and management of the disease in the affected fields. Reduction of inoculum by killing the affected plants by injecting herbicide followed by burning them was also demonstrated in the wilt affected field itself.

Distribution of VCGs in different major Cavendish banana growing states of India

A survey was conducted in Bihar, Gujarat, Kerala, Maharashtra, Madhya Pradesh, Tamil Nadu and Uttar Pradesh to study the distribution and diversity of *Fusarium oxysporum* f. sp. *cubense* (Foc) biotypes. A total of 26 Fusarium wilt infected corm samples were collected from six different banana cultivars for possible isolation of Foc TR4. Among these, Foc R4 (which includes Foc STR4 and TR4) was present only in cv. Grand Naine and in cv. Ney Poovan, Karpuravalli, Rasthali, Sanna Chenkathali and Big Ebanga. The race-specific molecular marker (PCR) analysis revealed that VCG 120 was distributed in Gujarat and Madhya Pradesh. However, VCG 01213/16 was distributed in Bihar and Uttar Pradesh. Out of 26 samples subjected to molecular marker analysis, only five samples were found to be Foc R4 and the remaining 21 are considered as unknown VCGs. The races of the known and unknown VCGs are subjected to sequence analysis using Translation Elongation Factor 1α (TEF) gene to confirm the race and to study the genetic diversity and relatedness. The overall analysis revealed that the Foc R1 was distributed in Tamil Nadu (Theni and Coimbatore), Kerala, Maharashtra, Gujarat and Madhya Pradesh, while Foc STR4 was distributed in Gujarat and Madhya Pradesh based on TEF1α. Foc TR4 was distributed in the Bihar and Uttar Pradesh which is in accordance with the molecular marker study.

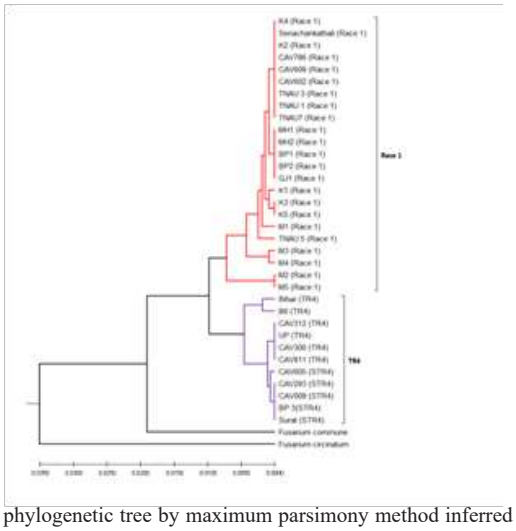


Fig. 81. A phylogenetic tree by maximum parsimony method inferred from the translation elongation factor-1α (TEF) gene of isolates representing all vegetative compatibility groups of Fusarium oxysporum f. sp. cubense (Foc). The tree was rooted with Fusarium commune and Fusarium circinatum as outgroup

Whole genome sequence analyses of Fusarium wilt pathogens infecting Cavendish banana

Draft genome sequence of Foc Race 1

A genome sequencing study was initiated to understand the ability of *Foc* R1 strain which displayed different host-specificity i.e. on Cavendish banana. The whole genome of *Foc* VCG 0124 of Race 1 strain infecting Cavendish bananas was 48,596,450 bp with 2,635 contigs and 15,111 protein-coding regions. Of the total annotated proteins, 2,008 (13.3%) were associated with biological processes, 5,963 (39.5%) were associated with cellular processes and signalling, and 7140 (47.4%) were associated with molecular functions. About 20 (0.13%) protein-coding genes were not categorized into any of the GOC classes, and thus considered as proteins of uncharacterized functions/features. Plant

Host Interaction (PHI) search showed that there were 1042 genes in the genome, in which 30 are unique with reference to Foc R1 genome.

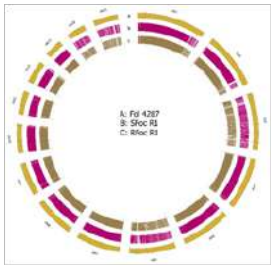


Fig. 82. Genome comparison map of the genome Foc R1 with reference genome, RFol 4287 and RFoc R1

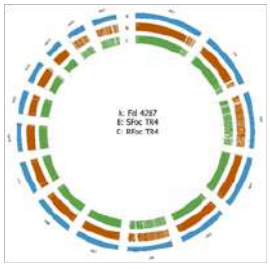


Fig. 83. Syntony map of Foc TR4 in comparison with the reference genome, RFol 4287 and RFoc TR4

Draft genome sequence of Foc TR4

To understand the genome organization of the devastating soil-borne Foc strain, TR4 (VCG01213/16), genomic fungal libraries of ~300bp were sequenced using the Illumina NextSeq® 500 system for 150×2 cycles. The genome pipeline including MaSuRCA v.3.2.4, BWA v0.7.12 and AUGUSTUS v.3.3 were used to assemble, map and predict the sequenced genome. The genome of *Foc* TR4 of VCG 01213/16 was 47.38 mb with 51.1% GC content. A total of 15,508 (96.15%) proteins were annotated from 16,129 using UniProt database with a cutoff E-value of 10^{-5} and remaining 621 (3.85%) were unannotated or uncharacterized proteins. Plant Host Interaction (PHI) search showed that there were 365 putative virulence-associated genes that have been identified against reference Foc TR4 of which 19 are unique in nature. The genes that are found to change the phenotype of the organisms specifically the pathogenicity are ABC1, kdpB, acrB, oqxA & B and pstB which belong to cellular transporter protein-encoding unigenes, which are essential for import of nutrients and export of secondary metabolites. Among the 14 secreted in xylem (SIX) protein gene clusters (SIX1-SIX14), SIX1, SIX2, SIX6, SIX8 and SIX9 have been found to be present in the Foc TR4 genome. Moreover, the presence of homologues SIX8, both SIX8a and SIX8b in the genome of Foc TR4 strains is a major difference noticed.

Biocontrol for management of Fusarium wilt disease

Isolation and evaluation of native endophytic and rhizospheric bacteria and fungal antagonist against Foc TR4

A total of 73 antagonistic microbes comprising 73 bacteria (57 endophytic and 16 rhizospheric) and 4 fungal isolates were isolated from 17 different diploid varieties belonging to AA and BB genomic groups. The single spore/cell culture of these bacterial and fungal isolates were screened for their multiple actions such as mycelial growth and spore germination inhibition, protease production against Fusarium wilt pathogen *Foc* TR4 under *in vitro* condition. Besides these antagonistic microbes were also screened for zinc solubilizing ability. The results of the experiment showed that eight out of 73 endophytic antagonist microbes exhibited multiple actions such as mycelial growth inhibition (75 to 78%), spore germination inhibition (78 to 93.8%), positiveness for protease production and zinc solubilization. Further work on their evaluation under *in vivo* conditions are in progress.

Evaluation of *Trichoderma* spp. isolates against Foc TR4

In this study, five *Trichoderma* spp. (endophytic *T. asperellum* prr2; rhizospheric *T. hamatum*; rhizospheric *T. asperellum* NRCB 3; rhizospheric *T. harzianum* and *T. pseudokoningii*) which are available at the Pathology lab, ICAR-NRCB and found effective against *Foc* R1 infecting Cavendish were evaluated for their multiple actions against *Foc* TR4 under *in vitro* condition. The results of the study indicated that most of the *Trichoderma* spp. isolates recorded about cent percent inhibition of spore germination (except *T. asperellum* NRCB3), 68 to 80% mycelial growth inhibition by dual culture plate assay and 38% inhibition of volatile production (by *T. asperellum* Prr2) and highest category of

chitinase production. Further compatibility test was conducted with good results.

Fig. 84. Dual culture plate assay on effect of *Trichoderma asperellum* on Foc TR4 (a): Control; (b): Mycelial growth inhibition of Foc by endophytic *Trichoderma asperellum* (Prr2); (c): Mycelial growth inhibition of rhizospheric *T. pseudokoningii* .

Fig. 85. Evaluation of different consortia of native bioagents for the management of Fusarium wilt Tropical Race 4 under glass house condition T2: *Trichoderma asperellum* (Prr2) + *Pseudomonas extremorientalis* (B1); T11: *Bacillus flexus* (Tvpr1) + *Pseudomonas extremorientalis* (B1) + *Ochrobactrum anthropi* (B5) + Bacteria (B3)

Evaluation of different consortia of native bioagents for the management of Foc, TR 4 under glass house condition

The evaluation of native endophytic and rhizhospheric bioagents combinations such as *Trichoderma* sp. (NRCB3) + *Penicillium phinophilum* and *Trichoderma asperellum* (prr2) + *Bacillius flexus* against *Foc* TR4 under pot culture condition in cv. Grand Naine indicated significant suppression of the disease as compared to Foc alone inoculated plants.

A total of 11 different consortia comprising of 9 bacterial isolates such as *Pseudomonas* spp., *Bacillus* spp., *Ochrobacterium* spp. and *Serratia* sp. and two *Trichoderma asperellum* isolates were evaluated for the suppression of Tropical race 4 of Fusarium wilt disease in cv. Grand Naine under glass house condition. After 5 months of planting the internal vascular discoloration in the corm was observed. The results of the study showed that the consortia Endophytic *Bacillus flexus* + Endophytic *Pseudomonas extremorientalis* recorded a wilt score of 0.25 followed by Endophytic *T. asperellum* + Endophytic *P. extremorientalis,* and Endophytic *T. asperellum* (Prr2) + *Ochrobacterium anthropi* consortia which recorded a wilt score of 0.5 on a 0-5 disease scale. Besides, these consortia significantly increased the plant growth parameters.

Studies on native endophytic and rhizospheric bacteria and their root exudates for effective management of Foc TR4

The study aims at isolation and identification of endophytic bacterial communities in different banana genome types which has antagonistic activity against Foc TR4 and to check the host-pathogen interaction by profiling root exudates of banana against Foc TR4. A total of 118 endophytic (80) and rhizospheric (38) bacteria were isolated from 12 banana accessions available in the germplasm of ICAR-NRCB, Tiruchirappalli. Of the 118, six isolates have higher mycelial growth inhibitory activity against Foc TR4 in dual culture plate assay. Further molecular analysis of 16s rRNA sequencing revealed that effective isolates belong to the genera *Firmicutes* and γ-proteobacteria. The results showed that the root exudates of red banana have a significantly higher (11.5%; P>0.01) spore inhibition activity when compared to uninoculated red banana (30%). Similarly, the mycelial growth inhibition activity showed that the root exudates of *Foc* inoculated red banana had a significantly (P>0.05) higher activity over control at 2nd (20%) and 4th (27.9%) DAI.

Table 21. Source, name and mycelial growth inhibition of endophytic bacteria isolated from various banana genome types available in ICAR-NRCB, Tiruchirappalli

Bacterial isolates	Cultivar name	Source	NCBI Accession No.	Name of the organism	Mycelial growth inhibition (%)
ESCR3	Sanna Chengadali-201 (AA)	Root	MN330069	*Serratia rubidaea*	65.0a,b
EBPS2	Baluk Pang Wild-1717 (AA)	Stem	MN330070	*Bacillus velezensis*	71.2a
ENNR1	Nedu Nendran-0702 (AAB)	Root	MN330071	*Klebsiella variicola*	50.0c
RSNN	Nedu Nendran-0702 (AAB)	Soil	MN330072	*Serratia marcescens* ssp. *sakuensis*	65.3a,b
RSSC2	Sanna Chengadali-201 (AA)	Soil	MN330073	*Serratia marcescens* ssp. *sakuensis*	69.6a
RSPJ	Pisang Jari Buaya-640 (AA)	Soil	MN330074	*Bacillus velezensis*	55.8b,c

Isolation, identification and evaluation of endophytic and rhizopheric bacteria against Foc TR4

A total of 33 bacteria isolated from 12 different banana germplasm being maintained at ICAR-NRCB, Tiruchirappalli were subjected to *in vitro* growth inhibition by dual culture plate assay and the results revealed that 9 (8 endophyte and 1 rhizosphere) bacteria showed maximum growth inhibition and were selected for further studies. Molecular analysis revealed that the selected isolates were grouped into different genera, which belonged to the phyla Firmicutes and γ proteobacteria. A Pot culture experiment was conducted with individual isolates and consortia for effective management of Foc TR4. The results showed that among 20 different endophytic bacterial consortia evaluated, the consortia B1 (*Pseudomonas extramorientalis*) + B3 (endophyte) + B5 (*Ochrobactrum anthropi*) recorded a wilt score of 1.75 on a 0-5 disease scale. Besides, it also increased the plant growth parameters such as plant height (29.01 %), girth (30.78 %), leaf number (36.0 %), leaf area (59.24 %) and root length (11.2 %) as compared to control. The effective consortia was further adopted for field evaluation in different fusarium wilt infected districts of India in Bihar, Gujarat and Uttar Pradesh.

Impact of Zimmu plant leaf extract on mycelial inhibition of Foc TR4

Based on our previous experience on controlling *Foc* R1, an experiment was conducted using Zimmu plant leaf extract at various concentrations for the control of *Foc* TR4. Zimmu leaves collected from the greenhouse-grown plant were ground in a pestle and mortar and filtered through a three-layer cheesecloth. The result of poison food technique showed that 50% of Zimmu leaf extract has completely inhibited the mycelial growth of *Foc* TR4 *in vitro*.

Fig. 86. Effect of Zimmu leaf extract on the mycelial growth of the Foc TR4 under *in vitro* using poison food technique

Field evaluation of consortia of bioagents for the management of Foc TR 4/ R1 VCG 0124 in cv. Grand Naine

Field evaluation of biocontrol agents against Foc TR4 in Uttar Pradesh

A set of field experiments was initiated for the management of the Foc TR4 in Uttar Pradesh using newly developed mass multiplied consortia at different combinations. The randomized block design experiment comprised five treatments with two replications and each block consisted of 24 plants. The treatments included, T1: Endophytic *Trichoderma asperellum* (Prr2) + Endophytic *Penicillium pinophilum* (BC2); T2: Endophytic *Bacillus flexus* (Tvpr1) + Rhizospheric *Trichoderma asperellum* (NRCB3); T3: Endophytic *Pseudomonas extremorientalis* (B1) + *Ochrobactrum anthropi* (B5) + Endophytic bacteria (B3); T4: Carbendazim (0.3 %); and T5: Control. The preliminary results showed the experimental plot that received T2 registered maximum plant height (128.3 cm), plant girth (50.3 cm) and leaf area (5329.6 cm^2), while T1 registered the maximum number of leaves (10.8 nos.) when compared to control. The experiment is in progress.

Field evaluation of biocontrol agents against Foc TR4 in Bihar

Similar to the above study, a randomized block design experiment was established to control the *Foc* TR4 in Bihar using newly developed consortia with five treatments with two replications. The composition of treatments and observational attributes were the same as applied to Uttar Pradesh but each block consisted of 50 plants. Our initial observations showed that there was no external symptom of wilt disease in both control and treated plots during the period under report. The preliminary results observed after three months (DAI) showed that experimental plots that received T2 and T3 registered maximum plant height (35%), plant girth (23-26%), maximum number of leaves (38%) and leaf area (42-61%) when compared to control. The experiment is in progress.

Interaction of native bioagents on Foc TR4 in cv. Grand Naine (AAA) through biochemical and scanning electron microscope studies

As Fusarium wilt is a lethal disease difficult to manage by single-source remedy, a sustainable method has to be established. To understand the biochemical mechanisms of beneficial endophytes and their mode of action, cell wall degrading hydrolytic enzymes, cellulase, protease, chitinase, pectinase and peroxidase of bacterial and fungal isolates collected from different cultivars were assessed. The study also aims to establish the host-pathogen-biocontrol agents' interaction using scanning electron microscopy (SEM).

Scanning electron microscopy study of infection and spread of Foc TR4 in cv. Grand Naine

In order to study the days taken to infect and spread inside the banana plant system, the *Foc* strain tropical race 4 was inoculated in the root zone of three-month old tissue cultured cv. Grand Naine (@ 30g / pot) maintained in pots under green house condition. Samples of root, corm, pseudostem and leaves were collected at 0, 7, 14, 21 and 28 days after *Foc* inoculation, and subjected to SEM analysis at the Department of Plant Pathology ICAR-IIHR, Bengaluru. The results of the study indicated that the presence of mycelial structure was observed on 2^{nd} day of inoculation itself in the root, corm and stem where as in the leaf; it was observed on 7^{th} day of inoculation. Further work to study the spread of the pathogen in other parts of the plant is in progress.

4.5.12 Development and utilization of diagnostics to viruses of banana under Consortium research platform on vaccines and diagnostics

(R. Selvarajan and C. Anuradha)

Validation of LFIA strip for detection of CMV

The LFIA strips developed for CMV (Fig. 87) was validated with forty-five banana leaf samples of commercial cultivars collected from different locations in banana growing states of India. The validation results showed that only symptomatic samples were positive and healthy did not react in the strip. (Fig. 88).

Fig. 87. Lateral flow immune assay device for on-site detection of Cucumber Mosaic Virus in banana

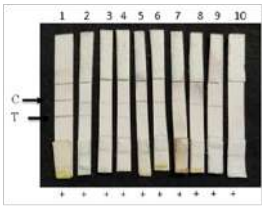


Fig. 88. Validation of LFIA strip for detection of CMV in survey samples respectively. C-Control line; T- Test line

Ready to use ELISA kit for simultaneous detection of BBrMV and CMV in banana samples

ICAR-NRCB ELISA kit is a rapid, sensitive and economical serological assay for simultaneous detection of BBrMV and CMV. This kit uses indirect ELISA system.

Monoclonal antibodies against BBrMV produced and used to develop LFIA

The recombinant coat protein of BBrMV was expressed and purified in a soluble form and used as the immunogen to produce monoclonal antibodies against the virus using the hybridoma technology. Antigen-coated-plate enzyme-linked immunosorbent assay (ACP-ELISA) was established for BBrMV detection (Fig. 89) using horse radish peroxidase-conjugated anti-mouse antibodies. Out of 18 hybridoma lines tested two were chosen and monoclonal antibodies were raised through outsourcing.

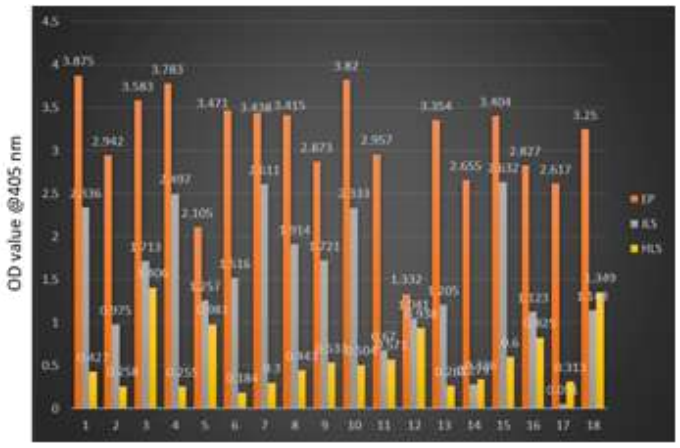


Fig. 89. Screening of cell supernatant of 18 no. of hybrids tested against BBrMV antigen for production of monoclonal antibody byACP-ELISA.EP-BBrMV recombinant protein; ILS- BBrMV infected leaf sample; HLS-Healthy leaf sample

Novel approach for the construction of expression vector for coat protein genes of BBrMV and CMV

A dual expression vector was constructed for the expression of coat protein genes of BBrMV and CMV using Gibson Assembly. For the assembly of dual construct, two sets of primers were designed to amplify two coat protein genes with a 20–22 nucleotides (nt) overlap region between BBrMV and CMV, and 20 nt overlap between coat protein segments and plasmid. The recombinant plamid clones were confirmed by RE analysis and mobilized into BL21 *E. coli* strain for expression of dual viral coat proteins.

Recombinase polymerase amplification-based detection system for banana viruses

A reverse transcription-recombinase polymerase amplification (RT-RPA)-based detection assay was standardized for banana bract mosaic virus. A multiplex reverse transcription-recombinase polymerase amplification-based detection system for DNA and RNA viruses (BBTV and CMV) was standardized using nuclear shuttle protein gene of BBTV and coat protein gene of CMV specific primers. To compare the sensitivity of the RPA method and conventional RT-PCR, we conducted 10-fold serial dilution of RNA (100 ng/µl – 1pg/ µl) and subjected

them to sensitivity testing. The detection limit for RPA was 10.0 pg/µl of RNA, 10-fold higher than that of conventional RT-PCR. (Fig. 90 & 91).

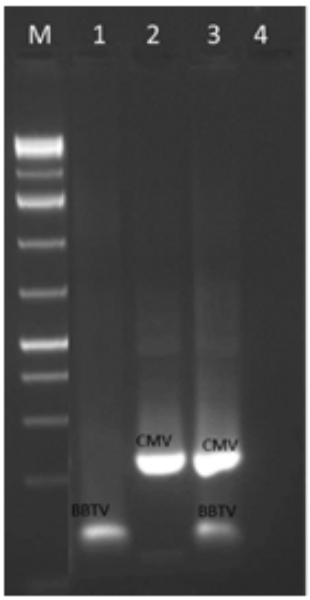


Fig. 90. Multiplex RT-RPA assay for simultaneous detection of BBTV and CMV. (A) Agarose gel showing simplex and multiplex RT-RPA assay. M- 1kb DNA ladder plus; Lane1- BBTV infected ; Lane-2: CMV infected; Lane-3: BBTV+CMV; Lane-4: Healthy

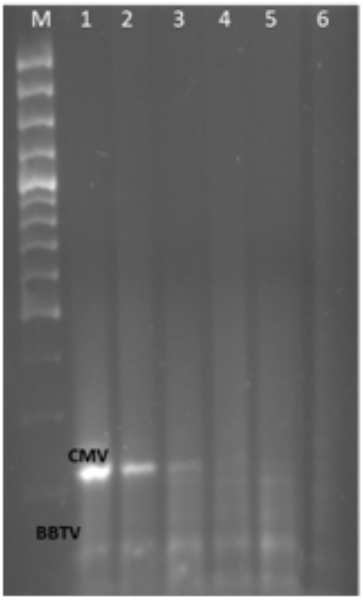


Fig. 91. Sensitivity of multiplex RT- RPA assays for BBTV and CMV detection: M- 100 bP DNA ladder plus; Lane 1, -100ng; Lane2-10 ng; Lane 3-1 ng; Lane-4:100 pg; lane 5-10pg; Lane 6-1 pg

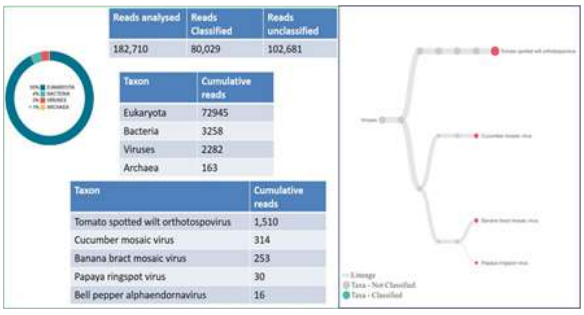
Standardization of nucleic acid based lateral flow kit development of BBTV

Primers were designed targeting the replicase gene and major common region of BBTV Hill banana isolate. All sets of primers were BLAST analysed to confirm their specificity. All the HPLC purified thiol functionalized and biotin labelled oligonucleotides were synthesized. Different sized gold nanoparticles, probe concentration and other parameters were standardized to develop NA based LFA.

Application of nanopore sequencing technology for detection of RNA and DNA viruses infecting banana and other crops

A diverse set of viral pathogen infected plants were selected for the cDNA sequencing . The total RNA samples were isolated from banana, chilli, tomato, papaya, tuberose, black gram, sweet potato, *Diascoria* and *Amorphophallus* were taken. 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. A total of 255,719 reads were undergone in a preliminary analysis using WIMP program. A cumulative read of 2242 was obtained for viruses among the super kingdom in the 1 to 10 barcodes (Fig. 92). The highest number of 1486 reads was found in Tomato spotted wilt orthotospovirus (TSWV) found associated with the tomato sample and this is the first report of TSWV occurrence in tomato in India. 308 reads of cucumber mosaic virus and 246 reads of BBrMV were obtained. The number of reads of Papaya ringspot virus and Bell pepper alphaendorna virus were 30 and 16 respectively. Pathogens were identified in real time within 1–2 h of running the Nanopore sequencer and were classified to the species or genus level.

Total DNA was isolated from virus infected banana, sugarcane and cassava plant samples and RCA was performed. MinION sequencing libraries were prepared as recommended by Oxford Nanopore Technologies. A total of 144719 reads were undergone in preliminary analysis using WIMP program. A cumulative read of 31522 was obtained for viruses. The highest number of 22157 reads were found in Sri Lankan cassava mosaic virus followed by 4096 reads of Indian cassava mosaic virus and 1419 reads of begamovirus. Besides, 2048 reads of BSMYV and 1019 reads of BBTV were obtained.



Reads analysed	Reads Classified	Reads unclassified
182,710	80,029	102,681

Taxon	Cumulative reads
Eukaryota	72945
Bacteria	3258
Viruses	2282
Archaea	163

Taxon	Cumulative reads
Tomato spotted wilt orthotospovirus	1,510
Cucumber mosaic virus	314
Banana bract mosaic virus	253
Papaya ringspot virus	30
Bell pepper alphaendornavirus	16

Fig. 92. Results obtained by WIMP workflow following Nanopore sequencing of RNA from diseased plant samples

Supply and evaluation of virus free banana TC plants

Virus free mother plants of cv. Hill banana were supplied to TC industries for mass propagation and during 2019-20, 6500 virus free banana TC plants were supplied to banana farmers under SC-Sub-Plan. The previous year's beneficiaries' fields were monitored for disease incidence and quality was assessed during surveys. The performance of these plants was superior, and there was no disease incidence compared to locally sourced plants by the farmers.

4.5.13 Assessment of post-harvest losses in banana (under ICAR - AICRP on Fruits)

(K. N. Shiva)

Surveys were conducted by the four different centers namely, Bengaluru, Jalgaon, Kannara, Kovvur and Tiruchirappalli (ICAR-NRCB) to estimate the post - harvest losses in banana at various levels/ stages (Field, transport level, assembly/wholesale market, storage and ripening and retail level). Overall post – harvest losses of banana recorded were 11.03, 30.35, 38.77, 22.49, and 11.46% at Bengaluru, Jalgaon, Kannara, Kovvur and Tiruchirappalli centers, respectively. Among the centers, Bengaluru was registered with the lowest post –harvest loss of 11.03%, while Kannara center was recorded with the highest post-harvest loss of 38.77%. Among the stages/levels of post-harvest losses, the maximum post-harvest loss was recorded at retail level market (9.83%), followed by field level (4.14%), assembly market (3.77%), storage and ripening (2.86%), and the minimum was in transport (2.78%), irrespective of the centers. Among the varieties, maximum post-harvest losses of 38.77% was recorded in 'Nendran' variety, followed by Karpura Chakkara Keli(KC Keli) (22.17%), Grand Naine (19.90%), Poovan (11.15%) and the minimum was in Ney Poovan (11.03%). At various levels/stages, the maximum post-harvest loss was recorded at retail level market (8.53%), followed by assembly market (4.09%), field level (3.63%), storage and ripening (2.52%), and the minimum was in transport (2.30%), irrespective of the varieties (Fig.93).

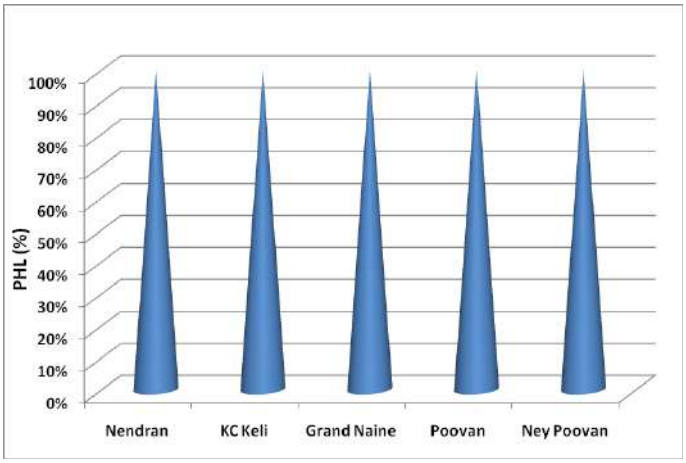


Fig. 93 Post-harvest losses in banana varieties

Contract Services

Genetic fidelity testing

About 13 batches of tissue culture plants of cvs. Grand Naine, Nendran, Swarnamukhi, Poovan, Monthan *etc*. have been tested for their genetic fidelity using ISSR markers and reports were issued.

Virus indexing

During the report period, 130 tissue culture banana mother plants were tested against four banana viruses and test report issued under contract service 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 presence of banana viruses. Totally 90 germplasm samples were tested against four viruses.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Technology assessed

Trial Name	Variety	Organization	Location	No. of trials
Adoptive Research Trials (ART)	Nendran based F1 hybrids	Farmers' Fields	Tiruchirappalli, Coimbatore and Pollachi (Tamil Nadu)	3
Front Line Demonstrations (FLDs)	Kaveri Saba	ICAR-KVKs	Ariyalur, Karur, Tiruchirappalli and Salem (Tamil Nadu)	4
On-Farm Trials (OFT)	Udhayam, Kaveri Saba, Kaveri Kalki	ICAR-KVKs	Ariyalur and Pudukkottai (Tamil Nadu)	2
Demonstration Blocks on ICAR-NRCB released varieties	Udhayam, Kaveri Kalki and Kaveri Saba	Anand Agriculture University (AAU), TNAU and ICAR-KVKs	Jabugam (Gujarat); Ariyalur, Karur, Ramanathapuram, Periyakulam, Salem, Thanjavur, Tiruchirappalli, Vellore (Tamil Nadu)	10

5.2 Radio talk

Name of the Scientist	Topic	Date of broadcast	Channel
M. Mayil Vaganan	Nutritive values and health benefits of banana flower	29 February, 2019	All India Radio, Tiruchirappalli
P. Giribabu	'Nematode management in banana cultivation'	21 May, 2019	
S. Uma	Live phone in program on 'ICAR-NRCB released banana varieties'	25 June, 2019	
R. Selvarajan	'Virus diseases of banana'	8 July, 2019	
K. J. Jeyabaskaran	Advanced soil and nutrient management strategies in banana cultivation	17 July, 2019	
P. Suresh Kumar	Export potential of banana	21 August, 2019	

5.3 Exhibitions conducted / participated

Name of the event	Organizer & Venue	Date	Name of the participating staff
Agri Expo & Golden jubilee celebration and exhibition	HRS (Dr. YSRUHS), Kovvur, Andhra Pradesh at HRS, Kovvur, Andhra Pradesh	8 January, 2019	P. Ravichamy

National Horticultural Fair – 2019	ICAR-IIHR, Bengaluru	23 - 25 January, 2019	V. Kumar P. Durai P. Ravichamy
Jack Day	TNAU at HC & RI for Women, Tiruchirappalli, Tamil Nadu	8 June, 2019	S. Uma K. N. Shiva P. Ravichamy
26th Foundation Day and Kisan Mela of ICAR-NRCB	ICAR - NRCB, Tiruchirappalli, Tamil Nadu	21 August, 2019	V. Kumar K. N. Shiva P. Suresh Kumar P. Ravichamy K. Kamaraju
District level seminar on 'Hi-tech banana cultivation'	Deputy Director of Horticulture, Tiruchirappalli at Kalayarangam Thirumana Mandapam. Tiruchirappalli, Tamil Nadu	15 November, 2019	V. Kumar K. N. Shiva K. Kamaraju
Workshop on 'Banana value added products including fiber based handicrafts'	YUGAA (Women Social Welfare Organization) with Dinamalar Pengal Malar for Empowerment of Women at Bishop Heber School Auditorium, Puthur, Tiruchirappalli, Tamil Nadu	30 November, 2019	S. Uma K. Kamaraju
North East's biggest food innovation exhibition	Meghalaya and SIAL at Shillong, Meghalaya	3-4 December, 2019	-

5.4. Publicity

A total of 35 press notes on ICAR-NRCB's activities/ functions/ technological information (popular articles) were published in different national and local dailies (in English and Tamil), Tamil magazines/ journals, AIR-farm division,etc. for the benefit of the banana farmers.

Mr. S. Sivarasu, I.A.S, District Collector, Tiruchirapalli inaugurates exhibition stalls during 26th foundation day of ICAR-NRCB

5.5. Training/ Extension

More than 7500 visitors including farmers, agriculture & horticulture officers, SHG, entrepreneurs, students and stakeholders from different parts of India visited the ICAR-NRCB exhibition (for getting first-hand information about technologies developed by ICAR-NRCB on banana) and they were explained about ICAR-NRCB's activities/ technologies. Under the outreach programmes, ICAR-NRCB scientists have trained more than 6000 farmers across the country.

Visit of Banana Farmers from Vijayawada to ICAR - NRCB on 27 November 2019

6.1.1 Students Guided

Student Name	Degree	Project title	Chairperson
R. Aravindh	M.Sc. (Biotech.)	Pathogenic expression of Protease (Pr1) and chitinase (chitin gene) of *Beauveria* spp.	B. Padmanaban
S. Kulasekara Pandi	M.Sc. (Biotech.)	Pathogenic expression of Protease (Pr1)and chitinase (chitin gene) of *Metarhizium* spp.	
S. Tilakshana	M.Sc.(Microbiol.)	Identification of volatile secondary metabolites of entomopathogenic fungi	
K. Saranya	M.Sc.(Microbiol.)	Cuticle degrading enzymes of entomopathogenic fungi (*Beauveria, Metarhizium* and *Lecanicillium* sp.)	
P. Pushpa	M. Sc. (Biotech.)	Studies on mass production of *Trichoderma asperellum* on cheaper organic materials for the control of *Fusarium oxysporum* f. sp. *cubense* race TR4	R. Thangavelu
R. Thenmozhi	M. Sc. (Biotech.)	Studies on native endophytic and rhizospheric bacteria and their root exudates for effective management of *Fusarium oxysporum* f. sp. *cubense* TR4	
S. Radhipriya	M. Sc. (Biotech.)	Interaction of native bioagents on *Fusarium oxysporum* f. sp. *cubense* TR4 in banana cv. Grand Naine (AAA) through biochemical and scanning electron microscope studies	
M. Akila	M.Sc. (Biotech.)	Cloning and characterization of suppressor of gene silencing genes of BBrMV and CMV	R. Selvarajan
N. Vidhya	B. Tech. (Biotech.)	Physiological and biochemical response of banana cultivars in altered soil moisture regime	I. Ravi
G. Kannan	Ph.D. (Biotech.)	Development of Fusarium wilt resistance in banana (*Musa* spp.) cv. Rasthali (AAB, Silk) through mutation breeding and confirmation through molecular approaches	M. S. Saraswathi
N. Kavitha	Ph. D. (Biotech.)	Identification of a suitable explant and regeneration pathway for the mass propagation of three recalcitrant commerical varieties of banana	
E. Harshini	B. Tech. (Biotech.)	Effect of different wavelengths of light using LEDs on tissue culture multiplication of banana (*Musa* spp.)	
Krishnaveni	B. Tech. (Biotech.)	Effect of PGPRs on the growth and development of tissue cultured banana (*Musa* spp.) cvs. Grand Naine (AAA) and Red banana (AAA) and their validation through biochemical analysis	
Sripriya	M. Sc. (Biotech.)	Molecular and biochemical profiling of newly released banana (*Musa* spp.) varieties	
Mohanya	B. Tech. (Biotech.)	Screening of North-eastern banana accessions for Sigatoka leafspot resistance using juglone	

Prathyasa P. Babu	M. Sc. (Food Tech. & Qual. Assur.)	Standardization and development of banana flour and peel powder based extruded product – Pasta	K. N. Shiva
Silpa S. Babu	M. Sc. (Food Tech. & Qual. Assur.)	Physico-chemical and sensory characters of banana chips influenced by types/flavour and varieties	
S. Jeganathan	M. Sc. (Food Process.)	Development of low glycemic, fibre rich pasta: Effect of native and modified banana starches	P. Suresh Kumar
R. Kowsalya	M. Sc. (Microbiology)	Studies on effect of application of salicylic acid on root-knot nematode (*Meloidogyne incognita*) and root-lesion nematode (*Pratylenchus coffeae*) infecting banana (*Musa* sp.)	P. Giribabu
G. Pradeep	B. Tech. (Biotech.)	Cloning and characterization of eIF4E gene from banana	C. Anuradha

6.1.2 Internship Training Programme organized by HRD Cell, ICAR-NRCB

S. No.	Degree of Students & Year	College/Institution	Dates & Duration	No. of Students
1.	B. Tech. (Biotechnology); II Year	Sri Venkateshwara College of Engineering, Chennai, Tamil Nadu	26 November – 10 December, 2019; 15 Days	2
2.	B. Tech. (Biotechnology); II Year	Kamaraj College of Engineering and Technology, K. Vellakulam, Madurai Dt., Tamil Nadu	26 November – 10 December, 2019; 15 Days	1
3.	B. Tech. (Biotechnology) II & III Year	Karpaga Vinayaga College of Engineering and Technology, Chinna Kolambakkam, Kanchipuram Dt., Tamil Nadu	3 – 10 December, 2019; 8 days	17
4.	M. Sc. (Foods and Nutrition); I Year	Mother Teresa Women's University Research and Extension Centre, Madurai, Tamil Nadu	9 – 24 December, 2019; 16 days	3

6.1.3 List of students completed Ph. D. in 2019

S. No.	Name	Research Guide	Title
1.	M. Kumaravel	S. Uma	Studies on molecular basis of somatic embryogenesis and its manipulation in recalcitrant banana cultivars
2.	K. P. Sajith		Regeneration systems, economics and genetic feasibility studies in banana (*Musa* spp).

6.2 Trainings

6.2.1. On-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Training on 'Practices for the production of innovative banana chips'	K. N. Shiva	1	28 - 29 January, 2019
Training on 'Banana fruit and central core (stem) juice / RTS beverage and stem pickle'	K. N. Shiva	1	27 February - 2 March, 2019
Minimal processing of cut banana slices and cubes and basil seed suspended ready to drink banana juice	P. Suresh Kumar K. N. Shiva	1	9 – 10 May, 2019
Internship training programme on 'Processing technologies in banana' to M.Sc. (Food Science & Nutrition) students	P. Suresh Kumar K. N. Shiva	7	21 May - 19 June, 2019
Training on 'Banana flour (Bhimkol)'	K. N. Shiva P. Suresh Kumar	1	13-14 June, 2019
Training on 'Banana chips'	K. N. Shiva P. Suresh Kumar	2	26-27 June, 2019
Hands on training on 'Banana tissue culture techniques'	M. S. Saraswathi	2	29 June - 5 July, 2019
Training on 'Extraction of banana fibre and production of handicrafts' to the women entrepreneurs of Manipur	K. N. Shiva P. Suresh Kumar	4	8-11 July, 2019
Training on 'Banana fig'	K. N. Shiva P. Suresh Kumar	1	18-20 September, 2019
Training on 'Banana chips'	K. N. Shiva P. Suresh Kumar	1	19-20 September, 2019
Training on 'Banana flour from unripe banana/plantain and fig from ripe banana'	K. N. Shiva P. Suresh Kumar	1	18-20 September, 2019
Training on 'Banana fig' and banana central core (stem) juice (RTS Beverage)	K. N. Shiva P. Suresh Kumar	1	18-20 September, 2019
Training on 'Banana central core (stem) Juice	K. N. Shiva P. Suresh Kumar	1	18-20 September, 2019
Training on 'Post-harvest handling, storage of banana flower'	K. N. Shiva P. Suresh Kumar	1	31October – 5 November, 2019
Training on 'Macropropagation of banana - A farmer friendly mass multiplication technology' - jointly funded by ICICI foundation, Tiruchirappalli Zone and SEED Division – DST, New Delhi	S. Backiyarani M. S. Saraswathi	55	19 November, 2019
Training on 'Banana fig'	K. N. Shiva P. Suresh Kumar	1	19-20 November, 2019

Internship training programme on 'Processing technologies in banana' to M.Sc. (Food Science & Nutrition) students	P. Suresh Kumar K. N. Shiva	3	9 -24 December, 2019

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of particpants	Date
Training cum workshop for 'Banana fruit crop' to farmers, organized by ATMA, Solapur Dt., Maharashtra at Sri Guruseva Mangal Karyasala, Kandar village, Karmala Taluk, Solapur, Maharashtra	B. Padmanaban R. Thangavelu V. Kumar K. N. Shiva	100	7 - 8 February, 2019
Training on 'Macropropagation of banana - A farmer friendly mass multiplication technology' - jointly funded by ICICI foundation, Tiruchirappalli Zone and SEED Division – DST, New Delhi	S. Backiyarani	60	26 December, 2019

Trainees at hands on training on 'Macropropagation of banana' at ICAR-NRCB

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
ICAR-NRCB	'Bharat Vidya Ratan Award' from International Business Council, New Delhi.
S. Uma	'Dr. M. H. Mari Gowda National Endowment Award' for the best horticulture research in recognition of the research contributions by Dr. S. Uma and her team for their innovation in the development of 'Next generation plant tissue culture system for high throughput production of banana planting material using bioreactors'.
	Elected as the 'Chair of Banana Network for Asia & Pacific Region' by the members of BAPNET, Philippines
B. Padmanaban	'Lifetime Achievement Award 2019' from Dr. B. Vasantharaj David foundation, Chennai for commendable contribution to Agricultural Entomology, notably on banana pest management in November, 2019.
J. Poorani	'Ernst Mayr Travel Grant' from the Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts, USA, for visiting the Natural History Museum, London, United Kingdom, during 17 July – 29 August, 2019, for examination of type specimens of Coccinellidae.
R. Thangavelu	'Outstanding Scientist Award-2019' by the Society for Biotic and Environmental Research, Tripura.
	'CHAI-Appreciation Award -2019' by Confederation of Horticulture Associations of India, New Delhi.
	'Outstanding Contribution to Science Award -2019' for commendable contribution to Fusarium wilt and leaf spot disease management in banana by Dr. B. Vasantharaj David foundation, Chennai.
M. Gopi R. Thangavelu	'CHAI - Dr. Ray Best Dissertation Award-2019' for the thesis entitled "Identification and evaluation of antagonistic microbes and botanicals for the management of fusarium wilt disease (*Fusarium oxysporum* f.sp. *cubense*) in banana.
R. Selvarajan	'Fellow of Horticultural Society of India' (FHSI) conferred at 8th Indian Horticulture Congress-2018, IGKVV, Raipur during 17 - 21 January, 2019.
	'Jeersannidhi Award' by Indian Phytopathological Society at National symposium on 'Recent challenges and opportunities in sustainable plant health management' held at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi on 28 February, 2019.
I. Ravi	'A. P. J Abdul Kalam Distinguised Fellow Award' in recognition of service to the field of Science by Bose Science Society, Tamil Nadu.
K. N. Shiva	'Best poster award' at 'XIV Agricultural science congress' held at National Agricultural Science Complex, New Delhi during 20 - 23 February, 2019.
M. S. Saraswathi	'Fellow of Horticultural Society of India' (FHSI) conferred at 8th Indian Horticulture Congress-2018, IGKVV, Raipur during 17 - 21 January, 2019.
	'CHAI fellow' at CHAI meet held at Pusa, New Delhi during 28 - 31May, 2019.

P. Suresh Kumar	'Lal Bahadur Shastri Outstanding Young Scientist Award' conferred on In the 91st foundation day of the Indian Council of Agricultural Research (ICAR) held on 16 July, 2019 at New Delhi.
	'CHAI Fellow-2019' at International conference on 'Innovative horticulture and value chain management – Shaping future horticulture' held at GBPUA&T, Pantnagar, Uttarkhand during 28-31 May, 2019.
C. Anuradha	Awarded DST-SERB project titled 'A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.)'.
P. Ravichamy	'Best poster award' at National conference on 'Farmers orientation towards climate change & upgrading to sustainable agriculture' (FOCUS-2019) held at National college, Tiruchirapalli during 23 - 24 February, 2019.

Dr. S. Uma, Director, ICAR-NRCB, receiving 'Dr. M. H. Mari Gowda National Endowment Award'

Dr. B. Padmanaban, Principal Scientist receiving
'Lifetime Achievement Award 2019' by Dr. B. Vasantharaj David foundation

Dr. P. Suresh Kumar, Senior Scientist, ICAR-NRCB, receiving
'Lal Bahadur Shastri Outstanding Young Scientist Award'

7.2 Recognitions

Name of the Scientist	Details
S. Uma	Served as 'Country Representative of the MusaNet Expert Committee of the Alliance of Bio-versity and CIAT
	Chief Guest – Club Formation Day at HC&RI-Women(TNAU), Tiruchirapalli.
	Expert member, Dean & Registrar (TNAU) selection committee meet at TNAU, Coimbatore during 9 – 10 January, 2019
	Lead talk at 8th Indian Horticulture Congress-2019 held at IGKVV, Raipur, Chhattisgarh during 17-21 January, 2019
	Chief guest at 'Pre-rabi season campaign' for Karur organized by SKVK, Karur, Tamil Nadu, on 22 January, 2019
	Chairperson, Technical session and Co-Chairperson for one session at 6th Group discussion meet of ICAR-AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Board member - IIFPT Board Meeting at Panchseel Bhawan, New Delhi on 20 February,2019
	Chief guest, National conference on 'Farmers orientation towards climate change & upgrading to sustainable agriculture' (FOCUS-2019) held at National college, Tiruchirapalli.
	Chief Guest - International Women Day Celebration, ICAR-NBAIR, Bengaluru.
	Organizer, one day workshop on 'Arabi to Banana : Potential & fruitful research project' at ICAR-NRCB, Tiruchirappalli, on 13 March, 2019
	Member, NABARD project review meet held at KNCET, Thottiyam, Tamil Nadu.
	Invited guest lecture on 'Women in Agriculture' at NIT, Tiruchirappalli, on 20 March, 2019
	Chief guest, Inauguration of Dinamani's (Tamil daily) 'Higher Education Fair' held at Tiruchirappalli on 23 March, 2019
	Chairperson, workshop on 'Krishi Portal' at ICAR-NRCB, Tiruchirappalli, on 26 March, 2019
	Expert member - Sabri banana project review meeting at ICAR-NRCB, Tiruchirappalli.
	Country representative, BAPNET Steering Committee Meet, Guangzhou, China.
	Special invitee - Jackfruit show, HC&RI-Women(TNAU), Tiruchirappalli, on 8 June, 2019
	Review member - Review of NABARD funded Project at KNCET, Tiruchirappalli.
	Expert member - DBT's Sabri banana Project expert committee meeting at Agartala, on 13 July, 2019
	Chief guest – National seminar on 'Advances in bulk grain storage and smart sensor and IoT applications in warehouses', IIFPT, Thanjavur, Tamil Nadu, on 26 July, 2019
	Chairperson, RAC meet, IIFPT, Thanjavur, Tamil Nadu, on 4 September, 2019
	Special address at National conference on 'Climate smart agriculture' held at ADAC&RI (TNAU), Tiruchirappalli, Tamil Nadu, on 13 September, 2019
	Co-convener, TR-4 Workshop at NAAS, New Delhi, on 25 September, 2019
	Member, IIFPT board meet held at New Delhi, on 22 November, 2019
	Chief Guest – Yuga – Dinamalar Women Empowerment programme on 30 November, 2019
	External reviewer of three Ph.D. theses from Jain University, Bangalore; University of Mumbai and UHS, Bagalkot, Karnataka
	Reviewer for BME Biology, *Physiologia Plantarum*, *Scientia Horticulturae* and PLOS one

B.Padmanaban	Convener for session at 6th group discussion meet of ICAR-AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Member Secretary, RAC & QRT, ICAR-NRCB, Tiruchirappalli
	Reviewer for Indian Journal of Entomology
	Evaluated four Ph.D. theses and acted as external examiner for one Ph.D. thesis
J. Poorani	Subject editor, Zookeys (Journal)
R. Thangavelu	Covener for session at 6th Group discussion meet of ICAR -AICRP (Fruits) held at AAU, Jorhat during 14 -16 February, 2019
	Country representative for 11th BAPNET steering committee meeting, held at Gunagzhou, Guangdong, China on 7-9 May 2019, organized by Bioversity International, Banana Asia-Pacific Network (BAPNET) and Guangdong Academy of Agricultural Sciences.
	Delivered lead talk on 'Importance and status report on TR-4 in India and characterization of the isolates' at brainstorming workshop on 'Tropical Race 4 affecting banana cultivation' conducted by and at NAAS, New Delhi on 25 September, 2019.
	Deputed as an expert on the invitation by the Ministry of Agriculture and Food Security (MASA) of Mozambique and Technoserve and participated as lead speaker and panelist at 'International conference on controlling banana diseases in the African banana industry' on 21 - 22 November 2019.
	Deputed as an expert to participate in the "Foc TR4 strategy meeting" held on 18-19 November, 2019 in Maputo organized by Altus Viljoen, Plant Expert at the Department of Plant Pathology, University of Stellenbosch in collaboration with the Gates Foundation
	Delivered keynote lecture on 'Fusarium wilt Tropical race 4 - An emerging threat of banana cultivation and its management' at National conference on 'Innovative horticulture and value chain management' held at GBPUA&T, Pantnagar, Uttarkhand during 28-31 May, 2019.
	Chairman for a session at National conference on 'Challenges and innovative approaches in agriculture and allied sciences research' held at Sona college of Arts and Science, Salem on 27 July, 2019.
	Secretary, Confederation of Horticultural Association of India (CHAI)
	Recognized as PG teacher in Plant Pathology for University of Horticultural Sciences, Bagalkot, Karnataka
	Panelist in the awareness programme on 'Impact of Fusarium wilt TR4 in Banana' jointly organized by CIH, Medziphema and ICAR and delivered a lead talk on "Status of Fusarium wilt Tropical Race-4, impact and its management" at Police Complex, Dimapur on 9 November, 2019.
	Delivered plenary lecture on 'Fusarium wilt : An emerging threat to banana cultivation in India' at International conference on Innovative and emerging trends in botany (ICIETB'2019)' Organized by Department of Botany, Alagappa University, Karaikudi, Tamil Nadu, India from 6 - 7 November, 2019
	External examiner for two Ph. D theses

R. Selvarajan	Chief guest, Biofest' 2K19 on the future prospectus of Life Sciences held at Department of Biotechnology, Bioinformatics and Nutrition and Dietetics, Bishop Heber College, Trichy on 25 January, 2019
	Co-chairman, one technical session at 6th group discussion meet of ICAR-AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Co-chaired a technical session at the International conference on 'Plant protection in Horticulture - Advances and challenges' (ICPPH-2019) organized by Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE) and ICAR-IIHR during 24-27 July, 2019.
	Doctoral committee member, School of Bio Sciences and Technology at Vellore Institute of Technology (VIT), Vellore, Tamil Nadu
	External examiner for M.Sc. and Ph.D. theses
	Delivered invited lecture on 'Advances in the development of *on-site* diagnostic kits for disease' in CAFTA training programme on "Advanced agro-techniques and agronomic interventions for doubling farmer's income" at Department of Agronomy, Directorate of Crop Management, TNAU, Coimbatore on 4 December, 2019
	Delivered an invited lecture on 'Protein-based diagnosis and its applications in plant virus diagnosis' under a NAHEP-CAAST sponsored training programme on 'Genome assisted diagnosis of plant viruses, viroids and phytoplasmas' at Division of Plant Pathology, ICAR-IARI on 19 October, 2019
M. Mayil vaganan	Delivered talk on 'Biofortification of iron in bananas by expression of *Oryza sativa* nicotianamine synthase genes' at International conference on 'Next generation plant production and bioresources utilisation technologies' at the Indian Institute of Technology, Guwahati, Assam during 11 - 13 February, 2019.
	Convener, workshop on 'Arabi to banana: Potential and fruitful research projects' held at ICAR-NRCB, Tiruchirappalli on 13 March, 2019.
I. Ravi	Expert member for DPC meeting for 'Technical staff' of IIFPT, Thanjavur on 1 May, 2019
	Delivered a valedictory lecture in the 9th National conferene on Natural Sciences, on 24 August, 2019 organised by Bose Science Society at Pushkram Agricultural College, Pudukkottai, Tamil Nadu.
	Member for recruitment of Scientists, SMS and supporting staffs for RVS KVK, Tenkasi, Tamil Nadu, on 8 December, 2019.
	Participated in developing guidelines on priority research areas for schemes to be implemented through the 'National Food Processing Policy (NFPP)' for the Ministry of Food Processing Industries, Govt. of India, at IIFPT, Tanjavur, Tamil Nadu.
K. J. Jeya-baskaran	Recognized as ASCI Trainer for KVKs/ SAUs/ ICAR institutes for vermicompost production

K. N. Shiva	"Appreciation certificate" from Tamil Nadu Banana Growers Federation, Tiruchirappalli, Tamil Nadu for the project: BANANA 4 GROWTH
	Lead presenter at 6th Group discussion of ICAR-AICRP on Fruits held at AAU, Jorhat, Assam on 15 February, 2019.
	ICAR Nominee for recruitment of SMS in ICAR-KVK (CENDECT), Kamatchipuram, Theni, Tamil Nadu on, 7 December, 2019.
	Nominated as ICAR – Nominee/SMS by the Director, NRCB for participation in the XX Scientific Advisory Committee (SAC) Meeting of ICAR-KVK (CENDECT), Kamatchipuram, Theni, Tamil Nadu on 7 December, 2019 and delivered special address on programs/FLD/OFT to be taken up on recent advances in varieties, production, processing and value addition in banana.
	Nominated as member, Assessment Committee for Scientist (Food Technology) of ICAR-CTCRI, Tiruvananthapuram, Kerala, on 28 December, 2019.
S. Backiyarani	Lead talk at 8th Indian Horticulture Congress-2019 held at IGKVV, Raipur, Chhattisgarh during 17-21 January, 2019
M. S. Saraswathi	Reviewed three research articles
	External examiner for 3 M. Sc. and one Ph. D. Theses
D. Ramajayam	Selected as an expert by The Makran Agro-Industry, Iran for 'Assessment of suitability and production/economic values of different tropical fruit cultivars including bananas in 1500 ha in the South-Eastern of Iran, near to Chabahar Region'.
	External examiner for 2 M. Sc. and one Ph. D. Theses
	Reviewer of eight research papers for Scientia Horticulturae
M. Loganathan	Reviewer for two international and national journals each
	External examiner for 3 M. Sc and one Ph. D. Theses
	Member, Doctoral committee, Bharathiyar University
	Nodal officer - CeRA
P. Suresh kumar	Editor - Pharmacology, Toxicology and Pharmaceutics
	Reviewer - Scientia Horticulturae, Journal of Food Science & Technology, Indian Journal of Horticulture, Innovative Food Science and Emerging Technologies, Journal of food processing and preservation, Ciência e Agrotecnologia, Agricultural Water Management
	Rapporteur at Section on Action taken Report in the 6th Group Discussion of AICRP Fruits at AAU, Jorhat on 14-16 February, 2019
	Convenor, one session at 6th Group discussion of AICRP (Fruits) held at AAU, Jorhat on 14-16 February, 2019
	Member - Organizing committee ICAR- Krishi Portal- A central research data repository on 25 March 2019.
	Delivered keynote lecture on 'Export of Banana from India: Problems & Prospects' at International conference on 'Innovative horticulture and value chain management – Shaping future horticulture', GBPUA & T, Pantnagar, Uttarkhand, 28-31 May, 2019.
	Delivered keynote lecture on 'Value addition and byproduct utilization in Banana'at NAU, Navsari, Gujarat, 6 December, 2019.
	Evaluated 4 M.Sc. theses and external examiner to two M.Sc. students
	Management representative of ISO 9001: 2015
	Associate editor - 6th Group Discussion on ICAR-AICRP Fruits, Research report -2017. ICAR- IIHR, Bengaluru, Tech Doc. No. 127. Pp. 274.
	Associate editor - Research report, ICAR-AICRP Fruits; Annual Report 2018-19, ICAR-AICRP Fruits

P. Giribabu	Life member of Society for Biocontrol Advancement; Association for Advancement of Pest Management in Horticultural Ecosystem.
	Rapporteur, QRT meet, ICAR-NRCB on 25 February, 2019.
C. Anuradha	Co-Chairperson for two Ph. D. Students
	Honorary life membership from International Society of Root Research (ISRR).
	Life Member of Indian Virological Society and TNAU-MASU
	Editorial board member, International Journal of Current Research and Development
	Reviewer in Journal of Plant Pathology, Virus Disease, The Open Virology Journal.
	Rapporteur, QRT meet, ICAR-NRCB on 25 February, 2019.

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
Development of non chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	DAE, Mumbai, Maharashtra
Co-ordinated horticulture assessment & management using geoinformatics (CHAMAN-Phase-II)	Department of Agri., Co-oper. & Farmers Welfare, Govt. of India
'Knowledge Partner' in developing technologies towards value chain management, supporting banana export, organic production and waste utilization	Government of Andhra Pradesh
Development of protocol for sea shipment of banana to Gulf countries	APEDA, Bengaluru & M/s. Fair Exports India Ltd., Kochi, Kerala
Development of protocol for sea shipment of Nendran banana to European Union	VFPCK, Kerala
Technology demonstration and training to banana farmers	NABARD
Developing various instruments for banana production and value addition	ICAR-CIAE (Regional Centre), Coimbatore, Tamil Nadu
Assessment of post-harvest losses in banana	ICAR-AICRP on Fruits
Framing crop specific DUS guidelines for banana (*Musa* spp.)	PPV & FRA
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 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)
1. 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, Guajarat Utkal University, Bhuaneshwar, Odisha Tripura University, Suryamaninagar, Tripura National Botanical Research Institute, Lucknow Jawaharlal Nehru Troipical Botanic Garden & Research Instt., Thiruvananthapuram Kohima Science Collge, Jotsoma, Nagaland Nagaland University, Medzhiphema, Nagaland Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal Patkai Christian College, Dimapur, Nagaland 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, Bhubaneshwar, 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, Bhubaneshwar, 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
2. Collection, evaluation, documentation and conservation of banana genetic resources from NE region	
3. Diversity assessment, germplasm conservation and database development on banana resorucs in NE India	
4. Whole genome and transcriptome study to stress tolerant banana cultivars	
5. Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system	
6. Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	
7. Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	
8. Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	
9. Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	
10. *In vitro* mass propagation of high value hill area banana	
11. Characterization of high value phyto-chemicals of anti diabetic and immune-modulatory properties in NE banana varieties	
12. Development of pre & post harvest bunch care management methods for fresh banana	
13. Genetic resource assessment, *in-situ* conservation and impact of banana waste as a feed for animals in NE region of India	
14. Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	
15. Management of low temperature and soil moisture deficit stresses in banana growth in NE India	
16. Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	

9. PUBLICATIONS

9.1 Research Papers

International

Backiyarani, S., Vignesh Kumar, B., Chandrasekar, A., Saranya, S., Ramajayam, D., Saraswathi, M.S., Durai, P., Kalpana, S. and Uma, S. 2020. Strengthening of banana breeding through data digitalization. *Database: the Journal of Biological Databases and Curation*, doi:10.1093/database/baz145. 93a-93f.

Dita, M., Teixeira, L.A.J., O'Neill, W., Pattison, A.B., Weinert, M.P., Li, C.Y., Zheng, S.J., Staver, C., Thangavelu, R. and Viljoen, A. 2020. Current state of Fusarium wilt of banana in the subtropics. *Acta Horticulturae*, **1272**, 45-56. DOI: 10.17660/ActaHortic.2020.1272.7.

Jeyabaskaran, K.J, Kumar, V. and Uma, S. 2019. Development and validation of fertiliser adjustment equations for banana cv. Grand Naine (AAA). *International Journal of Innovative Horticulture*, **8**(2):135-142. DOI:10.5958/2582-2527.2019.00007.1.

Kumaravel, M., Uma, S., Backiyarani, S. and Saraswathi, M. S. 2020. Proteomic analysis of somatic embryo development in *Musa* spp. cv. Grand Naine (AAA). *Scientific Reports*, **10**(1), 4501. https://doi.org/10.1038/s41598-020-61005-2.

Kumaravel, M., Uma, S., Backiyarani, S., Saraswathi, M.S. and Vaganan, M.M. 2020. Antioxidant enzyme activities during somatic embryogenesis in *Musa acuminata* Colla (AAA group) 'Grand Naine' and *Musa* spp. (AAB group) 'Rasthali'. *In Vitro Cellular & Developmental Biology - Plant*, **56**:41–50.

Kumaravel, M., Uma, S., Backiyarani, S., Saraswathi, M.S., Kannan, G. and Chandrasekar, A. 2019. Differential proteomic analysis of germinating and non-germinating somatic embryos of banana. *International Journal of Innovative Horticulture*, **8**(2):158-166. DOI: 10.5958/2582-2527.2019.00010.1.

Prathapan, K.D., Poorani, J., Amritha Kumari, S., Anuradha, C., Padmanaban, B., Thanigairaj, R. 2019. Species composition and diagnoses of leaf- and fruit-scarring beetles (Coleoptera, Chrysomelidae) infesting bananas and plantains (Zingiberales, Musaceae) in the Indian subcontinent. *Deutsche Entomologische Zeitschrift*, **66**(2): 179-202.

Revathi, S., Sivakumaran, N., Ramajayam, D., Saraswathi, M.S., Backiyarani, S. and Uma, S. 2019. Growth estimation during hardening phase of tissue cultured banana plantlets using bootstrapped artificial neural network. *Journal of Environmental Biology*, **40**: 729-724.

Saraswathi, M.S., Uma, S., Ramaraj, S., Durai, P., Mustaffa, M.M., Kalaiponmani, K. and Chandrasekar, A. 2019. Inter retrotransposon based genetic diversity and phylogenetic analysis among the *Musa* germplasm accessions. *Journal of Plant Biochemistry and Biotechnology,* 10.1007/s13562-019-00519-x.

Selvarajan, R., Balasubramanian, V., Priyanka, P. Manohar Jebakumar, R, Prasanya Selvam. K. and Uma, S. 2020. Evidence of seed transmission of banana bract mosaic virus in *Musa* synthetic diploid H-201, a possible threat to banana breeding. *European Journal of Plant Pathology,* 10.1007/s10658-019-01924-7.

Subramanian, A. R., Kumar, V., Ravichamy, P. and Sivabalan, K. C. 2019. The effect of organic and inorganic sources of nutrients on fruit quality including shelf life of banana cv. Grand Naine. *International Journal of Chemical Studies,* **7**(6): 728-731, P-ISSN: 2349–8528, E-ISSN: 2321–4902.

Suresh Kumar, P., Saravanan, A., Sheeba, N. and Uma, S. 2019. Structural, functional characterization and physicochemical properties of green banana flour from dessert and plantain bananas (*Musa* spp.). *LWT - Food Science and Technology*, **116**. 108524. https://doi.org/10.1016/j.lwt.2019.108524.

Thangavelu, R., Arthee, R., Loganathan, M. and Uma, S. 2019. Fusarium wilt-Tropical Race 4-An emerging threat to banana cultivation and its management. *International Journal of Innovative Horticulture,* **8**(1):9-21.

Uma, S., Sasikala, R., Sharmiladevi, S., Backiyarani, S. and Saraswathi, M.S. 2020. Unravelling the regulatory network of transcription factors in parthenocarpy. *Scientia Horticulturae*, **26**: 144-156.https://doi.org/10.1016/j.scienta.2019.108920.

National

Alagesan, A., Tharani, G., Padmanaban, B., Manivannan, S. and Jawahar, S. 2019. An assessment of biological control of the banana pseudostem weevil *Odoiporus longicollis* (Olivier) by entomopathogenic fungi *Beauveria bassiana*. *Biocatalysis and Agricultural Biotechnology.* doi.org/10.1016/j.bcab.2019.101262.

Aruna, R., Srinivasan, M.R. and Selvarajan. R. 2019. Reverse Transcriptase-Loop Mediated Isothermal Amplification (RT-LAMP): a rapid detection method for Sac brood viral disease infecting *Apis cerana indica* Fabricius. *Annals of Plant Protection Sciences*, **27** (1), 64-69.

Giribabu, P., Anitha Sree, T. and Saraswathi, M. S. 2019. Screening of banana genotypes for resistance to root-knot nematode, *Meloidogyne incognita*. *Indian Journal of Nematology*, **49**(1): 103-104.

Padmanaban, B., Kannan, M., Uma, S., Saraswathi, M.S., Backiyarani, S. and Ashif, K.K. 2020. Field evaluation and *in vivo* screening of *Musa* germplasm against banana stem weevil, *Odoiporus longicollis*, *Journal of Entomology and Zoology Studies,* **8**(1): 290-296.

Palanichamy, S. and Mayil Vaganan, M. 2019. Aggregation pheromone and kairomones in attracting banana pseudostem weevil, *Odoiporus longicollis* Oliver. *Indian Journal of Entomology,* **81**(3): 623-626.

Palanichamy, S., Padmanaban, B., Mayil Vaganan, M. and Uma, S. 2019. Olfactory responses of banana pseudostem weevil, *Odoiporus longicollis* Oliver (Coleoptera: Curculionidae) to pheromone and host plant volatiles. *Indian Journal of Entomology,* **81**(2): 306-308.

Palanichamy, S., Padmanaban, B., Mayil Vaganan, M., Backiyarani, S. and Uma, S. 2019. Electrophysiological responses of banana pseudostem weevil, *Odoiporus longicollis* Olivier (Coleoptera: Curculionidae) to methyl jasmonate, 1-hexanol and host plant extract. *Indian Journal of Experimental Biology,* **58**: 53-57.

Poorani, J. and Thanigairaj, R. 2019. Record of *Asprothrips navsariensis* Tyagi (Thysanoptera: Thripidae) as a pest of banana from Tamil Nadu, with notes on other thrips infesting banana. *Indian Journal of Entomology*, **81**(3): 434-438.

Sundaram, S., Selvarajan, R., Savithri, H.S. and Sangita. V. 2020. Towards understanding the structure of the capsid of Banana Bunchy Top Virus. *bioRxiv,*https://doi.org/10.1101/2020.02.12.945212.

Suresh Kumar, P. Durgadevi, S. Saravanan A. and Uma. S. 2019. Antioxidant potential and Antitumour activities of Nendran Banana peel against cancer cell line. *Indian Journal of pharmaceutical Sciences,* **81**(3): 464-473.

Tamilnayagan, T., Srinivasan, M.R., Saravanan, P.A., Muthuswami, M. and Selvarajan, R. 2019. Survey and documentation of sacbrood virus attacking Indian honeybee, *Apis cerana indica*, Fabricius in Tamil Nadu. *Annals of Plant Protection Sciences*, **27**(2): 226-231.

Tamilnayagan, T., Srinivasan, M.R., Selvarajan, R., Subramanian, S., Saravanan, P.A., Muthuswami, M., Sivakumar, U. and Kumaranag, K. M. 2020. Designing of RT-lamp primers and detection of sac brood virus from Indian honey bee *Apis cerana indica* (F.). *Indian Journal of Entomology,* **82**(1): 162-166.

9.2 Popular articles

Jeyabaskaran, K.J., Pitchaimuthu, R. and Uma, S. 2019. Fertiliser management in banana -*Vazhaiyil Ura Melanmai* (Tamil) Part - I. Published in *Vivasaya Malar –Dinamalar* (Tamil) Newspaper on 13 October, 2019.

Jeyabaskaran, K.J., Pitchaimuthu, R. and Uma, S. 2019. Fertiliser management in banana -*Vazhaiyil Ura Melanmai* (Tamil) Part - II. Published in *Vivasaya Malar –Dinamalar* (Tamil) Newspaper on 20 October, 2019.

Jeyabaskaran, K.J., Uma, S. and Pitchaimuthu, R. 2019. How to manage abiotic stress in banana? - *Vazhaiyil kaalanilai pirachinaigalai samlippathu eppadi?* (Tamil) Part - I. Published in *Vivasaya Malar –Dinamalar* (Tamil) Newspaper on 22 December, 2019.

Shiva, K.N., Suresh Kumar, P., Kamaraju, K., Jeyabaskaran, K.J. and Uma, S. 2019. Wealth Generation from Banana Waste - *Vazham Serkkum Vazhai Kazhivugal* (Tamil). *Malarum Velanmai*, **18**(6): 23-25.

Gavas, R., Bisane, K.D., Padmanaban, B. and Pushpalatha, P.B. 2019. *Vazhai pazathil thrumbu kandal* (Malayalam), *Karshakan* (Monthly Malayalam magazine published by Rashtriya Deepika), October 2019, 27-29.

Selvarajan, R. 2019. Protein-based diagnosis and its applications in plant virus diagnosis. In: Baranwal *et al* (Eds.) Genome assisted diagnosis of plant viruses, viroid's and phytoplasmas - A Training manual. ICAR-IARI, New Delhi. Pages.124. ISBN: TB-ICN;226/2019.PP.23-44.

9.3 Books / Book chapters

Ramajayam, D., Shiva, K.N. and Suresh Kumar, P. 2019. Handling, processing, value addition and waste utilization of Banana and Oil Palm. In: Manual of training programme on 'Waste management in fruit processing Industries'. (Eds. T.R. Ahlawat, Dev Raj, Chirag. S. Desai, Jilen M. Mayani, A.D. Chaudhary). CAAST&SA, NAU, Gujarat. Pp. 23-42.

Uma, S., Saraswathi, M.S. and Durai, P. 2019. Banana Genetic Resources. *Conservation and Utilization of Horticultural Genetic Resources*, 321-361.

9.4 Scientific reviews / Technical bulletins / Extension folders / Technical folders / Factsheets / Reports etc.

Shiva, K.N., Kumar, V., Thangavelu, R., Padmanaban, B., Suresh Kumar, P., Kamaraju, K. and Uma, S. 2019. Modern technologies for export of banana (Tamil). Extension Folder No. 27. ICAR–National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Thangavelu, R., Loganathan, M., Arthee, R., Prabakaran, M. and Uma, S. 2020. Fusarium wilt: A threat to banana cultivation and its management. *CAB Reviews 2020*, **15**(4). doi: 10.1079/PAVSNNR202015004.

Uma, S., Kumar, V., Suresh Kumar, P., Thangavelu, R. and Shiva, K.N. 2019. Commercial cultivation and value addition of banana for doubling the farmers' income (Tamil). Technical Folder No. 13. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

9.5 Training manuals

Shiva, K.N., Suresh Kumar, P. and Kamaraju, K. 2019. Technical know-how of banana flour. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P. and Kamaraju, K. 2019. Technical know-how of banana chips / crisps. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P. and Kamaraju, K. 2019. Technical know-how of banana central core (stem) juice (RTS beverage). ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P. and Kamaraju, K. 2019. Technical know-how of 'Post-harvest handling, packing and storage of banana flower. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P. and Kamaraju, K. 2019. Technical know-how of 'Banana fig'. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P. and Kamaraju, K. 2019. Technical know-how of 'Banana flour from unripe (green) banana / plantain and fig from ripe banana'. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P., Kamaraju, K. and Uma, S. 2019. Extraction of banana fiber and production of handicrafts. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

Shiva, K.N., Suresh Kumar, P., Kamaraju, K., Kumar, V. and Uma, S. 2019. Value addition and marketing of banana. ICAR – National Research Centre for Banana, Tiruchirappalli, Tamil Nadu, India.

9.6 Research papers / Abstracts / Presentations in Conferences / Symposia / Seminars / Workshops etc.

9.6.1 International

Anuradha, C., Bharat, R., Backiyarani, S. and Uma, S. 2020. Identification of Candidate Gene(s) for Resistance to *Fusarium oxysporum* f. sp. *cubense* in Bananas. In: 5th International conference on plant genetics and genomics – 'Germplasm to genome engineering', organized by SELECTBIO held at New Delhi, India during17-18 October, 2019.

Giribabu, P., Backiyarani, S., Durai, P. and Uma, S. 2019. Evaluation of promising banana diploid hybrids for resistance to root-knot nematode, *Meloidogyne incognita*. In: 'International conference on plant protection in horticulture (ICPPH-2019) - Advances and challenges', jointly organized by AAPMHE, ICAR-IIHR, Bangalore and NIPHM, Hyderabad held at ICAR-IIHR, Bangalore during 24 - 27 July, 2019.

Mayil Vaganan, M., Palanichamy, S., Amala Claret, E., Ravi, I. and Uma, S. 2019. Processing and microencapsulation of anthocyanins from banana flower bracts for food colorant and nutraceutical. In: International conference on advances in food and industrial biotechnology, held at Mar Athanasios College for Advanced Studies, Thiruvalla, Kerala during 24-26 November, 2019.

Mayil Vaganan, M., Sivagandhi, C., Ganesan, S., Kumaravel, M., Ravi, I., Jeyabaskaran, K. J., Backiyarani, S. and Uma, S. 2019. Iron biofortification in bananas by expression of *Oryza sativa* nicotianamine synthase genes. In: International conference on 'Next generation plant production and bioresources utilisation technologies' held at IIT, Guwahati, Assam during 11-13 February, 2019.

Padmanaban, B., Ashif, K.K., Baskar, N., Selvarajan, R., and Uma, S. 2019.Volatile secondary metabolite release in banana plants due to aphid, *Pentalonia nigronervosa Coq. cv. typica* infestation. In: XIX International plant protection congress (IPPC 2019), held at Hyderabad during 10-14 November, 2019.

Saravanan A., Divya, P., Ribu Dilshad, P.P., Suresh Kumar, P., Shiva, K.N. and Uma, S. 2019. Synthesis and characterization of biodegradable bioplastic from banana peel. In: International conference on 'Innovative and emerging trends in botany- 2019 (ICIETB-2019)', held at AlagappaUniveristy, Karaikudi during 6-7 November, 2019.

Selvarajan, R. 2019. Molecular diagnostics, virus-free certification and management options for banana viral diseases. In: International conference on plant protection in horticulture – Advances and challenges' (ICPPH-2019), held at ICAR-IIHR, Bengaluru during 24-27 July, 2019.

Selvarajan, R. 2019. On-site detection of plant viruses to ensure quality planting materials in vegetatively propagated horticultural crops. In: XIX International plant protection congress (IPPC 2019), held at Hyderabad during 10-14 November, 2019.

Sharmiladevi, S., Backiyarani, S., Sasikala, R., Anuradha, C. and Uma, S. 2019. Discovery of genes responsible for seedlessness in banana. In: 5th International conference on 'Plant genetics & genomics', held at New Delhi during 17-18 October, 2019.

Subesh Kumar, P., Backiyarani, S., Saravanakumar, A., Thangavelu, R., Chandrasekar, A., Anuradha, C., Saraswathi, M.S. and Uma, S. 2019. Development of Cavendish banana resistant to *Eumusae* leaf spot (*Pseudocercospora eumusae*) using CRISPR/ Cas9 technology. In: International conference on 'Plant genetics & genomics', held at New Delhi during 17-18 October, 2019.

Suresh Kumar, P., Dharani, R. and Uma, S. 2019. Adsorptive removal of lead (PB (II)) using banana pseudostem fibre: Isotherms & kinetic study. In: International conference on 'Innovative horticulture and value chain management – Shaping future horticulture', organized by ASM Foundation, held at New Delhi during 28-31 May, 2019.

Uma, S., Suresh Kumar, P. and Shiva, K.N. 2019. Export of bananas from India: Problems and prospects. In: International conference on 'Innovative horticulture and value chain management – Shaping future horticulture', organized by ASM Foundation, held at New Delhi during 28-31 May, 2019.

9.6.2 National

Backiyarani, S., Thangavelu, R., Saraswathi, M. S., Durai, P., Selvaraj, V. and Uma, S. 2019. Success of banana polyploidy breeding in India. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.

Divya, P., Suresh Kumar, P., Saravanan, A., Shiva, K.N., Kamaraju, K. and Uma, S. 2019. Extraction and structural characterization of cellulose from banana sheath fibers. In: 7th Bioprocessing India conference, held at CSIR-CFTRI, Mysuru during 14-16 December, 2019.

Jeyabaskaran, K. J. 2019. Developing yield estimates for banana. In: Workshop cum discussion for finalising the work plan of Phase-II of the CHAMAN project held at IARI, New Delhi on 24 January, 2019.

Mayil Vaganan, M., Amala Claret, E., Palanichamy, S., Padmanaban, B., Ravi, I. and Uma, S. 2019. Red Banana (*Musa* sp., AAA) peel as a functional food. In: National symposium on 'Nutraceuticals and functional foods' held at IIFPT, Thanjavur on 30 January, 2019.

Mayil Vaganan, M., Ravi, I. and Nandakumar, A. 2019. Enzymatic, catabolomic and proteomic analyses to understand the biochemical mechanism of 'green ripening' of Cavendish bananas. In: National conference on 'Integrative plant biochemistry and biotechnology', held at ICAR-IIRR, Hyderabad during 8-9 November, 2019.

Mayil Vaganan, M., Sowmiya, R., Palanichamy, S., Backiyarani, S., Suresh Kumar, P., Ravi, I. and Uma, S. 2019. Characterisation of banana flower bracts anthocyanins for utilising as a potential health promoting functional food ingredient. *Ibid*.

Ravichamy, P. 2019. Role of print media as communication channel on transfer of technology for banana farmers in Tamil Nadu. In: 'National conference on 'Farmers orientation towards climate change and upgrading to sustainable agriculture - FOCUS-2019)' held at National College, Tiruchirapalli during 23-24 February, 2019.

Ravichamy, P. and Shiva balan, K. C. 2019. Socio-eco nomic status and impact of mass media exposure on banana farmers: A case study. *Ibid*.

Saravanan, A., Amelia Karan, D., Suresh Kumar, P., Shiva, K. N. and Uma, S. 2019. Resistant

starch in green banana as a prebiotic source for pasta. In: National symposium on 'Nutraceuticals and functional foods' held at IIFPT, Thanjavur on 30 January, 2019.

Selvarajan, R. 2018. Field-usable lateral flow immunoassay kit for the rapid detection of cucumber mosaic virus (CMV) Infecting banana and plantains. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.

Suresh Kumar, P. 2019. Functional characterization of flour and starch of different banana varieties. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.

Uma, S., Karthic, R., Kumaravel, M., Backiyarani, S. and Saraswathi, M.S. 2019. High-throughput technology for mass production of quality planting material in banana *Ibid*.

Vignesh Kumar, B., Backiyarani, S., Mariadoss, A., Selvaraj, V., Durai, P., Saraswathi, M. S. and Uma, S. 2019. Characterization and development of dichotomous key using information system for banana hybrids *Ibid*.

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

Mobile apps

Uma, S., Selvarajan, R., Ramajayam, D., Padmanaban, B., Poorani, J., Thangavelu, R., Mayilvaganan, M., Ravi, I., Kumar, V., Jeyabaskaran, K.J., Shiva, K.N., Backiyarani, S., Saraswathi, M.S., Loganathan, M., Suresh Kumar, P., Giribabu, P. and Anuradha, C. 2019. Banana Info (English & Tamil). ICAR-NRCB, Tiruchirappalli, Tamil Nadu.

Uma, S., Selvarajan, R., Ramajayam, D., Shiva, K.N., Kumar, V., Jeyabaskaran, K.J. and Suresh Kumar. 2019. Banana export and value addition (English & Tamil). ICAR-NRCB, Tiruchirappalli, Tamil Nadu.

Uma, S., Selvarajan, R., Ramajayam, D., Padmanaban, B., Poorani, J., Thangavelu, R., Loganathan, M. and Giribabu, P. 2019. Banana pest and disease management (English & Tamil). ICAR-NRCB, Tiruchirappalli, Tamil Nadu.

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Release of ICAR- NRCB 4th QRT Report at DG Office, ICAR, New Delhi

10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

Consultancy Services / Contract Research / Commercialization of Technologies

S. No.	Date	Name of the Technology	Address of the Client	Revenue (Rs. in Lakhs)
I	**Consultancy Services / Contract Research**			
1	November, 2019	Sea shipment protocol for Nendran banana to European Union.	VFPCK, Kerala	9.15
2		Supply of polyclonal antiserum		1.91
II	**Commercialisation of Technologies**			
1	14 June, 2019	Banana flour	Ms. Nazneen, M/s Aasraf Concept Foods	0.20
2	20 September, 2019		Mr. Naveen Prasad, M/s. PSN Athulya Group	
3	27 June, 2019	Banana chips	Mr. N. Ramaraj	0.30
4	27 June, 2019		Mr. C. Seralathan	
5	September, 2019		Mr. J. B. Rajesh	
6	20 September, 2019	Banana fig	M/s. Kamathens Enterprises, Kerala	0.4
7	20 September, 2019		M/s. Swara Natural foods, Gujarat	
8	20 September, 2019		M/s. PSN Athulya Group, Tamil Nadu	
9	20 November, 2019		Mr. Siju G, Kerala	
10	20 September, 2019	RTS beverage (CCSB)	M.G. Krishnaveni, Telangana	0.5
11			M/s. Swara Natural foods, Gujarat	
12	5 November, 2019	Post-harvest management of banana flower	Mr. Lourdu Prabu, Lalgudi, Tamil Nadu	
III	**Other Services**			
1.	Enumeration of microbial population		ICAR-CTRI (RS), Vedasanthur, Tamil Nadu	0.19

Signing of MoUs / MoCs / MoAs

MoU was signed by ICAR-NRCB with Vegetable and Fruit Promotion Council Keralam (VFPCK), Kerala on 27 November, 2019 for export of banana cv. Nendran to Europe via Sea.

Trademarks registered

Trademarks	ICAR-NRCB	3495923	Nil	March 2017	Published
Trademarks	ICAR-NRCB	3495925	Nil	March 2017	Registered (26/12/2019)

1823 plants of Udhayam and 9156 suckers of other varieties have been supplied to banana growers of various districts of Tamil Nadu.

During the reporting period, 13 batches of tissue cultured Grand Naine, Nendran, Swarnamukhi, Poovan, Monthan etc. have been tested for their genetic fidelity using SSR and ISSR markers and test reports issued.

Signing of MoA between ICAR-NRCB and VFPCK, Kerala

11. RAC/ IRC / IMC/QRT MEETS

QRT meet

First sitting of the Quinquennieal review meet of ICAR – NRCB was held at the institute during 25 – 26 February, 2019 under the chairmanship of Dr. K. V. Peter, Former Vice - Chancellor, KAU and attended by the members *viz.*, Dr. B. P. Singh, Dr. K. Anjaneyalu, Dr. P. K. Ray, Dr. Abraham Varghese and the scientists of ICAR-NRCB. Dr. S. Uma, Director, ICAR-NRCB, welcomed the QRT members and presented the salient research achievements of the centre for 2018-19. Dr. B. Padmanaban, Member secretary, QRT presented the action report of the last QRT meet. Scientists made presentations of their research findings for the reporting period. The review team visited all the laboratories and the farm and had discussions with the scientists on the research program.

QRT members with Scientists, ICAR-NRCB

RAC meet

The 20th Research Advisory Committee (RAC) meet of ICAR-NRCB was held during 10-11 April, 2019 with the newly formed committee under the chairmanship of Dr. V. A. Parthasarathy, Retd. Director, ICAR-IISR, Calicut with the members *viz.*, Dr. W. S. Dhillon, ADG (Hort. Science), ICAR, New Delhi; 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; Dr. S. C. Dubey, Head Quarantine, ICAR-NBPGR, New Delhi and non-official members *viz.*, Mr. M. N. Vaidyanathan and Mr. K. Rajendran. The team visited the research farm and laboratories of the institute. Dr. S. Uma, Director, ICAR-NRCB had presented the salient achievements of the centre during 2018-19. Research work carried out during 2018-19 in Crop Improvement, Crop Production and Post Harvest Technology, and Crop Protection sections were presented by the Heads of the respective sections. The recommendations made by the team were prepared and submitted to SMD for approval.

20th RAC meet at ICAR-NRCB

QRT cum IMC meet

The Quinquennial Review Team (QRT) of the ICAR-NRCB held an interaction meet with the XXV Institute Management Committee (IMC) of ICAR-NRCB on 2 July, 2019 under the chairmanship of Dr. K. V. Peter, Chairman, QRT and the members *viz.*, Dr. P. K. Ray; Dr. K. Anjaneyalu; Dr. B. P. Singh and Dr. Abraham Verghese. The IMC members present in the meeting include Dr. N. Pugalendi, Dean, HC&RI, TNAU, Coimbatore; Dr. A. T. Sadashiva, Principal Scientist & Head, ICAR-IIHR, Bengaluru; Dr. S. K. Singh, Head, Division of Horticulture & Technology, ICAR-IARI, New Delhi; Dr. A. Selvi, Principal Scientist & Head, Division of Biotechnology, ICAR-SBI, Coimbatore and Mr. Babu, Finance and Accounts Officer, ICAR-CIBA, Chennai and the farmer representatives Mr. M. N. Vaithiyanathan and Mr. S. P. Rajendran. Dr. S. Uma, Director, ICAR-NRCB welcomed the gathering and briefed about the

meet. Mr. Murugan, AAO, ICAR-NRCB, presented the information pertaining to IMC and later, Dr. B. Padmanaban, Member Secretary, QRT Presented the consolidated recommendations of the QRT. The agenda items were discussed in detail and accepted by the members. Dr. I. Ravi, Principal Scientist & AO in-charge, ICAR-NRCB proposed a vote of thanks.

Interaction meet of QRT with banana stakeholders

The QRT had an interaction meet with banana stakeholders at ICAR-NRCB on 1 July, 2019. The meeting was attended by the Chairman and members of QRT and stakeholders *viz*., Mr. Tirukkattupalli S. Sundaram, Thanjavur; Mr. G. Ajeethan, General Secretary, TNBPCL; Mr. A. Subramanian, Director, TNBPCL & Madhur Bananas, Thottiyam; Mr. A. Sivakumar, M/s. K. P. Enterprises, Tiruchirappalli; Mr. Karthick Kumar, M/s. KRL Foods, Namakkal; Er. Raja Manikantan, Assistant Professor, KNCET, Thottiyam; Mr. Shekar Nagarajan, President, Tamil Nadu Hill Banana Growers' Association and Dr. Ravindra Naik, Head, ICAR-CIAE (RS),Coimbatore. Dr. K. V. Peter, Chairman, QRT appreciated all the stakeholders and ICAR-NRCB for the greater handholding and wished all for a greater achievements in the future. All the entrepreneurs overwhelmingly expressed their happiness over the service of ICAR-NRCB in different walks of banana cultivation and utilization.

IRC meet

The 23rd - Institute Research Council (IRC) meet of ICAR-NRCB was held during 17-20 December 2019. Scientists presented their salient research findings during 2018-19 and fruitful discussions were held and recommendations were given for further improvement.

Interaction meet of QRT with banana stakeholders at ICAR-NRCB

23rd - Institute Research Council (IRC) meet of ICAR-NRCB

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	Venue	Date
R. Neela Mega Shyamala Kannan	Capacity building programme for CJSC members	ICAR-NAARM, Hyderabad	27-31 January, 2019
K. J. Jeyabaskaran	Management Development Programme for HRD Nodal Officers of ICAR for Effective Implementation of Training Functions.	ICAR-NAARM, Hyderabad	14-16 March, 2019
D. Ramajayam M. Badrinath	Training course on 'Radiation safety aspects of gamma irradiation chamber – (Category-I Irradiators)-GIC-06'	CT & CRS, BARC, Anushaktinagar, Mumbai	April 22-30, 2019
M. Loganathan	Training cum Awareness Workshop on J Gate @CeRA	UAS, GKVK, Bengaluru	14, September, 2019
R. Selvarajan	NABL Assessor training programme	ICAR-CIBA, Chennai	16-20 September, 2019
S. Uma M. Mayilvaganan S. Backiyarani	Eighth Biosafety Awareness Training Workshop for ICAR Scientists	BCIL, New Delhi / ICAR-NIPB, New Delhi	20 September, 2019
M. S. Saraswathi	Intellectual Property Valuation and Technology Management	ICAR-NAARM, Hyderabad	15-19, October, 2019
P. Suresh Kumar	Training program on 'Agricultural Extension: From ToT to Agripreneruship and Startups'	MANAGE, Hyderabad	21-25 October, 2019
I. Ravi	Workshop on 'Gene Editing for Enhancing Plant Productivity and Stress Tolerance'	ICAR- IIRR, Hyderabad	10-12, November 2019
V. Kumar K. J. Jeyabaskaran	ASCI Training of Trainers (ToT) of KVKs /SAUs /ICAR Institutes	ICAR-ATARI, Hyderabad	27-29 November, 2019
D. Ramajayam	Workshop of Nodal Officers of ICAR Research Data Repository for Knowledge Management	ICAR-IASRI, New Delhi	10-11, December, 2019

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

Name of the Staff	Event	Venue	Date
All staff of ICAR-NRCB	One day workshop on Arabi to Banana: Potential & Fruitful Research Projects	ICAR - NRCB Tiruchirappalli	13 March, 2019
	One day workshop on 'ICAR- KRISHI Portal – A Central Research Data Repository'		25 March, 2019
S. Uma B. Padmanaban R. Thangavelu V. Kumar K.J. Jeyabaskaran S. Backiyarani K. N. Shiva P. Suresh Kumar	6th Group Discussion of ICAR-AICRP (Fruits)	AAU, Jorhat, India	14 – 16 February, 2019
S. Uma R. Thangavelu S. Backiyarani M. S. Saraswathi P. Durai	State variety release committee meet	Secretariat, Chennai	7 January, 2019
S. Uma R. Thangavelu	11th BAPNET steering committee meeting, organized by Bioversity International, Banana Asia-Pacific Network (BAPNET) and Guangdong Academy of Agricultural Sciences	Gunagzhou, Guangdong, China	7-9 May, 2019
S. Uma R. Selvarajan S. Backiyarani M. S. Saraswathi P. Suresh Kumar	8th Indian Horticulture congress- 2019. Shaping future of Indian Horticulture.	Indira Gandhi Krishi Vishwa Vidyalaya, Raipur, Chattisgarh	17 - 21 January, 2019
S. Uma V. Kumar P. Suresh Kumar	Launching the development of sea protocol for Nendran to Europe	Secretariat, Govt. of Kerala	27 November, 2019
S. Uma P. Ravichamy	National conference on 'Farmers orientation towards climate change & upgrading to sustainable agriculture (FOCUS-2019)'	Life Science Society, National College, Tiruchirapalli	23 - 24 February, 2019

S. Uma	CGIAR Review Meeting	ICAR, New Delhi	24 – 25 January, 2019
	ICAR Institute Directors' Conference	New Delhi	31 January to 1 February, 2019
	Annual review meet for DBT-NER projects	DBT, New Delhi	7 February, 2019
	TR-4 Fusarium wilt meet	ICAR, New Delhi	19 February, 2019
	Annual meeting of the IITA / Bioversity International funded project	Uganda	27-31 May, 2019
	DBT – NER Project review meet	Guwahati	16-17 June, 2019
	Foreign aided project review meet	SMD-ICAR, New Delhi	18 June, 2019
	QUT-BIRAC project annual review meet	New Delhi	19 June, 2019
	Virtual meet with Secretary, Dept. of Agriculture, Govt. of Kerala on export of banana	ICAR-NRCB, Tiruchirappalli	24 June, 2019
	Review meet	Hort. Science Division, ICAR, New Delhi	17 July, 2019
	National seminar on 'Advances in bulk grain storage and smart sensor and IoT applications in warehouses	IIFPT. Thanjavur	26 July, 2019
	Central variety release committee meet	New Delhi	2 September, 2019
	RAC meet	IIFPT, Thanjavur	4 September, 2019
	ICAR regional committee meet	Bengaluru	6-7 September, 2019
	National conference on 'Climate smart agriculture'	ADAC&RI (TNAU), Tiruchirappalli	13 September, 2019
	Workshop on 'Water management awareness'	KVK, Sirugamani	14 September, 2019
	Signing of MoA with IIFPT	Thanjavur	17 September, 2019
	Biosafety workshop	BCIL, New Delhi	20 September, 2019
	Signing og MoA with VCPKF	Trivandrum	27 November, 2019
B. Padmanaban R. Thangavelu V. Kumar K. N. Shiva	Workshop cum training on banana organized by ATMA, Solapur	Solapur, Maharashtra	7 - 8 February, 2019

B. Padmanaban R. Selvarajan P. Giribabu	International conference on 'Plant protection in Horticulture: Advances and Challenges (ICPPH-2019)', jointly organized by AAPMHE, ICAR-IIHR, Bangalore and NIPHM, Hyderabad	ICAR-IIHR, Bangalore	24 - 27 July, 2019
R. Thangavelu R. Selvarajan	National symposium on "Recent challenges and opportunities in sustainable plant health management"	Banaras Hindu University, Varanasi	26-28 February, 2019
R. Thangavelu	"Foc TR4 strategy meeting" organized by Altus Viljoen, Plant expert at the Department of Plant Pathology, University of Stellenbosch in collaboration with the Gates Foundation	Maputo, Mozambique	18-19 November, 2019
	International banana conference on controlling banana diseases in the African banana industry"		21-22 November, 2019
	National conference on "Challenges and innovative approaches in agriculture and allied sciences research" organized by the 'Society for biotic and environmental research', Tripura	Sona college of arts and science, Salem, Tamil Nadu	27 July, 2019
	International conference on 'Innovative and emerging trends in botany (ICIETB'2019) Organized by Department of Botany, Alagappa University, Karaikudi, Tamil Nadu	Alagappa University, Karaikudi, Tamil Nadu	6-7 November, 2019
R. Selvarajan	Brainstorming meeting organized by DBT on Pathogenomics of plant viruses	New Delhi	25 April, 2019
	DBT-NER project review meeting	New Delhi	18 October, 2019

M. Mayilvaganan	International conference on 'Next generation plant production and bioresources utilisation technologies'	IIT, Guwahati	11 - 13 February, 2019
	Board meeting of Department of Biochemistry, Holy Cross College, Tiruchirappalli, Tamil Nadu.	Department of Biochemistry, Holy Cross College, Tiruchirappalli, Tamil Nadu.	5 April, 2019
	Mid-Term Review meeting of project 'Biofortification and development of disease resistance in banana'	BIRAC Office, CGO Complex, Lodhi Road, New Delhi	19 June, 2019
	National Conference on Integrative Plant Biochemistry and Biotechnology organised by Society for Plant Biochemistry and Biotechnology, New Delhi	ICAR-IIRR, Hyderabad	8 - 9 November, 2019
	Annual Review meeting of project 'Biofortification and development of disease resistance in banana'	BIRAC Office, CGO Complex, Lodhi Road, New Delhi	15 November, 2019
	International Conference on Advances in Food and Industrial Biotechnology	Mar Athanasios College for Advanced Studies, Tiruvalla, Kerala, India.	24-26 November, 2019
V. Kumar K. J. Jeyabaskaran K. N. Shiva	Seminar cum workshop on 'Improved banana cultivation and value chain management'	Kalaiyarangam, Tiruchirappalli, Tamil Nadu	15 November, 2019
V. Kumar K. N. Shiva	National level 'Stakeholders consultation meeting on mango/ banana / pomegranate cluster development', organized by NHB, Gurugram	NAAS Complex, New Delhi	23-24 April, 2019

V. Kumar K. N. Shiva P. Suresh Kumar	Interactive meeting for exploiting the Use of irradiation in Banana	INNOVA pack house, Malur, Karnataka	4 April, 2019
	Farmers-Scientists' interactive meeting on 'Hi-tech cultivation and post-harvest technology of 'Grand Naine' banana for export', organized by Tamil Nadu State Agriculturist Association with ICAR-NRCB, Tiruchirappalli	Hosur, Tamil Nadu	5 April, 2019
V. Kumar P. Durai P. Ravichamy	National Horticultural Fair - 2019 organised by Society for promotion of Horticulture	ICAR-IIHR, Bengaluru	23 - 25 January, 2019
V. Kumar	Survey and selection of farmers for 'Development of farmers' clusters	Goalpara District, Assam	2-5 May, 2019
	Field survey and investigation of the problems in the TC Grand Naine fields	Cumbum, Gudalur, Theni, Tamil Nadu	8 July, 2019
	'Banana interface meeting cum workshop', organized by Dept. of Horti., Govt. of Andhra Pradesh	Guntur, Andhra Pradesh	11 September, 2019
	Banana stakeholders meet	NHB, Gurugram	23 September, 2019
	Banana stakeholders meet for the 'Development of protocol and promotion of banana export", organized by APEDA	New Delhi	30 September, 2019
	"Workshop cum buyer seller meet for cluster development programme for banana", organized by APEDA	Pulivendula, YSR Dist., Andhra Pradesh	30 October, 2019
	Survey on banana plantations	Jalgaon and Raver, Maharashtra	20-23 December, 2019
K. J. Jeyabaskaran	CHAMAN Phase-II workshop cum review meeting	Centre for Environment Science and Climate Resilient Agriculture, ICAR-IARI, New Delhi	29 July, 2019
	Seminar on Jal Shakti Abhyaan	ICAR-KVK, Tiruchirappalli, Tamil Nadu	14 September, 2019
	Fertiliser Application Awareness Workshop in Agriculture	ICAR-KVK, Karur, Tamil Nadu	22 October, 2019

K. N. Shiva	Reconnaissance survey to identify potential banana growers for EDP in Horticulture under NHB Scheme	Goalpara Dt., Guwahati, Assam	2-5 May, 2019
	Meeting with TNBPCL on 'Export of Red banana, inspection of APEDA approved modern pack house facilities being developed and developing maturity standards for traditional varieties of banana for export market'	ICAR-NRCB, Tiruchirappalli	15 October, 2019
S. Backiyarani	BIRAC review meet	ICAR-NRCB, Tiruchirappalli	20 - 21 January, 2019
	Annual review meeting of IITA project - 'Improvement of banana to small holder farmers in the Great Lakes Region of Africa'	Mbrara, Uganda	26-30 May, 2019
	27th meeting of 'Central sub-committee on crop standards, notification and release of varieties for horticulture crops'	Krishi Bhawan, New Delhi	2 September, 2019
	BIRAC review meeting	BIRAC, New Delhi	15 November, 2019
	12th NPFGGM review meeting	NIPB, New Delhi	13-14 November, 2019
M. S. Saraswathi	Interactive meeting with the tissue culture companies	ICAR-NRCB, Tiruchirappalli	27 April, 2019
	First review meeting of NER-banana program (Group – 6)	Guwahati University, Assam	4 June, 2019
	First review meeting of NER-banana program (Group – 1)		16-17 June, 2019
D. Ramajayam	11th Scientific Advisory Committee meet	ICAR-KVK, Krishnagiri	13 March, 2019
	10th Scientific Advisory Committee meet	ICAR-KVK, Vamban	14 March, 2019
	Scientific Advisory Committee meet	ICAR-KVK, Thirunelveli	28 March, 2019
	4th National workshop of officer in-charge, Data Management for KRISHI portal	NASC complex, New Delhi	10-11 December, 2019
	Stakeholder consultation-cum-planning workshop organized by South Asia Office of the International Food Policy Research Institute (IFPRI-SAO).	NASC Complex, New Delhi	12 June, 2019

P. Suresh Kumar	National workshop on Horti-produce transport in India - Present status and issues for a reduction in postharvest losses	NASC complex, New Delhi	8 January, 2019
	Setting up Incubation facility on Banana: Opportunities. Govt. of Andhra Pradesh		12 February, 2019
	International conference on 'Innovative horticulture and value chain management – Shaping future horticulture'	GBPUA & T, Pantnagar, Uttarkhand	28-31 May, 2019
	Horti-millet workshop	ICAR-IIMR, Hyderabad	13 September, 2019
	Presentation and review meeting for the progress report of DBT-NER projects	DBT, New Delhi	18 October, 2019
C. Anuradha	DBT-Review meet on development of network project on field demonstration of TC raised Sabri banana in Tripura	ICAR-NRCB, Tiruchirappalli,	27 April, 2019

Workshop on Arabi to Banana

A workshop on "Arabi to Banana: Potential & Fruitful Research Project" was held at ICAR-NRCB on 13 March, 2019. Students from various colleges located in and around Tiruchirappalli participated in the workshop. Dr Albert Premkumar, visiting guest scientist from Istanbul University, Turkey, gave special lecture and practical demonstrations to students. Drs. S. Backiyarani, I. Ravi and M. Mayil Vaganan, Principal Scientists of the centre gave technical lectures to students.

Dr Albert Premkumar, visiting scientist along with scientists of ICAR-NRCB and winners of quiz competition held during workshop on 'Arabi to banana'

Workshop on 'ICAR-KRISHI Portal'

A workshop on 'ICAR-KRISHI Portal – A central research data repository' was held at ICAR-NRCB on 25 March, 2019. Dr. K. Alagusundaram, DDG (Agril. Engg.), ICAR, New Delhi was the Chief Guest of the Workshop. Nodal Officers of KRISHI Portal of various ICAR Institutes were participated in the deliberations.

Dr. K. Alagusundaram, DDG (Agril. Engg), ICAR addressing scientists during workshop on 'ICAR-Krishi portal'

Training on banana fiber extraction and utilization for North Eastern entrepreneurs

ICAR-NRCB organized a five day training program (8-11 July, 2019) on banana fibre extraction and utilization to the entrepreneurs from Manipur. The training was organized with the three-pronged strategies of the present government – 'Skill development for the least developed states; Wealth generation from waste and doubling the farmers' income'. Mr. Adithya Senthil Kumar, I.A.S., Sub-Collector, Srirangam appreciated the institute for supporting the youth on developing business acumen. Dr. S. Uma, Director, ICAR-NRCB congratulated the trainees for their successful completion of training. Dr. K. N. Shiva and Dr. P. Suresh Kumar, Course-coordinators briefed the entrepreneurs on the technology of extraction, preservation and utilizing banana fibre for making handicrafts, bio-plates and sanitary napkin. The trainees were also exposed to more than 30 different value added products produced from flour, ripe banana and wastes like central stem, flower and pickle. The training was supported by the ICAR- Manipur centre.

ICAR-NRCB Foundation Day cum Kisan Mela

ICAR-NRCB celebrated its 26th foundation day as farmers' day on 21 August, 2019with the theme "Recent interventions for doubling the banana farmers' income". Dr. S. Uma, Director, ICAR-NRCB, motivated farmers to double the income using technologies developed by the centre and informed about the release of ICAR-NRCB selections *viz.,* Kaveri Kalki (a high yielding cyclone tolerant selection), Kaveri Sugantham (a selection with unique aroma) and Kaveri Saba (a drought tolerant selection). Guest of honour, Mr. T.V. Manjunatha, Additional Principal Chief Conservator of Forests, Chennai in his address pointed out the ways and means to increase the banana farmers' income. He also emphasized the need for conserving the soil health and improving the water use efficiency and urged the farmer's society to conserve water by planting more trees. He also called for market study to get better price, creation of cold chains at taluk level, value addition, growing multiple varieties of banana to avoid slash, soil health test to ensure balanced application of nutrients, water budgeting and finally the need for living in tune with nature. Chief guest of the function, Mr. S. Sivarasu, I.A.S, Collector, Tiruchirapalli, in his address, praised the contributions made by ICAR-NRCB for the benefit of banana farmers and he emphasized the need for value addition and export. He stressed the need for judicious use of chemical fertilizers to conserve the soil health and he also intimated that efforts are being taken to open five pack houses for

banana in the Trichy District. He also distributed Best Farmer Award, Best Entrepreneur Award and Technology Disseminator award. Mr. G. Ajeethan, General Secreatory, TNBGF, Thottiyam, Tamil Nadu spoke about "Supply chain management in banana" and he stressed the importance of pack houses in each banana growing area. Mr. Santhana Krishnan, JDA, Ms. Vimala, Ms. Esther Sheela, JD Animal Husbandry and Er. P. Paul, Asst. Executive Engineer, Dept of Agril. Engineering, Trichy explained the schemes and subsidies in agriculture, horticulture, farm machineries, solar power etc. About 900 participants including banana farmers, entrepreneurs, KVK scientists, state horticultural officers and exporters attended the function. An exhibition was also arranged showcasing various agriculture inputs and banana based products.

Awardees with Director, ICAR-NRCB and Chief Guest at ICAR-NRCB foundation day

Hands on training to Gaja cyclone affected banana farmers on low cost planting material production techniques

ICAR-NRCB organized a one day training programme on 'Macropropagation Technology' at the centre for the benefit of the Gaja Cyclone affected banana farmers of Thanjavur and Namakkal districts. The training program was jointly funded by ICICI foundation, Trichy Zone and SEED Division – DST, New Delhi. Macropropagation is a low cost farmers' friendly technology for the mass multiplication of banana planting material at the farm level There was an overwhelming response as more than 100 farmers participated and benefitted by this programme. Dr. S. Uma, Director, ICAR-NRCB in her inaugural address briefed about the significance of this low cost technology and its spread in various parts of the country.

Mr. Asif Iqbal, Project Manager (Trichy) and Mr. P. Satyanathan, Project Manager (Madurai), ICICI foundation attended the training and addressed the farmers. The training was organised by Drs. M. S. Saraswathi and S. Backiyarani, Principal Scientists, ICAR-NRCB. The technology was demonstrated by Dr. R. Karthic, Young Scientist (DST) and Technical officers of the centre.

Dr. S. Uma, Director, ICAR-NRCB addressing farmers at training on 'Macropropagation'

Sensitisation programme on Fusarium wilt

ICAR-NRCB in association with ICAR-CISH, Lucknow and CIH, Nagaland conducted an awareness programme to sensitize all the stakeholders on prevention of spread of Fusarium wilt, tropical race 4 (TR-4) in banana at Dimapur, Nagaland on 9 November, 2019. The programme was inaugurated by Y. Kikheto Sema, Commissioner and Secretary of Horticulture, Nagaland. Other dignitaries who attended the event include Dr. N. K. Krishnakumar, Country representative of Bioversity International, New Delhi; Dr. B. N. S. Murthy, Horticulture Commissioner, India; Dr. N. K. Patle, Deputy Commissioner of Horticulture, DAC & FW; Dr. Prakash Patil, Co-ordinator, ICAR-AICRP (Fruits) and Director, CIH, Nagaland. Dr. R. Thangavelu, Principal Scientist, ICAR-NRCB, Dr. T. Damodaran, Principal Scientist, ICAR-CSSRI, RRS, Lucknow, Dr. Aziz Seye, Scientist, ICAR Research complex for NEH, Jharmapani, Nagaland gave presentations on various aspects of Fusarium wilt TR-4 including management.

Participants at 'Sensitisation programme on Fusarium wilt' held at Dimapur, Nagaland

14. DISTINGUISHED VISITORS

Name	Date
Dr. K. V. Peter, Former Vice Chancellor, KAU, Kerala	25-26 February, 2019
Mr. N. Ravichandran, Commissioner, Tiruchirappalli City Corporation	7 March, 2019
Dr. V. Padmavathi, Principal, Seethalakshmi Ramasamy College, Tiruchirappalli	
Dr. Sujatha, Principal, Cauvey College for Women, Tiruchirappalli	
Dr Albert Premkumar, Visiting Guest Scientist, Istanbul University, Istanbul, Turkey	13 March, 2019
Dr. K. Alagusundaram, DDG (Agril. Eng.), ICAR, New Delhi	25 March, 2019
Dr. Prakash Patil, Project Co-ordinator, AICRP on Fruits	
Dr. S. K.Chaudhari, ADG (SWM), ICAR, New Delhi	
Mr. M. Girija Shankar, IAS., Secretary to Chief Minister of Andhra Pradesh & Secretary, APFPS	26 March, 2019
Shri. Y.S. Prasad, CEO-APFPS	
Dr. V. A. Parthasarathy, Retd. Director, ICAR-IISR, Calicut	10-11 April, 2019
Dr. W. S. Dhillon, ADG (Hort.Science), ICAR, New Delhi	
Dr. K.V. Bhat, Emeritus Scientist, ICAR- NBPGR, New Delhi	
Dr. Rema Menon, Retd. Prof. & Head, KAU, Thrissur	
Dr. N.K. Krishnakumar, Regional Coordinator – Bioversity International	3 June, 2019
Ms. Padma Raghunathan, CGM, TN Regional Office, NABARD, Chennai Mr. Rajaram, AGM-NABARD, Tiruchirappalli	20 June, 2019
Dr. K. V. Peter, Former Vice Chancellor, KAU, Thrissur	1 July, 2019
Dr. P. K. Ray, Retd. Professor, Bihar Agricultural University, Bihar	
Dr. Abraham Verghese, Director, GPS Institute of Agriculture Management, Bangalore	
Dr. N. Pugalendi, Dean, HC&RI, TNAU, Coimbatore,	
Dr. S. K. Singh, Head, Division of Horticulture & Technology, ICAR-IARI, New Delhi	
Mr. B. Karthikeyan, Director, Quest Certification (P) Ltd, Chennai	6 July, 2019
Mr. Sibi Adithya Senthil Kumar IAS, Sub Collector, Srirangam, Tiruchirappalli	11 July, 2019
Mr. K. Natarajan IBS, Station Director, All India Radio, Tiruchirappalli	
Dr. R.D.Iyer, Former Director, ICAR-CPCRI, Kasaragod	5 August, 2019
Dr. T.R. Ganapathi, BARC, Mumbai	8 August, 2019
Mr. V. Balakrishnan IPS, DIG, Tiruchirappalli Circle	27 September, 2019
Dr. Chandish R. Ballal, Former Director, ICAR-NBAIR, Bangalore	
Mr. Asif Ibal, Project Manager, ICICI Foundation	19 November, 2019
Dr.Michael Gomez Selvaraj, Scientist (Crop Physiology) - International Center for Tropical Agriculture (CIAT), Cali, Colombia	10 December, 2019
Dr. T.R. Sharma, Executive Director, NABI, New Delhi	29 December, 2019

15. EMPOWERMENT OF WOMEN

Training on banana fiber extraction and utilization to women entrepreneurs

ICAR-NRCB organized a training program (8-11 July, 2019) on banana fibre extraction and its utilization to three women entrepreneurs from Manipur. The women entrepreneurs learnt the technology of extraction, preservation and utilizing banana fibre for making handicrafts, bio-plates and sanitary napkin. The trainees were also exposed to more than 30 different value added products which are being produced from flour, ripe banana and wastes like central stem, flower and pickle. The training was supported by the ICAR-Manipur centre.

Women trainees from Manipur with Director, Course Co-ordinators, ICAR-NRCB and Mr. Adithya Senthil Kumar, IAS., Sub-Collector, Srirangam, Tamil Nadu

Visit of students from Cauvery College for Women, Tiruchirappalli to ICAR-NRCB on 30 July, 2019

16. PERSONNEL

16.1 Staff News

Name	Event	Date
Mr. R. Krishnamurthy, AAO	Superannuation	31 January, 2019
Dr. P. Giribabu, Senior Scientist	Promoted from Scientist (RGP 7000 – Level 11) Senior Scientist (RGP 8000 – Level 12)	w.e.f. 26 June, 2017
Dr. C. Anuradha, Senior Scientist	Promoted from Scientist (RGP 7000 – Level 11) Senior Scientist (RGP 8000 – Level 12)	w.e.f. 10 February, 2018
Mr. P. Murugan, AAO	Promoted from Assistant to Assistant Administrative Officer	w.e.f. 11 July, 2019
Mrs. S. Durgavathy, Assistant	Promoted from Upper Division Clerk to Assistant	w.e.f. 01 January, 2019
Dr. S. Palanichamy, Asst.Chi.Tech.Officer	Promoted from Senior Technical Officer to Assistant Chief Technical Officer	w.e.f. 15 March, 2015
Mrs. C. Sagayam Jacqueline, Senior Technical Officer	Promoted from Technical Officer to Senior Technical Officer	w.e.f. 01 January, 2018
Mr. D. Ramachandramurthi, Senior Technical Officer	Promoted from Technical Officer to Senior Technical Officer	w.e.f. 11 August, 2018

16.2 Staff position

Scientific Staff

Sl. No.	Name	Designation
1	Dr. S. Uma	Director
2	Dr. B. Padmanaban	Principal Scientist (Entomology)
3	Dr. J. Poorani	Principal Scientist (Entomology)
4	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
5	Dr. R. Selvarajan	Principal Scientist (Plant Pathology)
6	Dr. M. Mayil Vaganan	Principal Scientist (Plant Biochemistry)
7	Dr. I. Ravi	Principal Scientist (Crop Physiology)
8	Dr. V. Kumar	Principal Scientist (Horticulture)
9	Dr. K. J. Jeyabaskaran	Principal Scientist (Soil Science)
10	Dr. K. N. Shiva	Principal Scientist (Horticulture)
11	Dr. S. Backiyarani	Principal Scientist (Biotechnology)
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	Senior Scientist (Horticulture)

Sl. No.	Name	Designation
16	Dr. P. Giribabu	Senior Scientist (Nematology)
17	Dr. C. Anuradha	Senior Scientist (Biotechnology)

Technical Staff

Sl. No.	Name	Designation
1	Dr. P. Durai	Assistant Chief Technical Officer (Field)
2	Dr. S. Palanichamy	Assistant Chief Technical Officer (Field)
3	Dr. P. Ravichamy	Senior Technical Officer (Journalism)
4	Mrs. T. Anithasree	Senior Technical Officer (Field)
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	Senior Technical Assistant (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. P. Murugan	Assistant Administrative Officer
3	Mr. M. Krishnamoorthy	Private Secretary
4	Mr. R. Sridhar	Personal Assistant
5	Mrs. S. Durgavathy	Assistant
6	Mr. R. Neela Mega Shyamala Kannan	Steno Gr. III
7	Mrs. A. V. Suja	Upper Division Clerk
8	Mr. R. Mohanraj	Lower Division Clerk
9	Mr. V. Thangaraju	Skilled Supporting Staff
10	Mr. P. Kamaraj	Skilled Supporting Staff
11	Mr. V. Ganesan	Skilled Supporting Staff
12	Mr. V. Pandiyan	Skilled Supporting Staff
13	Mrs. K. Mariammal	Skilled Supporting Staff

17. OTHER INFORMATION

Inauguration of Pradhan Mantri Kisan Samman Nidhi

ICAR-NRCB Organized a live telecast of the launching of Govt. of India's "Pradhan Mantri Kisan Samman Nidhi" program on 24 February, 2019 and Which was attented witnessed by the around 200 farmers.

Visit of Secretary, Andhra Pradesh

In continuation with the MoU signed with ICAR-NRCB by the Govt. of Andhra Pradesh, Mr. M. Girija Shankar, IAS, Secretary to Hon'ble Chief Minister, Andhra Pradesh & Secretary, Food Processing and his team visited ICAR-NRCB on 26 March, 2019 to discuss about the sectors in banana supply chain including export and value addition for mutual collaboration. Dr. S. Uma, Director, ICAR-NRCB emphasized the success of shipments to Italy and West Asia through sea route for banana and assured that the institute's support in developing "Banana Board" to improve the fruit industry of Andhra Pradesh. Possible technological backstopping for the value chain development in Banana, creation of Farmer producers Companies, using of banana wastes like fibre, central stem, peel and flower, preparation of sustainable project for MSME were given major thrust in the meeting which was attended by the scientists and the stakeholders comprising FPOs, exporters and entrepreneurs.

Members of Andhra Pradesh Food Processing with staff of ICAR-NRCB

International Women's day

The International Women's day was celebrated at ICAR-NRCB on 7 March, 2019. Mr. N. Ravichandran, Special Officer and Commissioner of Tiruchirappalli Corporation, graced the occasion as chief guest. Dr. R. Padmavathy, Principal, Seethalakshmi Ramaswamy College, and Dr. V. Sujatha, Principal, Cauvery College were participated as guests of honour. The meet was attended by staff of ICAR-NRCB and students of HC&RI, TNAU, Tiruchirappalli.

Dr. S. Uma, Director, ICAR-NRCB addressing audience during International Women's Day

International Yoga Day

ICAR-NRCB celebrated International yoga day under the theme 'Festival of Yoga and Wellbeing' on 21 June, 2019. All the staff of the institute participated and practiced various 'asanas' at ICAR-NRCB farm premises. Dr. Sughumar, BNYS from Shri Jayaranga Nature Cure Hospital, Tiruchirappalli and his team members participated and conducted yoga practical sessions.

Staff of ICAR-NRCB practicing Yoga during International Yoga Day

Visit of Mrs. Padma Raghunathan, Central General Manager, NABARD, Chennai

Ms. Padma Raghunathan, Central General Manager, NABARD, Chennai visited ICAR-NRCB on 20 June, 2019 for identifying the areas where ICAR-NRCB and NABARD can collaborate. Mrs. Padma Raghunathan briefed about the various farmer-oriented programs offered by NABARD from infrastructure development to capacity building farmers. Dr. S. Uma, Director, ICAR- NRCB, briefed the long association of institute with NABARD on various activities. All the scientists of the Institute and Mr. V. Rajaraman, District Development Manager, NABARD, Tiruchirappalli attended the interaction meeting.

Satff of ICAR-NRCB with CGM, NABARD

Renewal of ISO 9001: 2015 to ICAR- NRCB

ISO certification body auditor Mr. B. Karthikeyan, Director, Quest Certification (P) Ltd, Chennai visited the Institute on 6 July, 2019. In the opening meeting, Dr. S. Uma, Director, ICAR- NRCB, detailed the initiatives of the institute corrective actions for implementing on retrieval mechanism for training, consumer redressal and overall system maintenance. Dr. P. Suresh Kumar, Management Representative briefed the auditor and the house about the works carried out for the implementation of ISO objectives. After visiting the farm and the laboratories to check the good laboratory practices (GLP), the auditor recommended for a renewal of award of ISO 9001:2015 certification to ICAR-NRCB for its research and development on banana towards attaining livelihood and nutritional security.

Staff of ICAR-NRCB with ISO member

Opening of ICAR-NRCB sales counter

For the benefit of public and promotion of value added products of banana, ICAR- NRCB opened a sales counter on 11 July, 2019 primarily to fulfil the vision of our Honourable Prime minister to encourage new entrepreneurs through Agri-start ups. Chief Guest, Mr. Adithya Senthil Kumar, IAS, Sub-Collector, Srirangam inaugurated the sales counter and the first product was sold to Guest of Honor, Mr. K. Natarajan, IBS, Station Director, AIR, Tiruchirappalli. Utilization of banana waste for making value added products *viz*., stem candy, stem juice, peel and flower pickle was very much appreciated by the guests. Dr. S. Uma, Director, ICAR-NRCB congratulated team of scientists and other staff for their concerted efforts in opening the sales counter.

Director, ICAR-NRCB with guests during opening ceremony of ICAR-NRCB sales counter

Independence Day

ICAR-NRCB celebrated Independence Day on 15 August, 2019. Dr. S. Uma, Director, ICAR–NRCB hoisted the National Flag and delivered a speech on patriotism and the role of ICAR institutes in the development of our country.

Dr. S. Uma, Director, ICAR-NRCB hoisting National Flag on Independence Day

Sadbhavana Diwas

Staff of ICAR-NRCB observed 'Sadbhavana Diwas' on 20 August, 2019 and took a pledge to promote 'National Integration and Communal Harmony among the people of India.

Hindi Day and Swachchatha Diwas

ICAR-NRCB celebrated Hindi Day and Swachchatha Diwas on 27 September, 2019. Dr. S. Uma, Director, ICAR-NRCB presided over the function. Mr. V. Balakrishnan, IPS, DIG of Police, Tiruchirapalli participated in the function as Chief Guest and Dr. Chandish R. Ballal, Director, ICAR-NBAIR, Bengaluru as Guest of Honour. Importance and necessity of adopting Hindi as Official language in the Central Government Offices were stressed during the function. As a part of Swachchatha Diwas, "avoiding single use of plastic" materials in our day-to-day life was stressed and awareness was created among the nearby school children and adopted village people, who were invited for this function. Competitions were conducted for the children of the local schools with regard to stringent management of plastics for pollution free environment. The Chief Guest and the Guest of Honour gave away the prizes to the winners of various competitions held in connection with Hindi day and Swachchatha Diwas celebrations. The function ended with a cultural programme related to Swachcha Bharat Abhyaan.

School children along with Director, ICAR-NRCB and dignitaries during celebration of Hindi Day and Swachchatha Diwas

Vigilance Awareness Week

ICAR-NRCB observed 'Vigilance Awareness Week' during 28 October – 2 November, 2019. Dr. B. Padmanaban, Director-in-charge, administered the 'Integrity Pledge' to the staff of ICAR-NRCB. The theme of this year was 'Integrity - A way of life'. The staffs have joined the 'Fight against corruption' campaign by taking 'Integrity pledge' at www.cvc.nic.in and received an e-certificate from Central Vigilance Commission.

Staff of ICAR-NRCB taking 'Integrity Pledge'

Sports Meet

ICAR – NRCB participated in ICAR Inter - Institutional sports meet for south zone held at Cochin, Kerala, organized by ICAR-CIFT, Cochin during 4 – 8 November, 2019. A sports contingent of seven members participated in various events.

Constitution Day

Staff of ICAR-NRCB celebrated the constitution day by reciting the preamble of the constitution of India on 26 November, 2019.

18. Important varieties or technologies identified for release during 2019

S. No.	Technology	Developed by	Important features	
1.	**Kaveri Kanya**	S. Uma M. S. Saraswathi S. Backiyarani P. Durai --- **Collaborator** R. Thangavelu	A dessert type, is highly suitable of banana growing states like Tamil Nadu, Kerala, Andhra Pradesh, Karnataka and West Bengal. It produces 26-28 kg bunches which tightly packed with 10-11 hands and tolerant to wind	
2.	**Kaveri Haritha**	S. Uma M. S.Saraswathi S. Backiyarani P. Durai --- **Collaborators** B. Padmanaban R. Thangavelu	A cooking type, is high suitable for cultivation in the states of Andhra Pradesh, Kerala, Tamil Nadu, Odisha and West Bengal. Its yielding potential is up to 28-30 kg/bunch. It is having good cooking characteristics but fruits are elongated end with pointed tip	
3.	**Kaveri Saba**	S. Uma I. Ravi M. S. Saraswathi S. Backiyarani P. Durai --- **Collaborators** B. Padmanaban R. Thangavelu	A dual purpose, is more suitable for marginal cultivation and saline sodic soils with pH ranging from 8.8 to 9.0. It is a drought tolerant and salinity tolerant variety and producing 26- 29 kg bunch /plant. It has a longer green life of 7-8 days as against 3-5 days in Mon-than and therefore the consumer preference and prices are high in the market.	

ANNEXURE – I

I. Institute projects

Name of the Project	Principal Investigator
Crop Improvement	
1. Improvement and management of banana genetic resources in 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 Naine (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 Naine (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. Development of clump management technology for enhanced productivity in banana	V. Kumar
11. Development of pre and post harvest techniques for leaf production in banana	K. N. Shiva
12. Functions of resistant starch and designer food development from banana flour	P. Suresh Kumar
Physiology & Biochemistry	
13. 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
14. Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower	M. Mayil Vaganan
Crop Protection	
15. Identification of banana stem weevil pheromone for the management of pest	B. Padmanaban
16. Pest mapping in bananas and plantains of India	J. Poorani
17. Integrated management of Tropical race 4 of *Fusarium* wilt disease in banana	R. Thangavelu
18. Survey, etiology and management of rhizome rot of banana	M. Loganathan
19. Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan
20. Proteomic analysis of host-BBTV interaction in banana	C. Anuradha
21. 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. Network project on Transgenic in crops – Banana functional genomics (Sigatoka & Drought component)	S. Uma R. Thangavelu S. Backiyarani M. S. Saraswathi I. Ravi
2. Integrated management of *Fusarium* wilt, Tropical race 4 – A devastating strain on banana	R. Thangavelu M. Loganathan C. Anuradha S. Uma
3. Development and utilization of diagnostics to viruses of banana under Consortium research platform on vaccines and diagnostics	R. Selvarajan C. Anuradha
4. Assessment of post-harvest losses in banana	K. N. Shiva
5. Development of banana sucker paring equipment, pseudostem injector, bunch harvester and pseudo-stem outer sheath plate making equipment (collaborating institute : ICAR-CIAE, RS, Coimbatore)	B. Padmanaban V. Kumar K. N. Shiva P. Suresh Kumar

III. Externally Funded Projects

Name of the Project	Funding Source	Principal and Co-Investigtor(s)
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	Bioversity International	S. Uma S. Backiyarani R. Thangavelu M. S. Saraswathi
2. Bio fortification and development of disease resistance in Banana	DBT - QUT	
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
3. Development of non-chimeral mutants with durable resistance to *Fusarium* wilt in Rasthali through induced mutagenesis	DAE	M. S. Saraswathi R. Thangavelu S. Uma S. Backiyarani
4. Framing crop specific DUS guidelines for banana (*Musa* spp.)	PPV & FRA	S. Uma M. S. Saraswathi S. Backiyarani

5. DBT sponsored consortium project for North east India (DBT – NER)	
a. Consortium for managing Indian banana genetic resources	S. Uma M. S. Saraswathi S. Backiyarani
b. 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
c. Whole genome and transcriptome study to stress tolerant banana cultivars	S. Backiyarani S. Uma I. Ravi
d. Collection, evaluation, documentation and conservation of banana genetic resources from NE region	M. S. Saraswathi M. Mayil Vaganan S. Uma
e. *In vitro* mass multiplication of high value hill area bananas of the North Eastern region	M. S. Saraswathi R. Thangavelu I. Ravi
f. Diversity assessment, germplasm conservation and database development on banana resources in NE India	M. S. Saraswathi S. Backiyarani
g. 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
h. Management of low temperature and soil moisture deficit stresses in banana growth in NE India	I. Ravi M. Mayil Vaganan M. S. Saraswathi
i. Development of pre & post harvest bunch care management methods for fresh banana	P. Suresh Kumar K. N. Shiva
j. 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
k. 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
l. Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	B. Padmanaban S. Backiyarani J. Poorani
m. Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	R. Thangavelu
n. Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	R. Thangavelu M. Loganathan
o. 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
p. Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	R. Selvarajan C. Anuradha

6. A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.)	DST-SERB	C. Anuradha
7. Co-ordinated horticulture assessment & management using geoinformatics (CHAMAN-Phase-II)	DAC & F W, Govt. of India	K. J. Jeyabaskaran D. Ramajayam
8. Development of Efficient IOT enabled plant disease pest detection system	DST	R. Selvarajan R. Thangavelu B. Padmanaban
9. Cost effective dot blot TAS-ELISA based diagnostic kit for simultaneous detection of multiple banana viruses in banana plants	DST	R. Selvarajan
10. Breaking frontiers for the improvement of plants natural defense against pathogens in Banana (*Musa* sp.) through genome mining	DST-INSPIRE	K. Panneerselvam
11. Popularization of banana macropropagation technology in the Cauvery delta region of Tiruchirappalli district as an income generation activity for rural women self-help groups	DST	R. Karthic S. Backiyarani M. S. Saraswathi S. Uma

IV. Contract Research Projects

Name of the Project	Funding Source	Principal Investigator
1. Evaluating their product *viz*., paraffinic oil adjuvant for the management of leaf spot diseases of banana	M/s. Pure Chemicals Co., Chennai	R.Thangavelu
2. Evaluation on the effect of foliar spray of Pronos and Dormulin for the suppression of *Eumusae* leaf spot disease of banana	M/s. Nagarjuna Fertilizers and Chemicals Limited, Hyderabad	R.Thangavelu
3. Evaluation of farmer's banana variety – Kamal Vikas A1	National Innovation Foundation – India, Ahmedabad	M. S. Saraswathi
4. Evaluating paraffinic oil for the management of leaf spot diseases of banana cv. Grand Naine	M/s. Raj Petro Specialities Pvt. Ltd., Chennai	R.Thangavelu
5. Development of liquid formulation of Entomopathogenic fungus isolate – *Beauveria bassiana*	State Bio Control Laboratory, Mannuthy, Thrissur, Kerala	B.Padmanaban

ANNEXURE – II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
January 2019	31	20.61	45.74	-
February 2019	34.32	23.6	42.89	-
March 2019	37.67	25.06	33.77	-
April 2019	40.8	27.4	41.16	2
May 2019	40.45	28.7	37.64	51
June 2019	39.5	28.63	34.6	50.4
July 2019	37.93	27.64	54.22	53
August 2019	36.45	26.83	60.32	47.3
September 2019	35.1	25.8	69.33	157.2
October 2019	33.25	25.29	78.96	166.3
November 2019	31.9	24.43	80.16	67.4
December 2019	29.8	22.9	81.8	71
Total				665.6

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