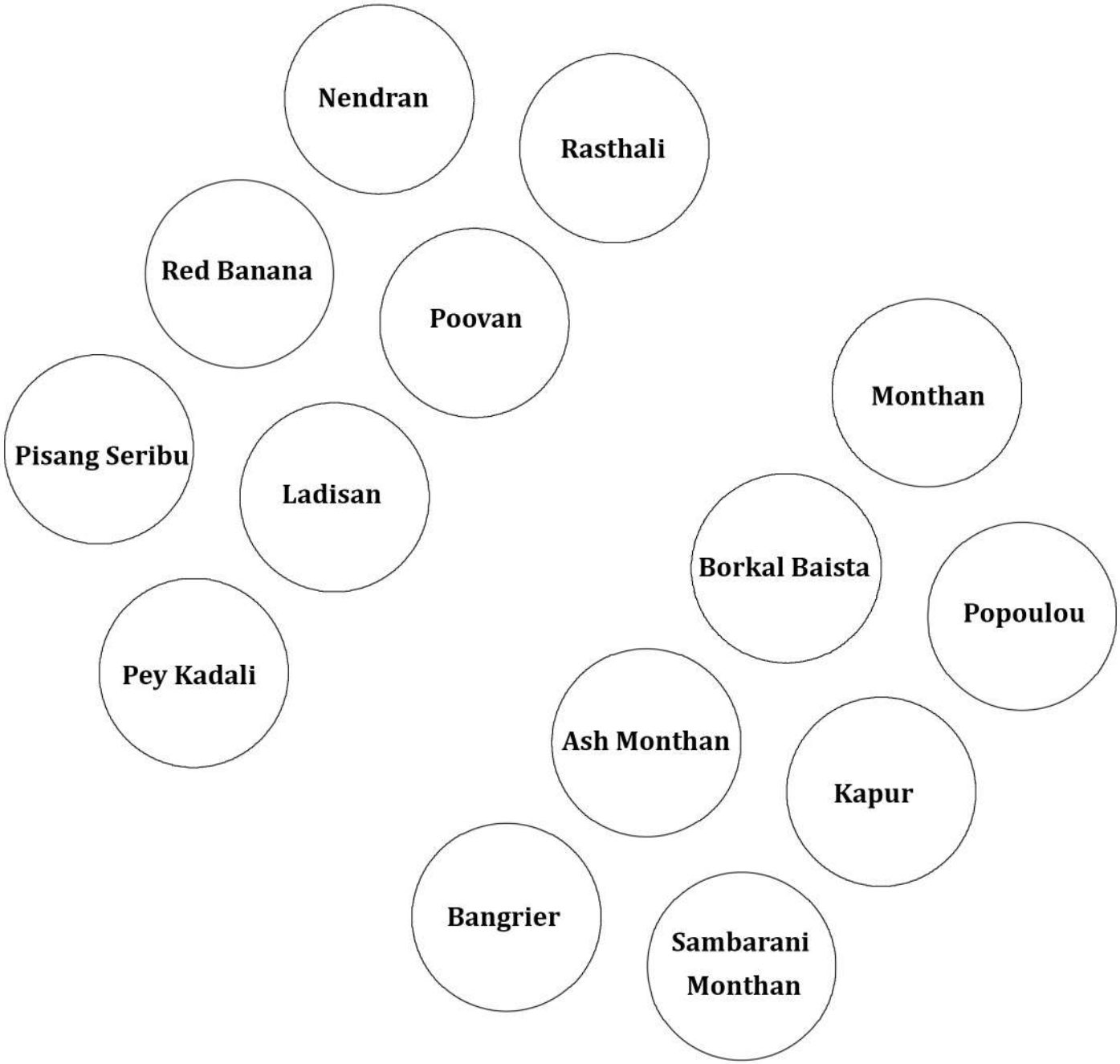
वार्षिक प्रतिवेदन
Annual Report
2020

भाकृअनुप – राष्ट्रीय केला अनुसंधान केंन्द्र

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

(ISO 9001:2015 Certified Institute)

Cover Page Photos



The Year 2021 is the UN's International Year of Fruits and Vegetables (IYFV). It is dedicated to raising awareness about the important role of fruits and vegetables in human nutrition, food security and health. Banana is highly nutritious and widely consumed both as a vegetable and fruit.

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(भारतीय कृषि अनुसंधान परिषद)
तायनूर पोस्ट, तोगमलै रोड, तिरूच्चिरापल्लि - ६२० १०२, तमिल नाडु, भारत

ICAR-NATIONAL RESEARCH CENTRE FOR BANANA
(Indian Council of Agricultural Research)
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Citation

ICAR – NRCB. 2021. Annual Report 2020.

ICAR – National Research Centre for Banana, Tiruchirappalli

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CONTENTS

PREFACE

Since early 2020, the world and India have been facing the scourge of the deadly Covid-19 pandemic, which has affected the economy and all spheres of life. We are facing the grim prospect of an impending second wave this year too. At this juncture, I am happy to present the annual report of the National Research Centre for Banana, Trichy, one of the top-rated National Research Centres of ICAR maintaining A+ status, for the year 2020. The ICAR-NRCB successfully hosted and conducted the International Conference on Banana (ICB-2020) during 23-25 February 2020, just in time before the calamity of Covid-19 and the resultant long lockdown came out of the blue. The conference was attended by more than 500 participants including international delegates from Australia, Belgium, France, Czech Republic, Turkey, South Africa, Zambia, Kenya, Uganda, Nigeria, Philippines and Indonesia, besides scientists and other stakeholders from different parts of India, students, entrepreneurs and farmers. Scientific deliberations and discussions were held in 11 technical sessions and a satellite workshop on "Fusarium wilt, Tropical Race 4 (Foc-TR4)" was also conducted. From ICAR-NRCB, 85 research papers were presented in the ICB-2020. The Institute bagged one best thesis, 10 best oral and 9 best poster presentations.

Despite the lockdown and other hurdles imposed by the restrictions imposed in the wake of COVID-19, the NRCB has reached remarkable research milestones. In the Crop Improvement section, hybrid progenies of different parental crosses were evaluated and progenies nos. 913, 940, 943 and 434 were found to be promising with respect to bunch yield and carotenoid content. Nendran based hybrid, NCR 17 performed well under ART at two locations. Our intensive screening efforts to identify sources of resistance to Fusarium wilt has led to the identification of 34 ITC accessions resistant to Fusarium wilt (Foc) Race 1 under sick plot conditions and few hybrid progenies were identified as immune to Foc Race 1. Mutation breeding for Foc resistance has also yielded a few promising mutant lines now under mass multiplication for further evaluation. Candidate resistant genes have been identified which are up-regulated upon Foc TR4 infection and genic SSR markers were identified for Foc Race 1 and TR4. One hybrid was found resistant to root-lesion nematode, *Pratylenchus coffeae*.

In Crop Production Section, nutrient dynamics studies were accomplished for cvs. Nendran and Grand Naine. In clump management studies, effect of number of suckers on crop cycle, fertilizer application on banana growth and yield was elucidated for cvs. Ney Poovan and Poovan. Few drought tolerant ABB cultivars were identified. Flavonoid compounds from the fruit peel and anthocyanidin compounds from the flower bracts of different cultivars were identified / quantified. Microencapsulation of anthocyanin compounds were attempted and analysed. In Post-Harvest Management, cultivars and season suitable for maximum leaf production were determined. Value added products like pizza, banana powder, low calorie stem juice, fruit syrup, pulp yogurt and edible cutlery were prepared and evaluated.

In Crop Protection Section, the bagworm, *Manatha albipes* was identified as a major pest of banana for the first time. Fall armyworm, *Spodoptera frugiperda*, an alien invasive pest in India, was found to affect banana in Tamil Nadu and Kerala. Many hitherto unknown natural enemies of banana pests were identified and documented. A rapid, reliable screening protocol for root-

lesion nematode, *Pratylenchus coffeae* was developed and validated. Race-specific primers were developed to differentiate the races of Fusarium wilt. A novel, rapid, accurate and cost-effective technique was developed for detecting Foc TR4. Promising biocontrol agents were identified and evaluated against Foc under pot conditions. PGPR isolates were isolated and identified. Outbreak of virus diseases *viz*, Cucumber Mosaic Virus and Banana Bract Mosaic Virus was reported from Maharashtra. Gene expression of BBTV, resistance to viruses, and virus-vector relationships were studied at molecular level.

During 2020, the Centre signed MoA with Andhra Pradesh Food Processing Society, Govt. of Andhra Pradesh; Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram; National Design and Research Forum, Bangalore; Dr. YSR Horticultural University, Andhra Pradesh and K. Ramakrishnan College of Technology, Tiruchirappalli.

During the lockdown, ICAR-NRCB organised a series of eight webinars covering all facets of banana production with lectures from experts for the benefit of banana stakeholders. Scientists of the centre participated in various virtual meets and trainings and shared their expertise. The Institute actively took part in social service and contributed to mitigate its impact on the vulnerable sections by distributing relief material. The staff of ICAR-NRCB contributed a day's salary to the PM-CARES fund. The institute also distributed around 7000 banana fruits to 2700 sanitary workers in Trichy Corporation. In order to facilitate rapid testing of COVID-19 samples, ICAR-NRCB handed over an advanced version of RT-PCR machine to the Government Hospital, Tiruchirappalli. The Centre felicitated the doctors of Tiruchirappalli during Independence Day celebrations for their selfless and untiring service.

I sincerely thank Dr. T. Mohapatra, Secretary-DARE and Director General, ICAR, for his valuable guidance and support. I profusely thank Dr. A.K. Singh, Deputy Director General (Hort. Sci.), ICAR, New Delhi, for his inspiring and constant encouragement. Our thanks are also due to Drs.V. Pandey and B. K. Pandey, I/c Assistant Director Generals (Hort. Science), ICAR, for their untiring support and guidance. Sincere thanks are due to the staff members of SMD (Hort. Science) for the continuous support and cooperation extended to ICAR-NRCB. I am also thankful to the Chairman and members of QRT, RAC and IMC for their guidance. I acknowledge the unstinting support from the Scientists, Technical, Administrative and Supporting staff of ICAR-NRCB who have stood by me in various institute activities at this difficult time. Finally, I thank the Publication Committee for compiling and shaping this document.

(S.Uma)

2. Introduction

The ICAR-National Research Centre for Banana, Tiruchirappalli, has recently celebrated its silver jubilee year after it was established on 21st August 1993 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. The ICAR-NRCB has contributed immensely for the present production estimated at 30.2 MT from an area of 8.47 lakh hectares making India the global leader 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 tissue culture, biotechnology, soil science, water and nutrient management, physiology, biochemistry, entomology, nematology, plant pathology and post-harvest technology research.

Significant achievements of the Centre during 2020 include successful conduct of the International Conference on Banana (ICB-2020) during 23-25 February, 2020 and signing of MoAs with Andhra Pradesh Food Processing Society, Govt. of Andhra Pradesh; Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram; National Design and Research Forum, Bangalore; Dr. YSR Horticultural University, Andhra Pradesh and K. Ramakrishnan College of Technology, Tiruchirappalli. During the extended lockdown due to Covid-19, the Centre successfully organised a series of eight webinars with lectures from experts for the benefit of banana stakeholders. The Institute actively took part in social service and contributed to mitigate the impact of covid-19 on the vulnerable sections by distributing relief material. The staff of ICAR-NRCB contributed a day's salary to the PM-CARES fund. The institute also distributed around 7000 banana fruits to 2700 sanitary workers in Trichy Corporation. In order to facilitate rapid testing of COVID-19 samples in Tiruchirappalli, ICAR-NRCB handed over an advanced version of RT-PCR machine to the Government Hospital. The Centre felicitated the doctors of Tiruchirappalli during the Independence Day celebrations.

The Centre has 19 in-house research projects and 30 externally funded projects funded by various agencies like ICAR, DBT, PPV& FRA, DAE, DST, Bioversity International, etc. The Centre signed MoU with VFPCK, Kerala for export of 'Nendran' banana to Europe. The Centre periodically conducts meetings of the Institute Research Council and Research Advisory Council to review the ongoing 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.

Vision

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

Mandate

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

* National banana gene bank management, coordination and validation of research for enhancing and sustaining the productivity of banana.

* Transfer of technology and capacity building of stakeholders for enhanced and sustained production of banana.

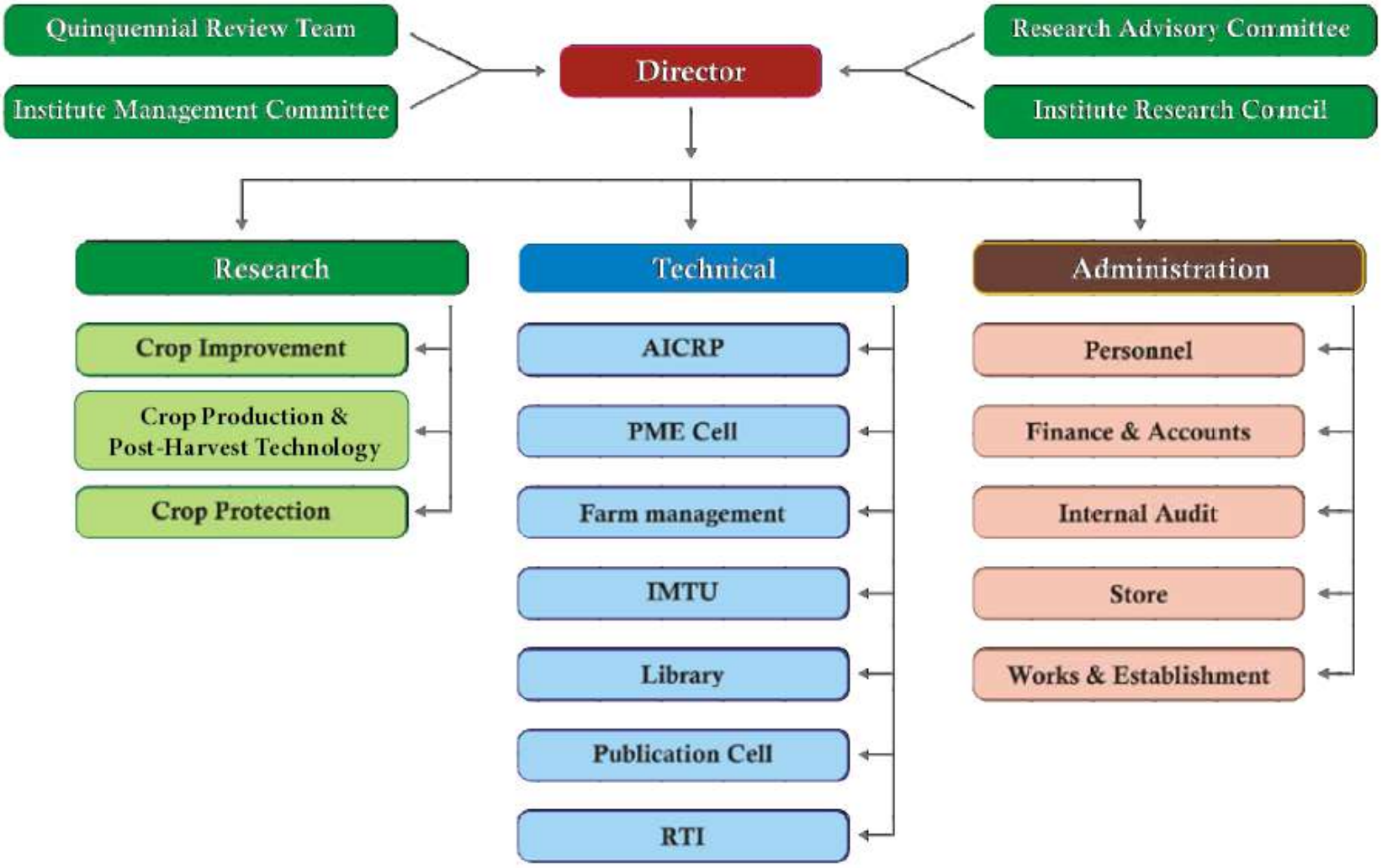
* Referral laboratory for monitoring the quality of micro-propagated banana plants.

Budget details for the year 2020

Head of account	Expenditure (upto 31.01.2021)
Equipment	
Library	
Establishment	683.85
OTA	0.03
TA	2.68
Research Expenses	12.34
Operational Expenses	89.59
Infrastructure	94.45
Communication	4.52
Repair of equipment,Vehicle etc.	13.79
Office building	29.64
Residential building	13.03
Other admin. (Other TA)	8.64
Publicity & Exhibition	0.56
HRD	0.00
Miscellaneous	2.89
Pension	76.30
Total	1032.31
SCSP-Capital	
SCSP-General	10.74
Grand Total	1043.05

A revenue of Rs. 32,34,305/- was generated by the centre during January–December,2020.

Organizational Setup of ICAR-NRC for Banana



EXECUTIVE SUMMARY

Crop Improvement

During the reporting period, five germplasm accessions have been collected from secondary sources, *viz.* TNAU, Coimbatore; UAS, Bengaluru; and BRS, Kannara. Morpho-taxonomic characterization has been completed for 217 accessions belonging to TNAU, Coimbatore as a part of ICAR-AICRP (Fruits), using IPGRI *Musa* descriptor. DNA fingerprints have been developed for NRCB released varieties using SCoT markers.

Performance of cv. Ney Poovan derived from different explants, namely shoot tip, male flower bud and cormlet, was evaluated and plants derived from shoot tip were the best with respect to yield and crop duration. Evaluation of ECS derived plants of cvs. Ney Poovan and Red banana in the farmers' fields along with sucker and shoot tip derived plants indicated no somaclonal variation in ECS derived plantlets. 124 ITC accessions were field evaluated for disease resistance and other unique traits like high yield, fruit quality etc.

A prototype has been developed for the preparation of synthetic seeds from somatic embryos @ 210-360 synthetic seeds per minute and 90-95% germination was observed in synthetic seeds. Thirty-three secondary hardened putative androgenic haploids were produced from diploid Ney Poovan (AB). Maximum shoot proliferation was obtained in shoot tip explants under red light while yellow light favored the growth and development of single shoots. In case of direct regeneration using immature male flower bud explants, red light favored the early development of meristematic clumps and more number of shoot buds.

Out of five Nendran based hybrids established, two progenies of Nendran x Pisang Jajee were seeded in nature and looked like Karpuravalli with an average bunch weight of 7 and 5 kg, respectively. One diploid progeny of the same cross combination looked like Nendran with an average yield of 4 kg with no seeds. Calcutta 4 was found to be the best compatible male parent for Poovan as their progeny (two) produced parthenocarpic fruits. Pisang Lilin was found to be the best male parent for Kaveri Saba, as they produce parthenocarpic bunches with good cooking quality. Both the open pollinated progenies of Ennabenian (Progeny No. 913 and 940) found to be tetraploids and produced 12 kg bunches having parthenocarpic fruits. Out of two OP progenies of Kaveri Saba x Chengdawt, one tetraploid (progeny 943) were found to be promising with an average yield and high cooking quality irrespective of the presence of one to two seeds per bunch. Open pollinated Kothia progenies produced good parthenocarpic bunches. Progeny No. 434 (Udhayam x Chengdawt) yielded 15 kg bunch weight and was found to be superior with long shelf life (12 days) and high carotenoid content (93.62 µg/gDW) which was 14-fold greater than that of Grand Nain (4 µg/gDW).

Adaptive research trial for NCR 17 along with the other Nendran based hybrids has been conducted at two locations, Udumalaipettai and Coimbatore which exhibited high standard heterosis. Sixty-three inter-specific ornamental banana hybrids were shortlisted out of 362 based on the attractive colour of the pseudostem, foliage, fruits and bracts.

About 124 ITC accessions have been planted in the sick plot at Muthalapuram, Theni, Tamil Nadu, for screening against *Fusarium* wilt, Race-1 and the internal disease scoring has been completed for 80 accessions and 34 exhibited resistant reaction. Progeny No. 15 (Sanna Chenkadali x Lairawk), 97 (Pisang Jajee x Matti), 426 (*Musa ornata* x *M. ac. burmannica*), 428 (cv. Rose x Pisang Lilin), 528 (Kothia x Calcutta – 4), 821 (Udhayam x Pisang Lilin) were found to be immune to *Foc* Race 1 under sick plot conditions. NRCBGNM 1 derived from gamma irradiated ECS showing resistance to Race 1 under sick plot conditions was mass multiplied and planted for large scale field evaluation in two hotspots of Tamil Nadu. NRCBGNM 1, 3, 13 and 15 derived from EMS treated ECS and NRCBGNM 3 derived from DES treated ECS which showed resistance to race 4 under pot culture conditions were mass multiplied *in vitro* for sick plot evaluation. For the development of trait specific markers for

Fusarium wilt resistance through association mapping, 61 accessions were screened for *Fusarium* wilt resistance under pot culture conditions and only H-2 was found to be resistant. Genotyping of 153 germplasm accessions has been completed for 15 primers using automated electrophoresis system. Progeny 115 was found to be resistant to root-lesion nematode (*Pratylenchus coffeae*) under pot conditions.

Candidate resistant genes, R2 (CC-NBS-LRR), R3 (LRR-RLP) showed four-fold and R4 (LRR-RLK) showed three-fold up-regulation in resistant cultivars upon *Foc* TR4 infection than the susceptible cultivars. Genic SSR markers associated with *Foc* Race 1 and TR4 were identified and found to differentiate the resistant and susceptible cultivars.

Twenty batches of tissue culture plants of cvs. Grand Nain, Nendran, Karpuravalli and Red Banana were tested for their genetic fidelity using ISSR markers and reports were issued. Around 722 tissue cultured plants and 8,725 suckers of other varieties have been supplied to banana growers.

Crop Production

Nutrient dynamics studies in cv. Nendran indicated that for obtaining a production of 31.5 t/ha, about 6–51% of the total nutrients taken up by the plants were removed from the soil through bunch harvest and the rest of the total nutrients remained in the plant residues like root, corm, pseudostem, petiole, leaves and male flower bud. In the case of cv. Grand Nain, with production of 45 t/ha, the soil nutrient removal was about 7–63%. The nutrients remaining in the residues were available for *in situ* nutrient recycling. Potassium was the major nutrient that accounted for more than 50% of the total nutrients taken up for crop production. In Nendran and Grand Nain, about 642 kg and 807 kg of potassium per hectare respectively were removed through bunch harvest and it is an indication of 'potassium mining' in banana cultivated soil. In organic banana farming, combined application of organics like 5kg poultry manure, 1 kg groundnut cake, 3kg rural compost, and 3kg wood ash alone per plant produced 25.3 kg of Grand Nain and it was on a par with that of 100% inorganic fertilizer application only. The soil health and fertility were satisfactory with the application of organics alone.

In field trials on clump management, in second sucker of Ney Poovan, earliest flowering (403.9 days), fruit maturity (97.3 days) and least total crop duration (501.1 days) were recorded in treatment S2 (mother plant (MP) with 2 suckers/clump). In Poovan, S2 recorded the earliest flowering and the least total crop duration and no difference was recorded among the treatments on number of suckers per clump. In the third sucker of Ney Poovan and Poovan, S3 (MP+ 3 suckers) took fewer days for flowering with shorter crop duration than S4 (MP + 4 suckers). Overall, total crop duration of S4 was extended by 131.7 days from S1 and in Poovan, the extension was 159.8 days. In second and third sucker crops of both, bunch weight decreased significantly with the increased number of suckers per clump with treatment S2 recording the highest bunch weight among the three levels of fertilizers, N3 (175% RDF) produced higher bunch weight, which wason par with N2 (150% RDF). Total bunch weight/clump (kg) and total yield (t/ha) was highest in S4 treatment. In both varieties, concentrations of P, K, Ca and Mg nutrients exhibited decreasing trend with increasing number of suckers per clump.

In a field experiment, ABB genotypes were evaluated for drought stress tolerance at flowering, Bluggoe, Kostha Bontha and Peyan produced normal fruits with yield on par with irrigated treatment. Application of silicon (Si) as foliar spray in banana during vegetative growth increased the dry matter production compared to control. Besides, it also increased proline production in selected genotypes like cv. Ney Poovan. In a controlled pot study, more dry matter (DM) allocation to leaves was recorded followed by pseudostem, corm, and roots, except in Rasthali, where more DM was allocated to corm, followed by leaves, pseudostem and roots. Most of the tested cultivars allocated higher percentage of DM towards corm under low level of irrigation (50% of Evaporation Demand). BB genome

bananas (Athiakol, Bhimkhol, Elaivazhai, Pagalpad Wild-1, Tani) were analysed for some of the biochemical parameters like proline and free amino acids and showed great diversity under drought.

Flavonoid compounds, *viz*. epicatechin, gallocatechinand catechin, were found in the peel of commercial varieties and gallocatechin was the predominant flavonoid. Monthan (ABB) and Udhayam (ABB) contained high amounts of gallocatechin (180 mg/100 g) and Ney Poovan (AB) and Red banana (AAA) contained low amounts of gallocatechin (140 mg). Antioxidant activities measured by TEAC and ORAC assays of cvs. Monthan and Udhayam, which contained higher amounts of gallocatechin, were as high as 93.4 and 87.5 µmol TE / 100 g FW, respectively. Grand Nain and Ney Poovan exhibited low antioxidant activity of around 70 µmol TE. Estimation of anthocyanins in flower bracts of 10 more genotypes from the germplasm bank revealed Borkal Baista (BB), Suti Jahaji (AA) and Gobin Tulci contained 45-50 mg/100 g. In flower bracts of commercial cultivars, cyanidin compound predominated among the six major anthocyanidins identified. Monthan, Popoulu, Saba, Udhayam, Grand Nain, NamwaKhom, Pachanadan, Hill Banana and Karpooravalli containing cyanidin 3-rutinosides as the major anthocyanin. Nutraceutical analyses of free and microencapsulated anthocyanins from Grand Nain flower bracts with 84% cyanidins and commercial cyanidin 3-*O*-rutinoside showed that the microencapsulated anthocyanins showed higher antioxidant activities than free and commercial cyanidin 3-*O*-rutinoside. Ripe pulp of Monthan and Nendran contained highest amount of fructans with 186 µg/g.

Leaf production in cv. Karpuravalli was maximum (6.43) followed by Sakkai (5.96) and Poovan (5.93), respectively and the maximum number of leaves was produced during April (6.18), followed by March (6.04) and June (6.03). At 22°C and 13.5°C, shelf life of leaves was high in 6-BAP treated leaves (10 days and 17 days) against 8 and 13 days of control, respectively. Karpuravalli leaves recorded longer shelf life than that of other varieties (Poovan, Sakkai, Phirima wild and Progeny 183). Leaf production was maximum during March (15.19) in Naadu, during June (14.55) in Poovan and during August (16.36) in Karpuravalli. Leaf area was in the order Naadu (1.05 m^2) >Poovan (0.89 m^2) > Karpuravalli (0.86 m^2).

Among five varieties tested for *in vitro* starch hydrolysis, Kaveri Saba and Monthan showed low hydrolysis rate due to higher resistant starch. Pizza prepared with 10% green banana flour was the most preferred with the highest sensory score. Foam mat dried ripe Red banana powder, banana starch film reinforced with cellulose nanofibre, low sodium pickle using flower and pseudostem, yoghurt using ripe banana pulp, low calorie banana stem juice and fruit syrup from banana were prepared and studied. Edible cutlery from banana waste and nanocellulose from banana fibre were prepared and a faster method of dewaxing of banana fibre using microwave was standardized.

Crop Protection

Bagworm, *Manatha albipes* (Moore) (Lepidoptera: Psychidae) was reported as a major pest of banana for the first time and infestation was found on 108 germplasm accessions. Hitherto, it was misidentified as *Kophene cuprea* by other banana entomologists and its identity was confirmed by COX 1 sequencing and morphology. Fall armyworm, *Spodoptera frugiperda*, an alien invasive pest of maize, was found to feed and complete its lifecycle on banana in Tamil Nadu and many natural enemies were identified. Severe infestation of eriophyid mite, *Phyllocoptruta musae*, was recorded for the first time on several ornamental banana (*Musa laterita*) accessions and other cultivars. Three species-specific coccinellid predators, *Stethorus pauperculus*, *S. indira* and *S. keralicus* were found to feed on *Oligonychus indicus, Eutetranychus orientalis* and *Raoiella indica*, respectively. One parasitoid (*Aphelinus* nr. *gossypii*) and one predator (*Scymnus nubilus*) of banana aphid were recorded.

Based on studies on race-specific effector genes identified from the *Foc* R1

and TR4 genomes, three highly race-specific primers were designed for detecting Fusarium wilt Race 1, Race 4 and TR4 isolates and validated. A Loop-mediated isothermal amplification (LAMP) assay was standardized for the detection of genes specific to *Foc* TR4 and assay conditions were optimized. This is a rapid, accurate and cost-effective novel technique for detecting TR4. Five phosphate solubilizing bacteria (PSB) isolates obtained from rhizospheric soil recorded maximum phosphate solubilization index. Two best isolates, identified by 16S rRNA analysis as *Enterobacter hormaechei* ssp. *xiangfangensis* (PSB52) and *Leclercia adecarboxylata* (PSB54), recorded the highest plant growth attributes, maximum available phosphorus and phosphatase enzyme activity in pot culture experiments. One endophytic and six rhizospheric *Trichoderma* isolates were tested against Foc TR4 in a pot culture experiment and Rhiz. *T. asperellum* (NRCB3) + Rhiz. *T. harzianum* and Rhiz. *Trichoderma* sp. (Assam) + Rhiz. *Trichoderma* sp. (UP4) recorded the lowest wilt score and enhanced the biometric attributes like plant height, girth, leaf area and root numbers. In pot culture, *Enterobacter cloacae* subsp. *dissolvens* in combination with endophytic *T. asperellum* effectively controlled Foc TR4 at 90 DAI and enhanced the biometric attributes.

Twenty-three isolates of rhizome rot were obtained from infected samples of cvs. Nendran and Grand Nain during surveys in Pudukottai (Alangudi), Tiruchirappalli (Egirimangalam and Kondayampettai) and Theni (Muthalapuram) districts of Tamil Nadu. Three isolates producing characteristic rhizome rot symptoms on Grand Nain TC seedlings were characterized and identified as *Klebsiella variicola* by 16S rDNA analysis and validated on Ney Poovan. Thirty isolates of Actinobacteria were isolated and characterized based on cultural morphology for possible use as plant growth promoters / bioagents. Fungal and bacterial biocontrol agents (PGPR) from rhizosphere regions of healthy banana were isolated and identified morphologically by 16srDNA (for fungi) and 18s rDNA (for bacteria) sequencing.

Severe outbreak of CMV as high as 11-52.17% and 41.15-75.96% was recorded in Jalgaon and Burhanpur, respectively, in two successive years (2019 and 2020). The incidence of BBrMV was also recorded in the research fields and the germplasm collection of BRS, Jalgaon. In Theni, the incidence of banana bunchy top virus (6.6– 60%), BBrMV (2–80%) and CMV (2–11%) was recorded. The BBrMD incidence was more in Red banana followed by Grand Nain.

Ornamental banana hybrid and *Musa velutina* expressing mosaic like symptoms have been confirmed to be due to infection of BBrMV. RNA-1, RNA-2 and RNA-3 of three CMV banana infecting isolates (Burhanpur, Jalgaon and Theni isolates) were amplified, cloned and sequenced. An infectious clone of Banana Streak Mysore Virus (BSMYV) was developed. The infectious clone constructs were confirmed by restriction digestion and colony PCR before immobilisation to *Agrobacterium* strain EHA105. Primers were designed for amplifying a full-length construct of BBrMV by an overlapping-extension PCR (OE-PCR) to produce infectious cDNA of BBrMV.

A total of 42 differently expressed genes (DEGs) were commonly identified for up- and down-regulated DEGs for validation of the gene expression levels revealed by the transcriptome data. Thirty-eight sets of primers were designed for the differentially expressed genes for BBTV.

Screening of diploid germplasm accessions (AA and BB) for resistance against BBTV using viruliferous aphids in an insect proof screenhouse was continued to confirm the previous results. Fourteen AA diploids expressed typical symptoms of BBTV infection. None of the BB diploids, except Manguthamang and Jungle Kela II, got infected even after three repeated inoculations with viruliferous aphids. Eleven transgenic lines obtained by RNAi with replicase gene / multiple virus gene construct were challenge inoculated on plants with BBTV in the net house and the plants yielded bunches without expressing any symptoms of bunchy top.

Field evaluation data on episomal BSMYV free tissue culture derived Poovan plants at seven locations showed significant difference in the growth and yield parameters compared to sucker grown plants and symptoms of streak disease were not expressed in tissue cultured plants at six locations.

A simple, rapid screening protocol was developed for evaluation of banana genotypes for resistance to root-lesion nematode (*Pratylenchus coffeae*) and validated with standard reference genotypes. In this method, reaction of genotypes can be determined within three months based on the extent of damage (lesions) and nematode population.

Under pot conditions, soil drenching with salicylic acid @ 50 and 100µM concentration at 24hrs prior to inoculation on tissue cultured Grand Naine reduced the of root population of root-knot nematode (30 and 41%, respectively) and root-lesion nematode (67 and 68%, respectively) over control.

Transfer of Technology

During 2020, nine radio talks were delivered and 32 press notes in various dailies and magazines were published by ICAR-NRCB. The institute successfully conducted 'International Banana Conference (ICB-2020)' and participated in two exhibitions at the national level. Four on-campus trainings, including one 'International Training Program on Fusarium wilt Tropical Race 4' and two off-campus trainings were conducted. Besides these, ICAR-NRCB organized / participated in seven training programs on virtual platform and conducted eight webinars in a series on various aspects of banana cultivation, value addition and export. The institute signed MoA with Andhra Pradesh Food Processing Society, Govt. of Andhra Pradesh; Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram; National Design and Research Forum, Bangalore; Dr. YSR Horticultural University, Andhra Pradesh and K. Ramakrishnan College of Technology, Tiruchirappalli.

Linkages and Collaborations

ICAR–NRCB has research collaborations with international institutes which include IITA, Nigeria; Bioversity International, France; KUL, Belgium; and the University of Queensland, Australia. The institute has linkages with national institutes including BARC, Mumbai; DST and DBT, New Delhi; APEDA; TNAU, Coimbatore; NIT, Tiruchirappalli and KNCET, Thottiyam, Tamil Nadu. The centre has research collaborations with other ICAR institutes including ICAR–NBPGR, New Delhi; ICAR–IIHR, Bengaluru; and ICAR–CIAE (RS), Coimbatore. Under DBT-NER, more than 50 institutes located in different parts of the country are associated with ICAR-NRCB. ICAR–NRCB also coordinates with ICAR-AICRP (Fruits) centers (11 nos.) working on banana. 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,12 training programs on virtual platform were attended by the scientists of the centre. The scientists of NRCB published 11 research papers in various journals of International and National repute and a total of 85 research papers were presented in the 'International Banana Conference (ICB-2020)' and four research papers were presented in various e-conferences. The institute bagged one best thesis, 14 best oral and 10 best poster presentations at various conferences. During 2020, three students successfully completed their Ph.D. and 17 students are pursuing B.Tech., M.Tech., M.Sc., Ph.D. and postdoctoral research at the centre.

Revenue Generated

A revenue of Rs. 32,34,305/- was generated by the centre during January–December, 2020.

विशिष्ट सारांश

फसल सुधार

रिपोर्टाधीन अवधि के दौरान द्वितीयक स्रोतों नामतः तमिल नाडु कृषि विश्वविद्यालय, कोयम्बतूर; कृषि विज्ञान विश्वविद्यालय, बंगलुरू और बीआरएस कन्नारा से पांच जननद्रव्य प्रविष्टियां एकत्र की गई हैं। भा.कृ.अ.प.–अखिल भारतीय समन्वित अनुसंधान परियोजना (फल) के एक अंग के रूप में आईपीजीआरआई *म्यूसा* के विवरणें का उपयोग करके तमिल नाडु कृषि विश्वविद्यालय, कोयम्बत्तूर की 217 प्रविष्टियों का आकृतिविज्ञानी–वर्गीकरण विज्ञानी लक्षण–वर्णन किया गया है।

विभिन्न कर्ततकों (एक्प्लांट्स) नामतः प्ररोह शीर्ष, नर पुष्प कलिका और कार्मलेट से व्युत्पन्न वाणिज्यिक किस्म नेईपूवन के निष्पादन का मूल्यांकन किया गया तथा प्ररोह शीर्ष से व्युत्पन्न पौधे उपज तथा फसल की वृद्धि के संदर्भ में सर्वश्रेष्ठ पाए गए। वाणिज्यिक किस्मों नामतः नेईपूवन और रेड बनाना के ईसीएस व्युत्पन्न पौधों का मूल्यांकन प्ररोह शीर्ष से व्युत्पन्न पौधों और भूस्तारियों के साथ किसानों के खेतों में किया गया तथा ईसीएस व्युत्पन्न कर्ततकों में किसी कायक्लोनी विविधता का संकेत नहीं मिला। कुल 124 आईटीसी प्रविष्टियों का मूल्यांकन रोग प्रतिरोध व उच्च उपज, फल गुणवत्ता आदि जैसे अन्य अनोखे गुणों के लिए किया गया।

कायक्लोनी भ्रूणों से 210–360 कृत्रिम बीज/मिनट की दर से कृत्रिम बीज तैयार करने के लिए एक प्रोटोटाइप विकसित किया गया है तथा इन कृत्रिम बीजों में 90–95 प्रतिशत अंकुरण पाया गया। द्विगुणित नेईपूवन (एबी) से 33 द्वितीयक कठोरीकृत प्यूटेटिव एंड्रोजनिक अगुणित उत्पन्न किए गए। जिन पौधों को लाल हल्के प्रकाश के अंतर्गत प्ररोह शीर्ष से प्राप्त किया गया था उनमें सर्वाधिक प्ररोह प्रचुरभेदक पाया गया, जबकि पीला प्रकाश एकल प्ररोह की वृद्धि और विकास के लिए अनुकूल पाया गया। अपरिपक्व नर पुष्प कलिका कर्ततकों का उपयोग करके प्रत्यक्ष पुनर्जनन के मामले में लाल प्रकाश से मेरिस्टेमेटिक कलम्प का आरंभिक विकास हुआ

तथा अधिक संख्या में प्ररोह कलिकाएं विकसित हुई।

नरेन्द्रन x पिसांग जाजी की दो संततियां प्राकृतिक अवस्थाओं में रोपी गईं तथा ये क्रमशः 7 और 5 कि.ग्रा. गुच्छे के औसत भार के साथ करपूरवल्ली की जैसे दिखाई दी। इसी संकर संयोग की एक द्विगुणित संतति नरेन्द्रन के समान दिखाई दी जिसकी औसत उपज 4 कि. ग्रा. था और फल में कोई बीज भी नहीं थे। कलकत्ता–4 को पूवन के लिए सर्वश्रेष्ठ तुलनीय नरजनक पाया गया क्योंकि उनकी संततियों (2) से अनिषेकजनित फल उत्पन्न हुए। पिसांग लिलिन को कावेरी साबा के नरजनक के रूप में सर्वश्रेष्ठ पाया गया क्योंकि उनसे अनिषेकजनित गुच्छे उत्पन्न हुए और फलों को पकाने की गुणवत्ता भी श्रेष्ठ थी। एन्नाबिनियन की दोनों खुली परागित संततियां (संतति सं. 913 और 940) चतुर्गुणित पाई गईं और उनसे अनिषेकजनित फलों से युक्त 12 कि.ग्रा. के गुच्छे उत्पन्न हुए। कावेरी साबा x चेंगदाव्त की दो ओपी संततियों में से एक चतुर्गुणित संतति (संतति 943) आशाजनक पाई गई जिसकी औसत उपज अच्छी थी तथा पकाने की गुण्वत्ता उच्च थी जबकि प्रत्येक गुच्छे में एक से दो बीज मौजूद थे। खुली परागित कोठियां संततियों से श्रेष्ठ अनिषेकजनित गुच्छे उत्पन्न हुए। संतति संख्या 434 (उद्यम x चेंगदाव्त) से 15 कि.ग्रा. भार के गुच्छे उत्पन्न हुए तथा इसे ग्रेंड नैन की तुलना में (4 µg/ग्रा. शुष्क भार) 14 गुना अधिक कैरोटेनॉयड अंश से युक्त पाया गया (93.62 µg/ग्रा. शुष्क भार)। इसके फलों की निधानी आयु भी अधिक (12 दिन) थी।

नेन्द्रन पर आधारित संकरों के साथ एनआरसी 17 पर दो स्थानों नामतः उदुमलैपेट्टी और कोयम्बत्तूर ने अनुकूल संबंधी अनुसंधान किया गया जिसमें उच्च स्तर का संकर ओज प्रदर्शित हुआ। छ्दम तने, पत्तियों, फलों और सह–पत्रों के आकर्षक रंगों के आधार पर 362 में से 63 अंतरजातीय शोभाकारी केला संकरों को छांटा गया।

फ्यूजेरियम मुर्झान, प्रजाति 1 के विरुद्ध छंटाई के लिए मुथालापुरम, थेनी, तमिल नाडु में रोगी प्लॉट में लगभग 124 आईटीसी प्रविष्टियां रोपी गई तथा 80 प्रविष्टियों के लिए आंतरिक रोग स्कोरिंग पूरी की गई जिनमें से 34 में प्रतिरोधी प्रक्रिया प्रदर्शित हुई। संतति संख्या 15 (सान्ना चेनकदली x लेईराउक), 97 (पिसांग जाजी x मत्ती), 426 (*म्यूसा ओरंटा* x *एम. एसी. बर्मानिका*), 428 (वाणिज्यिक किस्म - रोज x पिसांग लिलिन), 528 (कोठिया x कलकत्ता 4), 821 (उद्यम x पिसांग लिलिन), रोगी प्लाट की दशाओं के अंतर्गत *एफओसी* प्रजाति 1 के विरुद्ध रोगरोधी पाई गई। रोगी प्लाट की दशाओं के अंतर्गत प्रजाति 1 के विरुद्ध प्रतिरोध प्रदर्शित करने वाली गामा किरणित ईसीएस से व्युत्पन्न एनआरसीबीजीएनएम–1 को बड़े पैमाने पर प्रगुणित किया गया तथा तमिल नाडु के दो हॉट–स्पॉट में बड़े पैमाने पर प्रक्षेत्र मूल्यांकन के लिए रोपा गया। ईसीएस से उपचारित ईएमएस से व्युत्पन्न एनआरसीबीजीएनएम 1, 3, 13 और 15 तथा ईसीएस से उपचारित डीईएस से व्युत्पन्न एनआरसीबीजीएनएम 3, जिन्होंने पॉट कल्चर दशा के अंतर्गत प्रजाति 4 के विरुद्ध प्रतिरोध प्रदर्शित किया था, उन्हें रोगी प्लॉट मूल्यांकन के लिए स्वपात्रे दशा में बड़े पैमाने पर प्रगुणित किया गया। सम्बद्ध मानचित्रण के माध्यम से *फ्यूजेरियम मुर्झान* प्रतिरोध के लिए गुण विशिष्ट मार्करों के विकास हेतु पॉट कल्चर दशाओं के अंतर्गत *फ्यूजेरियम मुर्झान* रोग प्रतिरोध के लिए

61 प्रविष्टियां छांटी गईं जिनमें से केवल एच–2 प्रतिरोधी पाई गई। स्वचालित इलेक्ट्रोफोरेसिस प्रणाली का उपयोग करके 15 प्राइमरों के लिए 153 जननद्रव्य प्रविष्टियों के जीनप्ररूपण का कार्य पूरा किया गया। संतति 115 पॉट दशाओं के अंतर्गत जड़ में घाव करने वाले सूत्रकृमि (*प्रैटाइलेंकस कॉफीई*) के विरुद्ध प्रतिरोधी पाई गई।

प्रत्याशी प्रतिरोधी जीनों, आर 2 (सीसी–एनबीएस–एलआरआर), आर 3 (एलआरआर–आरएलपी) में *एफओसी* टीआर4 का संक्रमण कराने पर संवेदी किस्मों की तुलना में चार गुना तथा आर4 (एलआरआर–आरएलके) में प्रतिरोधी किस्मों के संदर्भ में तीन गुना अपरेगुलेशन प्रदर्शित हुआ। *एफओसी* प्रजाति 1 तथा टीआर4 से संबंधित आनुवंशिक एसएसआर मार्कर पहचाने गए तथा पाया गया कि ये प्रतिरोधी और संवेदनशील किस्मों के बीच भेद करने में सक्षम हैं।

वाणिज्यिक किस्मों ग्रेंड नयन, नेन्द्रदन, करपूरवल्ली और रेड बनाना के ऊतक संवर्धित पौधों के 20 बैच का परीक्षण आईएसएसआर मार्करों का उपयोग करके उनकी आनुवंशिक उपयुक्तता के लिए किया गया तथा रिपोर्टें जारी की गईं। अन्य किस्मों के लगभग 722 ऊतक संवर्धित पौधे और 8,725 भूस्तारी केले की खेती करने वालों को आपूर्त किए गए।

फसलोत्पादन

वाणिज्यिक किस्म नेन्द्रन में किए गए पोषक गतिकी संबंधी अध्ययनों से यह संकेत मिला कि 13.5 टन/है. उत्पादन प्राप्त करने के लिए पौधों द्वारा ग्रहण किए गए कुल पोषक तत्वों का लगभग 6–51 प्रतिशत भाग गुच्छों की तुड़ाई के माध्यम से मृदा से हट जाता है और पोषक तत्वों का शेष बचा भाग जड़ों, प्रकंद, छद्म तने, पर्णवृंत, पत्तियों तथा नर पुष्प कलिका के रूप में पादप अपशिष्ट बना रहता है। वाणिज्यिक किस्म ग्रेंड नैन ने 45 टन/है. उत्पादन के लिए मृदा से लगभग 7–63 प्रतिशत पोषक तत्व हट जाते हैं। अपशिष्ट में रहने वाले पोषक तत्व स्वस्थाने पोषक तत्व पुनश्चक्रण के लिए अपशिष्टों में बने रहते हैं। पोटेशियम व प्रमुख पोषक तत्व था जिसका फसल उत्पादन के दौरान फसल द्वारा ग्रहण किए गए कुल पोषक तत्वों में से 50 प्रतिशत से अधिक का योगदान था। नेन्द्रन और ग्रेंड नैन किस्मों के मामले में केले की तुड़ाई के माध्यम से प्रति हैक्टर क्रमशः लगभग 642 कि.ग्रा. और 807 कि.ग्रा. पोटेशियम मृदा से हटा। यह इसका संकेत है कि केले की खेती के दौरान मृदा से (पोटेशियम खनन) होता है। केले की जैविक खेती में प्रति पौधा 5 कि.ग्रा. कुक्कुट खाद, 1 कि.ग्रा. मूंगफली की खली, 3 कि.ग्रा. ग्रामीण कम्पोस्ट और 3 कि.ग्रा. काष्ठ भस्म का उपयोग करने से ग्रैंड नैने की प्रति पौधा 25.3 कि.ग्रा. उपज हुई जो 100 प्रतिशत अकार्बनिक उर्वरक के उपयोग से प्राप्त होने वाली उपज के बराबर थी। केवल जैविक खादों का उपयोग करने पर मृदा स्वास्थ्य तथा उर्वरता का स्तर संतोषजनक पाया गया।

नेईपूवन के द्वितीयक भूस्तारियों के मामले में क्लम्प प्रबंधन पर किए गए प्रक्षेत्र परीक्षणों में उपचार एस2 (मातृ पौधा (एमपी)– दो भूस्तारी/क्लम्प) में सबसे अगेती पुष्पन (403.9 दिन), फल परिपक्वता (97.3 दिन) और सबसे कम कुल फसल अवधि (501.1 दिन) रिकॉर्ड किए गए। पूवन के मामले में एच–2 में सबसे अधिक अगेती पुष्पन तथा फसल की सबसे कम कुल अवधि रिकॉर्ड किए गए तथा प्रति क्लम्प भूस्तारियों की संख्या पर उपचारों के संदर्भ में कोई अंतर नहीं रिकॉर्ड किया गया। नेई पूवन और पूवन के तीसरे भूस्तारी, एस3 (एमपी+3 भूस्तारी) ने एस 4 (एमपी + 4 भूस्तारी) की तुलना में पुष्पन में कुछ कम दिन लिए तथा फसल की अवधि भी अपेक्षाकृत अधिक रही। कुल मिलाकर एस1 और पूवन में एस4 की कुल फसल अवधि 113.7 दिन बढ़ गई। यह विस्तार कुल 159.8 दिनों का था। दोनों फसलों के दूसरे और तीसरे भूस्तारियों के मामले में उपचार एस2 के अंतर्गत प्रति क्लम्प भूस्तारियों की संख्या में वृद्धि के साथ केले के भार में उल्लेखनीय कमी आई जिसमें उर्वरकों के तीन स्तर में से एस2 उपचार में गुच्छे का सर्वश्रेष्ठ भाग रिकॉर्ड किया गया, जबकि इन्हीं तीनों स्तरों में से एन3 (175 प्रतिशत आरडीएफ) से उच्चतर भार के केले उत्पन्न हुए और यह एन2 (150 प्रतिशत आरडीएफ) उपचार के बराबर था। एस4 उपचार में प्रति क्लम्प गुच्छे का कुल भार (कि.ग्रा.) तथा कुल उपज (टन/है.) सर्वोच्च थे। इन दोनों किस्मों में प्रति कलम्प भूस्तारियों की संख्या बढ़ने के साथ P, K, Ca और Mg पोषक तत्वों की सांद्रतों में कमी प्रदर्शित हुई।

प्रक्षेत्र प्रयोग में पुष्पन अवस्था में सूखा प्रतिबल सहिष्णुता के लिए मूल्यांकित एबीबी जीनप्ररूपों में से ब्लूगोए, कोस्था बोंथा और पेयन में सामान्य फल उत्पन्न हुए तथा उपज भी सिंचित उपचार से प्राप्त होने वाली उपज के बराबर थी। वानस्पतिक वृद्धि के दौरान केले में सिलिकॉन (Si) का केले की पत्तियों पर छिड़काव करके उपयोग करने से तुलनीय की अपेक्षा शुष्क पदार्थ उत्पादन में वृद्धि हुई। इसके अलावा इससे नेई पूवन जैसे कुछ चुने हुए जीनप्ररूपों में प्रोलीन का उत्पादन भी बढ़ा। नियंत्रित पॉट संबंधी अध्ययनों में पत्तियों पर अधिक शुष्क पदार्थ (डीएम) एकत्र हुआ जिसके बाद इस मामले में क्रमशः छद्म तने, प्रकंद और जड़ों का स्थान था। रसथली में इस मामले में अपवाद था जहां प्रकंद में अधिक शुष्क पदार्थ एकत्र हुआ जिसके पश्चात् क्रमशः पत्तियों, छद्म तने और जड़ों का स्थान था। जिन किस्मों का परीक्षण किया गया उनमें सिंचाई के निम्न स्तर (वाष्पन मांग के 50%) के अंतर्गत प्रकंद में शुष्क पदार्थ का उच्चतर प्रतिशत एकत्र हुआ। बीबी जीनोम के केलों (अथियाकोल, भीमकोल, एलाईवझाई, पागलवैउ वाइल्ड–1, तानी) का प्रोलीन तथा मुक्त एमिनो अम्लों जैसे जैव रासायनिक प्राचलों का विश्लेषण किया गया।

वाणिज्यिक किस्मों के छिलके में फ्लेवोनॉइड यौगिक, नामतः इपिकैटेचिन, गैलोकेटेचिनेंड कैटेचिन पाए गए और इनमें से गैलोकेटेचिन प्रमुख फ्लेवोनॉइड था।

मोंथन (एबीबी) और उद्यम (एबीबी) में गेलोकैटेचिन की उच्च मात्रा थी (180 मि.गा./100 ग्रा.), जबकि नेई पूवन (एबी) और रेड बनाना (एएए) में गैलोकैटेचिन की मात्रा कम थी (140 मि.ग्रा.)। वाणिज्यिक किस्मों मोंथन और उद्यम के टीईएसी और ओआरएसी मूल्यांकनों के द्वारा प्रतिऑक्सीकारक क्रियाएं मापी गईं। उल्लेखनीय है कि इन किस्मों में उच्च मात्रा में गैलोकैटेचिन था तथा ये क्रमशः 93.4 और 87.5 μ मोल टीई/100 ग्रा. ताजा भार थे। ग्रेंड नैन और नेई पूवन में लगभग 70 μ मोल टीई प्रतिऑक्सीकारक क्रिया देखी गई जो अपेक्षाकृत कम थी। जननद्रव्य बैंक से प्राप्त 10 से अधिक जीनप्ररूपों के पुष्प सहपत्रों में एंथोसियानिन के आकलन से यह स्पष्ट हुआ कि बोरकल बाइस्ता (बीबी), सुति जहाजी (एए) और गोबिन तुल्की में यह 45–50 मि.ग्रा./100 ग्रा. था। वाणिज्यिक किस्मों के पुष्प सहपत्रों में छह प्रमुख एंथोसियानिन में से सियानिडिन यौगिक की प्रमुख यौगिक के रूप में पहचान की गई। मोंथन, कोपाउलु, साबा, उद्यम, ग्रैंड नैन, नमवाखोम, पंचनंदन, हिल बनाना और करपूरवल्ली में सियानिडीन 3–रूटिनोसाइड प्रमुख एंथोसियानिन के रूप में पाए गए। ग्रेंड नयन के पुष्प सहपत्रों से मुक्त और सूक्ष्म कवचित एंथोसियानिन के म्यूटाक्यूटिकल विश्लेषण में 84 प्रतिशत सियानाडिन तथा वाणिज्यिक सियानाडिन 3–o–रूटिनोसाइड था जिससे यह प्रदर्शित हुआ कि सूक्ष्म कवचित एंथोसियानिन में मुक्त तथा वाणिज्यिक सियानाडिन 3–o–रूटिनोसाइड की तुलना में उच्चतर प्रतिऑक्सीकारक क्रियाएं होती हैं। मोंथन और नेन्द्रन के पके हुए गूदे में फ्रक्टांस की सर्वोच्च मात्रा (186 μg/ग्राम) होती है।

वाणिज्यिक किस्म करपूरवल्ली में पत्ती उत्पादन सर्वाधिक (6.43) था जिसके पश्चात् क्रमशः सक्कई (5.96) और पूवन (5.93) का स्थान था। सर्वाधिक पत्तियां अप्रैल के दौरान उत्पन्न हुईं (6.18) जिसके पश्चात् मार्च में (6.04) और जून में 6.03 पत्तियां उत्पन्न हुईं। 22^0 से. और 13.5^0 से. पर पत्तियों की निधानी आयु 6–बीएपी उपचारित पत्तियों में उच्च थी (क्रमशः 10 दिन और 17 दिन), जबकि तुलनीय में क्रमशः 8 और 13 दिन की निधानी आयु थी। करपूरवल्ली की पत्तियों में अन्य किस्मों (पूवन, सक्कई, फिरिमा वाइल्ड और प्रोजेनी 183) की तुलना में अपेक्षाकृत लंबी निधानी आयु रिकॉर्ड की गई। नाडु में मार्च के दौरान सर्वाधिक पत्ती उत्पादन था (15.19), जबकि पूवन में जून के दौरान (14.55) और करपूरवल्ली में अगस्त के दौरान (16.36) यह सर्वाधिक था। पत्ती क्षेत्र का क्रम इस प्रकार थाः नादु (1.05 मी.^{2}) > पूवन (0.89 मी.^{2}) > करपूरवल्ली (0.86 मी.^{2})।

जिन पांच किस्मों का स्वपात्रे स्टार्च जलापचयन परीक्षण किया गया उनमें से कावेरी साबा और मोंथन में उच्चतर प्रतिरोधी स्टार्च के कारण जलापचयन की दर निम्न थी। दस प्रतिशत हरे केले के आटे से तैयार किया गया पीज़ा अधिक पसंद किया गया जिसका संवेदी स्कोर सर्वोच्च था। फोम मेट पर शुष्कित रेड बनाना का चूर्ण सेल्यूलोज़ नैनोफाइबर से युक्त केले के स्टार्च की फिल्म से आवृत्त था। इसी प्रकार, पुष्प और छद्म तने का उपयोग करके निम्न सोडियम वाले अचार, पके केले के गूदे का उपयोग करके योघर्ट, निम्न कैलोरी वाला केले के तने का रस तथा फल के सीरप जैसे उत्पाद तैयार किए गए और उनका अध्ययन किया गया। केले के अपशिष्ट से खाने योग्य कटलरी तथा केले के रेसे से नैनो सेल्यूलोज तैयार किया गया तथा माइक्रोवेव का उपयोग करके केले के रेशे से मोम हटाने की तीव्र विधि मानकीकृत की गई।

फसल सुरक्षा

बैगवर्म, *मनाथा एल्बिपेस* (मूरे) (लेपिडोप्टेराः साइकिडी) को पहली बार केले का प्रमुख पीड़क रिपोर्ट किया गया और इसका 108 जननद्रव्य प्रविष्टियों में संक्रमण पाया गया। इसके पूर्व इसे केले के अन्य कीटविज्ञानियों द्वारा *कोफेने क्यूपेरी* के रूप में पहचाना गया था जो गलत था। इसकी नई पहचान की पुष्टि कॉक्स 1 अनुक्रमण और आकृतिविज्ञान के द्वारा हुई। फाल आर्मीवर्म, *स्पोडोप्टेरा फ्रुगीपर्डा,* जो मक्का का एक विदेशी आक्रामक पीड़क है, तमिल नाडु में केले के सम्पूर्ण जीवन चक्र के दौरान इसका भरण करते हुए पाया गया और अनेक प्राकृतिक शत्रुओं की पहचान की गई। *इरोफाइड कुटकी, फाइलोकोप्ट्रटा म्यूसी* का अनेक शोभाकारी केलों (म्यूसा लेटराइटा) प्रविष्टियों तथा अन्य किस्मों पर पहली बार रिकॉर्ड किया गया। तीन जाति विशिष्ट कोकीनेलिड परभक्षी, *स्टेटहोरस पोउपरकुलस, एस. इंदिरा* और *एस. कैशालिकस* क्रमशः *ओलिगोनाइकस इंडिकस, इयूटेट्रानाइकस ओरिएंटेलिस* और *राउएल्ला इंडिका* पर भरण करते हुए पाए गए। केला माहू का एक परजीव्याभ *(एफेलीनस* एनआर. *गोसिपी*) और एक परभक्षी (*स्काइम्नस नुबिलस*) रिकॉर्ड किए गए।

एफओसी आर1 तथा टीआर4 जीनोम से पहचाने गए परजाति–विशिष्ट प्रभावक जीनों के अध्ययनों के आधार पर प्रजाति 1, प्रजाति 4 और टीआर4 नामक *फ्यूजेरियम मुर्झानि* का पता लगाने के लिए तीन अत्यधिक उच्च प्रजाति–विशिष्ट प्राइमरों को निर्धारित करके उनका सत्यापन किया गया। *एफओसी* टीआर4 के प्रति विशिष्ट जीनों की पहचान के लिए एक लूप–मध्यित समतापीय आवर्धन (लैम्प) मूल्यांकन का मानकीकरण किया गया तथा इस मूल्यांकन की दशाओं को उपयुक्ततम बनाया गया। यह टीआर4 को ज्ञात करने की सबसे त्वरित, सटीक तथा सस्ती नई तकनीक है। जड़ क्षेत्र की मृदा से प्राप्त किए गए फास्फेट को घुलनशील बनाने वाले पांच जीवाणु (पीएसबी) विलगकों में सर्वाधिक फास्फेट घुलनशीलता सूचकांक रिकॉर्ड किया गया। 16S rRNA विश्लेषण से पहचाने गए दो सर्वश्रेष्ठ विलगकों *एंटेरोबैक्टर होर्मेकेई* उपजाति *जियांगफैगेंसिस* (पीएसबी52) और *लेक्लेसिया ऐडेकार्बोजाइलेटा* (पीएसबी54), में पॉट कल्चर प्रयोगों में सर्वोच्च पादप वृद्धि संबंधी गुण, सर्वाधिक उपलब्ध फास्फोरस तथा फास्फटेज एंज़ाइम क्रिया रिकॉर्ड की गई। एक अधिपादपीय तथा छह जड़ क्षेत्र के *ट्राइकोडर्मा*

विलगकों का पॉट कल्चर उपयोग और रिज़ में एफओसी टीआर4 के विरुद्ध परीक्षण किया गया। *टी. एस्पेरेलम* (एनआरसीबी3) + रिज़. *टी. हार्जिएनम* और रिज़ *ट्राइकोडर्मा* जाति (असम) + रिज़. *ट्राइकोडर्मा* जाति (यूपी4) में न्यूनतम मुर्झान स्कोर रिकॉर्ड किया गया तथा पौधे की ऊंचाई, मोटाई, पत्ती क्षेत्र तथा जड़ों की संख्या जैसे ज्यामितीय गुण बढ़ हुए पाए गए। पॉट कल्चर में, *एंटेरोबैक्टर क्लोएकी* उप जाति *डिसोल्वेंस* को अधिपादपीय *टी. एस्पेरेलम* के साथ मिलाकर प्रयोग करने से 90 डीएआई पर एफओसी टीआर4 का प्रभावी नियंत्रण हुआ तथा जैवमितीय गुणों में भी वृद्धि हुई।

तमिल नाडु के पुदेकोट्टई (आलंगगुडी), त्रिचुरापल्ली (इगिरिमांगलम और कोंडायमपेट्टई) तथा थेनी (मुथलापुरम) जिलों में किए गए सर्वेक्षण के दौरान वाणिज्यिक किस्मों नेंद्रन और ग्रेंड नयने के संक्रमित नमनों से प्रकंद सड़न के 23 विलगक प्राप्त किए गए। ग्रेंड नयन टीसी पौध पर विशिष्ट प्रकंद सड़न के लक्षण उत्पन्न करने वाले तीन विलगकों का लक्षण–वर्णन किया गया तथा इनकी 16 S rDNA विश्लेषण द्वारा *क्लेबसिएला वेरिकोला* के रूप में पहचान की गई और नेई पूवन पर सत्यापन भी किया गया। पादप वृद्धि प्रवर्धक/बायोएजेंट के रूप में संभावित उपयोग के लिए एटिनोबैक्टीरिया के 30 विलगकों का कल्चरल आकृतिविज्ञानी आधार पर लक्षण–वर्णन किया गया। स्वस्थ केले के जड़ के आस–पास के क्षेत्र से कवकीय तथा जीवाण्विक जैव नियंत्रण एजेंटों (पीजीपीआर) का विलगन किया गया तथा 16S rDNA (कवकों के लिए) तथा 18S rDNA (जीवाणुओं के लिए), अनुक्रमण के द्वारा आकृतिविज्ञान की दृष्टि से पहचान की गई।

जलगांव तथा बुरहानपुर में क्रमशः दो लगातार वर्षों (2019 और 2020) के दौरान सीएमवी का गहन प्रकोप रिकॉर्ड किया गया जो 11–52.17% और 41.15–75.96% था। इसके अलावा बीआरएस, जलगांव के अनुसंधान खेतों तथा जननद्रव्य संकलन में BBrMV का प्रकोप रिकॉर्ड किया गया। थेनी में केला के बंचीटॉप विषाणु (6.6–60%), BBrMV (2–80%)और सीएमवी (2–11%) प्रकोप रिकॉर्ड किया गया। रेड बनाना में BBrMV का प्रकोप अधिक था और इसके पश्चात् ग्रेंड नैन का स्थान था। शोभाकारी केला संकर और *स्यूसा वेलुनटीना में* चित्ती रोग जैसे लक्षणों की पुष्टि की गई और इसका कारण BBrMV का संक्रमण था। तीन सीएमवी केलों को संक्रमित करने वाले विलगकों (बुरहानपुर, जलगांव और थेनी विलगक) के आरएनए 1, आरएनए2 और आरएनए3 को आवर्धित, क्लोन तथा अनुक्रमित किया गया। केले के धारी मैसूर विषाणु (बीएसएमवाईवी) का एक संक्रामक क्लोन विकसित किया गया। इसे *एग्रोबैक्टीरियम* प्रभेद ईएचए105 के प्रति निश्चल बनाने के पूर्व रेस्ट्रिक्शन डाइजेशन तथा कालोनी पीसीआर द्वारा संक्रामक क्लोन कांस्ट्रक्ट की पुष्टि की गई। BBrMV का संक्रामक c DNA उत्पन्न करने के लिए एक ओवरलैपिंग–एक्सटेंशन पीसीआर (ओई–पीसीआर) के द्वारा BBrMV के पूर्ण लंबाई के कांस्ट्रक्ट के आवर्धन हेतु प्राइमर निर्धारित किए गए।

जीन अभिव्यक्ति के स्तरों के सत्यापन के लिए अप तथा डाउन रेगुलेटिड डीईडी हेतु कुल 42 भिन्न रूप से व्यक्त जीनों (डीईजी) की सामान्य रूप से पहचान की गई जिससे ट्रांसक्रिप्टोम आंकड़ों द्वारा जीन अभिव्यक्ति के स्तरों का पता चला। बीवीटीवी के लिए भिन्न रूप से व्यक्त जीनों के प्राइमरों के 38 सैट निर्धारित किए गए।

पूर्व परिणामों की पुष्टि के लिए एक कीटरोधी जालघर में उग्र माहुओं का उपयोग करके डीबीटीवी के विरुद्ध प्रतिरोध हेतु द्विगुणित जननद्रव्य प्रविष्टियों (एए और बीबी) की छंटाई का कार्य जारी रहा। कुल 14 एए द्विगुणितों ने बीबीटीवी संक्रमण के विशिष्ट लक्षण व्यक्त किए। मांगूथमांग और जंगल केला II को छोड़कर कोई भी अन्य द्विगुणित उग्र माहू से बार–बार 3 बार संरोपित किए जाने के बावजूद भी संक्रमित नहीं हुआ। रिप्लीकेस जीन/बहुविषाणु जीन कांस्ट्रक्ट से RNAi द्वारा प्राप्त किए गए 11 पराजीनी वंशक्रमों को जालघर में बीबीटीवी के साथ पौधों को संरोपित करते हुए चैलेंज किया गया तथा इन पौधों में जो गुच्छे लगे उनमें बंचीटॉप के कोई भी लक्षण व्यक्त नहीं हुए।

सात स्थानों पर पूवन पौधों से व्युत्पन्न ईपिसोमल बीएसएमवाईवी से मुक्त ऊतक संवर्धन पर प्रक्षेत्र मूल्यांकन के आंकड़ों से भूस्तारी द्वारा उगाए गए पौधों की तुलना में वृद्धि तथा उपज संबंधी प्राचलों में उल्लेखनीय अंतर प्रदर्शित हुआ तथा छह स्थानों पर ऊतक संवर्धित पौधों में धारी रोग के लक्षण व्यक्त नहीं हुए।

जड़ में घाव करने वाले सूत्रकृमि (*प्रेटिलेंकस कॉफीई*) के विरुद्ध प्रतिरोध के लिए केले के जीनप्ररूपों के मूल्यांकन हेतु एक सरल त्वरित छंटाई प्रोटोकॉल विकसित किया गया तथा मानक संदर्भ जीनप्ररूपों के साथ इसका मूल्यांकन किया गया। इस विधि में हानि की सीमा (घावों) तथा सूत्रकृमि की समष्टि के आधार पर तीन महीनों में ही जीनप्ररूपों की प्रतिक्रिया ज्ञात की जा सकती है।

ऊतक संवर्धित ग्रैंड नैन पर संरोपण के 24 घंटे पूर्व 50 और 100 µM सांद्रता की दर पर सेलिसिलिक अम्ल युक्त पानी के साथ मृदा का भराव करने पर तुलनीय की अपेक्षा पॉट दशाओं के अंतर्गत जड़ गांठ सूत्रकृमि (क्रमशः30 और 41%) तथा जड़ में घाव करने वाले सूत्रकृमि (क्रमशः 67 और 68%) जड़ समष्टि कम हुई।

प्रौद्योगिकी हस्तांतरण

वर्ष 2020 के दौरान भा.कृ.अ.प.–एनआरसीबी द्वारा नौ रेडियो वार्ताएं प्रसारित की गईं तथा विभिन्न दैनिक समाचार–पत्रों और पत्रिकाओं में 32 प्रेस टिप्पणियां प्रकाशित हुईं। संस्थान द्वारा 'अंतरराष्ट्रीय केला सम्मेलन (आईसीबी–2020)' सफलतापूर्वक आयोजित किया गया और केन्द्र ने राष्ट्रीय स्तर की दो प्रदर्शनियों में भाग लिया। 'फ्यूजेरियम मुर्झान' उष्णकटिबंधीय प्रजाति 4 पर अंतरराष्ट्रीय प्रशिक्षण कार्यक्रम तथा परिसर से इतर दो प्रशिक्षणों सहित कुल चार परिसर प्रशिक्षण कार्यक्रम आयोजित किए गए। इनके अलावा केले की खेती, मूल्यवर्धन और निर्यात के विभिन्न पहलुओं पर भा.कृ.अ.प. –एनआरसीबी द्वारा वर्चुअल प्लेटफार्म पर सात प्रशिक्षण कार्यक्रमों में भाग लिया गया और आठ वेबिनार की श्रृंखला आयोजित की गई। संस्थान में आंध्र प्रदेश फूड प्रोसेसिंग सोसायटी, आंध्र प्रदेश सरकार; भारतीय सूचना प्रौद्योगिकी, डिजाइन एवं विनिर्माण संस्थान, कांचीपुरम; राष्ट्रीय डिजाइन एवं अनुसंधान फोरम, बंगलुरू; डॉ. वाईएसआर बागवानी विश्वविद्यालय, आंध्र प्रदेश और के. रामाकृष्णन प्रौद्योगिकी महाविद्यालय, त्रिचुरापल्ली के साथ समझौता ज्ञापन पर हस्ताक्षर किए।

सम्पर्क एवं सहयोग

भा.कृ.अ.प.–एनआरसीबी के अनेक अंतरराष्ट्रीय संस्थानों के साथ अनुसंधान सहयोग संबंधी कार्यक्रम चल रहे हैं। इन संस्थानों में आईआईटी, नाइजीरिया; बायोवर्सिटी इंटरनेशनल, फ्रांस; केयूएल, बैल्जियम; और क्वींसलैंड विश्वविद्यालय, आस्ट्रेलिया शामिल हैं। संस्थान के कई राष्ट्रीय संस्थानों के साथ भी सम्पर्क स्थापित हैं जिनमें शामिल हैं बीएआरसी, मुम्बई; विज्ञान एवं प्रौद्योगिकी विभाग तथा जैवप्रौद्योगिकी विभाग, नई दिल्ली; एपीडा; तमिल नाडु कृषि विश्वविद्यालय, कोयम्बटूर; एनआईटी, त्रिचुरापल्ली और केएनसीईटी, थोट्टायम, तमिल नाडु केन्द्र के भा.कृ.अ.प. के अन्य संस्थानों के साथ भी अनुसंधान सहयोगी कार्यक्रम चल रहे हैं। इन संस्थानों में शामिल हैं – भा.कृ.अ.प. –एनबीपीजीआर, नई दिल्ली;भा.कृ.अ.प.–आईआईएचआर, बंगलुरू और भा.कृ.अ.प.–सीआईएई (क्षेत्रीय केन्द्र), कोयम्बतूर। डीबीटी–एनईआर के अंतर्गत देश के विभिन्न भागों में स्थित 50 से अधिक संस्थान भा.कृ.अ.प. –एनआरसीबी से सम्बद्ध हैं। भा.कृ.अ.प.–एनआरसीबी फलों पर कार्यरत भा.कृ.अ.प.–अखिल भारतीय समन्वित अनुसंधान परियोजना (फल) के 11 केन्द्रों के साथ भी सम्पर्क बनाए हुए है। ऊतक संवर्धन उद्योग केले के बड़े पैमाने पर प्रबंधन, किसानों, निर्यातकों, राज्य बागवानी तथा कृषि विभागों और स्वयं सहायता समूहों के साथ इस केन्द्र के विभिन्न अनुसंधान एवं विकासात्मक गतिविधियों में संबंध बने हुए हैं।

मानव संसाधन विकास एवं शिक्षा

मानव संसाधन विकास के अंतर्गत केन्द्र के वैज्ञानिकों द्वारा वर्चुअल प्लेटफार्म पर 12 प्रशिक्षण कार्यक्रमों में भाग लिया गया। एनआरसीबी के वैज्ञानिकों ने अंतरराष्ट्रीय तथा राष्ट्रीय प्रतिष्ठा प्राप्त विभिन्न जर्नलों में 11 अनुसंधान पत्र प्रकाशित किए; अंतरराष्ट्रीय केला सम्मेलन (आईसीबी–2020) में 85 अनुसंधान पत्र प्रस्तुत किए गए तथा विभिन्न ई–सम्मेलनों में भी चार अनुसंधान पत्र प्रस्तुत किए गए। संस्थान को विभिन्न सम्मेलनों में एक सर्वश्रेष्ठ शोध प्रबंध, 14 सर्वश्रेष्ठ मौखिक और 10 सर्वश्रेष्ठ पोस्टर प्रस्तुतियों के पुरस्कार प्राप्त हुए। वर्ष 2020 के दौरान तीन छात्रों ने अपनी पीएच.डी. उपाधि सफलतापूर्वक पूरी की, जबकि 17 छात्र केन्द्र में बी.टेक, एम.टेक, एम. एससी., पीएच.डी. तथा तथा डॉक्टरेट उपरांत अनुसंधान कार्य में रत हैं।

केन्द्र द्वारा जनवरी–दिसम्बर 2020 के दौरान कुल 32,34,305 रुपये का राजस्व सृजित किया गया।

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

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

Collection

During the reporting period, five germplasm accessions have been collected from secondary sources, *viz.* TNAU, Coimbatore; UAS, Bengaluru; and BRS, Kannara.

Table 1. Germplasm accessions collected from the secondary sources

Sl. No.	Name	Source
1	Neyvedia kadali	TNAU, Coimbatore
2	Nakietemb	TNAU,Coimbatore
3	Ornamental banana	GKVK, Bengaluru
4	KNR 290	BRS, Kannara
5	Makkale Potty	BRS, Kannara

Characterization

Morphotaxonomic characterization

Morpho-taxonomic characterization has been completed for 217 accessions belonging to TNAU, Coimbatore, using IPGRI *Musa* descriptor leading to the identification of duplicates and synonyms. Morpho-taxonomic characterization was done for the four accessions collected using IPGRI Musa descriptor leading to the identification of genomic and subgroups.

Table 2. List of accessions characterized

Sl. No.	NRCB accession No.	Name	Identified genome	Subgroup and Type
1	2601	Phule Pride	AAA	Cavendish
2	2612	Co 2	AB	Ney Poovan
3	2613	H 531	AAB	Mysore
4	2614	H 97/7.4	ABB	Pisang Awak

Molecular characterization

DNA finger prints have been developed for the NRCB released varieties using SCoT markers and the variety-specific bands produced by individual primers have been documented. This will facilitate the registration of new varieties with PPV&FRA, New Delhi, and protect our varieties in the context of IPR issues.

Biochemical profiling / analysis of total sugars, reducing sugars, chlorophyll, total carotenoid, phenols and flavonoids have been completed for the newly released varieties.

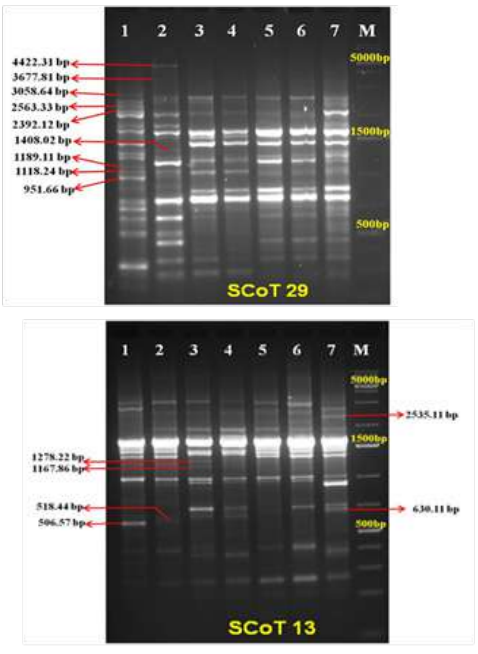


Fig.1. DNA profling of ICAR-NRCB released varieties

Registration

IC numbers have been obtained for three AICRP centres, namely BRS, Kannara (6 Nos.), BRS, Kovvur (5 Nos.), and TNAU, Coimbatore (1 No.) and ICAR-NRCB, Trichy (38 accessions). This included varieties like Phule Pride and CO 2 released from BRS, Jalgaon and TNAU, Coimbatore respectively and it facilitated their varietal notification.

Evaluation

Field evaluation of cv. Ney Poovan derived from different explants Performance of cv. Ney Poovan (main crop) derived from different explants, namely shoot tip, male flower bud and cormlet, was evaluated and plants derived from shoot tip were the best with respect to yield and crop duration, followed by those derived from cormlet, sucker and male flower bud.

Table 3. Attributes of cv. Ney Poovan derived from different explants in field evaluation

Explant	Plant height (cm)	Pseudostem girth (cm)	No.of leaves	Bunch weight (kg)	No. of fruits/ hands	Total no. of fruits	Crop duration (days)
Sucker	269.48±5.25^{ab}	74.42±0.99^{bc}	10.28±0.80^{ab}	13.50±0.44^{b}	12.85±0.50^{ab}	159.85±0.81^{b}	315.28±1.25^{a}
Shoot tip	279.57±4.18^{a}	78.33±0.69^{a}	11.57±0.64^{a}	15.12±0.30^{a}	14.00±0.43^{a}	168.14±1.30^{a}	332.57±2.79^{c}
Cormlet	267.12±7.14^{b}	76.77±1.11^{ab}	10.42±0.57^{ab}	14.52±0.38^{ab}	13.62±0.47^{a}	164.28±2.43^{ab}	343.85±5.39^{d}
Male bud	263.15±0.74^{b}	69.71±0.98^{d}	9.14±0.50^{b}	11.50±0.40^{c}	11.85±0.50^{b}	152.00±1.11^{c}	372.14±1.75^{e}

Field evaluation of cvs. Ney Poovan and Red Banana derived from ECS explants

Evaluation of ECS derived plants of cvs. Ney Poovan and Red banana in the farmers' fields along with sucker and shoot tip derived plants indicated no somaclonal variation in ECS derived plantlets and the bunch weight of ECS derived plantlets of both cultivars were on par with those of controls.

Field evaluation of ITC accessions

Out of 124 ITC accessions evaluated under field conditions, eight diploid ITC accessions, namely Selangor 2 (ITC 0629), Pa Rayong (ITC 0672), Tjau Lagada (ITC 0090), Pahang (ITC 0727), Pu te La Bum (ITC 0446), Type 2x (ITC 0069), M.ac. 11/9-02 (ITC 1520) and A 3617/9 (ITC 0530) were found to be pollen fertile, Sigatoka resistant and produced more number of fruits.

Evaluation of germplasm for their special traits

Field evaluation of the germplasm has led to the identification of some promising ones with special traits like high yield, taste and high carotene rich pulp, wilt resistance, etc. and the details are tabulated below.

Fig. 2. Bunches of tissue culture bananas cv. Ney Poovan derived from different explants

Fig. 3. Performance of ECS derived plants of cvs. Ney Poovan and Red Banana under field conditions

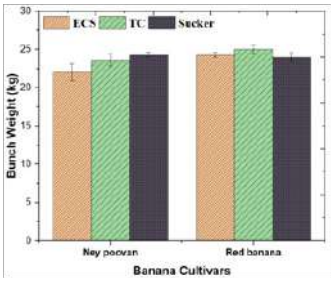


Fig. 4. Bunch weight of Ney Poovan and Red Banana derived from different explants

Table 4. Promising germplasm accessions with desirable traits

Sl. No.	NRCB Accession No.	ITC No.	Name	Special traits
1	1664	547	Chinese Cavendish	High yield than local Madhukar
2	00 17		Manjahaji	High yield, Resistant to *Foc* field (Race 1)
3	0670	553	NRCB selection 0012	Aromatic and carotene rich fruit pulp with strong fruit pedicel
4	0645	570	Williams	High yielding (40 kg bunches)
5	1144	1437	TMB2 x 9128-3	Synthetic hybrid (Tjau Lagada x Pisang Lilin). Resistant to fusarium wilt race 1. Long bunch with 16-20 hands. Light Orangish pulp with TSS of 23-24^{0}Brix.

Fig. 5. ITC 570 Williams with high yield

Fig. 6. NRCB selection with carotene rich pulp

Screening of ITC accessions for *Fusarium* wilt resistance under sick plot conditions

About 124 ITC accessions have been planted in the sick plot at Muthalapuram, Theni of Tamil Nadu for screening against *Fusarium* wilt resistance and the internal disease scoring has been completed for about 80 accessions. Out of 80 accessions scored for internal symptoms, 34 showed resistant reactions and the rest were susceptible. The details of resistant accessions are tabulated below.

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

S.No.	Level of Resistance	Disease Score	No. of diploids	No. of triploids	No. of tetraploids	Total
1.	Immune	0	10	6	3	19
2.	Highly Resistant	1	2	4	1	7
3.	Resistant	2	5	2	1	8

Effect of different spectral LEDs on growth and development of banana under *invitro* conditions

Maximum shoot proliferation was obtained in shoot tip explants under red light while yellow light favored the growth and development of single shoots. In case of direct regeneration using immature male flower bud explants, red light favored the early development of meristematic clumps and more no. of shoot buds, while green light promoted shoot elongation. The highest percentage conversion of somatic embryos and plantlet development was obtained under blue and red light spectrum. In contrast, green light recorded the minimum conversion of somatic embryos compared to white fluorescent light indicating their inhibitory effect on *in vitro* growth and development of somatic embryos.

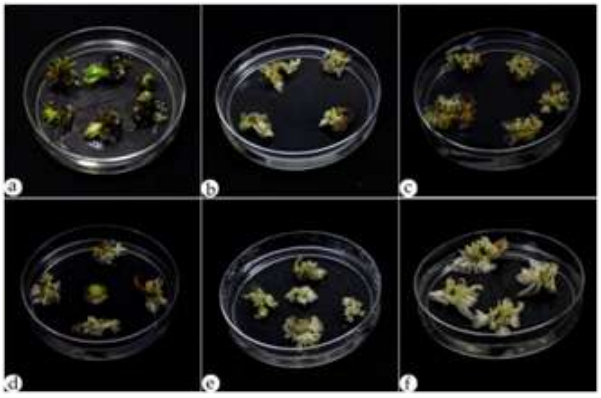


Fig. 7. Meristematic clump formation in a. Fluorescent lights; b. White LEDs; c. Red LEDs; d. Blue LEDs; e. Green LEDs; f. Yellow LEDs

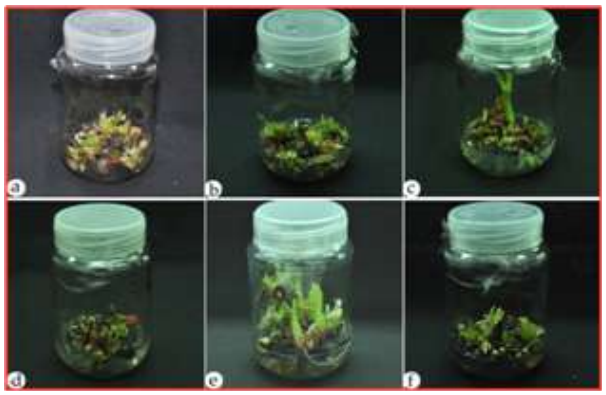


Fig. 8. Shoot meristem conversion in a. Fluorescent lights; b. White LEDs; c. Red LEDs; d. Blue LEDs; e. Green LEDs; f. Yellow LEDs

Synthetic seed maker

A prototype has been developed for the preparation of synthetic seeds from somatic embryos @ 210-360 synthetic seeds per minute and 90-95% germination was observed in synthetic seeds.

Fig. 9. Encapsulation of somatic embryos and their germination

Genetic fidelity testing

About 20 batches of tissue culture plants of cvs. Grand Naine, Nendran, Karpuravalli and Red Banana were tested for their genetic fidelity using ISSR markers and reports were issued.

Supply of planting material

Around 722 tissue cultured plants and 8,725 suckers of other varieties have been supplied to banana growers.

High yielding variant of TMB 2 x 9128 - 3 (ITC N0. 1437)

Each four plants of 120 ITC accessions have been planted at Muthalpuram, Theni district for screening against Foc Cavendish infecting race 1. Of which, TMB 2 x 9128-3 (ITC N0. 1437), an improved diploid derived from Tjau Lagada x Pisang Lilin was found to be resistant to race 1. In this accession, one plant showed better performance in terms of number of fruits per hand (20) with the bunch weight of 19.5 kg. which is 34.5% higher yield than the average yield of original plant (14.5kg/ bunch). To confirm its performance the shoot multiplication has been initiated from the suckers extracted from this elite plant for large scale evaluation.

Fig. 9a. TMB 2 x 9128-3 (ITC N0. 1437)

4.1.2 Improvement of banana through conventional breeding

Nendran (IC 251068) based progenies

Out of five Nendran based hybrids established, two progenies of Nendran x Pisang Jajee were seeded in nature and exhibited Karpuravalli traits with an average bunch weight of 7 and 5 kg, respectively. One diploid porgeny of the same cross combination was similar to Nendran with an average yield of 4 kg with no seeds. The remaining two progenies from Nendran x Pisang Lilin (Progeny No. 900) and Nendran x cv. Rose (Progeny No. 901) were similar to Nendran; progeny 900 had less pollen grains and pulpless fruits with seeds and progeny 901, a polleniferous diploid.

Fig. 10. Progeny No. 900 (Nendran x Pisang Lilin)

Fig. 11.Progeny No. 901 (Nendran x cv. Rose)

Poovan based progenies

All the established Poovan based progenies (8) were similar to the female parent, Poovan. The male parent, Pisang lilin, was not a good, compatible parent for Poovan as all the six progenies of this cross combination produced pulpless fruits whereas Calcutta 4 was found to be the best compatible male parent as their progeny (two) produced parthenocarpic fruits.

Both the open pollinated progenies of Ennabenian (Progeny No. 913 and 940) were found to be tetraploids and produced 12 kg bunches with parthenocarpic fruits.

Fig. 13. Progeny No. 913 (Ennabenian OP)

Fig. 12. Progeny No. 910 (Poovan x Calcutta 4)

Fig. 14. Progeny No. 940 (Ennabenian OP)

Kaveri Saba (Accession no. 2574) based progenies

A total of four open pollinated progenies of Kaveri Saba x Pisang Lilin produced an average bunch yield of 9-12 kg of which three were found to be tetraploids and one was a diploid. Out of two OP progenies of Kaveri Saba x Chengdawt, one (progeny 943) was found to be tetraploid and promising with average yield and high cooking quality irrespective of the presence of one to two seeds per bunch. Out of three progenies of Kaveri Saba x Calcutta 4, (914, 915 and 916), one was found to be Pisang Awak group tetraploid (914) and the remaining two were like Saba.

Pisang Lilin was found to be the best male parent for Kaveri Saba, as they produce parthenocarpic bunches with good cooking quality. Progeny 964 yielded 28 kg bunch

which had 11 hands and 13 fruits per hand. It should be further evaluated on a large scale to confirm its potential.

Fig. 15. Progeny No. 943 (Saba x Chengdawt)

Fig. 16. Progeny No. 965 (OP of Saba x Pisang Lilin)

Kothia (IC No. 250543) based progenies

In general, Kothia based progenies produced only pulpless fruits but the open pollinated progenies produced good bunches. Of the two open pollinated progenies, Progeny No. 932 (OP of Progeny No. 480) produced parthenocarpic bunch with high carotenoid content whereas Progeny number 933 (OP of No. 647.), a triploid produced Cavendish type parthenocarpic bunches with an average yield of 12 kg.

Fig. 17. Progeny No.932 –OP of 480 (Kothia x C4)

Fig. 18. 932 –OP of 480 (Kothia x C4)

Promising hybrids

Progeny No. 434 (Udhayam x Chengdawt) yielded 15 kg bunch weight and was found to be superior for long shelf life (12 days) and high carotenoid content (93.62 µg/gDW) which was 14-fold greater than that of Grand Naine. It had 8–10 hands per bunch and fruits are like Peyan and the fruit skin is very thick, pulp is orange colored and granular as in Peyan.

Fig. 19. Progeny No 434 (Udhayam xChengdawt)

Progeny No 964 (OP of Saba x Pisang Lilin) yielded 28.5 kg bunch weight having good cooking quality and highly preferred by consumer than Saba and other cooking type cultivars like Monthan.

Fig. 20. Progeny No. 964 (OP of Saba x Pisang Lilin)

Screening of progenies against *Foc* Race1 in hotspot area (Theni)

Out of 52 progenies screened, Progeny No. 15 (Sanna chenkadali x Lairawk), 97 (Pisang Jajee x Matti), 426 (*Musa ornata* x *M. ac. burmannica*), 428 (cv. Rose x Pisang Lilin), 528 (Kothia x Calcutta – 4), 821 (Udhayam x Pisang Lilin) were found to be immune to *Foc* race 1 under sick plot conditions.

Screening of diploid hybrids for resistance to root-lesion nematode, *Pratylenchus coffeae*

Seven diploid hybrids, *viz*. 15 (Sanna chenkadali x Lairawk), 97 (Pisang Jajee x Matti), 115 (Karpooravalli x Pisang Lilin), 134 (Anaikomban x Matti), 148 (Pisang Jajee x Lairawk), 207 (Matti x cv.Rose), and 429 (cv. Rose x Pisang Lilin) were evaluated for their reaction to root-lesion nematode (*Pratylenchus coffeae*) under pot conditions by challenge inoculation method. Based on nematode damage and its reproduction, progeny 115 was found resistant.

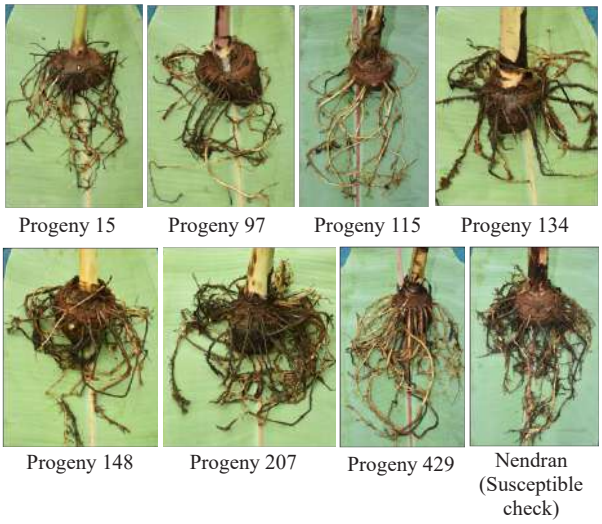


Fig. 21. Response of diploid hybrid progenies to root-lesion nematode, *Pratylenchus coffeae*

Adaptive Research Trial on NCR 17

Adaptive Research Trial for NCR 17 along with the other Nendran based hybrids has been conducted at two locations, namely Udumalaipettai and Coimbatore. In general, Nendran x cv.Rose progenies are performing better than Nendran x Pisang Lilin progenies for all the yield parameters. NCR 2, NCR 10 and NCR 17 performed better at Coimbatore location than Udumalaipettai. At Udumalaipattai, all the progenies recorded greater number of fruits/ bunch than the better parent, Nendran. Standard heterosis was calculated for yield parameters of all the hybrids and three hybrids recorded high standard heterosis for bunch weight in both locations of which more than 20% standard heterosis was recorded in NCR 2 and NCR 17 (Table 6).

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

Sixty-three inter-specific ornamental banana hybrids were shortlisted out of 362 based on the attractive colour of the pseudostem, foliage, fruits and bracts (Table 7) and planted in a replicated trial for further evaluation. In addition to attractive colour, few short listed progenies possess 1–5 persistent non-revolute bracts during male phase with long and erect rachis for cut-flower usage (**Fig. 22 and 23**).

Fig. 22. Progenies with 1 to 5 numbers of persistent non-revolute bracts during male phase

Table 7. Number of inter-specific ornamental banana hybrids short-listed for replicated trials

S. No.	Crosses	Nos.	Shortlisted
1	*M. rubra* × *M. acuminata* subsp. *zebrina*	37	10
2	*M. ornata*× *M. rubra*	116	14
3	*M. ornata* × *M. acuminata* subsp. *zebrina*	119	35
4	*M. ornata* × *M. velutina* subsp. *markkuana*	90	4
	Total	362	63

Fig. 23. Progenies with long and erect rachis possessing non-revolute bracts for cut-flower usage

Table 6. Standard heterosis of Nendran based hybrids for yield traits at two locations

Udumalaipettai					Coimbatore			
Progeny Name	Bunch weight	Total no. of fruits	Number of hands	No. of fruits in 2nd hand	Bunch weight	Total no. of fruits	Number of hands	No. of fruits in 2nd hand
NCR-2	44.944	11.168	6.06	6.45	46.429	12.023	14.286	3.226
NCR- 5	5.618	-12.437	0.00	0.00	2.381	6.158	14.286	0.000
NCR-8	0.000	1.523	0.00	-3.22	0.000	10.557	14.286	3.226
NCR-10	-4.494	-2.284	0.00	-3.22	10.714	5.279	14.286	0.000
NCR-17	46.067	9.391	9.09	9.67	50.000	13.196	17.857	3.226
NCR-18	-5.618	-5.330	-3.03	-1.61	-3.571	-5.572	17.857	-1.613
NCR-19	-12.360	-9.898	0.00	-8.06	-1.190	1.173	17.857	0.000
NCR-21	0.00	-7.107	-3.03	-1.61	5.952	1.760	14.286	-6.452
NPL 28	-19.10	1.015	3.03	4.83	-14.286	2.639	10.714	-3.226
NPL-30	-17.97	5.838	9.09	8.06	-21.429	22.287	14.286	-1.613
NPL-33	-14.60	-2.792	9.09	-1.61	-10.714	0.293	10.714	-4.839
NPL-34	-23.59	-11.16	-6.06	0.000	-10.714	-0.880	10.714	-3.226
NPL-36	-25.84	-14.97	-15.15	0.000	-21.429	-1.466	3.571	-1.613
NOP-43	-14.60	-5.58	-3.03	3.22	-8.333	5.572	14.286	0.000
NOP-44	-8.98	-8.37	-3.03	-4.83	-2.381	-2.053	14.286	0.000
NOP-45	-4.49	-11.67	-3.03	-8.06	3.571	-2.933	14.286	0.000
NOP-46	-14.60	-4.06	-3.03	-1.61	-10.714	-0.880	10.714	0.000
NOP-47	-3.37	4.56	0.00	1.613	-7.143	4.692	10.714	1.613

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

A total of 13 core collection accessions representing various genomic groups which showed resistance in the earlier pot screening trials were established in pots with five replications each for confirmation. Out of 61 accessions screened for *Fusarium* wilt resistance under pot culture conditions, only H-2 was found to be resistant.Genotyping of 153 germplasm accessions has been completed for 15 primers using automated electrophoresis system.

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

In vitro mutagenesis in cv. Grand Naine

Physical mutagenesis alone and combination of physical + chemical mutagenesis of ECS have been attempted in cv. Grand Naine and the cultures are in the germination medium as listed below (Table 8). The optimal dose of Beauvericin to be used for *in vitro* screening of mutated Grand Naine has been determined as 6 microM.

Table 8. Details of the combined treatment of physical and chemical mutagens given to cv. Rasthali ECS

S.No.	Mutagen	Explant	Stage of multiplication
1	20 Gy	ECS	Germination
2	EMS + Gamma irradiation at 15, 20, 25 and 30 Gy	ECS	Germination
3	Gamma irradiation at 10 & 40 Gy	Shoot tip	Single plant
4	Gamma irradiation at 10 & 20 Gy		Primary hardening
5	SA + in-vitro screening in Beauvericin		Primary hardening
6	EMS + *in-vitro* screening in Beauvericin	ECS	

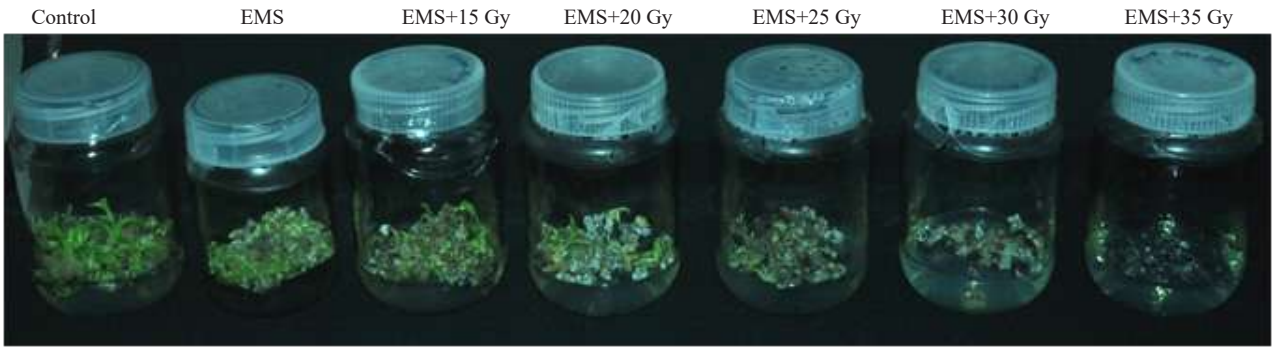


Fig. 24. Response of cv. Rasthali ECS treated with Gamma irradiation + EMS
EMS + Gamma treated ECS of Grand Nain in germination medium

Screening of *in vitro* derived putative mutants for *Fusarium* wilt (Race 1) resistance

NRCBGNM 1 derived from gamma irradiated ECS showing resistance to race 1 under sick plot conditions was mass multiplied and planted for large scale field evaluation in two hotspots of Tamil Nadu. NRCBGNM 2 derived from EMS treated ECS which showed resistance to race 1 under pot culture conditions were mass multiplied *in vitro* and planted in the sick plot at Theni for confirmation. One set of plants derived from EMS treated shoot tips has been subjected to pot culture studies for screening against race 1.

Cv. Grand Naine for Tropical Race 4

NRCBGNM 1, 3, 13 and 15 derived from EMS treated ECS and NRCBGNM 3 derived from DES treated ECS which showed resistance to race 4 under pot culture conditions were mass multiplied *in vitro* and planted at ICAR-NRCB farm and in the sick plot at Theni for confirmation. One set of plants derived from EMS treated shoot tips have been subjected to pot culture studies for screening against tropical race 4.

Fig. 25. Large scale field evaluation of NRCBGNM 1 in hot spot area

Cv. Rasthali

Nine *Fusarium* wilt tolerant mutants of cv. Rasthali identified from sick plot conditions were multiplied through macropropagation and planted in the sick plot at Theni for further confirmation and simultaneously they have been initiated *in vitro* for mass multiplication and large-scale evaluation in hotspot areas.

Fig. 26. Macropropagated Fusarium wilt race 1 tolerant mutants of cv. Rasthali ready for sick plot evaluation

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

Thirty-three secondary hardened putative androgenic haploids were produced from diploid Ney Poovan (AB). The ploidy analysis of 20 putative haploid plants out of 33 using flow cytometry (Fig. 27) and stomatal characteristics (Fig.28) revealed all as tetraploids (4n=44). All the 20 confirmed tetraploids of putative microsporial origin were field planted on 4th October, 2020 to study their growth and yield traits (Fig. 29).

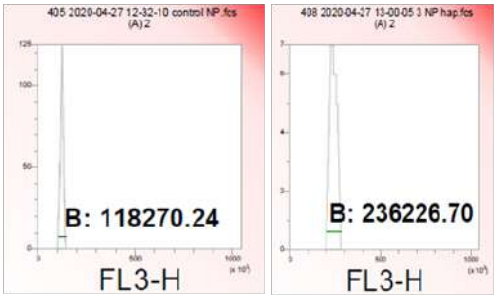


Fig. 27. The PI (propidium iodide) fluroscence histogram peak of nuclei from diploid (2n=22) and tetraploid (4n= 44) Ney Poovan leaf samples using flowcytometry (CyFlow, Cube8 from Sysmex).

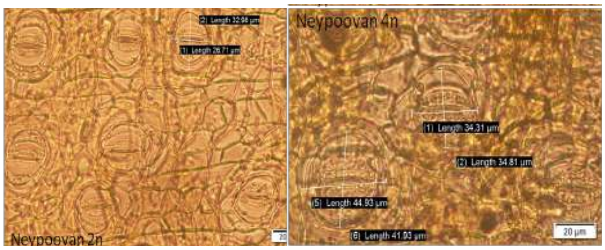


Fig. 28. Stomata characteristics in the leaf epidermis (Adaxial) of diploid and tetraploid Ney Poovan

Fig. 29. Field view of Ney Poovan tetraploids (4n=44) with putative androgenic origin

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

Virescent (greenish) pseudostem, a somaclonal variant found in tissue culture raised Nendran gardens grown in Tamil Nadu and Karnataka at the rate of 1.0 to 2.0% were collected and evaluated for their growth and yield characteristics at ICAR-NRCB Research Farm (Fig. 30). All the measured growth and yield parameters of Nendran with virescence were statistically on par with that of normal clones (Table 9).

Fig. 30. Somaclonal variation within the virescent (green) pseudostem of Nendran with pinkish and virescent petiole margin

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)

gRNA sequence was designed for the conserved region of candidate R gene (LRR-RLP) against Foc race 1 and cloned into binary vector pRGEB31 under rice snoRNA U3 promoter using BsaI restriction site and confirmed through PCR.

Table 9. Growth and yield characteristics of Nendran with virescent (greenish) pseudostem and normal clones at ICAR-NRCB Research Farm

Treatment*	Plant girth (cm)	Plant height (cm)	Number of leaves at shoot-ing	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Days taken for shooting	Num-ber of hands	Number of fruits in second hand
Virescent Nendran (15 Nos.)	48.9±5.7	238.3±15.1	13.5±2.1	148.4±13.7	57.3±4.0	42.1±15.2	219.7±21.8	5.6±0.5	9.8±0.8
Normal Nendran (5 Nos.)	51.6±1.1	239.0±17.5	13.2±1.5	148.6±19.5	54.6±3.8	51.4±14.4	229.8±35.7	5.8±0.4	10.2±0.8
CV (%)	10.26	6.56	14.56	10.24	6.97	33.85	11.50	8.75	7.97
SE(d)	2.624	8.077	1.008	7.847	2.039	7.761	13.198	0.255	0.407

Eighteen genes were selected based on RNA Seq data for validation through QRT-PCR analysis in resistant and susceptible cultivars upon Foc TR4 infection at 0, 24 and 48 hrs. Based on the expression, three candidate R genes (R2, R3, R4) were selected. R2 (CC-NBS-LRR), R3 (LRR-RLP) showed four-fold and R4 (LRR-RLK) showed three-fold upregulation in the resistant cultivar upon infection than the susceptible cultivar (Fig. 31). All the three candidate R genes were cloned and sequenced from resistant and susceptible cultivars (Fig. 32). Motifs and domains were identified for R gene candidate(s) which clearly shows that R2 is a CC-NBS-LRR class of plant disease R gene and R3 and R4 are TM-LRRs with signal peptide, TM domain and an additional kinase domain in R4.

Genic SSR markers associated with Foc race 1 and TR4 were identified which was found to differentiate the resistant and susceptible cultivars (Fig. 33 and 34). These markers were also validated on reported Race1 and TR4 resistant and susceptible cultivars as well as in the mapping population of Matti x cv. Rose.

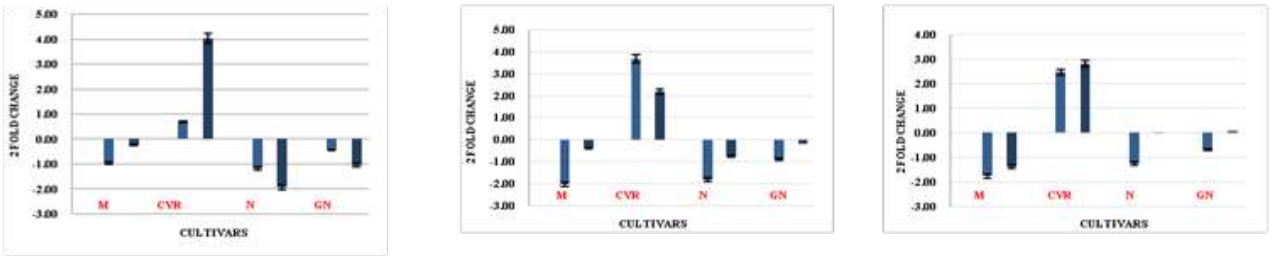


Fig. 31. Expression of R2, R3 and R4 upon Foc TR4 inoculation at 0, 24 and 48 hrs in resistant (cv. Rose - CVR) and susceptible cultivars (Grand Naine - GN, Matti-M and Namarai-N)

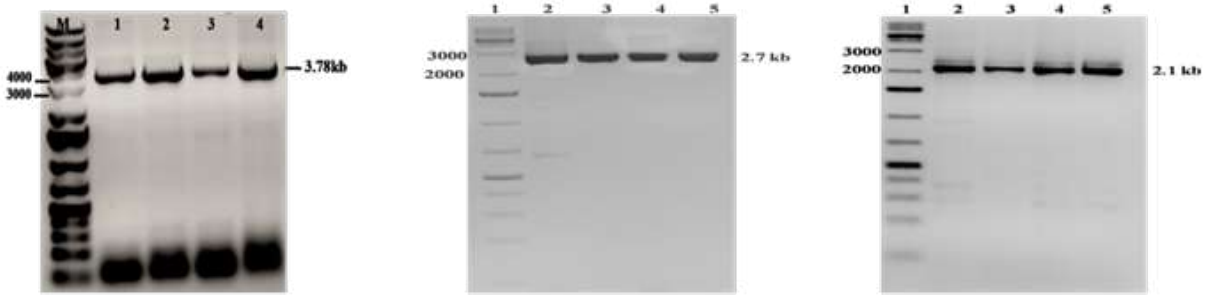


Fig. 32. Amplification and cloning of candidate R genes (R2, R3 and R4). Lane 1: 1kb Plus Marker; Lane 2: cv. Rose; Lane 3: Matti; Lane 4: Grand Naine; Lane 5: Namarai

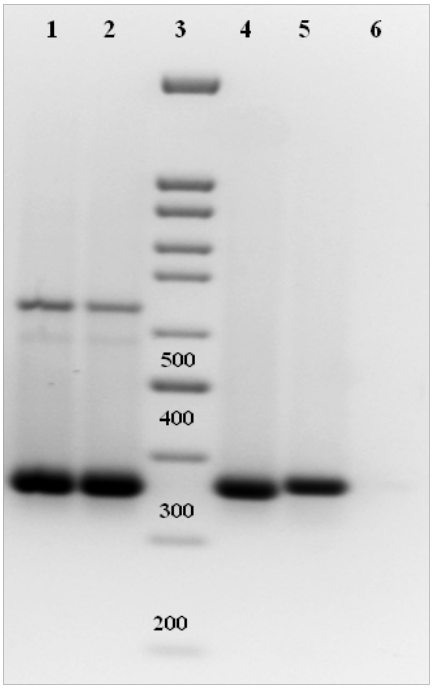


Fig.33. Genic SSR marker (SSR-430) associated with Foc Race 1. Lane 1 – Williams; Lane 2 – Grand Naine; Lane 3 – 100 bp marker; Lane 4 – Gros Michel; Lane 5 – Lady Finger; Lane 6 – Negative

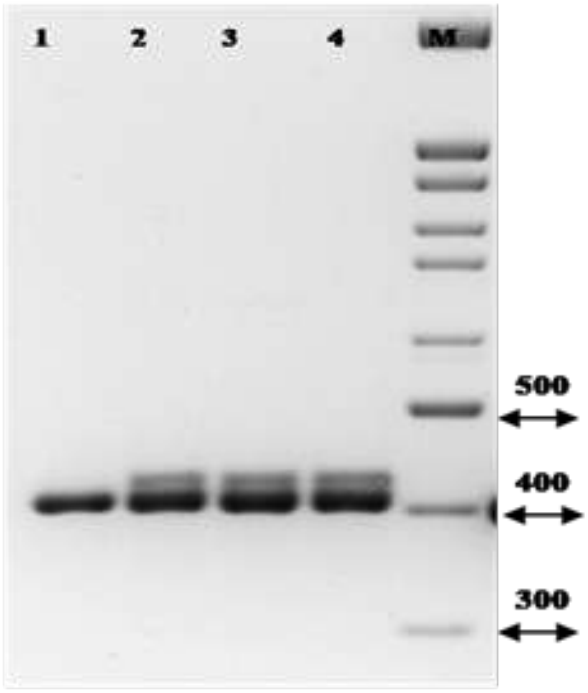


Fig. 34. Genic SSR marker (SSR-R3) associated with Foc TR4. Lane 1 – cv. Rose; Lane 2 – Grand Naine; Lane 3 – Matti; Lane 4 – Namarai; Lane 5 – 100 bp marker

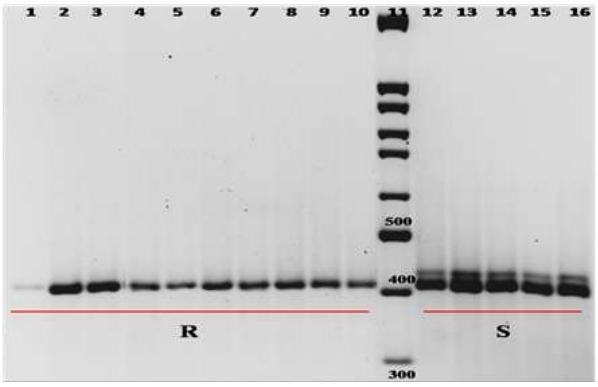


Fig. 35. Validation of genic SSR marker (SSR-R3) associated with Foc TR4. Lane 1 – Pisang Linin; Lane 2 – C4; Lane 3 – CVR; Lane 4 - FHIA 21; Lane 5 – Tani; Lane 6 – PJB; Lane 7 – P berlin; Lane 8 – Imbogo; Lane 9 – Alphon; Lane 10 – H201; Lane 11 –100bp marker; Lane 12 – GN; Lane 13 –Anaikomban; Lane 14 – Matti; Lane 15 – Kadali; Lane 16 – Namarai

Fig. 36. Validation of genic SSR marker (SSR-R3) associated with FocTR4 in Matti x cv. Rose progenies. Lane 1 - cv. Rose (AA); Lane 2 – Matti (AA); Lane 3-13 – IIHR 1 to 11; Lane 14 – 200; Lane 15 – 201; Lane 16 – 207; Lane 17 – 213; Lane 18 – 53; Lane 19 – 953; Lane 20 – 11; Lane M –100 bp marker

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

Crop Production

4.2.1 Studies on nutrient dynamics in banana

In cv. Nendran, with production of 31.5 t/ha, the nutrient removal (kg/ha) through bunch harvest was worked out to be N-230.9, P-39.6, K-678.7, Cu-0.9, Mn-0.4, Zn-2.5 and Fe-2.9. The nutrients left out in the plant residues (kg/ha) were worked out to be N-369.2, P-70.3, K-642.1, Cu-3.54, Mn-5.9, Zn-5.2 and Fe-3.1. In cv. Grand Naine, with production of 45 t/ha, the nutrient removal (kg/ha) through bunch harvest was worked out to be N-294, P-40.2, K-807.7, Cu-0.9, Mn-0.7, Zn-1.8 and Fe-0.6. The nutrients left out in the plant residues (kg/ha) were worked out to be N-359.9, P-62.1, K-483.6, Cu-2.6, Mn-3.1, Zn-1.5 and Fe-7.3. The percent nutrient removal through bunch harvest and available nutrients for *in situ* recycling are given in Fig. 37.

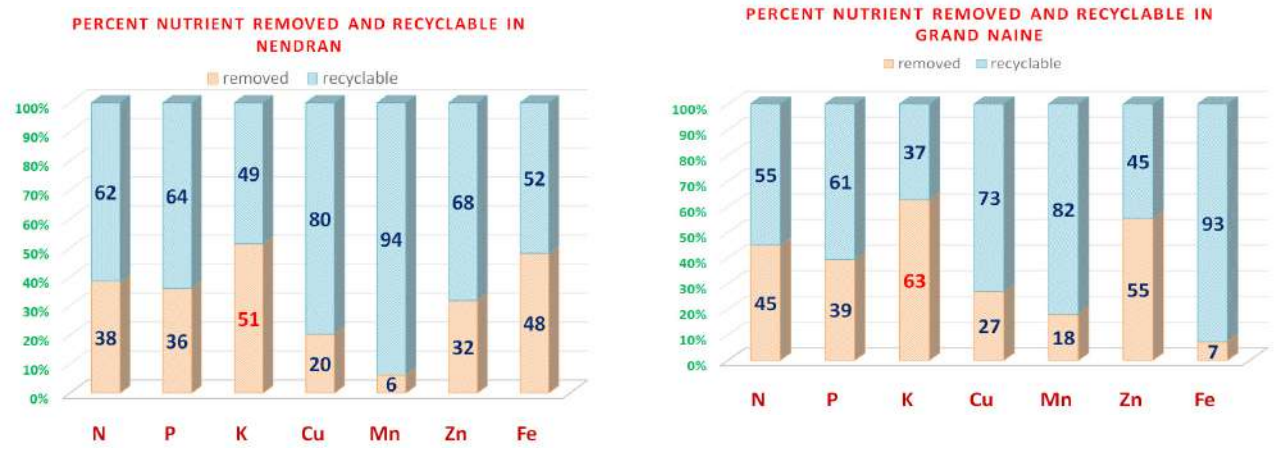


Fig. 37. Percent nutrient removal through bunch harvest in Nendran and Grand Nain bananas

In Nendran, the harvesting index (%) for DMP, N, P, K were 39.47, 38.45, 36.04, 51.37 while that of cv. Grand Naine were 42.34, 44.96, 39.31, 62.55, respectively. In Nendran, the harvesting index (%) for Cu, Mn, Zn, Fe were 20.27, 6.22, 31.86, 48.45 while that of Grand Naine were 26.80, 17.85, 55.45, 7.10, respectively. In both cultivars, vermicomposting of residues after harvesting reduced the C/N ratio from 60/1 to 9/1 with a recovery of about 58.5% of N, 56.7% of P and 47.5% of K.

Table 10. Total dry matter production and nutrient uptake by Nendran at different growth stages

Growth stage	DMP (t/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Cu (kg/ha)	Mn (kg/ha)	Zn (kg/ha)	Fe (kg/ha)
5 leaf	2.06	19.11	5.35	93.43	0.82	1.64	0.32	2.39
10 leaf	5.30	53.67	17.49	235.66	1.69	2.95	0.82	4.24
20 leaf	12.67	256.21	47.31	718.95	3.03	3.10	1.10	5.80
Shooting	18.07	380.51	62.59	934.29	3.51	4.15	4.52	6.88
Harvest	51.43	600.50	109.86	1321.26	4.44	6.27	7.69	5.96

Table 11. Total dry matter production and nutrient uptake by Grand Naine at different growth stages

Growth Stage	DMP (t/ha)	N (kg/ha)	P (kg/ha)	K (kg/ha)	Cu (kg/ha)	Mn (kg/ha)	Zn (kg/ha)	Fe (kg/ha)
5 leaf	2.54	24.70	7.45	118.94	1.26	2.19	0.39	2.21
10 leaf	5.31	52.07	17.32	244.95	2.56	2.61	0.91	3.56
20 leaf	10.86	133.07	40.31	657.70	2.68	3.14	1.54	5.38
Shooting	19.26	408.33	59.87	804.72	2.94	3.66	2.27	5.66
Harvest	54.70	654.01	102.36	1291.21	3.62	3.81	3.30	7.89

The nutrient uptake patterns in 3rd order polynomial graphs were worked out for different growth stages of Nendran and Grand Naine. In Nendran, the N uptake increased from 19.1 kg/ha at 5-leaf stage to 600.5 kg/ha at harvest with decreasing rate and that of Grand Naine increased from 24.7 kg/ha at 5-leaf stage to 654.0 kg/ha at harvest with increasing rate. A gradual increase in P uptake of Nendran (from 5.3 to 109.9 kg/ha) and Grand Naine (from7.4 to 102.4 kg/ha) from 5-leaf stage to harvest was observed. The K uptake from 5-leaf stage to harvest in Nendran showed a sigmoid increase (from 93 to 1321 kg/ha) and in Grand Naine, showed a steady and sharp increase (from 110 to 1291 kg/ha). In both Nendran and Grand Naine, order of micronutrient uptake was Fe > Mn > Cu > Zn at growth stages from 5-leaf stage to harvest. In both varieties, Fe, Cu and Mn uptake showed increasing trend with decreasing rate but Zn uptake showed increasing trend with increasing rate, indicating an increase in Zn demand in the later stage of crop growth.

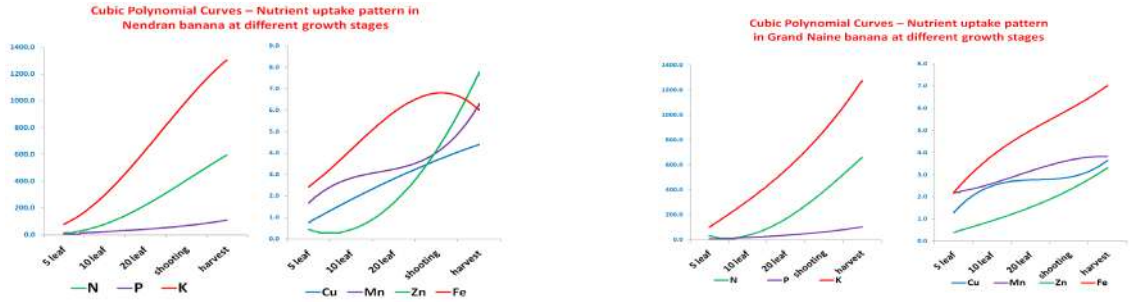


Fig.38. Cubic polynomial curves of nutrient uptake pattern of Nendran and Grand Naine

The soil Q/I parameters of potassium were estimated at different growth stages. The soil recorded potential buffering capacity for potassium ($cmol.kg^{-1}.(M/L)^{-0.5}$) of 18.58, 18.92, 17.36 and 19.22 at 10-leaf, 20-leaf, shooting and harvesting stages, respectively. The nutrient budgeting in soil was done for cultivation of Nendran and Grand Naine (Table 12 and 13).

Table 12. Nutrient budgeting in Nendran cultivation

	A	B	C	D	E	F	G	H	I
	Initial Soil content	Added through fertilizer	Total A+B	Uptake by plant	Balance in the soil (Calculated) C-D	Actual in post harvest soil (Estimated)	Loss of nutrient E-F	Nutrient added through recycling	Dose required for next season B-F-H+G
N(kg/ha)	195	600	795	600.5	194.5	110.1	84.4	369	205.3
P(kg/ha)	7.2	105	112.2	109.9	2.3	1.9	0.4	70.3	33.2
K(kg/ha)	174	1200	1374	1321	52.7	51.0	1.7	642.1	508.6
Cu(kg/ha)	5.9	0.65	6.55	4.44	2.11	0.15	1.96	3.54	0.10
Mn(kg/ha)	13.8	1.21	15.01	6.27	8.74	1.04	7.7	5.88	1.99
Zn(kg/ha)	12.1	1.42	13.52	7.69	5.83	0.98	4.85	5.24	0.05
Fe(kg/ha)	10.3	1.28	11.58	5.96	5.62	1.21	4.41	3.09	1.39

Table 13. Nutrient budgeting in Grand Naine cultivation

	A	B	C	D	E	F	G	H	I
	Initial Soil content	Added through fertilizer	Total A+B	Uptake by plant	Balance in the soil (Calculated) C-D	Actual in post harvest soil (Estimated)	Loss of nutrient E-F	Nutrient added through recycling	Dose required for next season B-F-H+G
N(kg/ha)	195	600	795	654	141	108.2	32.8	359.9	164.7
P(kg/ha)	7.2	105	112.2	102.4	9.8	5.1	4.7	62.1	42.5
K(kg/ha)	174	1200	1374	1291	82.8	80.1	2.7	483.6	639.0
Cu(kg/ha)	5.9	0.65	6.55	3.62	2.93	1.25	1.68	2.64	0.11
Mn(kg/ha)	13.8	1.21	15.01	3.81	11.2	3.11	8.09	3.14	3.05
Zn(kg/ha)	12.1	1.42	13.52	3.3	10.22	2.92	7.3	1.47	4.33
Fe(kg/ha)	10.3	3.14	13.44	7.89	5.55	0.5	5.05	7.34	0.35

4.2.2 Organic banana farming for sustainable soil health and nutritional security

At harvest of Grand Naine, organic treatment M2 (application of poultry manure @ 5kg/pl + groundnut cake @ 1kg/pl + rural compost @ 3kg/pl + wood ash @ 3kg/pl) recorded a bunch weight of 25.3 kg, which was on a par with that of 100% inorganic fertilizer application (25.9 kg) and significantly higher than the other two organic treatments (M1 (21.1 kg) and M3 (20.7 kg)). The absolute control M5 recorded very low bunch weight of 9.0 kg only (Fig. 39). The treatment M2 recorded higher average single finger weight of 98.0g than other organic treatments but the treatment M4 (100% inorganic source) recorded 112.3g which was on par with that of M2.

Fig. 39. Effect of different organic manures on Grand Nain

The same treatment recorded higher average fruit firmness of 12.1N among the organic treatments, while M4 recorded the highest value of 13.2N, which was again on a par with that of M2.The higher average pulp to peel ratio of 3.08 was recorded by M2 among the organic treatments, while M4 recorded the highest value of 3.15, which was on a par with that of M2.

M2 recorded the highest and significant TSS/acidity ratio of 92.2 among all the treatments including 100% inorganic source, which recorded only 83.8. The same treatment recorded the highest shelf life period of 17 days (14-green and 3-yellow) at room temperature among the organic treatments and the M4 (100% inorganic) also recorded the same. M2 recorded the highest shelf life period of 26 days (23-green and 3-yellow) in cold room (13.5°C) among all treatments including the M4 (100% inorganic), which recorded only 24 days.

Among the organic treatments, M1 recorded the highest soil fungal population (cfu/g) of 18.1 x 10^6 at 3rd month after planting (MAP), followed by M3 (3.3 x 10^6) and M2 (2.8 x 10^6). The M4 (100% inorganic) recorded the soil fungal population of 4.5 x 10^6 cfu/g, while the absolute control M5 recorded 3.5 x 10^6 cfg/g, which were significantly less than that of M1.

Among the organic treatments, at 3 MAP, M3 recorded the highest soil actinobacteria population (cfu/g) of 31.18 x 10^6 followed by M1 (6.9 x 10^6) and then by M2 (5.4 x 10^6). The M4 (100% inorganic) recorded only 2.25 x 10^6 cfu/g of actinobacteria and the absolute control M5 recorded 5.75 x 10^6 cfu/g.

Among organic treatments, at 3 MAP, M3 recorded the highest soil bacterial population (cfu/g) of 44.3 x 10^6 followed by M2 (26.4 x 10^6) and M1 (25 x 10^6). The absolute control M5 recorded the highest bacterial population of 50.25 x 10^6 cfu/g and the 100% inorganic treatment M4 recorded 16.75 x 10^6

cfu/g. Microbial population analysed after harvest indicated that there was increase in bacterial population in the organic treatment (M1) over inorganic and chemical treatments while the trend was *vice versa* in case of fungal and actinobacterial populations. This indicates that further studies related to soil physical, chemical and population of endophytic microbes are to be carried-out to understand microbial population dynamics in different treatments over the period.

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*. In M_2 the maximum 'r' values of 0.68**, 0.65**, 0.65** and 0.55** were observed with SAN(5-leaf) vs. NU(10-leaf), SAN(10-leaf) vs. NU(20-leaf), SAN(20-leaf) vs. NU(shooting) and SAN(shooting) vs. NU(harvest), respectively, which indicated significant matching of nutrient releasing and uptake patterns in organic banana farming (Table 14).

Table 14. Correlation coefficients (r values) between soil nutrient contents and overall nutrient uptakes at different growth stages in M_2

Soil nutrient contents	Overall nutrient uptakes				
	5-leaf stage	10-leaf stage	20-leaf stage	Shooting	Harvesting
5-leaf stage	0.42*	0.68**	0.52*	0.33	0.32
10-leaf stage		0.46*	0.65**	0.55*	0.44
20-leaf stage			0.34	0.65**	0.41
Shooting				0.30	0.55**
Harvesting					0.51*

4.2.3 Development of clump management technology for enhanced productivity in banana

The project was continued in the second, third and fourth suckers of cv. Ney Poovan and Poovan.

Effect on days taken for flowering, maturity and crop duration of the second sucker

Data was recorded on days taken for flowering, fruit maturity, total crop duration, yield and physiological parameters and leaf nutrient concentrations in both cultivars.

Results in the second sucker crop of Ney Poovan (Table 15) revealed significant differences for days taken for flowering and the earliest flowering (403.9 days) was recorded in treatment S2 (mother plant (MP) + 2 suckers/clump) followed by S3 (MP + 3 suckers/clump) and allowing more number of suckers per clump *i.e.*, S4 (MP + 4 suckers/clump) took 413.4 days for flowering. Similarly, the earliest fruit maturity (97.3 days) was recorded in S2, which was on par with S3 (98.4 days). The least total crop duration of the second sucker was 501.1 days in S2 and was extended to 513.4 days in plants under S4. Among levels of nutrition, total duration ranged from 504.3 days (N3-175% RDF) to 517.5 days (N1-125% RDF).

In Poovan (Table 16), the treatment S2 took the least 435.9 days for flowering of the second sucker followed by S3 (447.6 days), which was on par with S4 (453.0 days). However, differential doses of fertilizers per clump did not influence the days taken for flowering. Similarly, time taken for fruit maturity of second sucker of Poovan was not influenced by the number of suckers per clump (S) and levels of nutrition (N) and no significant differences were recorded among the treatments. Allowing two suckers per clump (S2) recorded the least

total crop duration of 528.9 days and the same was extended to 548.2 days when four suckers were retained per clump (S4). However, no significant differences were recorded among the three levels of nutrition tested.

Table 15. Effect on days taken for flowering, maturity and crop duration in cv. Ney Poovan (second sucker)

Treatments	Days taken for flowering				Days taken for fruit maturity				Total crop duration			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S2	406.2	403.1	402.3	403.9[a]	98.5	97.0	96.3	97.3[a]	504.7	500.1	498.6	501.1
S3	413.7	410.5	409.1	411.1[bc]	99.2	98.4	97.5	98.4[ab]	512.9	508.9	506.6	509.5
S4	416.2	414.7	409.3	413.4[c]	101.3	100.1	98.5	100.0[b]	517.5	514.8	507.8	513.4
Mean	412.03[a]	409.4[a]	406.9[a]		99.7[a]	98.5[a]	97.43[a]		511.7[a]	507.9[a]	504.3[a]	

Table 16. Effect on days taken for flowering, maturity and crop duration of second sucker in cv. Poovan

Treatments	Days taken for flowering				Days taken for maturity				Total crop duration (Days)			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S2	438.6	435.6	433.5	435.9[a]	90.8	94.8	93.6	93.07[a]	529.4	530.4	527.1	528.9[a]
S3	453.1	446.3	443.5	447.6[bc]	94.3	93	92.1	93.13[a]	547.4	539.3	535.6	540.8[ab]
S4	456.3	453.5	449.3	453.0[c]	96.2	95.3	94.1	95.20[a]	552.5	548.8	543.4	548.2[b]
Mean	449.3[a]	445.1[a]	442.1[a]		93.77[a]	94.37[a]	93.27[a]		543.1[a]	539.5[a]	535.4[a]	

Effect on days taken for flowering, maturity and crop duration of the third sucker

In Ney Poovan, days taken for flowering of treatment S3 took 437.67 days as against S4 of 456.1 days (Table 17). Similarly, in Poovan, allowing four suckers per clump (S4) delayed flowering of third sucker to 510.2 days, while S3 took 498.2 days (Table 18).

In both cultivars, number of suckers per clump and three levels of nutrition per clump had no significant differences on time taken for fruit maturity. However in cv. Ney Poovan, total crop duration of third sucker was 533.8 days in treatment S3 (MP + 4 suckers) and the same was delayed to 553.1 days under S4 (MP + 4 suckers). Similar trend was witnessed in cv. Poovan in which treatments S3 and S4 recorded total crop duration of 594.0 days and 607.4 days, respectively (Table 17 & 18).

Table 17. Effect on days taken for flowering, maturity and crop duration in cv. Ney Poovan (third sucker)

Treatments	Days taken for flowering				Days taken for maturity				Total crop duration			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S3	441.2	438	433.8	437.7[a]	95.8	96.6	96.0	96.13[a]	537	534.6	529.8	533.8[a]
S4	460.3	455.3	452.8	456.1[b]	98.2	96.6	96.2	97.00[a]	558.5	551.9	549.0	553.1[b]
Mean	450.8[a]	446.6[a]	443.3[a]		97.00[a]	96.60[a]	96.10[a]		547.8[a]	543.3[a]	539.4[a]	

Table 18. Effect on days taken for flowering, maturity and crop duration in cv. Poovan (third sucker)

Treatments	Days taken for flowering				Days taken for maturity				Total crop duration			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S3	501.0	498.3	495.3	498.2[a]	97.3	95.6	94.5	95.80	598.3	593.9	589.8	594.0[a]
S4	515.3	511.3	503.9	510.2[b]	99.8	96.3	95.6	97.23	615.1	607.6	599.5	607.4[b]
Mean	508.15[a]	504.8[a]	499.6[a]		98.55	95.95	95.05		606.0[a]	600.6[a]	594.7[a]	

In Ney Poovan, total crop duration of the entire clump of all treatments ranged from 463.9 days (S1-MP + 1 sucker) to 595.6 days (S4-MP + 4 suckers per clump) with extension of 131.7 days by allowing three additional suckers per clump (Table 19). In Poovan, total crop duration was 643.6 days in treatment S4 as against treatment S1 (483.8 days) (Table 19). Total crop duration was not influenced significantly by different levels of nutrition in both cultivars.

Table 19. Effect on total crop duration of the entire clump in Ney Poovan and Poovan

Total crop duration of cv. Ney Poovan					cv. Poovan			
Treatments	N1	N2	N3	Mean	N1	N2	N3	Mean
S1	467.3	464.3	460.2	463.93[a]	482.6	485.9	482.9	483.80[a]
S2	504.7	500.1	498.6	501.13[b]	529.4	530.4	527.1	528.97[b]
S3	537	534.6	529.8	533.80[c]	598.3	593.9	589.8	594.00[c]
S4	601.6	593.8	591.4	595.60[d]	651.4	642.9	636.5	643.60[d]
Mean	527.65[a]	523.20[a]	520.00[a]		565.43[a]	563.28[a]	559.08[a]	

Effect on bunch weight in Ney Poovan and Poovan - second sucker

The bunch weight significantly decreased with the increased number of suckers per clump in the second sucker crop of Ney Poovan and Poovan bananas. The treatment S2 (MP + 2 suckers) recorded the highest bunch weight of 10.57 kg and 16.57 kg/plant in Ney Poovan and Poovan, respectively. Among three levels of nutrition tried, application of 175% RDF (N3) produced higher bunch weight in both Ney Poovan (10.3 kg) and Poovan (15.87 kg) that was on par with the bunch weight recorded in treatment N2 (150% RDF) (Table 20).

Table 20. Effect on bunch weight (kg/plant) in Ney Poovan and Poovan (second sucker)

Treatments	cv. NeyPoovan				cv. Poovan			
	N1	N2	N3	Mean	N1	N2	N3	Mean
S2	10.1	10.7	10.9	10.57[a]	16	16.8	16.9	16.57[a]
S3	9.6	10.3	10.4	10.10[b]	15	16.1	15.9	15.67[b]
S4	8.8	9.3	9.5	9.20[c]	14.1	14.5	14.8	14.47[c]
Mean	9.5[a]	10.1[bc]	10.3[c]		15.03[a]	15.80[bc]	15.87[c]	

Effect on bunch weight in Ney Poovan and Poovan - third sucker

Bunch weight of third sucker decreased gradually in both cultivars as compared to the second sucker (Table 21) and the highest bunch weight of third sucker in Ney Poovan of 9.23 kg/plant was recorded in S3 and the same treatment recorded 12.63 kg bunch weight in Poovan.

Application of increased dose of fertilizers increased the bunch weight in both cultivars and 175% RDF (N3) recorded the highest bunch weight of 12.40 kg and was on par with N2 (12.35 kg).

Table 21. Effect on bunch weight (kg/plant) in Ney Poovan and Poovan (third sucker)

Treatments	cv. Ney Poovan				cv. Poovan			
	N1	N2	N3	Mean	N1	N2	N3	Mean
S3	8.9	9.2	9.6	9.23[a]	12.1	12.8	13	12.63[a]
S4	8	8.6	8.9	8.50[b]	11.5	11.9	11.8	11.73[b]
Mean	8.45[a]	8.90[b]	9.25[c]		11.80[a]	12.35[bc]	12.40[c]	

Effect of total bunch weight/clump (kg) and total yield (t/ha)

In Ney Poovan, total bunch weight of entire clump was 22.4 kg (S1) to 42.1 kg (S4) and accordingly total fruit yield ranged from 39.1 t/ha (S1) to 73.2 t/ha (S4-MP + 4 suckers per clump) (Table 22). In Poovan, highest total bunch weight of 69.2 kg per clump and 96.19 t/ha was recorded in S4 and the least was in S1 (38.57 kg/clump and 53.61 t/ha) (Table 23).

Table 22. Effect on total bunch weight/clump (kg) and total yield (t/ha) in cv. Ney Poovan

Treatments	Total bunch weight (kg/clump)				Total yield (t/ha)			
	N1	N2	N3	Mean	N1	N2	N3	Mean
S1	21.4	22.9	22.9	22.40[a]	37.24	39.85	40.20	39.10[a]
S2	30.9	32.9	32.9	32.23[b]	53.77	57.25	57.77	56.26[b]
S3	38.2	40.3	41.0	39.83[c]	66.47	70.62	71.35	69.31[c]
S4	39.4	42.6	44.2	42.1[d]	68.56	74.89	76.91	73.20[d]
Mean	32.48[c]	34.68[ab]	35.25[a]		56.50[c]	60.65[b]	61.56[ab]	

Table 23. Effect on total bunch weight/clump (kg) and total yield (t/ha) in cv. Poovan

Treatments	Total bunch weight (kg/clump)				Total yield (t/ha)			
	N1	N2	N3	Mean	N1	N2	N3	Mean
S1	37.7	38.7	39.3	38.57[a]	52.40	53.79	54.63	53.61[a]
S2	51.3	54.3	55	53.53[b]	71.31	75.48	69.87	72.22[b]
S3	61	63.1	64.2	62.77[c]	84.79	87.71	89.24	87.25[c]
S4	67.6	69.8	70.2	69.20[d]	93.96	97.02	97.58	96.19[d]
Mean	54.40[a]	56.48[bc]	57.18[c]		75.62[c]	78.50[ab]	77.83[b]	

Effect on physiological parameters

The plant physiological parameters viz., relative water content (%), membrane stability index and the leaf chlorophyll contents were studied in both the varieties (Table 24 & 25). In Ney Poovan, among four different sucker population per clump, the relative water content ranged from 70.79 (S4) % to 77.10% (S3) and it was in the range of 70.15% (N2) to 78.67% (N3) among the three levels of nutrition.

Table 24. Effect on plant physiological parameters in cv. Ney Poovan

Ney Poovan												
Treatments	Relative water content (%)				Membrane stability index				Chlorophyll (CCM)			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S1	72.22	71.99	77.78	74.00	91.0	86.0	89.9	89.0	37.10	26.60	28.70	30.80
S2	70.24	68.73	82.98	73.98	89.7	90.3	87.8	89.3	22.40	34.40	19.70	25.50
S3	76.01	74.85	80.43	77.10	90.2	89.3	81.6	87.0	28.30	26.20	22.20	25.57
S4	73.84	65.02	73.5	70.79	89.9	90.8	89.1	89.9	21.50	26.80	32.70	27.00
Mean	73.08	70.15	78.67		90.2	89.1	87.1		27.33	28.50	25.83	

Similarly in cv. Poovan, the leaf RWC ranged from 71.49 % (S1- MP + 1 sucker) to 76.03% (S3-MP + 3 suckers) and among the levels of RDF nutrition it ranged from 71.73% (N1- 125% RDF) to 74.95% (N3-175% RDF).

Table 25. Effect on plant physiological parameters in cv. Poovan

Poovan												
Treatments	Relative water content (%)				Membrane stability index				Chlorophyll (CCM)			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S1	73.10	69.50	70.60	71.07	71.49	71.41	78.00	73.63	45.87	59.58	38.85	48.10
S2	67.60	72.60	73.40	71.20	74.57	74.63	79.17	76.12	42.50	54.67	50.08	49.08
S3	73.30	75.10	79.70	76.03	82.38	79.17	75.79	79.11	40.95	53.02	50.12	48.03
S4	72.90	74.90	76.10	74.63	77.19	76.56	74.20	75.98	42.77	65.22	50.78	52.92
Mean	71.73	73.03	74.95		76.41	75.44	76.79		43.02	58.12	47.46	

Effect on leaf nutrient contents

Leaf nutrient contents were studied in both Ney Poovan and Poovan bananas (Table 26). In Ney Poovan, the concentrations of P, K, Ca and Mg exhibited decreasing trend with increasing number of suckers per clump. In Ney Poovan, the leaf P was 0.04% to 0.07%, leaf K contents ranged from 0.91% to 1.29 % while leaf Ca reduced with increasing number of suckers per clump and the highest Ca of 2.91% was recorded in S1. In Poovan, leaf contained 0.098% to 0.156% P, 1.36%- 2.14% K, 1.68%- 3.25% Ca and 0.51%-0.97% Mg.

Table 26. Effect of no. of suckers and nutrition on leaf nutrient contents (%) in Ney Poovan and Poovan

Treatments	cv. Ney Poovan				cv. Poovan			
	P (%)	K (%)	Ca (%)	Mg (%)	P (%)	K (%)	Ca (%)	Mg (%)
No. of suckers per clump								
S1	0.07	1.29	2.91	0.07	0.13	1.75	2.45	0.83
S2	0.07	1.13	1.62	0.07	0.11	1.41	1.50	0.62
S3	0.05	0.91	1.36	0.06	0.09	1.46	1.83	0.76
S4	0.04	0.74	1.35	0.05	0.09	1.68	1.77	0.73
Levels of nutrition per clump								
N1	0.06	1.25	1.54	0.07	0.120	1.66	1.95	0.76
N2	0.05	0.91	1.42	0.06	0.108	1.53	1.83	0.72
N3	0.06	0.90	2.47	0.06	0.100	1.53	1.89	0.73

Post-Harvest Technology

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

Month wise leaf production of banana varieties

Leaf production from main and side suckers of five varieties, *viz.* Poovan, Karpuravalli, Sakkai, Phirima wild and Progeny 183 were recorded after five months of planting (January to October) at monthly interval (Fig. 40). Karpuravalli produced the maximum number of leaves (6.43) followed by Sakkai (5.96) and Poovan (5.93), respectively. The lowest number of leaves were recorded in Phirima wild (4.72) and Progeny 183 (4.83). Maximum number of leaves were produced during April (6.18) followed by March (6.04) and June (6.03) and minimum was recorded in October (3.96). Significant differences (P <0.05) were found between the varieties, months and its interaction.

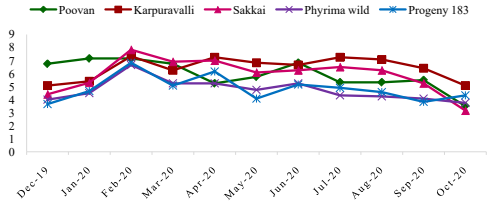


Fig. 40. Leaf production of banana varieties (month-wise)

Shelf life of leaves from selected varieties namely Poovan, Karpuravalli, Sakkai, Phirima wild and Progeny 183 was analyzed in both control and treated with 6-benzylaminopurine (BAP) at room temperature, 22 and 13.5 °C. On comparing with control of four days and shelf life of leaves was high in 6-BAP treated leaves (9 days) at room temperature. At 22 and 13.5 °C, shelf life of leaves was high in 6-BAP treated leaves (10 days and 17 days) against 8 and 13 days, respectively of controls. The 6-BPA treatment increased leaf shelf life by five days. On comparison, Karpuravalli leaves recorded longer shelf life than that of other varieties (Poovan, Sakkai, Phirima wild and Progeny 183).

Number of suckers on leaf production

Leaf production three varieties *viz.*, Naadu, Poovan and Karpuravalli based on the number of suckers was in different clumps of mother plant + daughter suckers with combinations like 1+3, 1+4 and 1+5 during February - October, 2020. Significant variations (P< 0.05) were observed among the number of suckers, months and interactions between them. The highest number of leaves was produced in 1+5 combination, irrespective of the varieties.

The months of higher leaf production varied with varieties. Leaf production was maximum during March (15.19) in Naadu, during June (14.55) in Poovan and during August (16.36) in Karpuravalli.

Leaf area analysis recorded in the order of Naadu (1.05 m^2) >Poovan (0.89 m^2) > Karpuravalli (0.86 m^2) (Fig. 41). On leaf thickness, Naadu had the lowest (0.19 mm), while Poovan and Karpurvalli recorded 0.25 and 0.22 mm, respectively. The lower the leaf thickness, the better is the leaf quality. Naadu produced more side suckers (3.83) followed by Poovan (3.50) and Karpuravalli (3.08). Poovan registered higher chlorophyll content (11.90 mg/100 g). Colour index ('L', 'a', 'b') of leaves of these varieties showed lightness ('L' value) ranging from 40 to 49, 'a' value (positive value - redness and negative value - greenness) from-26 to -21 and 'b' value (positive value - yellowness and negative value - blueness) from 31 to 39. Negative 'b' value indicates the presence of green colour in leaves is attributed to chlorophyll presence.

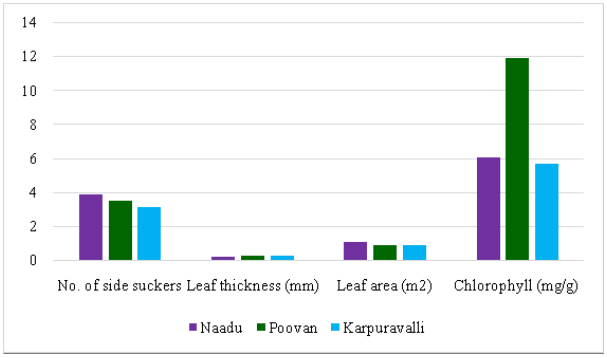


Fig. 41. Leaf parameters of three banana varieties

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

In vitro starch hydrolysis

In vitro starch hydrolysis was conducted for banana starch compared to corn starch as control. Irrespective of time, maximum hydrolysis was observed in corn starch. Low hydrolysis rate was identified in Kaveri Saba and Monthan starches due to the presence of resistant starch. Grand Naine recorded the peak by 120 min and then reduced.

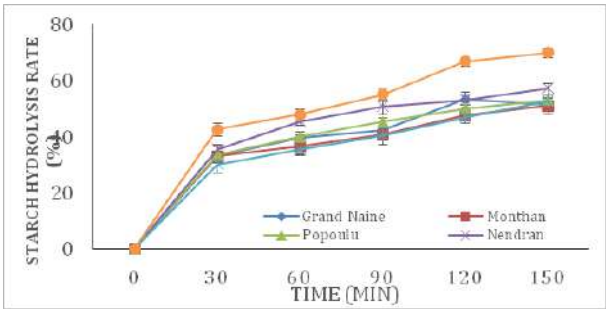


Fig. 42. Starch hydrolysis rate of cvs. Grand Nain, Popoulu, Monthan and Nendran

Starch modification

Modification of banana starch was carried out with various chemical process (oxidation, acid thinning and acetylation). In oxidation, swelling power and pasting temperature was reduced, whereas solubility and paste clarity increased. Swelling power was increased in acetylation and acid thinning methods. Lowest carboxyl content was noticed with acid thinning (0.7%) followed by oxidation 1.02%.

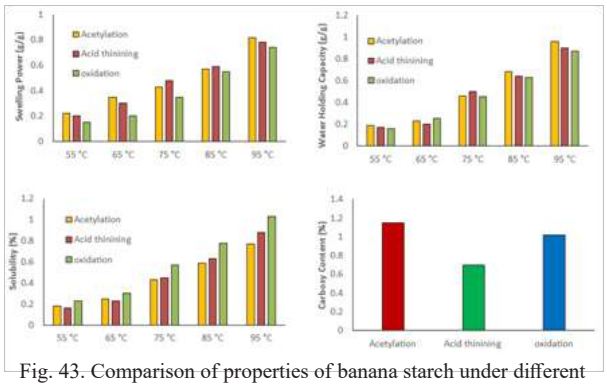


Fig. 43. Comparison of properties of banana starch under different chemical processes

Modified starch rich functional pizza

Pizza base was prepared by partially replacing semolina with banana based composite flours, *viz.,* green banana flour (GBF), banana modified starch (BMS) and banana peel flour (BP). Addition of GBF, BMS and BP increased the ash and crude fibre content in the formulated dough. Low gluten content (up to 18-24% reduction) in developed product was a positive outcome on substitution of semolina. Sensory evaluation revealed that formulation with 10% GBF, 0.4% BMS and 0.6% BP was preferred with the highest sensory score.

Table 27. Properties of modified starch with different formulations of green banana flour

Formulation	Spread ratio (%)	Specific volume (cm^3/g)	Weight loss (g)	Dry Gluten content (%)	Reduction in gluten content (%)	Crude fiber (%)	Fat (%)
0% GBF	9.84^{a}	1.98	2.21^{a}	11.39^{a}	-	1.05^{d}	4.32^{a}
5.0% GBF	8.62^{b}	1.82	1.63^{b}	9.32^{a}	18.18^{a}	4.17^{c}	3.57^{c}
7.5% GBF	8.40^{b}	1.82	1.59^{b}	8.82^{b}	22.57^{b}	4.52^{bc}	3.30^{cd}
10.0% GBF	8.33^{bc}	1.89	1.40^{c}	8.71^{bc}	23.53^{bc}	4.73^{bc}	3.26^{d}
12.5% GBF	8.20^{c}	1.71	1.41^{c}	8.72^{bc}	23.45^{bc}	4.81^{b}	3.22^{cd}
15.0% GBF	8.22^{c}	1.70	1.41^{c}	8.60^{c}	24.50^{c}	5.40^{a}	3.11^{b}

Foam mat dried ripe banana powder

The possibility to adapt foam mat drying technology for drying ripe bananas was studied. Water holding capacity, swelling index and solubility power were higher with gum acacia as foaming agent. Highest moisture content (12.06 g 100 g^{-1}) was observed in red banana without any foaming or stabilising agent (i. e. RBP). Red banana powder (RBP) recorded the highest Carr index (CI) (23.40 %) and Hausner ratio (HR) (1.30) and were considered to have lesser flowability. Foam mat dried powder with carrageen gum and gelatin showed much deviation in colour than control. Foam mat dried RB powder showed positive prebiotic activity with extended stationary phase on probiotic bacteria. From the foam stability studies, it was observed that RBFS has given the product with the highest foam stability whereas the RBGE (Red banana with gelatin) lost its structure over the period of time.

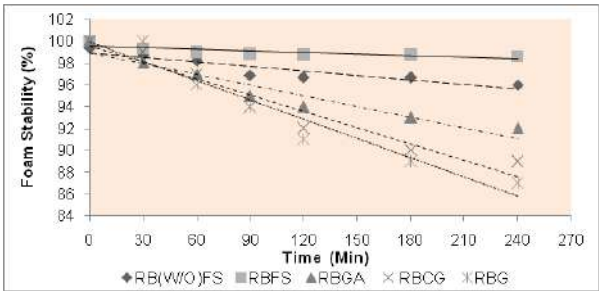


Fig. 44. Foam stability of banana pulp with different foaming and stabilizing agents

Fig.45. CNF reinforced biofilm from banana starch

Banana starch film reinforced with cellulose nano-fibre

Cellulose was evaluated as a reinforcing agent in banana starch film. Cellulose was isolated from banana fiber by acid hydrolysis method and biofilm film was prepared by casting method using plasticizer and the effect of reinforcement behaviour was investigated. The biofilm showed good saleability and low bursting strength. Biofilm exhibited lesser water uptake due to interaction between cellulose and starch matrix, promoting a remarkable improvement on mechanical and barrier property, opacity, UV light barrier, and density compared to starch film. In characterization studies for biofilms with cellulose reinforcement, the 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%.

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, 67 genotypes (AAA, AAB, ABB, and AB) were evaluated for drought stress tolerance and allometric observations were recorded. At flowering stage, Pacha Bontha Batheesa (ABB) (Acc. No. 189) recorded a maximum height of 382.5 cm and Manohar (BB) (Acc. No. 47) recorded a maximum girth of 83.3cm under irrigated conditions. Among the tested genotypes, AAB genotypes recorded higher chlorophyll content

meter (CCM) reading (45.00 - 50.10), whereas CCM was in the range of 2.25 - 39.60 in the other genotypes. Invariably in all genotypes under drought, the CCM was less.

Table 28. Selected banana (AAB) genotypes with higher Chlorophyll Content Meter (CCM) readings

Genotypes	Chlorophyll Content Meter (CCM) Readings	
	Irrigated	Drought
Cheni Champa (AAB)	50.10	45.63
Garomonia (AAB)	45.25	41.92
Dasaman (AAB)	45.00	44.90

NDVI (Normalised Differential Vegetative Index) was recorded in these genotypes of different genomic groups. The AAA triploids recorded higher NDVI values compared to all other genomes and Bhat Manohar (ABBB) (Acc. No. 0075) recorded the lowest NDVI value.

Table 29. Selected banana (AAA) genotypes with higher Normalised Difference Vegetation Index (NDVI)

Genotypes	NDVI	
	Irrigated	Drought
Tulsi Manohar (AAA)	0.93	0.88
Borjahaji (AAA)	0.90	0.89
Grand Naine (AAA)	0.90	0.88
Jahaji (AAA)	0.89	0.87
Bhat Manohar (ABBB)	0.79	0.67

Agni Malbhog (ABB) (Acc. No. 59) recorded higher leaf area index in both irrigated (5.94) and drought (4.61) conditions. In most of the evaluated banana genotypes, days to flowering was increased by 7.25 to 39.75 days under drought condition compared to irrigated control. However, Bharat Moni and Kait Khullung recorded less number of days (12.25 and 39.33 days respectively) to flower under drought treatment compared to irrigate condition. Effect of drought stress at flowering in ABB genotypes was also evaluated in the ratoon crop. Under irrigation, Bluggoe, Kostha Bontha and Peyan apparently yielded on par with normal fruit development (Fig. 43). In pot experiment, effect of application of silicon (Si) on growth was studied. Dry matter production was increased in the plants treated with sodium silicate as foliar spray compared to control indicating that sodium silicate can be used to increase the vegetative growth in banana. Growth and proline production in response to Si application varied among genotypes. Ney Poovan positively responded, whereas proline synthesis decreased in Poovan.

Bluggoe (ABB) Kostha Bontha (ABB) Peyan (ABB)

Fig. 46. Drought tolerant ABB banana genotypes at flowering

In another pot study on dry matter (DM) production, five popular banana cultivars (Grand Naine, Rasthali, Poovan, Ney Poovan, and Kaveri Saba) were grown for three months and treated with three different levels of irrigation to check the tolerance level. The level of irrigation (100%, 75% and 50%) was determined based on the evaporative demand of plants. In all genotypes, more DM was allocated to leaves followed by pseudostem, corm, and roots, except in Rasthali, where more DM was allocated to corm, followed by leaves, pseudostem and roots. Invariably most of the varieties allocated higher percentage of

DM towards corm under low level of irrigation (50%).

The BB genome bananas (Athiakol, Bhimkhol, Elaivazi, Pagalpad Wild-1, Tani) were analysed for some of the biochemical parameters like proline and free amino acids. A great diversity was observed in response to drought in terms of proline and free amino acid contents in the leaves. Proline production ranged from 0.72 to 6.71 µg/g with the genotype Tani (BB) producing lesser proline content (0.72 µg/g) and Paglapahad Wild-2 producing 6.71 µg/g. Some BB genomes like Athiakol, Bhimkol, Elavazhai, Paglapahad Wild-1had increased production of free amino acids (FAA) and most of the BB genomes recorded lesser FAA under drought stress compared to irrigated control.

4.3.2 Biochemistry

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

Flavonoids compounds in bananas

Peel of fruits of commercial bananas contain more flavonoids than pulp, the individual flavonoid compounds in peel of twelve commercial banana cultivars were extracted, profiled and quantified using reverse phase-high performance liquid chromatography. Extraction of flavonoids was done with acidified-methanol followed by acid hydrolysis. Flavonoid compounds like epicatechin, gallocatechin and catechin with R_t of 6.0, 9.1 and 13.8 min, respectively were prominently detected in the peel of all the commercial banana varieties. Among these three major flavonoids, the gallocatechin was the predominant flavonoid compound followed by epicatechin and catechin. Quantification of the predominant compound gallocatechin, which has highest anti-oxidant potential, showed that cultivar like Monthan (ABB) and Udhayam (ABB) contained high amounts of gallocatechin of around 180 mg/100 g (Fig. 47 & 48). Ney Poovan (AB) and Red banana (AAA) contained low amounts of gallocatechin with 140 mg.

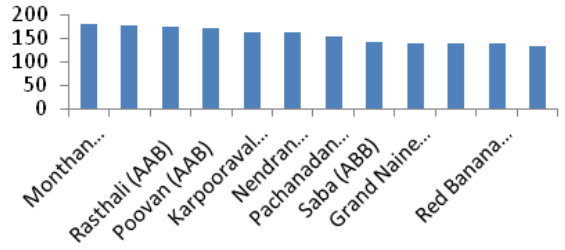


Fig. 47.Gallocatechin flavonoid contents (mg as QE/100 g) in peel of ripe fruits of commercial banana varieties

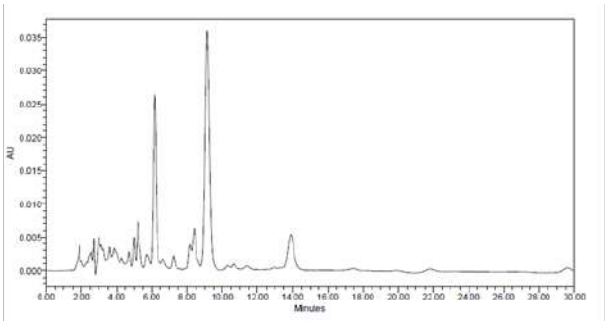


Fig. 48. Chromatogram of major flavonoid compounds in peel of ripe fruit of cv. Monthan; Peak with Rt of 6.0 min is epicatechin; peak with Rt of 9.1 min is gallocatechin and peak with Rt of 13.8 min is catechin

Antioxidant assay of gallocatechin

Antioxidant activities of flavonoid extracts of some high and low gallocatechin containing banana cultivars were measured by Trolox Equivalent Antioxidant Capacity (TEAC) and Oxygen Radical Antioxidant Capacity (ORAC) assays. The banana cultivars such as Monthan (ABB) and Udhayam (ABB), which had higher amounts of gallocatechin, exhibited higher levels of antioxidant activities of 93.4 and 92.8 µmol TE / 100 g FW, respectively by TEAC assay. Grand Naine (AAA) and Ney Poovan (AB) exhibited low antioxidant activity of around 70 µmol TE (Fig. 49). In OROC assay, again Monthan and Udhayam showed higher antioxidant potential with 87.5 and 86.5 µmol TE / 100 g FW, respectively and Grand Naine and Ney Poovan showed low activity of little above 60 µmol TE (Fig. 50).

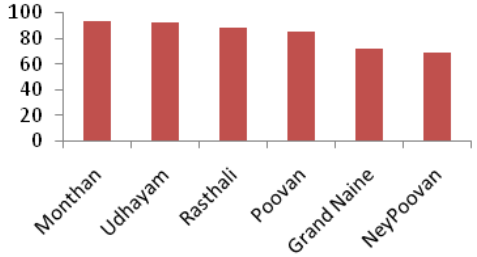


Fig. 49. TEAC (µmol TE / 100 g FW) assay of flavonoid extracts of some high and low gallocatechin containing banana cultivars

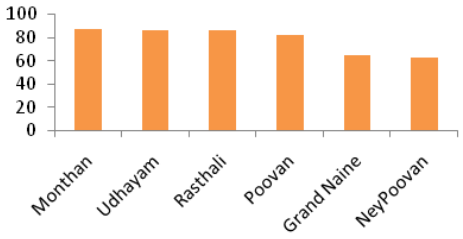


Fig. 50. OROC (µmol TE / 100 g FW) assay of flavonoid extracts of some high and low gallocatechin containing banana cultivars

Anthocyanins in flower bracts of bananas from NE region

Total anthocyanin pigment contents in bracts of male flower buds of 10 genotypes from germplasm collections of North Eastern region were estimated. Among the genotypes, the highest content was found in Borkal Baista (BB) (50 mg / 100 g bracts) followed by Suti Jahaji (AA) (46 mg) and Gobin Tulci (44 mg) and Bharatmoni possessed lowest amount of 12.7 mg / 100 g (Fig. 51). Individual anthocyanin compounds in bracts of these 10 genotypes were profiled using RP-HPLC and Vennutu Mannan (ABB) (Fig. 52), Suti Jahaji (AAA) and Kaith Kullung (ABB) contained cyanidin 3-rutinosides; Borkal Baista (BB) contained pelagornidin 3-rutinosides and Beula (ABB) contained delphinidin 3-rutinosides as predominant compounds.

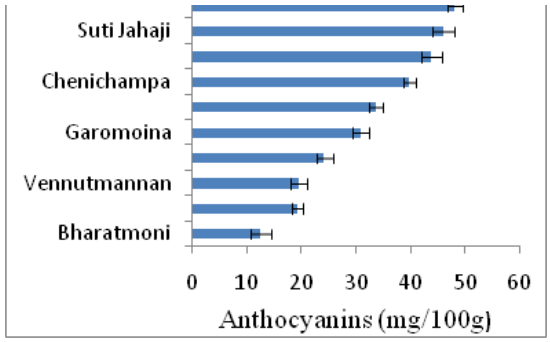


Fig. 51. Anthocyanins content in flower bracts of Musa germplasm from North Eastern region

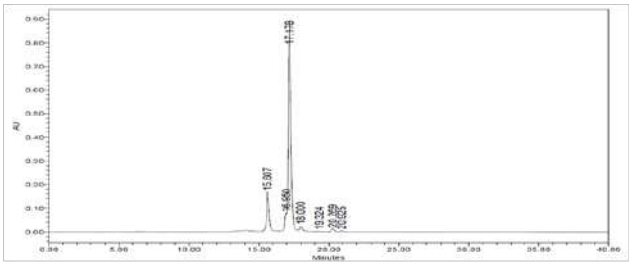


Fig. 52. Chromatogram of anthocyanin compounds of flower bracts of Vennettu Mannan; Peak with Rt 17.17 min is cyanidin 3-rutinosides constituting 92% of anthocyanins

Anthocyanin compounds in banana flower bracts

Individual anthocyanin compounds in bracts of 15 commercial banana cultivars Grand Naine (AAA), Red Banana (AAA), Manoranjitham (AAA), Poovan (AAB), Rasthali (AAB), Pachanadan (AAB), Hill Banana (AAB), Popoulu (AAB), Ney Poovan (AB), Nendran (AAB), Karpooravalli (ABB), Udhayam (ABB), Saba (ABB), Monthan (ABB) and Namwakhom (ABB) were profiled and major compounds were identified. Cyanidin compound predominated among the six major anthocyanidins identified. Monthan, Popoulu, Saba, Udhayam, Grand Naine, Namwakhom, Pachanadan, Hill Banana and Karpooravalli contained cyanidin 3-rutinosides as major anthocyanin compound and Manorantjitham contained malvidin 3-rutinosides. The two predominant compounds with contents in percentage and colour of the first predominant compound are summarized in Table 30.

Table 30. Major anthocyanidins identified in flower bracts of commercial bananas

Cultivar	Predominant Compound I	Predominant Compound II	Colour of predominant compound I
Grand Naine (AAA)	Cyanidin (84%)	Pelargonidin (6%)	Magenta & crimson
Red Banana (AAA)	Cyanidin (39%)	Malvidin (35%)	Magenta & crimson
Manoranjitham (AAA)	Malvidin (63%)	Cyanidin (19%)	Purple
Poovan (AAB)	Malvidin (44%)	Cyanidin (27%)	Purple
Rasthali (AAB)	Malvidin (41%)	Cyanidin (26%)	Purple
Pachanadan (AAB)	Cyanidin (80%)	Pelargonidin (9%)	Magenta & crimson
Hill Banana (AAB)	Cyanidin (73%)	Pelargonidin (11%)	Magenta & crimson
Popoulu (AAB)	Cyanidin (91%)	Pelargonidin (5%)	Magenta & crimson

Ney Poovan (AB)	Peonidin (33%)	Malvidin (31%)	Magenta
Nendran (ABB)	Malvidin (36%)	Cyanidin (35%)	Purple
Karpooravalli (ABB)	Cyanidin (72%)	Unknown (13%)	Magenta & crimson
Udhayam (ABB)	Cyanidin (88%)	Delphinidin (7%)	Magenta & crimson
Saba (ABB)	Cyanidin (90%)	---	Magenta & crimson
Monthan (ABB)	Cyanidin (91%)	---	Magenta & crimson
Namwakhom (ABB)	Cyanidin (83%)	Delphinidin (13%)	Magenta & crimson

Nutraceutical characterisation of Grand Naine anthocyanins

As Grand Naine is major cultivar grown in the country and the flower bracts of cultivar contains 84% cyanidins (72% cyanidin 3-*O*-rutinoside and 12% cyanidin 3-*O*-rhamnosides), nutraceutical potential of both free and microencapsulated anthocyanins extracted from Grand Naine flower bracts was characterised. The anthocyanins were microencapsulated with maltodextrin (~20 DE) as wall material. The best spray dried product was obtained at 140 °C and retention, solubility and encapsulation efficiency of anthocyanins were 74.43 mg, 95.82% and 75.12%, respectively with mean particle size of microencapsulated-anthocyanins of around 10 µm. Extraction and analysis of anthocyanins profile from microencapsulated maltodextrin particles showed only 80% cyanidin compounds with reduction in encapsulation efficiency of cyanidin 3-*O*-rutinoside (Fig.53). Antioxidant activities of free and microencapsulated-anthocyanins along with commercial cyanidin 3-*O*-rutinoside were measured by TEAC and ORAC assays. Microencapsulated anthocyanins showed higher antioxidant activities that free and commercial cyanidin 3-*O*-rutinoside. In ORAC assay, the activity of microencapsulated anthocyanins was 624 µmol TE/100 g compared to 512 and 501 by free anthocyanins from Grand Naine flower bracts and commercial cyanidin 3-*O*-rutinoside. As the Grand Naine flower bracts are dominated by cyanidin compound, the antioxidant potential is ascribed to the compound.

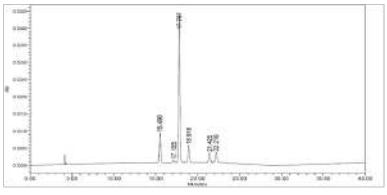


Fig. 53. Anthocyanins profile of microencapsulated in maltodextrin

Fructans in banana fruit pulp

Fructans contents in fruits of seven commercial banana varieties *viz.*, Grand Naine (AAA), Ney Poovan (AB), Poovan (AAB), Nendran (AAB), Karpooravalli (ABB), Udhayam (ABB) and Monthan (ABB) were estimated and the total fructans ranged between 112 and 186 µg/g of pulp with Monthan and Nendran containing the highest amount of fructans and Ney Poovan containing lowest amount.

4.4 CROP PROTECTION

4.4.1 Pest mapping in bananas and plantains in India

Manatha albipes, a new pest of banana

Severe infestation of bagworm, *Manatha albipes* (Moore) (Lepidoptera: Psychidae) was observed on cv. Karpuravalli and totally 108 germplasm accessions were found to be infested by this species. This is the first report of this pest on banana. Hitherto, it was misidentified as *Kophene cuprea* by other banana entomologists. It is known to be a serious pest on various palms including arecanut, coconut, and oil palm. COX 1sequencing was done for banana bagworm and it was found to be conspecific with available sequences of *M. albipes* in GenBank. Three parasitoids and one predator were also identified for the first time in association with *M. albipes*. The identity of this pest was also confirmed in comparison with its type specimen at the Natural History Museum, London.

Incidence of the invasive alien pest, *Spodoptera frugiperda,* on banana

Fall armyworm, *Spodoptera frugiperda*, an alien invasive pest of maize, was found to feed on banana leaves and complete its lifecycle on banana. It was found on banana plants in the vicinity of maize fields in Trichy District, Tamil Nadu, and it was quite likely to have moved to banana from maize. Several natural enemies were recorded on other host plants.

Fig. 54. Fall armyworm, *Spodoptera frugiperda* on banana

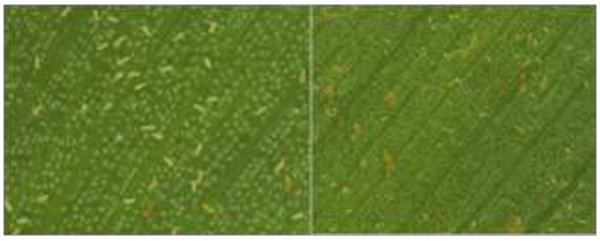


Fig.55. Eriophyid mite, *Phyllocoptruta musae* on banana

Incidence of eriophyid mite on banana

Eriophyid mite, *Phyllocoptruta musae*, a lesser known mite pest of banana, was recorded for the first time on several cultivars, particularly ornamental banana (*Musa laterita*) accessions, in large numbers. Eriophyid mite infestation was observed on a large scale on 26 germplasm accessions and the population was as high as 79–117 / cm^2 during March 2020 on cv. Grand Naine.

Major mite pests of banana and their natural enemies

Extensive mite damage due to five species of mites was observed during summer months. *Oligonychus indicus* infestation was observed on 81 germplasm accessions including popular cultivars. Its population ranged from 13 to 21 / cm^2 on cv. Virupakshi. *Raoiella indica* was found on all major cultivars and its population density was 93 + 61 eggs, 97 + 54 eggs, 73 + 64 eggs on cv. Attikol. *Eutetranychus orientalis* was recorded on10 varieties. *Tetranychus* spp. were found at negligible levels compared to the other mites in Tamil Nadu conditions. Three species-specific mite predators, *Stethorus pauperculus*, *S. indira* and *S. keralicus* were found to feed on *Oligonychus indicus, Eutetranychus orientalis* and *Raoiella indica*, respectively, in banana ecosystem.

Other banana pests and their natural enemies

Regular monitoring of banana insect pests was done on all germplasm accessions. Fruit fly (*Bactrocera dorsalis*) was observed only on damaged fruits and not on fresh fruits of cv. Grand Naine. Severe infestation of *Ferrisia virgata* and *Dysmicoccus brevipes* was recorded on cvs. Poovan, Ney Poovan, Saba, Grand Naine, Nendran, Williams and other germplasm accessions. Among fruit mealybugs, *Maconellicoccus hirsutus* was the most predominant species on all ruling cultivars.

Aphelinus sp. nr. *gossypii* was found to parasitize banana aphid, *Pentalonia nigronervosa* on cv. Grand Naine and ornamental banana. One coccinellid predator, *Scymnus nubilus,* was found to feed on banana aphids.

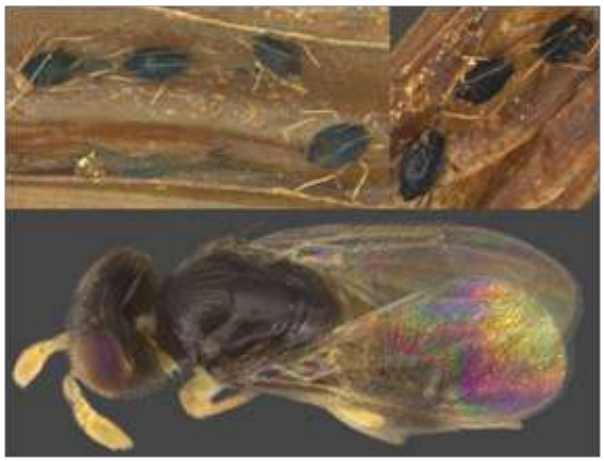


Fig. 56. *Aphelinus* sp. nr. *gossypii,* parasitoid of banana aphid, *Pentalonia nigronervosa*

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

Diagnosis and detection of Fusarium wilt pathogen in banana

A. PCR based molecular markers

A set of race-specific effector genes was identified from the *Foc* R1 and TR4 genomes and primers were synthesized for the specific identification of *Foc* races found in India as known markers failed to identify Indian races. A total of 35 primers targeted to *Foc* R4 and nine primers for Race 1 were tested and three primers which are very specific in detecting Race 1, Race 4 and TR4 isolates were identified.

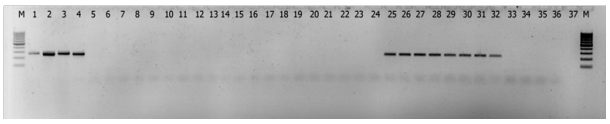


Fig. 57. Development of molecular marker for the specific detection of *Fusarium oxysporum* f. sp. *cubense* (Foc) TR4; Lanes M – 100 bp Marker; Lane 1- 01213; Lane 2-01216; Lane 3- 0121; Lane 4-01213/16; Lanes 5-24- Race 1 VCGs; Lanes 25 to 32 – Bihar and Uttar Pradesh *Foc* TR4 isolates; Lanes 33 to 36 – Race 1 *Foc* strains; Lane 37- Negative control

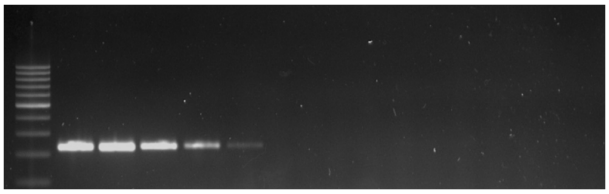


Fig. 58. Detection of sensitivity of the primer set FocS1-F/FocS1-R amplified fragment in genomic DNA of Foc TR4. A serial dilution of *Foc*TR4 DNA ranging from 200 to 10-8 ng were used as templates. Lanes M – 100 bp Marker; N – Negative control

B. Loop-mediated isothermal amplification (LAMP) for the detection of *Foc* TR4

LAMP, a rapid, accurate and cost-effective novel technique, was standardized for detection of genes specific to *Foc* TR4. The optimised assay conditions for the detection were: 25 µL reaction mixture containing 1x thermopol buffer, 1 M betaine, 400 µM dNTPs, 0.8 µM each of FIP and BIP primers, 0.2 µM of F3 B3, 0.4 µM each of loop F1 and B1 primers, 4 mM MgSO4, 8U of *Bst* DNA polymerase large fragment (M/s. New England Biolab) with 2 µL template DNA incubated at 65 °C for one hour. The assay was confirmed by the change in colour from orange to yellowish-green, which was considered a positive result. Further, the amplified product was subjected to agarose electrophoresis and formed a ladder-like pattern in the tested samples.

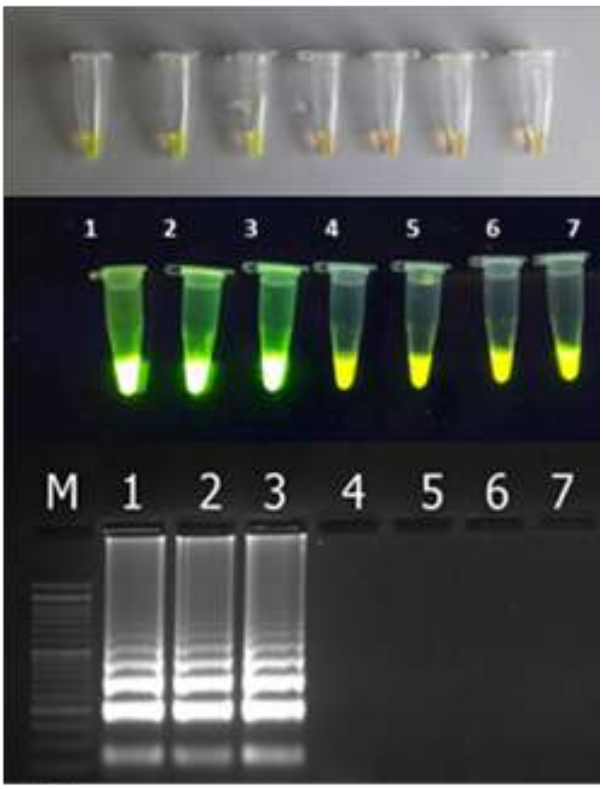


Fig. 59. Development of Loop mediated isothermal amplification assay for rapid and sensitive detection of *Foc* TR4

C. Isolation and evaluation of nutrient solubilizers (Phosphorus) for increasing the soil and plant health

Potential phosphate solubilizing bacteria (PSB) were isolated from therhizospheric soilto increase the soil and plant health for combating fusarium wilt. Of the 55 bacterial isolates with phosphate solubilization efficiency, PSB27 (6.21), PSB39 (5.36), PSB45 (5.36), PSB52 (5.27) and PSB54 (5.37) recorded maximum phosphate solubilization index. Quantitative estimation of available phosphorus in the culture supernatant showed that PSB52 and PSB54 have highest available P (24.12 and 32.0 µg mL-1, respectively) and suitable for further evaluation. These isolates were identified by 16S rRNA analysis as *Enterobacter hormaechei* ssp. *xiangfangensis* (PSB52) and *Leclercia adecarboxylata* (PSB54). In apot culture experiment with 12 treatments including various soil types (Black, Alluvial and Red soil) and inorganic phosphate sources, 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.

Management of Foc TR4 disease in banana

Evaluation of native endophytic and rhizospheric fungal bioagents against Foc TR4

One endophytic and six rhizospheric *Trichoderma* isolates were tested against Foc TR4 in a pot culture experiment with 13 treatment combinations. The results showed that the treatment T8 (Rhiz. *T. asperellum* (NRCB3) + Rhiz. *T. harzianum*) recorded the lowest internal wilt score (0) followed by T11 (Rhiz. *Trichoderma* sp. (Assam) + Rhiz. *Trichoderma* sp. (UP4)) with 0, which had a profound effect on controlling the disease under glasshouse conditions at 90 DAI when compared to Foc alone (T12) inoculated plantlets. The treatment T8 also showed an increase in the biometric attributes such as plant height (57 %), girth (27 %), leaf area (40%) and root numbers (85%).

Fig. 60. Combined application of endophytic and rhizospheric fungal isolates and the internal wilt score of banana. T8 - Rhiz. *T. asperellum* (NRCB3) + Rhiz. *T. harzianum*

Evaluation of native endophytic and rhizospheric bacterial and fungal isolates against Foc TR4

A combination of bacterial and fungal isolates of both endophytic and rhizospheric origin were (six bacterial isolates with an endophytic *Trichoderma asperellum*) evaluated against Foc TR 4 under glasshouse conditions. The results revealed that the treatment (T3) *Enterobacter cloacae* subsp. *dissolvens* in combination with endophytic *T. asperellum* effectively controlled the disease at 90 DAI when compared to Foc alone inoculated plantlets. The treatments also effected an increase in plant height, girth, leaf area, root length and numbers. The treatment T8 also showed an increase in the biometric attributes such as plant height (65 %), girth (39 %), leaf area (50%) and root numbers (64 %).

Fig. 61. Combined application of endophytic and rhizospheric bacterial and fungal isolates and the internal wilt score of banana. T3 - Endo. *E. cloaceae* ssp. *dissolvens* + Endo. *T. asperellum* (Prr2)

Evaluation of combined application of endophytic and rhizospheric Trichoderma isolates against Foc VCG O1213/16 under pot-culture conditions

In a pot culture experiment under greenhouse condition, one endophytic and five rhizospheric *Trichoderma* isolates were tested against Foc TR4 with seven combinations of newly isolated and existing effective *Trichoderma* sp. The results showed that the treatment T1 (Rhiz. *Trichoderma* sp. (UP4) + Endo. *T. asperellum* (Prr2)) recorded the lowest internal wilt score (0) followed by T4 (Rhiz. *Trichoderma* sp. (UP4) + Rhiz. *T. harzianum*) with 0, which had a profound effect on controlling the disease under glasshouse conditions at 90 DAI when compared to Foc alone (T6) inoculated plantlets. The treatment T1 resulted in an increase in biometric attributes such as plant height (76 %), girth (46 %), leaf area (60 %) and root numbers (105 %).

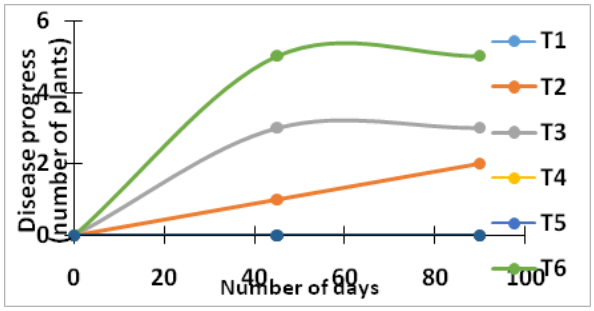


Fig.62. Effect on combined application of endophytic and rhizospheric *Trichoderma* isolates on plant growth attributes against *Foc* VCG O1213/16 under pot-culture conditions

Fig. 63. Combined application of endophytic and rhizospheric *Trichoderma sp*. isolates and internal wilt score of banana. T1- Rhiz. *Trichoderma* sp. (UP4) + Endo. *T. asperellum* (Prr2); T4 -Rhiz. *Trichoderma* sp. (UP4) + Rhiz. *T. harzianum*

4.4.3 Survey, etiology and management of rhizome rot of banana

Survey and characterization of rhizome rot isolates

Survey for rhizome rot of banana was conducted in Pudukottai (Alangudi), Tiruchirappalli (Egirimangalam and Kondayampettai) and Theni (Muthalapuram) districts of Tamil Nadu during 2020. Rhizome rot infected samples from cvs. Nendran and Grand Naine were collected and 23 isolates obtained from the infected samples.

Three samples from Ney Poovan (Kulithalai, Karur District, Tamil Nadu), Grand Naine (Thayanur village, Tiruchirappalli District, Tamil Nadu,) and Thellachakkarakeli (Pulitinddi village of East Godavari District, Andhra Pradesh) did not yield any bacteria on Crystal Violet Pectate medium (CVP). However, when plated on NA, they produced whitish to dull white, mucoid, raised, round and translucent colonies and the isolates were named as NPK-3-48, GTC-5 and 1-1B-3 respectively. As these colonies were found to be unique compared to *Pectobaterium* sp. colonies obtained on CVP medium, they were further characterized based on pathogenicity, biochemical and molecular methods.

The three isolates produced characteristic rhizome rot symptoms on Grand Naine TC seedlings after 30-35 d of inoculation. The isolates were Gram negative, catalase positive, oxidase negative and able to utilize glucose, maltose and citrate. More specifically all three cultures were able to the later two carbon sources which are specific to *Klebsiella variicola* (Fig. 64 and Fig. 65). PCR amplification of 16S rDNA gene using universal primers, sequencing and blast analysis indicated that these isolates were belonging to *Klebsiella variicola.* All three sequences were submitted to NCBI and obtained accession numbers. Besides, inoculation of *K. variicola* (NPK 48-3) isolate on Ney Poovan suckers showed characteristic rhizome rot symptoms after 50-60 days of inoculation.

Fig. 64. Utilization of citrate by *K. variicola* isolates

Fig. 65. Utilization of maltose by *K. variicola* isolates

Isolation, characterization and evaluation of biocontrol agents

Thirty isolates of Actinobacteria were isolated and characterized based on cultural morphology. These Actinobacterial isolates are being evaluated for plant growth promotion and rhizome rot control besides the decomposition ability of banana waste.

4.4.4 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 district of Tamil Nadu, Jalgaon district of Maharashtra and Burhanpur district of Madhya Pradesh for banana viral diseases. In 2019, severe outbreak of CMV was recorded in Jalgaon and Burhanpur and the per cent infection was as high as 60% in some of the orchards. During 2020, there was an outbreak of CMV in the banana plants planted in the month of July-August and the incidence has increased drastically in the same region. Survey conducted on virtual mode with 210 banana farmers with the help of BRS Jalgaon and KVK Burhanpur, indicated the CMV incidence was 11-52.17% in Jalgaon and 41.15-75.96% in Burhanpur. The incidence of BBrMVwas also recorded in the research fields and the germplasm collection of BRS, Jalgaon. In Theni, the incidence of banana bunchy top

virus (6.6– 60%), BBrMV (2–80%) and CMV (2–11%) was recorded. The BBrMD incidence was more in Red banana followed by Grand Naine.

Molecular characterization of banana viruses

Ornamental banana hybrid and *Musa velutina* expressing mosaic like symptoms have been confirmed to be due to infection of BBrMV. HC-Pro, VPg and CP genes of BBrMV infecting ornamental banana hybrid isolates were amplified, cloned and sequenced. Analysis of the nucleotide sequences of the HC-Pro, VPg and CP genes of BBrMV infecting ornamental banana hybrids showed 97.67%, 97.72 % and 99.67 % identities with that of published sequences of NCBI. Complete genome of BSV infecting cv. Champa kola collected from Assam has been amplified using rolling circle amplification. Digoxigenin-labelled DNA probes was synthesized by PCR with the specific primers and applied in dot-blot hybridization to detect the virus in DNA isolated from the infected banana leaves. RNA-1, RNA-2 and RNA-3 of three CMV banana infecting isolates (Burhanpur, Jalgaon and Theni isolates) were amplified, cloned and sequenced.

Isolation and identification of biocontrol agents for consortium development

Fungal and bacterial biocontrol agents (PGPR) from rhizosphere regions of healthy banana were isolated using pour plate method and identified morphologically and by 16s rDNA and 18s rDNA sequencing for bacteria and fungi, respectively. The genomic DNA from the isolates of *Bacillus*, *Pseudomonas* sp. and *Trichoderma* sp. were isolated using the Cetyltrimethyl ammonium bromide (CTAB) method. The bacterial isolates were identified by sequencing the Internal Transcribed Spacer (ITS) region of the rDNA and comparing the sequences with those in GenBank database using BLAST searches. The PCR amplified products were approximately 1500 bp in size. The PCR products from *Bacillus* and *Pseudomonas* isolates were sequenced. Analysis of the nucleotide sequences of the ITS regions of isolates *Bacillus* and *Pseudomonas* using NCBI-BLAST search showed 98% and 99.5% identities with that of *Pseudomonas putida* and *Bacillus altitudinis,* respectively. A few more fungal and bacterial rhizosphere putative antagonists have not yet been identified. The *Trichoderma* isolate was identified by sequencing the Internal Transcribed Spacer (ITS) region of the rDNA and comparing the sequences with those in GenBank database using BLAST searches. The ITS region, which includes the ITS regions 1 and 2, and the 5.8S rRNA genes was amplified with primers ITS1 and ITS4. The PCR amplified products were approximately 550 bp in size. The PCR products from *Trichoderma* isolate was sequenced. Analysis of the nucleotide sequences of the ITS regions of *Trichoderma* isolate using NCBI-BLAST search showed 97.8% homology with *T. virens.*

Pathogenicity analysis of BSMYV

The infectious clone of Banana Streak Mysore Virus (BSMYV) was developed. Tissue cultured Grand Naine plants (total 45) of 30 cm height were placed in plastic trays and incubated in the greenhouse. The infectious clone constructs were confirmed by restriction digestion and colony PCR before immobilisation to *Agrobacterium* strain EHA105. The transformed strain containing the BSMYV infectious vector construct was then streaked on LB plates with appropriate antibiotics. After 3 days of incubation at 28°C, a single colony was inoculated in LB broth supplemented with Rifampicin (25 mg/L) and Kanamycin (50 mg/L). The culture was incubated in a shaker at 28°C with 200 rpm. After incubation the culture was centrifuged at 5000 x g for 15 min. The bacterial pellet obtained was suspended in MMA solution (10 mM MES (containing 2-N-morpholino-ethane-sulphonic acid), 10 mM $MgCl_2$ and 200 µM acetosyringone) with absorbance 0.5 at O.D A600. The suspension was incubated for 2hr at room temperature with 200 rpm. The plants were injected into the pseudostem with 1ml of inoculum. Upon inoculation, two plants exhibited mild streak symptoms, and the rest of the plants are being kept in the glasshouse for the expression of symptoms. The symptomatic

plants are yet to be reconfirmed by RCA method.

Infectious clone construct of BBrMV-TRY

Primers were designed for amplifying a full-length construct of BBrMV by an overlapping-extension PCR (OE-PCR) to produce infectious cDNA of BBrMV.

Production of dsRNA derived from the BBrMV HC-Pro and CMV-2b genes

The primers were designed for the generation of the dsRNA, introduced a T7 promoter sequence at the 5' ends. This amplified PCR product employed as template used for dsRNA synthesis.

Validation of RNA-Seq Gene Expression for BBTV

For validation of the gene expression levels revealed by the transcriptome data, a total of 42 differently expressed genes (DEGs) were commonly identified for up- and down-regulated DEGs. Thirty-eight sets of primers were designed for the differentially expressed genes for BBTV and PCR is being standardized for each primer set and qRT-PCR will be done.

Screening of banana germplasm against BBTV and BBrMV

Screening of diploid germplasm accessions (AA and BB) for resistance against BBTV using viruliferous aphids in an insect proof screen house was continued to confirm the previous results. Fourteen AA diploids expressed typical symptoms of bunchy top viral infection. In case of BB diploids, except Manguthamang and Jungle Kela II, none got infected even after three repeated inoculations with viruliferous aphids. These two BB accessions took almost a year to express the visible symptoms in the nethouse conditions. In continuation of previous studies, screening of three diploid germplasm accessions (AA, BB and AB) for resistance against BBTV was done using sucker grown plants and transmission was done using viruliferous aphids. Thirty-one AA diploids, 36 BB diploids and 26 AB diploid accessions were taken for this study. Eight AA diploids expressed typical symptoms of bunchy top viral infection within 40 days.Screening of ornamental banana plants for resistance against BBTV and BBrMV was done using sucker grown plants and the virus was transmitted into the plants using viruliferous aphids.

Evaluation of transgenic lines resistant to BBTV

Eleven transgenic lines obtained by RNAi with replicase gene / multiple virus gene construct were challenge inoculated on plants with BBTV in the net house and the plants yielded bunches without expressing any symptoms of bunchy top.

Field evaluation of BSMYV free TC banana of cv. Poovan

Field evaluation data on episomal BSMYV free tissue culture derived Poovan plants showed significant difference in the growth and yield parameters compared to sucker grown plants. This experiment was conducted in five AICRP-F centres and in all the places, virus free plants outperformed. Symptoms of streak disease were not expressed in the tissue culture plants of Poovan at Arabhavi, Bhubaneswar, Coimbatore, Jalgaon, Tiruchirappalli and Mohanpur; however, in Kannara, two out of 72 tissue culture plants (ratoon) were infected with BSV and symptomatic.

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

Development of simple, rapid screening protocol for nematode resistance

A simple, rapid screening protocol was developed for evaluation of banana genotypes for resistance to root-lesion nematode (*Pratylenchus coffeae*) and validated with standard reference genotypes. Based on the extent of nematode damage (lesions) and nematode population, reaction of banana genotypes can be determined in a short period of time (three months). Using this assay, genotypes Pisang Lilin and Calcutta 4 were found resistant, whereas cv. Matti was found susceptible (Fig. 66).

YKM 5 (Resistant check) | Pisang Lilin | Calcutta 4

Nendran (Susceptible check) | Matti

Fig. 66. Response of some banana genotypes to root-lesion nematode (*Pratylenchus coffeae*)

Effect of application of salicylic acid on nematodes infecting banana cultivar Grand Naine

Under pot conditions, soil drenching with salicylic acid @ 50 and 100µM concentration at 24hrs prior to inoculation of root-knot nematode (*Meloidogyne incognita*) on tissue culture plants of cv. Grand Naine reduced the root population by 30 and 41%, respectively, over control. Similarly, root population of root-lesion nematode was reduced by 67 and 68%, respectively over control. Soil drenching with salicylic acid @ 100 and 200µM concentration at 24hrs prior to transplanting of tissue culture plants of cv. Nendran in nematode sick soil had no effect on nematode damage and root nematode population.

Survey for banana nematodes

Severe incidence of spiral nematode (*Helicotylenchus* sp.) was found in cv. Red Banana (5-75 nematodes / g root) at Namakkal District (Mullukurichi village), Tamil Nadu. Incidence of burrowing nematode (*Radopholus similis*) was observed in cv. Sirumalai (2.6 nematodes / g root) from Dindigul District (Sirumalai village), Tamil Nadu. Incidence of reniform nematode (*Rotylenchulus reniformis*) was recorded in cv. Nendran (8 nematodes /ml soil) from Thrissur District, Kerala.At NRCB farm, root-lesion nematodes were found abundant in root samples of *Musa velutina* (43 nematodes /g root).

4.5 EXTERNALLY FUNDED PROJECTS

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

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

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

Nine tetraploid lines of Ney Poovan have been developed through *in vitro* polyploidization using Oryzalin. Some of the plants were mixoploids and hence all the tetraploid and mixoploid plants were evaluated. Morpho-taxonomic characteristics proved the tetraploidy of all the lines and it was confirmed through flow cytometer. All the tetraploids had distinct plant morphology with inferior vegetative and yield characteristics with 20-35% lower bunch weight than diploid Ney Poovan. The pollen of the tetraploids was found to be highly viable and fertile (60-80% higher viability).

Five IITA hybrids were field evaluated and OSH No. 75 was found to be a high yielder and OSH No. 53 was found to be immune to Foc race 1 in the hotspot area.

4.5.2 DBT-QUT Project

Biofortification and development of disease resistance in banana

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

(S. Backyiarani and S. Uma)

Suckers of 12 transgenic lines showing

high expression of PVA content in main crop were freshly planted in net house for analyzing the stability of PVA expression. Now the plants are in 50 percentage bunch maturity stage. The suckers and flower buds of transgenic lines showing stable and high content of PVA with more than 35kg bunch weight were initiated for mass multiplication. Proximate analysis of other parameters like TSS content, acidity, total sugar and starch was done in the main crop fruits of transgenic lines.

In all, 22 lines were found to have 10-fold higher PVA content (α- and β-carotene) in pulp. One transgenic line showed higher content of lutein and high PVA which were 10 and 8 times higher respectively, than the wild Grand Naine. Interestingly this line had high lutein, α- and β-carotene in all the tissues except in leaf and sucker, especially so for lutein.

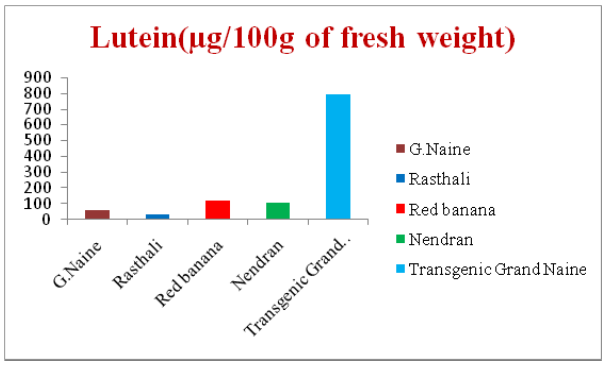


Fig. 67. Comparison of Lutein content in transgenic banana with other commercial cultivars

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

Based on the iron mineral contents in ripe fruit pulp of mother plants and ratoon 1 of Grand Naine transgenic lines transformed with GenII (*p*BMGF-DC-53) and GenIII (*p*BMGF-DC-53) iron constructs carrying *Os*NAS1 and 2 genes and also based on the agronomic performance, 10 lines that showed five-fold or greater iron content were selected for event selection trials. Large scale multiplication of these elite Grand Naine transgenic lines is being done by direct organogenesis from immature male flower buds and macropropagation from suckers.

4.5.3 PPV & FRA project

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 six reference accessions, *viz.* Bhat Manohar, Karpuravalli, Kunnan, Rasthali, Robusta and Poovilla Chundan.

Varietal Registration

DUS characterization data sheet has been prepared for two farmers' varieties, Kamal Vikas A1 and Numaran along with their respective reference variety and submitted to PPV&FRA for registration.

4.5.4 DBT-NER Projects

a. Consortium for managing Indian banana genetic resources

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

To identify the candidate genes associated with parthenocarpy, comprehensive network analysis of PA-PPI was carried out and validated through qRT-PCR in the ovary sample of seeded and seedless cultivars which revealed that AGL8, MADS16, IAA (GH3.8), RGA1, GID1C, HK2 and BAM1 are candidate genes in natural parthenocarpy.

Amplification of mitochondrial Di/Tri carboxylate carrier protein primers was seen in the 80% seedless accessions of AA genome but not in seeded accessions. Sequencing of the amplified product of mitochondrial Di/Tri carboxylate carrier protein primers of eh seedless accession hit with the intergenic region of chromosome 10 and chromosome 8 and found that parthenocarpy related genes such as AP2, GATA and MDC are flanking region in this intergenic region of the respective chromosome which suggested that these regions could act as an enhancer region of those parthenocarpic associated genes expression.

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)

Macropropagated plants of 10north-eastern varieties, *viz*. Bhimkol, Cheeni Champa, Malbhog, Jahaji, Pisang Jari Buaya, Tani, Khungsong wild, Jatikol, and Desikadali were planted at ICAR- NRCB farm for evaluation of growth performance compared with traditional planting material.

Seeds were stored at two different storage temperatures (4 and 25°C) and their viability was checked every month. Under *in vitro* conditions, fresh seeds of *M. thomsonii* exhibited maximum germination percentage of 86.67 and the least of 13.33% after six months of storage while *M. saddlensis* recorded maximum germination percentage of 46.66% and recorded poor germination of 20.00 % after four months of storage. Similarly, under *in vivo* conditions, fresh seeds of *M. thomsonii* recorded highest germination percentage of 76.66% while *M. saddlensis* recorded a germination per cent of 26.66% and least germination percentage of 20.00 % at three months after storage and did not germinate at all after four months of storage at 4°C. Overall results indicated that they remained viable for up to six months at a storage temp. of 4°C as against 25°C and the experiment is being continued.

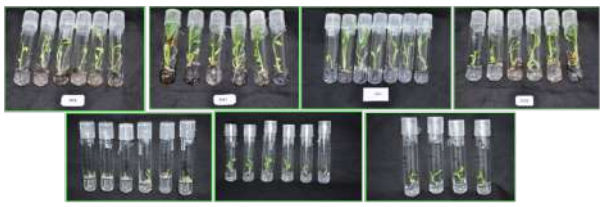


Fig. 68. *In vitro* germination of NE banana varieties

Fig. 69. Effect of sowing depth, hormonal concentration on germination in vermicompost : coco peat and sand medium under bed system

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

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

With the available RNA sequence data from drought tolerant cv.Saba and drought susceptible cv. Grand Naine, 13 genes were identified as candidate drought responsive genes through protein-protein interaction network analysis. Validation of these genes through qRT-PCR revealed that these genes (EG, NRT,FT, WRKY, RUP1, perox P51, LOX1, DPBF2, EXP, HSP) are inconsistent with those of the transcriptome analysis, except for the expression of COD, DREB, and SQE under drought induced condition in the tolerant cultivar.

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

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

A tissue culture protocol for traditional cultivars of north-eastern region, namely Cheeni Champa and Malbhog, has been standardized.

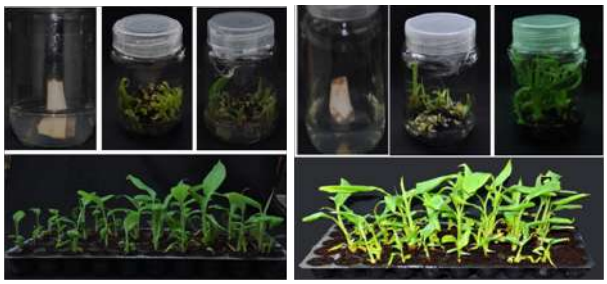


Fig. 70. *In vitro* regeneration of *Musa* cvs. Cheeni Champa and Malbhog

Biochemical analysis of the fruit-peel at unripe stage and fruit-peel and fruit-pulp at ripe stage of seven accessions *viz*. Attikol, Bhat Manohar, Kanai Bansi, Manjahaji, Phirima Wild, Pagalapahad I and Pagalapahad II has been completed.

Biochemical analysis of the fruit peel at unripe stage and peel and pulp at ripe stage of seven accessions, Attikol, Bhat Manohar, Kanai Bansi, Manjahaji, Phirima Wild, Pagalapahad I and Pagalapahad II has been completed.

Mineral analysis of fruit peel and pulp at ripe stage for five accessions (*M. velutina, M. aurantiaca*, Jahaji, Jatikol and Bhimkol) and fruit peel and pulp at unripe stage for nine accessions (*M. velutina* variant, *M. cheesmani*, *M. itinerans*, *M. aurantiaca*, *M. saddlensis, M. thomsoni,* Jahaji, Jatikol, Bhimkol) has been completed.

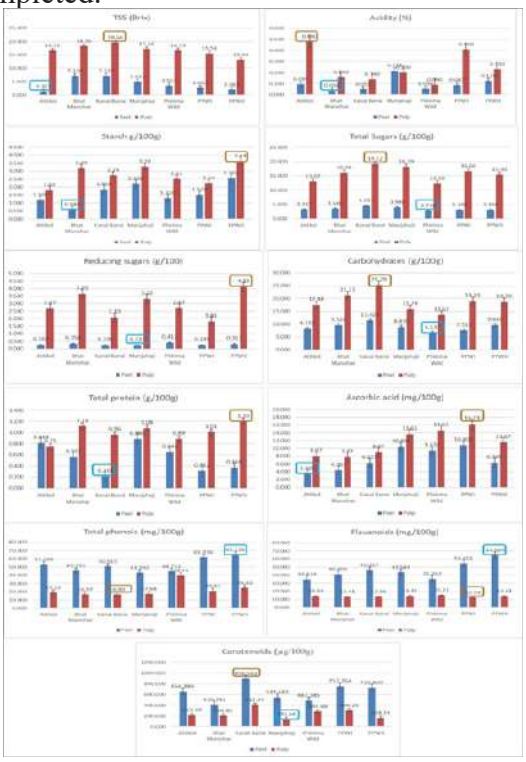


Fig. 6. Biochemical analysis of fruit-pulp and fruit-pulp samples at ripe stage

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

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

Standardization of micropropagation protocols using shoot tip explants has been completed Bharatmoni and it is in progress for Digjowa and Sabri.

Fig. 71. *In vitro* mass propagation of *Musa* cv. Bharatmoni using shoot tip explants

Standardization of micropropagation protocols using male flower buds has been completed for Amrit Sagar and it is in progress for the other three varieties.

Fig. 72. *In vitro* mass propagation of *Musa* cv. Amrit Sagar using immature flower bud explants

f. Diversity assessment, germplasm conservation and database development on banana resources of North Eastern India

(M.S. Saraswathi and S. Backiyarani)

Tissue culture plants of *Musa laterita* are in the secondary hardening stage and after establishment they will be challenge inoculated with spores of Foc TR4 and sampled for transcriptomic studies.

Fig. 73. *In vitro* propagation of *M.laterita* for use in transcriptomics

Cloning and sequencing of Sigatoka resistant gene (DIR 11) showed significant variations between resistant and susceptible varieties with 2 synonymous and 8 non-synonymous mutations. Sequence analysis indicated high sequence identity (100%) among susceptible cultivars (AAA genome) and resistant cultivars (BB genome), whereas the sequence identity between AA and BB genomes was 97.8%.

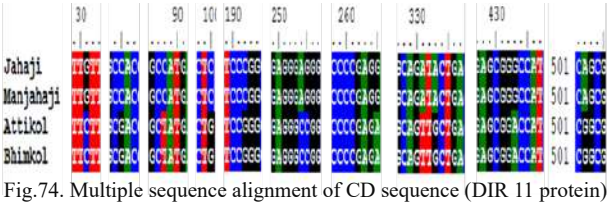


Fig.74. Multiple sequence alignment of CD sequence (DIR 11 protein)

Table 31. Sequence Identity Matrix for DIR 11 protein

Seq->	Jahaji	Manjahaji	Attikol	Bhimkol
Jahaji	ID	1.000	0.978	0.978
Manjahaji	1.000	ID	0.978	0.978
Attikol	0.978	0.978	ID	1.000
Bhimkol	0.978	0.978	1.000	ID

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

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

About 640 mg of crude fructans was extracted from the fruits of 'B' genome bananas (Attikol, Bhimkol, Beejikela and *Musa balbisiana*). *In vitro* analysis of immune-modulatory properties of the crude fructans with chicken DT40 cell line showed positive modulation with strong regulation of immune-related marker genes, interferon gamma (IFN-γ) and interleukin-4 (IL-4) as the transcript levels of these genes were higher in fructans-treated cells.

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)

Among the NER bananas evaluated against drought stress, Banria genotype recorded 20.12 kg with 12 hands and 200 number of fruits under irrigated condition, whereas under drought it yielded 15.15kg with 9 hands and 124 fruits. Bojhi Manohar recorded 20.35 kg with 11 hands and 155 fruits under irrigated conditions, whereas under drought it yielded 15 kg of bunch weight with 10 hands and 142 fruits.

i. Development of pre-and post-harvest bunch care management of fresh banana

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

Development of edible coating methodologies for Ney Poovan

Coating with wax (1:4) after infusing ethylene for ripening Ney Poovan showed good effect on the extension of yellow life and prevention of crown rot with 9 days of shelf life after ripening, when compared to the control (up to 4 days).

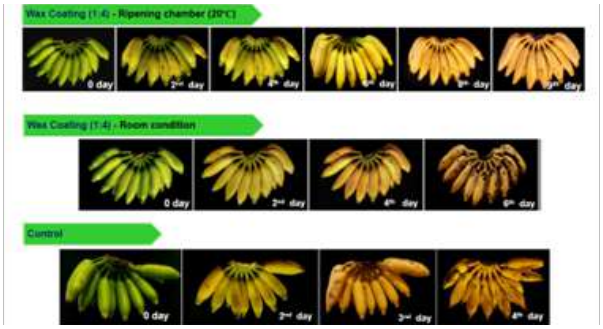


Fig. 75.Colour development during ripening

Growth degree days, photo thermal unit, helio thermal unit and heat unit efficiency requirement of different banana varieties

Crop duration was maximum in Udhayam (470 days) followed by Karpuravalli (415 days). The yield recorded in Udhayam (9500t/ha) was significantly higher with extended crop duration. Highest GDD of 8011 °C day was recorded for Udhayam during the entire growth period. Similarly, Karpuravalli (7114°days) and Rasthali (6975°days) required more GDD than other varieties, whereas Nendran (5338 °days) needed the least GDD. However, var. Ney Poovan required more GDD (2013.5°days) from flowering to fruiting whereas var. Popoulu required lesser GDD (1125.50°days)

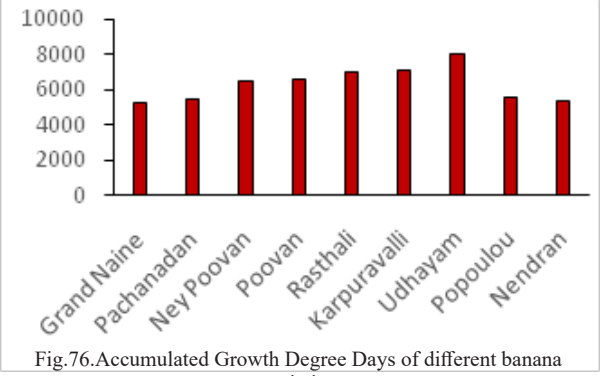


Fig.76.Accumulated Growth Degree Days of different banana varieties

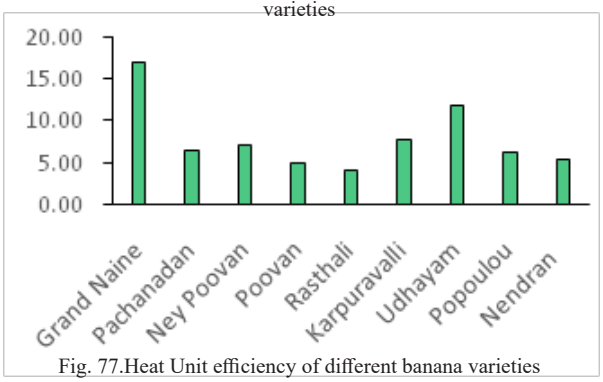


Fig. 77.Heat Unit efficiency of different banana varieties

Based on the maturation period, banana varieties require 210-340 days for flowering and 80-130 days for fruit maturation. Higher days of phenology with greater value of GDD, PTU and HTU were observed with the long duration varieties like Udhayam, Ney Poovan and Karpuravalli, while lower values were observed for short duration varieties like Popoulou and Rasthali. Accumulated GDD, PTU and HTU were linearly related to vegetative as well as reproductive stages of the banana. It is essential to breed higher HUE traditional banana varieties to enhance the energy as well as biomass productivity.

Identifying new molecule for extending the green life of Grand Naine

Grand Naine fruits treated with alum + carbendazim showed lower percentage of spoilage (5.93%) and the fruit under control recorded the highest spoilage percentage (38.56%). Fruit firmness showed differences among various treatments and storage intervals and the highest firmness was observed in alum + *Aloe vera* treated fruits and pulp: peel ratio was noticed in control (2.77) and the lowest in sodium hypochlorite + hexanal treated fruit with a value of 1.93. The shelf life was the highest in alum + carbendazim treated fruits (78 days) followed by sodium hypochlorite + carbendazim (62 day), alum + hexanal (56 days), alum + *Aloe vera* gel (52 days) treated fruits and the lowest was recorded in control.

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)

Anti-urolithiatic property of central core stem

Antioxidant and antiurolithiatic activities of the aqueous methanol extract of banana stem extract was studied. The total phenols and flavonoid content of stem extracts were in the range of 40-55 mg/ g and 90-128 mg/ g, respectively. DPPH assay showed dose-dependent activity for scavenging the radicals. Comparatively, Nendran and Manjahanji center core stem extracts exhibited good antioxidant activity. In nucleation assay, the stem extract of Nendran demonstrated slightly better results compared to standard solution to inhibit the formation of crystals. Maximum inhibition of 80.92% was observed with 5ml of stem extract.

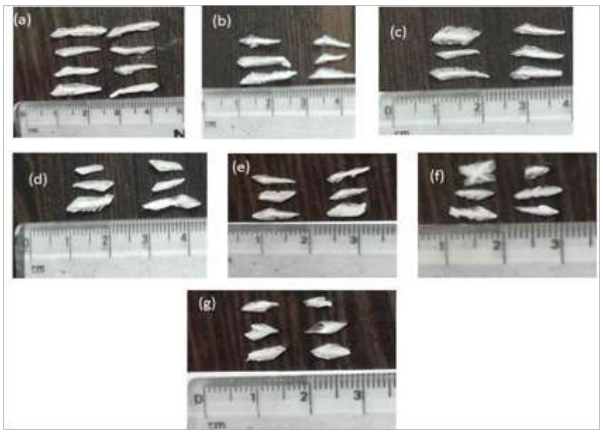


Fig. 78. Anti-urolithiatic efficiency of stem extracts

Low sodium pickle from underutilized part of banana (inflorescence and pseudostem)

Studies were done to examine the suitability of low sodium salts for the preparation of banana stem and flower pickles. Salt with 23.2% Na content (in place of salt with 38.7%) was considered the best treatment for both stem and flower pickles because physicochemical and sensory attributes were the same as in control. Studies showed that pickles can be packed and stored safely for up to 60 days in three types of packaging material such as PET, HDPE, and glass bottles.

Low fat set fruit yoghurt

Effect of addition of ripe banana pulp for the preparation of probiotic yoghurt was studied. Addition of fruit pulp increased the acidity and pH of the final product and did not have any marked effect on apparent viscosity (6.84%) and moisture content (51.58%). Protein and ash content also increased with the addition of fruit pulp and fat content decreased. Both banana and honey have the highest water holding capacity. Therefore, banana and honey can be used to produce low fat yogurts that can be stored for up to 14 days under refrigeration.

Low calorie banana stem juice

The suitability of low-calorie sweeteners for the preparation of banana stem juice was examined. Among the sweeteners, white sugar recorded maximum TSS (8.04° Brix) followed by Stevia, sucralose and aspartame. The lowest carbohydrate content was recorded in Aspartame (0.4g/100g). Maximum protein content was recorded in white sugar (0.66 g/ 100g) followed by aspartame (0.4 g/ 100g), Stevia (0.4 g/100g) and sucralose (0.2 g/ 100g). Sucralose added stem juice recorded lower starch hydrolysis and recorded higher viscosity (1.57 cp).

Banana Fruit Syrup

Banana fruit syrup with a TSS of 65˚Brix was prepared by condensation of raw banana juice (TSS 22-26 ˚Brix) at 70˚C for 5 hours and the product exhibited sensory properties similar to that of commercially available liquid sweeteners.

Fig. 79. Banana fruit syrup

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)

Development of biodegradable plates from banana waste

Outer layers (2-4) were used for making baskets, boxes and mats and inner sheath with 8-15 layers were used for both making handicrafts and disposable sheath plates. Plates prepared from the inner sheath had a hardness of 40.04 ± 0.03 N and thickness of 1.36 ± 1.25 mm. Scutcher waste plates showed good hardness (about 75.72 ± 0.01 N) than the other bioplates with burst strength of 2.29 ± 0.77.

Fig. 80. Plates made from banana leaf, sheath and scutcher

Fig. 81. Edible cutlery

Edible cutlery from banana waste

Among the compositions, peel flour (20%), wheat flour (65%), sugar (5%), oil (2%), salt (2%) and sooji (5%) gave best results for desired consumption. Sensory properties, texture profile, and water absorption remain to be evaluated.

Nanocellulose extraction from banana fibre

Nanocellulose was produced from cellulose. The process involved acid hydrolysis of the cellulose particles at 45°C with 65%wt sulphuric acid for 30 minutes under mechanical stirring (shaker). The precipitate was collected and freeze dried.

Standardization of faster dewaxing method

Microwave treatment showed good impact over soxhlet method for dewaxing of banana fibres. Microwave method required only 30–40 min of processing and up to 50% solvent can be recovered for repeated use whereas traditional soxhlet method requires 6–7 hr for removing the wax.

Fig. 82. Dewaxing using MW oven

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)

Two native NE isolates of *B. brongniartii* (NRCBEPF-27) and *M. anisopliae* (NRCBEPF-36) and four commercial myco-formulations, Biomagic (*M. anisopliae* 1.50% liquid formulation), Beauvericide (*B. bassiana* 1.50% liquid formulation) from TARI Biotech, Tamil Nadu and Bio-Control Research Laboratory (BCRL) were evaluated against fruit scarring beetle. The formulations were stored in polypropylene pouches for further laboratory bioassays and field evaluation trials.

The composition of volatile organic compounds (VOC) released by *Beauveria bassiana* and *Metarrhizium anisopliae* utilizing different sources was studied by gas chromatography mass spectrometry (GC-MS) analyses and significantly higher numbers of insect volatile compounds were present in fungus treated insects compared to the control.

m. 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)

Four CRISPR/Cas9 knockout constructs have been developed to mutate the viral ORFs of the endogenous BSV. Embryogenic cell suspension of cv. Poovan and Rasthali (AAB group) were used in co-cultivation. ECS of cv. Rasthali was obtained from Crop improvement division since it has B genome which contains the putative endogenous BSMYV sequences. In order to develop embryogenic cell suspension of cv. Chini Champa (Syn: Poovan), totally 910 virus-free Poovan male buds (30 per week) were collected from NRCB farm and farmer's fields after about 1 to 10 weeks of flowering. Totally 13650 inflorescences were initiated for embryogenic callus induction. Few embryogenic calli were transferred to Cell suspension culture medium.

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

(R. Selvarajan and C. Anuradha)

RNAi constructs developed for Rep and Movement protein gene and NSP gene were used for co-cultivation with ECS of Poovan. Co-cultivation has been taken up with Rasthali ECS (Supplied by Crop Improvement Department). All the components of BBTV isolate of Assam are being sequenced.

4.5.5 DST funded projects

a. Development of efficient IOT enabled plant disease pest detection system

(R. Selvarajan and R. Thangavelu)

Totally 3500 new images of pests and diseases of banana have been added for the machine learning. An IoT gadget has been developed and installed in the glasshouse and the data on temperature, humidity and soil moisture are being recorded in the cloud. An app and a website have been created for the purpose of acquiring the images of banana diseases and pests from the farmers. Seven gadgets developed by SSN shall be deployed in the farms in Theni and Lower Pulney Hills for recording the data and images for IoT and to develop DSS for the benefit of the farmers.

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

(R. Selvarajan)

Additional quantity of monoclonal antisera raised for BBrMV and CMV have successfully detected the respective viruses inan triple antibody coated sandwich ELISA using either alkaline phosphatase or peroxidase conjugates and these antibodies were supplied to the collaborating partner, PSG College of Technology, Coimbatore, Tamil Nadu, for

dot blot TAS-ELISA. Polyclonal antibodies of BBTV and BSMYV were also supplied for developing the dot ELISA. In addition, positive, negative freeze dried as well as the expressed coat proteins of the two viruses were also supplied for the development of Dot-TAS ELISA.

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

(K. Panneerselvam)

Plant type III polyketide synthases (PKSs) are associated with various functions in plant growth, development and defense by providing a multitude of polyketide scaffolds for diverse specialized metabolic pathways (SMPs). To decipher banana PKSs involved in specialized metabolism, genome-wide comparative analyses were conducted with A (*Musa acuminata*) and B (*M. balbisiana*) genomes. Both genomes retained eight chalcone synthases (CHSs), seven curcumin synthases (CURSs), three diketidyl-CoA synthases (DCSs) and one anther-specific CHS (ASC). Segmental (42%) and tandem (37%) duplication events majorly flourished the banana PKS family. Six of 19 PKSs of A genome (designated as MaPKSs) showed relatively higher expression in the root, corm, sheath, leaf and embryogenic cell suspension (ECS). To determine the defense response of MaPKSs and to highlight their candidacy in various SMPs, expression profiling was conducted by qPCR in ECSs treated with 100/200 µM of jasmonic acid (JA) and salicylic acid (SA) at 24/48 hr. Maximum and subordinate expression induction of MaPKSs was apparent respectively against JA and SA treatments. Notably, most MaPKSs achieved their peak expression within 24 hr of JA and the total flavonoid content was reached within 24 hr of JA/SA elicitations. Considering the homology, phylogeny, and expression levels in each analyzed sample (n=13), three CHSs, three DCSs along with three CURSs and one ASC were selected as most promising candidates respectively for flavonoids, phenylphenalenones and sporopollenin biosynthesis in banana. Our findings provide a first-line resource to disclose the functions of banana PKSs involved in distinct SMPs.

4.5.6 ICAR Funded Projects

a. Integrated management of Fusarium wilt, Tropical Race-4 – A devastating strain on banana (R. Thangavelu, M. Loganathan, C. Anuradha and S. Uma)

Survey to study the distribution and diversity of the *Fusarium oxysporum* f.sp. *cubense* (*Foc*)

A survey was conducted in different banana growing states, *viz*. Bihar, Gujarat, Kerala, Maharashtra, Madhya Pradesh, Tamil Nadu and Uttar Pradesh, to study the distribution and diversity of *Foc* biotypes. In all, 26 Fusarium wilt infected corm samples were collected from six cultivars for the possible isolation of *Foc* TR4. The characterization of *Foc* isolates by VCG and molecular methods indicated that *Foc* R4 (including *Foc* STR4 and TR4) was present only in cv. Grand Naine and absent in the cvs. Ney Poovan (AB), Karpuravalli (ABB), Rasthali (AAB), and Senna Chenkathali (AA). The analysis of *Foc* isolates collected from Grand Naine cultivars grown in Bihar and UP indicated the presence of VCGs 01220 and 0125 belonging to *Foc*Race1. In addition,the tropical race 4 (VCG 01213/16) was also identified from the *Foc* samples collected from Bihar and Uttar Pradesh.The presence of VCG 01220 and 0125 of *Foc* race 1 was also confirmed in *Foc* isolates collected from cv. Grand Naine grown in Surat. These isolates were further confirmed by molecular analysis using specific markers.The TEF1α gene sequencing analysis confirmed that *Foc*R1 was distributed in Tamil Nadu, Kerala, Maharashtra, Gujarat and Madhya Pradesh, while *Foc* STR4 was distributed in Gujarat and Madhya Pradesh. Analysis using race-specific molecular markers (PCR) revealed that VCG 120 was distributed in Gujarat and Madhya Pradesh.

Whole-genome sequence analyses of Fusarium wilt pathogens infecting Cavendish banana (*Foc* Race 1 and *Foc* TR4)

To understand the genome organization of the devastating soil-borne *Foc* strains, *Foc*

Race 1 (VCG 0124) and 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 was used to assemble, map and predict the sequenced genome.

The whole genome of *Foc* R1 infecting Cavendish bananas was 48.6 mb 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 7,140 (47.4%) were associated with molecular functions. Plant Host Interaction (PHI) search showed that there were 1042 genes in the genome, of which 30 are unique concerning Foc R1 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. Plant Host Interaction (PHI) search showed that 365 putative virulence-associated genes have been identified against reference Foc TR4 of which 19 are unique in nature. Among the 14 secreted in xylem (SIX) protein gene clusters (SIX1-SIX14), SIX1, SIX2, SIX6, SIX8 and SIX9 are present in the *Foc* TR4 genome and SIX1, SIX5, SIX6, and SIX9 have been found in the *Foc* R1 genome. Moreover, the presence of homologues SIX8, both SIX8a and SIX8b in the genome of *Foc* TR4 and SIX1 gene (alternatively AVR3) in *Foc* R1 indicate sequence polymorphism.

Table 32. General genome and predicted proteome statistics for reference and assembled genomes

Characteristics	*Fol* 4287†	*Foc* Race 1*	*Foc TR4*#
Genome size (Mb)	61.5	48.6	47.4
No. of contig (Count)	114	2,635	4,034
Maximum contig length	6,854,980	2,54,284	1,90,413
Minimum contig length	900	300	300
Average contig length	6,98,542	18,442	11,746
Median contig length	15,960	3,884	5,665
GC content	48.4	47.9	49.4
No. of protein coding genes	27,347	15,111	15,508
Total No. of genes	20,925	15,131	16,129
Gene BUSCO	96	97	98

Evaluation of native endophytic and rhizospheric bacterial bioagents against *Foc* TR4

A total of 73 bacteria (57 endophytic and 16 rhizospheric) were isolated from 17 different diploid varieties belonging to AA and BB genomic groups and were tested *in vitro* and in glasshouse for the control of *Foc* TR4. Preliminary *in vitro* screening shows that 10 bacterial isolates were effective against the pathogen based on spore germination assay and dual culture plate assay. A pot culture study conducted with 30 treatments with different bacterial combinations showed that the treatment T6 (Rhizo. *B. haynesii*+ Endo. *B. subtilis* ssp. *inaquosorum*) recorded the lowest internal wilt score (0.0) followed by T2 (Rhizo. *B. haynesii* +Endo. *B. velezensis*) at 90 DAI when compared to *Foc* alone (T29) inoculated plantlets. The treatment T6 also showed an increase in the biometric attributes such as plant height (44 %), girth (54 %), leaf area (86%) and root numbers (97%).

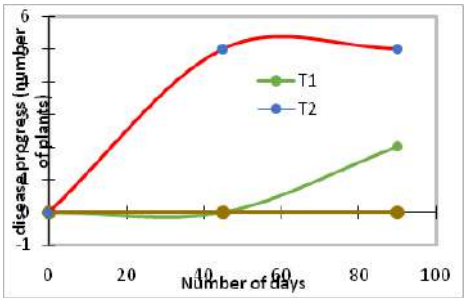


Fig. 83.Effect of endophytic and rhizospheric bacterial combination against FocTR4 in tissue culture banana

Fig.84. Effect of combined application of endophytic and rhizospheric bacterial isolates on the internal wilt score of banana. T6 - Rhizo. *B. haynesii* + Endo. *B. subtilis* ssp. *inaquosorum*

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

(R. Selvarajan and C. Anuradha)

A ready-to-use ELISA kit was developedfor simultaneous detection of BBrMV and CMV and released during the ICB-2020 organized during Feb2020.Monoclonal antibodies were also produced against CMV and it reacted well with the samples and expressed protein in DAS,PTA- ELISA and TAS-ELISA. Different parameters like pH and IgG concentration of monoclonal antibodies produced against CMV were standardized for LFIA preparation. To validate the M-RT-RPA developed, 27 leaf samples of cv. Grand Naine collected from various locations in banana growing states were tested. The validation results showed that amplification was observed in only symptomatic samples and amplification was not observed in healthy control samples. Using MinION sequencing approach, complete genome of BBrMV and CMV infecting banana and TSWV infecting tomato was detected and characterized.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Transfer of technology

S.No.	Technology details	District (Tamil Nadu)	Training Type
1.	Integrated crop management (Banana Sakthi as one of the components)	Trichy	Frontline Demonstration
2.	Banana leaf spot disease management	Karur	Demontration and training
3.	Integrated crop management (Banana Sakthi as one of the components)	Dharmapuri	Frontline Demonstration
4.	Banana Sakthi	Krishnagiri	Awareness and Training
5.	Popularisation of banana fibre extraction machine	Krishnagiri	Awareness and Training
6.	Micronutrient management in banana	Krishnagiri	Frontline Demonstration
7.	Popularisation of Kaveri Kalki	Thiruvarur	Frontline Demonstration
8.	Promoting cvs. Karpooravalli, Monthan and other popular varieties	Puthukottai	On Farm Trial
9.	Intercropping cowpea with banana	Namakkal	Frontline Demonstration
10.	Banana stem weevil management	Namakkal	Frontline Demonstration
11.	Integrated crop management for Hill banana with wilt management as a component	Namakkal	Frontline Demonstration
12.	Banana Sakthi	Namakkal	On Farm Trial
13.	Popularisation of Kaveri Saba	Ariyalur	Frontline Demonstration
14.	Popularisation of banana varieties	Ariyalur	On Farm Trial
15.	Demonstration unit for Poovan, Karpuravalli	Tirunelveli	Demonstration
16.	Promoting cv. Monthan	Tirunelveli	Demonstration and Training
17	Banana Sakthi	Tirunelveli	Demonstration

5.2 Radio talks

Name of the Scientist	Topic	Date of broadcast	Channel
S. Backiyarani	'Kela Vriddhi'- Quality Planting Material Production	11 February, 2020	All India Radio, Tiruchirappalli
K.N. Shiva	Scientific aspects of Post-Harvest Management, Value Addition and Waste Utilization of Banana	21February, 2020	
	Post-Harvest Technology of Banana, International Conference on Banana -2020	22February, 2020	
	About International Conference on Banana -2020 and Exhibition	22 February, 2020	
	Value Added Products in Banana including ABI activities	9 June, 2020	
P. Suresh Kumar	Future foods, Nutraceutical foods, and designer foods from banana and waste utilization	21 February, 2020	
	Use of banana flour for making functional foods and to avoid the market glut	31 March, 2020	
V. Kumar	Sucker Selection and Planting Techniques in Banana	7 April, 2020	
D. Ramajayam	Crop improvement in Banana	30 May, 2020	Multilocation audio conference organized by KVK, Vamban, and Reliance Foundation, Pudukottai, Tamil Nadu
V. Kumar	Crop Management in Banana		
J. Poorani	Crop protection in Banana		
P. Suresh Kumar	Value addition in Banana		

5.3 Exhibitions conducted / participated

Name of the event	Organizer & Venue	Date	Name of the staff participated
Mega Krishi Mela (107th Science Congress)	Govt. of Karnataka at UAS, GKVK, Bangalore	3-7 January, 2020	S. Uma V. Kumar
National Horticultural Fair-2020	SPH at ICAR-IIHR, Hessaraghatta, Bangalore, Karnataka	5-8 February, 2020	K.N. Shiva R. Karthic R. Kalpana
ICB-2020 Banana Show	ICAR-NRCB at Kalaiyarangam Hall, Tiruchirappalli, Tamil Nadu	22-24 February, 2020	All staff of ICAR-NRCB
Digital Exhibition on Food Processing Machineries under Digital Indo-Italian Business Mission	CII in association with the Italian Trade Agency (ITA) (*Via* Webex Meet)	15–16 July 2020	K.N. Shiva

5.4 Publicity

A total of 32 press notes on the ICAR-NRCB activities / ceremonies / technological information (popular articles) were published in different national and local dailies including Tamil magazines / journal, AIR- farm division etc. for the benefit of the banana farmers.

5.5 Extension/ farmers visit

Around 2480 visitors including agricultural & horticultural officers, SHG, entrepreneurs, students and stakeholders visited ICAR-NRCB and they were explained about ICAR-NRCB activities / technologies. Under the outreach programs, ICAR-NRCB has trained more than 825 farmers across the country.

ICAR-NRCB stall visited by Dr.Trilochan Mohapatra, Director General, ICAR, New Delhi at Mega Krishi Mela

Visitors at ICB-2020 Banana Show

Visit of banana farmers to ICAR - NRCB

Visit of students to ICAR - NRCB

6. EDUCATION AND TRAINING

6.1.1 Students Guided

Student Name	Degree	Project title	Chairperson
M. Kumaravel	Ph.D. (Biotech.)	Studies on molecular basis of somatic embryogenesis and its manipulation in recalcitrant banana cultivars	S. Uma
K. Raja	Ph.D. (Biotech.)	Transcriptomic profiling of *Musa* during interaction with *Pratylenchus coffeae*	S. Backiyarani
R. Manohar Jebakumar	Ph.D. (Biotech.)	Induction of systemic resistance against Banana Bunchy Top Virus	R. Selvarajan
S. Vaishnavi	M.Sc. (Biotech.)	Rolling circle amplification and cloning of complete genome of a BSV species from banana cv. Champa Kola	
L. Vineeth	B.Tech. (Industrial Biotech.)	Construction of an infectious clone for banana bract mosaic virus using oe-pcr and Gibson assembly	
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	
M. Srimathi	B.Tech. (Biotech.)	Molecular characterisation, structural modeling and validation of parthenocarpic associated proteins in *Musa* sp. (Banana) through *in silico* and *in vitro* approaches	S. Backiyarani
B. Sangeetha	B.Tech. (Biotech.)	Standardisation of media for *in vitro* culture of ornamental banana hybrid embryos	D. Ramajayam
G. Arunkumar	M.Sc. (Food Processing)	Standardization and evaluation of banana central core (stem) juice blended with spices and herbs	K.N. Shiva
J. Aiswarya	M.Sc. (Food Tech. & Quality Assurance)	Development of low sugar, ready to drink beverages from banana central stem	P. Suresh Kumar
Aleena Baby		Characterization of anthocyanin from banana leaves of hybrid progenies and development of nutraceutical bread	
K. Amrutha Krishnan		Minimal processing of fresh cut banana slices	
H. Fathima		Influence of banana starch and reinforcement of cellulose nanofibers on biofilms	
R. Lakshmi Priya		Low fat set yogurt with probiotic cultured flavoured banana yogurt	
Megha Thomas		Nutritional characteristics & shelf-life studies of banana flour incorporated bakery products	

Ridhu Pradeep	M.Sc. (Food Tech. & Quality Assurance)	Influence of drying environment on dehydration of ripe banana and studying the storage behaviour	P. Suresh Kumar
R. Rakhith		Identifying new molecules and methods for extending the green life of banana var. Grand Naine	
S.P. Rowena		Characteristics of basil seed suspended banana ready to serve juice	
S. Aiswarya		Development of low sodium banana flower and stem pickles	

6.2 Trainings

6.2.1. On-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Training on 'Value Addition and Marketing of Banana'	K.N. Shiva P. Suresh Kumar V. Kumar	15	28 January to 1 February, 2020
Macropropagation in banana	S. Backiyarani	40	3 January, 2020
		60	8 January,2020
		60	28 February, 2020
		40	3 February,2020
In vitro multiplication and molecular biology	S. Backiyarani	1	9-20 March, 2020
International training programme on"Epidemiology and Management of *Foc*TR4 in Banana"during 'International Banana Conference-2020' held at Tiruchirappalli	R. Thangavelu M. Loganathan	70	24 February, 2020
Training on 'Banana Fig'	K.N. Shiva P. Suresh Kumar	1	15-16 December, 2020

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Standard Operating Procedures (SOP) of APEDA approved Pack House to TNBPCL Officials and Employees, TN at APEDA approved Pack House, Thottiyum Tk., Trichy Dt., Tamil Nadu	V. Kumar R. Thangavelu K.N. Shiva	25	22 October, 2020
Standard Operating Procedures (SOP) of APEDA approved Pack House to Pack House employees, Chinnamanur, Tamil Nadu at APEDA Pack House, Chinnamanur, Theni Dt., Tamil Nadu		15	2 November, 2020

6.2.3. Trainings on Virtual Platform

Title	Panelists	Organizer	Date
Crop Management in Banana Cultivation	S. Backiyarani, ICAR-NRCB V. Kumar, ICAR-NRCB J. Poorani, ICAR-NRCB D. Ramajayam, ICAR-NRCB	Vivekananda Kendra - NARDEP, Kanyakumari, Tamil Nadu	12 June, 2020
Integrated Technologies in Banana Cultivation	K.J. Jeyabaskaran, ICAR-NRCB M.S. Saraswathi, ICAR-NRCB R. Thangavelu, ICAR-NRCB D. Ramajayam, ICAR-NRCB		19 June, 2020
Propagation, Crop Protection and Value Addition in Banana & Agri-Business Incubation Centre – An Introduction	R. Selvarajan, ICAR-NRCB K.N. Shiva, ICAR-NRCB D. Ramajayam, ICAR-NRCB		26 June, 2020
'*Kela Vriddhi*' – A Novel Technology in Banana Propagation	B.K. Venkatesh, Zonal Head, ICICI Foundation S. Backiyarani, ICAR-NRCB S. Uma, ICAR-NRCB S. Kalpana, ICAR-NRCB R. Raju Karthick, ICAR-NRCB	ICAR-NRCB & ICICI Foundation For Inclusive Growth	18 June, 2020
Banana tissue culture production: Opportunities for New Entrepreneurs	M.S. Saraswathi, ICAR-NRCB	IDP-NAHEP webinar organized by College of Horticulture and Forestry, CAU, Pasighat	20 October, 2020
Pre-harvest and postharvest handling practices to be followed for export markets	V. Kumar, ICAR-NRCB R. Thangavelu, ICAR-NRCB K.N. Shiva, ICAR-NRCB P. Suresh Kumar, ICAR-NRCB P. Giribabu, ICAR-NRCB	Consultancy Project for Nendran Export to Europe by VFPCK, Kerala (To VFPCK Officials, Kerala)	24 & 26 August, 2020
Standard Operating Procedures (SOP) for quality production and Scientific Handling of 'Nendran' banana for Export Market	V. Kumar, ICAR-NRCB R. Thangavelu, ICAR-NRCB K.N. Shiva, ICAR-NRCB P. Suresh Kumar, ICAR-NRCB K.J. Jeyabaskaran, ICAR-NRCB P. Giribabu, ICAR-NRCB		19-20 October 2020

ICAR-NRCB Webinar Series

During 2020, ICAR-NRCB conducted a series of eight webinars on various aspects of banana cultivation and export with eminent scientific / industrial / administrative delegates as panellists. The webinar series was inaugurated by Dr. A.K. Singh, DDG (Hort. Science), and the presidential address was delivered by Dr. S. Uma, Director, ICAR-NRCB. Dr. S. Uma, Director, ICAR-NRCB acted as Chairperson and Dr. R. Selvarajan, Principal Scientist, ICAR-NRCB acted as moderator and convenor for the webinars. The details of the webinar series are tabulated below.

Date	Webinar Topic	Panelists and their designation
3 July, 2020	Processing and Value Addition in Banana	Dr. S. Uma, Director, ICAR-NRCB Dr. K.N. Shiva, Principal Scientist (Horticulture), In-charge ABI, ICAR-NRCB Dr. P. Suresh Kumar, Principal Scientist (Horticulture), ICAR-NRCB Dr. Ravindra Naik, Principal Scientist, ICAR-CIAE, Coimbatore (Regional Centre)
18 July, 2020	Organic Banana Production and Certification – The Status and Way Forward	Mr. Mathew Sebastian, Founder, Executive Director, INDOCERT, Kerala Dr. M.L. Jyothi, Professor (Horticulture), KAU, Kerala Dr. K.J. Jeyabaskaran, Principal Scientist (Soil Science), ICAR-NRCB Mr. Gopalakrishnan Duraisamy, Organic Certification Inspector, Tamil Nadu Organic Certification Department, Tamil Nadu
22 July, 2020	Value Addition and Entrepreneurship Development in Banana	Mr. S. Selvaraj, Chief General Manager, NABARD, Tamil Nadu Dr. K.S. Mahesh, CFO, NABKISAN (NABARD) Dr. K. Muralidharan, Head, Dept. of Social Sciences, In-charge ABI, ICAR-CPCRI, Kasaragod, Kerala Dr. K.N. Shiva, Principal Scientist (Horticulture), In-charge ABI, ICAR-NRCB Dr. P. Suresh Kumar, Principal Scientist (Horticulture), ICAR-NRCB
25 July, 2020	Precision Farming in Banana	Dr. T.N. Balamohan, Former Dean, HC&RI for Women, TNAU Dr. K.B. Patil, Vice President (TC & Agri Services), JISL, Jalgaon Dr. I. Ravi, Principal Scientist (Plant Physiology), ICAR-NRCB Dr. V. Kumar, Principal Scientist (Horticulture), ICAR-NRCB
29 July, 2020	Integrated Disease Management in Banana	Dr. Rashmi Aggarwal, Joint Director (Education) and Dean, ICAR-IARI, New Delhi Dr. M. Krishna Reddy, Head, Division of Crop Protection, ICAR-IIHR, Bangalore Dr. R. Thangavelu, Principal Scientist (Plant Pathology), ICAR-NRCB Dr. R. Selvarajan, Principal Scientist (Plant Pathology), ICAR-NRCB

4 August, 2020	Integrated Insect Pest and Nematode Management in Banana	Dr. B. Padmanaban, Retired Principal Scientist (Entomology), ICAR-NRCB Dr. J. Poorani, Principal Scientist (Entomology), ICAR-NRCB Dr. K. Subaharan, Principal Scientist (Entomology), ICAR-NBAIR, Bangalore Dr. P. Giribabu, Senior Scientist (Nematology), ICAR-NRCB
7 August, 2020	Planting Material in Banana – Present and Next Generation Technologies	Dr. S. Uma, Director, ICAR-NRCB Dr. S. Backiyarani, Principal Scientist (Plant Biotechnology), ICAR-NRCB Dr. M.S. Saraswathi, Principal Scientist (Horticulture), ICAR-NRCB Dr. Sukhen Chandra Das, Assistant Professor, CAU, Tripura
21 August, 2020	Export of bananas from India	Dr. S. Uma, Director, ICAR-NRCB Mr. R. Ravindra, Regional Head, DGM, APEDA, Mumbai Dr. Azhar Pathan, Buisness Head, Mahindra Agri Solutions Ltd., Mumbai Dr. K.B. Patil, Vice President (TC & Agri Services), JISL, Jalgaon Dr. K.N. Shiva, Principal Scientist (Horticulture), In-charge ABI, ICAR-NRCB

Dr. S. Uma, Director, ICAR-NRCB receiving Dr. Kalayya Krishnamurthy National Award 2019-20 at UAS, Bengaluru

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
S. Uma	Dr. (Ms) Prem Dureja Endowment Award 2020 - NAAS, New Delhi
	Dr. Kalayya Krishnamurthy National Award 2019-20 - UAS, Bengaluru
	Biodiversity Conservation Award – 2019 - Dr. B. Vasantharaj David Foundation, Chennai
	Sir J.C.Bose Memorial Award – 2020 - The Indian Science Monitor, Chennai
R. Thangavelu	'Eminent Scientist Award-2020' by the Agricultural & Environmental Technology Developmental society (AETDS), Uttarakhand, India for the outstanding contribution and recognition in the field of Plant Pathology on the occasion of International Web Conference – perspective on agricultural and applied sciences in COVID-19 scenario(PAAS-2020)
	'Dr. A.P.J. Abdul Kalam Scientist Award-2020' by The Society of Tropical Agriculture, New Delhi at '11th International Conference on Agriculture, Horticulture and Plant Sciences' held during19-20 December 2020
	'Eminent Scientist Award' for the excellent contribution in the field of Agriculture and allied sectors at National Webinar on 'Prospectives, Priorities and Preparedness of Sustainable Agriculture Development in India' organized by Dr. Ram Avatar Shiksha Samiti (DRASS), UP, during December 28-29, 2020
R. Selvarajan S. Backiyarani	Outstanding Agricultural Scientist Award-2020 by Dr Vasantharaj David Foundation
M. MayilVaganan	Research Excellence Award-2020 from Institute of Scholars, Bengaluru
S. Backiyarani	IAHS Fellowship in Fruit Science-2020, IAHS, New Delhi
P. Suresh Kumar	Shri. D. P. Ghosh Memorial Young Scientist Award-2020 by the Indian Academy of Horticultural Sciences, New Delhi
P. Giribabu	'Fellow of Indian Society for Oilseeds Research' at National Seminar on 'Technological Innovations in Oilseed Crops for Enhancing Productivity, Profitability and Natural Security' at PJTSAU, Hyderabad during 7-8 February, 2020
P. Ravichamy	"Excellence in Extension Award" by Society for Scientific Development in Agriculture and Technology at International Web Conference on 'Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2020)' during 28-30 December, 2020
K. Panneerselvam	Recipient of JSPS Invitational Fellowship from Toyama University, Japan

Awards received in the 'International Banana Conference-2020' held at Tiruchirappalli during 23-25 February, 2020

Award	Authors	Title
Best Thesis	P. Ganga Devi	Genetic diversity analysis of Sigatoka leaf spot pathogens and its management through microbial consortia
Best Oral Presentation	R. Karthic, S. Kalpana, S. Backiyarani, M.S. Saraswathi, S.C. Das, S. Uma	Next generation tissue culture for the rescue of threatened banana landrace of Tripura, India
	Kuntal Kumar Dey, Nabarun Roy, Priyabrata Sen, S. Backiyarani, S. Uma, Mahendra Kumar Modi	Genome landscape of stress-tolerant banana cultivar
	M. S. Saraswathi, G. Kannan, R. Thangavelu, T.R. Ganapathi, M. Bathrinath, S. Sathish, S. Backiyarani, S. Uma	Development of Fusarium wilt race 1 tolerant mutants through mutation breeding
	D. Ramajayam, K.J. Jeyabaskaran, S. Uma, M.S. Saraswathi, S. Backiyarani, C. Anuradha, R. Pitchaimuthu, R. Sivasankari	Genetic diversity in fruit pulp mineral profile of Indian *Musa* germplasm.
	V. Kumar, K.N. Shiva, K. Kamaraju	Yield, fruit quality and cost economics of summer and winter grown bananas (*Musa* spp.) as influenced by use of polypropylene based non-woven bunch sleeves
	K.N. Shiva, P. Suresh Kumar, M. Sivakumar, S. Sridharan, K. Kamaraju, Prakash Patil, S. Uma	Assessment of post-harvest losses in banana in Tamil Nadu, a major banana hub in India
	P. Suresh Kumar, A. Saravanan, N. Sheeba, K.N. Shiva, I. Ravi, M. Mayil Vaganan, S. Uma	Functional and structural characteristics of starches derived from dessert, cooking and plantain bananas (*Musa* spp.)
	J. Poorani, K.D. Prathapan, S. Amritha Kumari, C. Anuradha, B. Padmanaban, R. Thanigairaj	Morphological and molecular characterization of banana leaf-and fruit-scarring beetles (Coleoptera: Chrysomelidae) from the Indian region with distribution and host records
	R. Selvarajan	Virus diagnostics and impact of certification of tissue cultured banana plants in India
	C. Anuradha, R. Barathvaj, R. Selvarajan, S. Backiyarani, S. Uma	Single Nucleotide Polymorphism (SNP) in eukaryotic translation initiation factor gene in banana accessions might confer resistance to Banana bract mosaic virus

Best Poster Presentation	R. Thangavelu, S. Uma, M. Gopi, M. Prabakaran, M. Loganathan, M.S. Saraswathi, S. Backiyarani, P. Durai, N. Marimuthu, R. Arthee	Sustainable management of Fusarium wilt –Tropical Race 4 – A boon to the banana growers
	R. Karthic, S. Kalpana, S. Backiyarani, M.S. Saraswathi, S. Uma	Macropropagation of traditional banana cultivars and development of technology package for empowerment of rural women
	M.S. Saraswathi, P. Durai, S. Sathish, B. Mahalakshmi, A. Thirugnanavel, S. Backiyarani, S.Uma	DUS characterization of farmer's variety Kamal Vikas at ICAR-NRCB, Trichy
	S. Kalpana, S. Backiyarani, R. Karthic, S. Saranya, D. Ramajayam, M.S. Saraswathi, S. Uma	Accelerated banana breeding through chromosome doubling of diploid banana
	K.J. Jeyabaskaran, V. Kumar, R. Pitchaimuthu, S. Uma	Nutrient budgeting in recycling of residues of banana cv. Rasthali (AAB)
	V.P. Shanti, N. Kumar, K.J. Jeyabaskaran	Effect of cement kiln flue dust as a source of potassium on physical, physiological and biochemical parameters of banana cv. Poovan
	V. Hema, T. Arulpandian, D. Amelia Keran, P. Suresh Kumar, K.N. Shiva, K. Kamaraju	Functional enrichment of muffin with dietary fibre rich banana peel flour
	S. Sundaram, V. Balasubramanian, R. Selvarajan	Detection and characterization of Banana bunchy top virus, single stranded DNA virus infecting banana using Oxford nanopore MinION sequencing
	V. Sangita, S. Sundaram, H.S. Savithri, R. Selvarajan	Structural studies on coat protein of banana bunchy top virus

Dr. R. Selvarajan reciving Outstanding Agricultural Scientist Award-2020 by Dr. Vasantharaj David Foundation

Awards received in Other International Conferences

Award	Authors	Conference Title
Best Oral Presentation	S. Backiyarani, S. Eugin, S. Saranya, A.S.S. Muneeswari, M. Mayil Vaganan, V. Selvaraj, S. Uma	International E-Conference on 'Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity' organised by the Department of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru during 24-27 November, 2020
	M. Mayil Vaganan	
	C. Anuradha, R. Barathvaj R. Thangavelu, S. Backiyarani and S. Uma	
Best Poster Presentation	R. Sasikala, S. Backiyarani, S. EuginPerianayagaraj, S. Sharmiladevi, S. Uma	
Best Oral Presentation	D. Amelia Keran, R. Renganathan, P. Suresh Kumar, K.N. Shiva, S. Uma	International Food E-Conference on "Science Technology and Innovation for Sustainable Food System - 2020" held during 15-16 December, 2020 at VFSTR, Guntur, Andhra Pradesh
Best Poster Presentation	P. Ravichamy, S. Nandakumar, V. Kumar	International Web Conference on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2020) during 28-30 December, 2020

7.2 Recognitions

Name	Details
S. Uma	Chief Guest at Inauguration of Green Chill – Refrigeration System (GEE-BEE-UNIDO Funded Project) – Thottiyam Banana Producers Co. Ltd., 4 December, 2020
	Nominated as Scientific Committee Member – International Horticultural Congress (IHC)-2022.
	Member - External Stakeholders Board (ESB) – Musarium Project Proposal by *Instito per la Protezione Sostenibiledelle Piante*, Italy
	Member - Committee for Common Incubation Facilities for Incubation Centers – PM FME Scheme, Ministry of Food Processing, Govt. of India
	Chair – Banana Asia, Pacific Network (BAPNET) - Alliance Bioversity-CIAT – 2020
	Member - CII- Tamil Nadu Agri and Food Processing Panel – 2020
	Member - Interview Selection Committee Meeting for the post of Dean (Forestry), College of Forestry, TNAU, 9 January, 2020
	Chairperson - Technical Session – 9th Women's Science Congress (ISC 2020), Bengaluru, 5 January, 2020
	Member - TNAU Agriculture Education - Private Colleges Affiliated to TNAU - Admission Committee
B. Padmanaban	Keynote address in the International Conference on 'Vectors: Menace and Management – VECMAN 2020' at St. Xavier's college, Palayamkottai, Tamil Nadu
J. Poorani	Member, Ladybird Specialist Group under the International Union for Conservation of Nature(IUCN) Species Survival Commission, Global Species Program
	Subject Editor, *Zookeys* (International journal)
	Lead lecture on "Lady Bird Beetles of Indian Subcontinent" in the National Webinar on "Beetle (Insecta: Coleoptera) Diversity of India" organized by the Zoological Survey of India, Kolkata, on 1 October, 2020
	Convenor for Technical Session on Entomology in the 'International Banana Conference-2020' held during 23-25 February, 2020 at Tiruchirappalli
R. Thangavelu	Lead talk in the virtual mini-symposium 'Towards the Integrated Management of Fusarium Wilt of Banana' organized in the framework of the CGIAR Research Program on Roots, Tubers and Bananas (RTB) during 16-17 December, 2020.
	Lead talk at IPS South Zone Virtual Symposium-2020 - Advances in Crop Health Management Organized by Indian Phytopathological Society (South Zone Chapter) and ICAR-IARI, Wellington (Regional Station) during 1-2 December, 2020
	Keynote lecture at the National Webinar on Prospective, Priorities and Preparedness of Sustainable Agriculture Development in India organized by Dr. Ram Avatar Shiksha Samiti (DRASS), UP, during December 28-29, 2020
	Lead lecture in the National Webinar on "Advances in Disease and Pest Management in Banana for Sustainable Production System" hosted by AAU, Jorhat during 3-4 July, 2020

R. Thangavelu	Lead lecture in the International Web Conference on Perspective on Agricultural and Applied Sciences in COVID-19 Scenario (PAAS-2020) during October 4-6, 2020
	Lead presentation in the National webinar organized by BRS, Kannara (ICAR-AICRP-Fruits) under KAU on 30 June, 2020
	Convener, Satellite Workshop on *Foc* TR4; Organizing Secretary - International Training on Epidemiology and Management of *Foc* TR4 in Banana; Chairman- Poster Committee during the International Conference on Banana- 2020 held at Tiruchirappalli
	Convener, Session VI in the 7th Group Discussion of ICAR-AICRP on Fruits held at PAU, Ludhiana from 16-19 January, 2020
	External Examiner – one Ph.D. thesis from TNAU Coimbatore on 7 February, 2020
R. Selvarajan	Member Secretary, IRC & QRT of ICAR-NRCB
	DBT nominee for the IBSC of ICAR-CTCRI, Kerala
	External expert for the Advisory committee of DBT Certificate Program at VIT School of Agricultural Innovations and Advanced Learning (VAIAL), VIT, Vellore
	Member, Board of Studies, Department of Biotechnology, Bishop Heber College, Tiruchirappalli
	Organizing Secretary & Convener for one session in the 'International Banana Conference-2020' held during 23-25 February, 2020 at Tiruchirappalli
	Member, National advisory committee, VIROCON 2020: International Conference on 'Evaluation of viruses and viral diseases', 18-20 February,2020, NASC, Pusa, New Delhi
	Chairman for one session in the International E-Conference on "Multidisciplinary approaches for plant disease management in achieving sustainability in agriculture", UHS, Bagalkot, 6-9th October, 2020
	Co-Chairman for conducting the Keynote Lectures and Convener, National Symposium (SZ)-Virtual (Advances in Crop Health Management) organized by IPS (South Zone) and ICAR-IARI, Regional Station, Wellington, held at ICAR-Indian Agricultural Research Institute, Regional Station, Wellington, The Nilgiris, Tamil Nadu, India. during 01- 02 December, 2020
	Doctoral committee member in the School of Bio Sciences and Technology at Vellore Institute of Technology (VIT), Vellore
	Acted as external examiner and conducted public viva-voice exam for Ph. D scholars of North Maharashtra University, Jalgaon; Mody University of Science & Technology, Lakshmangarh; A.N.G.Ranga Agricultural University; and Department of Plant Pathology, AC&RI, TNAU, Coimbatore
M. Mayil Vaganan	Convener for two Technical Sessions in the 'International Banana Conference-2020' held during 23-25 February, 2020 at Tiruchirappalli
	Reviewer - Agricultural Research Journal; InSc-International Journal of Basic and Applied Sciences
	Life member - Institute of Scholars, Bengaluru; Society for Promotion of Horticulture, ICAR-IIHR, Bengaluru

I. Ravi	Invited lecture in the National Webinar on "Abiotic Stress Management of Horticultural Crops" organized by SKUASTK, Jammu & Kashmir on 15 September, 2020
	Invited lecture in the National Seminar on "Climate Smart Agriculture for Sustaining Crop Productivity and Improving Livelihood Security" organised by Annamalai University, Chidambaram, Tamil Nadu held on 27 February, 2020
	Lead talk in the National Seminar on "Frontiers in Biological Innovations for Resource Management, Patents and Entrepreneur Development" organised by Jamal Mohammed College, Tiruchirappalli on 11March, 2020
V. Kumar	External Examiner for Ph.D. scholar of UHS, GKVK, Bengaluru & UHS, Bagalkot
K. J. Jeyabaskaran	Report presentation during the online workshop cum review meeting held under the chairmanship of the Director, MNCFC, ICAR-IARI, New Delhi on 9 April, 2020
	Rapporteur, Technical Session-5, 'International Banana Conference-2020' held during 23-25 February, 2020 at Tiruchirappalli
	Technical lecture in the webinar conducted on KISAN.NET (Public system) on 5 August, 2020
K.N. Shiva	Appreciation certificate from Addl. Chief Secretary, Agriculture Production Commissioner, Agriculture & Farmers Welfare Dept., Govt. of Kerala, Thiruvananthapuram, Kerala at the International Workshop on Value Addition for Income Generation in Agriculture (VAIGA-2020), organized by Dept. of Agriculture Development & Farmers' Welfare, Govt. of Kerala, VAIGA-2020 at Thrissur, Kerala on 4 January 2020.
	Lead Presenter for the project entitled "Assessment of Post-harvest losses in Banana", 7thGroup Discussion of ICAR - AICRP on Fruits on 17 January 2020at PAU, Ludhiana, Punjab
	Moderator for the webinar on 'Processing and Value Addition in Banana' organized by Agri Business Incubation Centre & Webinar hosting and Coordination by PME Cell, ICAR-NRCB, Trichy, Tamil Nadu on 3 July, 2020
	Expert for setting Question paper for selection of Research Associate for ABI under NAIF (Component-II) at ICAR-DCR, Puttur, Karnataka
S. Backiyarani	Screening committee member under the modified assured career progression scheme (MACPS) to the Personal Secretary to Director of the centre on 28 May, 2020
	External examiner for one Ph.D. thesis evaluation and viva-voce
M.S. Saraswathi	Reviewer - Physiology and Molecular Biology of Plants; International Journal of Fruit Science; Asian Journal of Research in Botany
	Referee to one Project submitted to BRNS, Mumbai
D. Ramajayam	External Examiner for two Ph.D. theses
	Reviewer for Scientia Horticulturae; Indian Journal of Genetics & Plant Breeding
M. Loganathan	Convenor, Satellite Workshop on *Foc* TR4; Co-Coordinator of International Training on *Foc* TR4 during the International Conference on Banana-2020 held at Tiruchirappalli

M. Loganathan	Convener, Media and Publicity committee during 26th Foundation day of ICAR-NRCB
	Reviewer for International journals, *viz*. 3Biotech.,Egyptian Journal of Biological Pest Control, Indian Phytopathology, Sugar Tech., Journal of Sugarcane Research.
	Recognized as External Expert by TNAU for evaluating M.Sc. thesis and conducting Ph.D. *viva voce* and Doctoral Committee member of Bharathiyar University
P. Suresh Kumar	Editor - *Pharmacology, Toxicology and Pharmaceutics*; *Journal of Agrometeorology*
	Reviewer - *Ciência e Agrotecnologia* ; *Scientia Horticulturae* ; *Hort. Science*; *Journal of Agrometeorology*; *Agricultural Water Management*; *Journal of Environmental Biology* ; *Journal of Natural Fibers* ; *Agropeodology Journal* ; *Journal of Food processing and preservation* ; *Journal of Food Science & Technology* ; *Asian Journal of Dairy and Food Research*
	Organized ISO 9001: 2015 Audit for ISO certificate on 26 August, 2020
	Convener and Associate Editor, 7th Group Discussion on ICAR-AICRP Fruits, Research report -2020
	Convener, Technical Session-X, 'International Banana Conference-2020' held during 23-25 February, 2020 at Tiruchirappalli
C. Anuradha	Life member - Indian Virological Society; TNAU-MASU and International Society of Root Research (ISRR)
	Reviewer for *3 Biotech*, *Journal of Plant Pathology*, *Virus Disease*, *The Open Virology Journal*
	External expert for the selection of JRF for ICMR project held on 22 January, 2020
	Co-Guide for one Ph.D. student from Annamalai University
P. Giribabu	Convenor for Technical Session–7 on "Advances in Insect and Nematode Management" in the "International Banana Conference 2020 -Innovations in Sustainable Production and Value Chain Management in Banana" held at Tiruchirappalli, Tamil Nadu on 23-25, February 2020.
	Life member - Society for Promotion of Horticulture, ICAR-IIHR, Bangalore

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 smallholders	IITA, Nigeria; Bioversity International, France; NARO, Tanzania; University of Malaya; SLU, Sweden; Stellenbosch University, South Africa; Cornell University, USA; KUL, Belgium; University of Queensland, Australia; Nelson Mandela African Institution of Science and Technology, Tanzania; Institute of Experimental Botany, Czech Republic and EMBRAPA, Brazil
Bio-fortification and development of disease resistance in banana	Queensland University of Technology, Australia; NABI, Punjab; BARC, Mumbai; TNAU, Coimbatore; ICAR-IIHR, Bangalore
Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	DAE, Mumbai, Maharashtra
Co-ordinated horticulture assessment & management using geoinformatics (CHAMAN-Phase-II)	Department of Agriculture, Co-operation& 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 centers (Jalgaon, Kannara and Kovvur)
Framing crop specific DUS guidelines for banana (*Musa* spp.)	PPV & FRA, New Delhi
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
Consultancy project: Study on the efficacy of an automated irrigation solution using Internet of Things (IoT) enabled sensors and satellite imaging to optimize the yield and quality of Grand Nain banana in Karnataka	M/s. Digite Infotech Pvt. Ltd., Mumbai
Fact finding survey with special emphasis on the identification ofyield limiting factors in banana plantations around the tailing pond of M/s. Uranium Corporation of India Ltd., Thummalapalli, Kadapa, Andhra Pradesh.	Andhra Pradesh Pollution Control Board, Hyderabad

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

Project Title	Collaborating Institute(s)
Consortium for managing Indian banana genetic resources	Mizoram University, Aizawl, 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, Bhubaneshwar, Odisha Tripura University, Suryamaninagar, Tripura National Botanical Research Institute, Lucknow Jawaharlal Nehru Tropical Botanic Garden & Research Instt., Thiruvananthapuram Kohima Science Collge, Jotsoma, Nagaland Nagaland University, Medziphema, Nagaland Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal Patkai Christian College, Dimapur, Nagaland North Eastern Regional Instt. Of Science and Technology, Nirjuli, Arunachal Pradesh
Collection, evaluation, documentation and conservation of banana genetic resources from NE region	
Diversity assessment, germplasm conservation and database development on banana resources in NE India	
Whole genome and transcriptome study to stress tolerant banana cultivars	
Knocking out the virus–Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system	
Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	
Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	
Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	
Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	

Project Title	Collaborating Institute(s)
Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	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, Kolkata 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 ICAR-National Bureau of Plant Genetic Resources – Regional Station, Shillong ICAR-National Bureau of Plant Genetic Resources – Regional Station - Hyderabad
In vitro mass propagation of high value hill area banana	
Characterization of high value phyto-chemicals of anti-diabetic and immune-modulatory properties in NE banana varieties	
Development of pre & postharvest bunch care management methods for fresh banana	
Genetic resource assessment, *in situ* conservation and impact of banana waste as a feed for animals in NE region of India	
Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	
Management of low temperature and soil moisture deficit stresses in banana growth in NE India	
Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	

9. PUBLICATIONS

9.1 Research Papers

International

Pothiraj, R. Ravikumar, J., Backiyarani, S., Uma, S. and Panneerselvam, K. 2021. Genome-scale analyses of polyketide synthases in banana: Phylogenetics and expression profiling forecast their candidacy in specialized metabolism. *Gene*, **778**. 145472. 10.1016/j.gene.2021.145472.

Selvarajan, R., Prasanya Selvam, K., Balasubramanian, V. and Sundaram, S. 2020. A rapid and sensitive lateral flow immunoassay (LFIA) test for the on-site detection of banana bract mosaic virus in banana plants. *Journal of Virological Methods,* **284**. https://doi.org/10.1016/j.jviromet.2020.113929.

Thangavelu, R., Edwin Raj, E., Loganathan, M., Pushpakanth, P. and Uma, S. 2020. Draft genome of *Fusarium oxysporum* f.sp. *cubense* strain Tropical Race-4 infecting Cavendish (AAA) group of bananas in India. *Plant Disease*, doi.org/10.1094/PDIS-06-20-1170-A.

Thangavelu, R., Gopi, M., Pushpakanth, P., Loganathan, M., Edwin Raj, E. and Uma, S. 2020. First report of *Fusarium oxysporum* f.sp. *cubense* VCG 0125 and VCG 01220 of Race 1 infecting Cavendish bananas (*Musa* sp. AAA) in India. *Plant Disease,* https://doi.org/10.1094/PDIS-09-20-2052-PDN

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

National

Angami, T., Kalita, H., Kumar, J., Ramajayam, D., Singh, R. and Chandra, A. 2020. Standardization of optimum planting time on yield and fruit quality of banana var. Grand Naine under midhill condition of Arunachal Himalaya. *Current Journal of Applied Science and Technology,* **39**(14): 119-124.

Giribabu, P., Thangavelu, R. and AnithaSree, T. 2019. Evaluation of biocontrol agents against root-lesion (*Pratylenchus coffeae*) and root-knot (*Meloidogyne incognita*) nematodes infecting banana (*Musa* sp.). *Indian Journal of Nematology,* **49**(2): 179-186.

Kumar, J., Kalita, H., Angami, T., Ramajayam, D., Chandra, A., Kumar D., Sinha, N.K. and Mohanty, M. 2021. Effect of mulching on growth and quality of tissue culture banana (Var. Grand Naine) and soil properties in mid hill jhum lands of Arunachal Pradesh. *Indian Journal of Agroforestry,* **22**(2): 86-89.

Kumar, J., Kalita, H., Angami, T., Ramajayam, D., Sen, A. and Shukla, K. 2020. Impact of application of fertilizer and lime on yield of banana (Grand Naine) and soil parameters in acidic soil of Arunachal Pradesh. *International Journal of Plant & Soil Science*, **32**(4): 9-17. DOI: 10.9734/IJPSS/2020/v32i430264.

Padmanaban, B., Kannan, M., Thangavelu, R., Uma, S., Backiyarani, S. and Ashif, K.K. 2020. Identification of banana corm weevil *Cosmopolites sordidus* germar resistance in *Musa* germplasm. *Indian journal* of *Entomology*, **82**(3):537-542.

Poorani, J., Padmanaban, B., Deshmukh, S., Thanigairaj, R. and Ragesh, G. 2020. A review of the pest status and natural enemy complex of banana skipper, *Erionota torus* Evans in South India and its management. *Indian Journal of Entomology,* **82**(3): 479–492.

Ravichamy, P., Siva Balan, K.C. and Nandakumar, S. 2020. A study on mass media channels in promulgating farm technologies among banana growers in Trichy District of Tamil Nadu. *International Journal of Environment and Climate Change,* **10**(11): 1-7.

Ravichamy, P., Nandakumar, S. and Kumar, V. 2020. An analysis on the media communication barrier and suitable interventions for effective adoption of advanced banana cultivation technologies in Tamil Nadu, India. *Progressive Research – An International Journal*, **15 (***special)*: 359 - 366.

9.2 Popular articles

Anuradha, C. 2020. Rapid identification of genes conferring resistance to pests and pathogens in banana through DNA capture technologies. https://www.scribd.com/document/490013785.

Anuradha, C. and Barathvaj, R. 2020. Transcription activator-like effector nuclease (TALEN) - A gene editing technique. https://www.scribd.com/document/491214227.

Bathrinath, M., Saraswathi, M.S., Durai, P. and Uma, S. 2020. *Vazhai kandru urpathiyil mempaduthapatta puthiya anugumurai* (Tamil). *Dinamalar*. 22 August, 2020.

Giribabu, P. and Anuradha, C. 2020. Gene silencing for nematode management. https://www.scribd.com/document/491214238.

Jeyabaskaran, K.J., Pitchaimuthu, R. and Uma, S. 2020. *Vaazaiyil gandakachsaththin avasiyam* (Tamil), Vivasaayamalar, *Dinamalar*, 24 July, 2020.

Jeyabaskaran, K.J., Pitchaimuthu, R. and Uma, S. 2020. *Vaazaiyil potassium saththin avasiyam* (Tamil). Vivasaayamalar, *Dinamalar*, 10 October, 2020.

Jeyabaskaran, K.J., Pitchaimuthu, R. and Uma, S. 2020. *Vaazhai saagupadiyil pirachinaiulla man – paguthi* I (Tamil). Vivasaayamalar, *Dinamalar*, 27 June, 2020.

Jeyabaskaran, K.J., Pitchaimuthu,R. and Uma, S. 2020. *Vaazhaisaagupadiyil pirachinaiulla man – paguthi* II (Tamil) Vivasaayamalar, *Dinamalar*, 4 July, 2020.

Suresh Kumar, P., Saravanan, A., Shiva, K.N., Ravi, I., Mayil Vaganan, M. and Uma, S. 2020. Tailored low glycemic foods with banana starch. *ICAR News,* **26**(1): 4-5.

Divya, P., Suresh Kumar, P., Saravanan, A., Arthee, R. and Shiva, K.N. 2020. Emerging non-thermal technologies for processed foods: Way to preserve the nutrients. *Food and Beverage Processing*, **7**(4): 12 October, 2020.

Suresh Kumar, P. and Uma, S. 2020. Banana Processing: Developments during corona commotion. *Processed Food Industry*, June, 2020. 11-13.

Suresh Kumar, P. and Uma, S. 2020. Banana Processing: A silver lining during corona commotion. *Research Today,* **2**(5): 305-307.

Suresh Kumar, P. and Uma, S. 2020. Promote banana processing: flour, health powder, puree; Utilizing banana waste like central stem, rhizome, flower bud must be prioritized. *Agri News Network* 24 May, 2020. http://www.agrinewsnetwork.in/articles.php.

Divya, P. and Suresh Kumar, P. 2020. Digital transformation: Revolutionizing food processing sector. *Food and Beverage News*, http://www.fnbnews.com/Food-Processing/digital-transformation-revolutionising-food-processing-sector-55848. 11 May, 2020.

9.3 Books / Book Chapters

Uma, S., Mayil Vaganan, M. and Agrawal, A. (Eds.) (2020) Bananas and Plantains – Leading Edge Research and Developments; Vol.1: Diversity, Improvement and Protection. Angkor Publishers, Noida.

Backiyarani, S., Uma, S. and Durai, P. 2020. Banana breeding is no more recalcitrant: A review. In: Uma, S., Mayil Vaganan, M. and Agrawal, A. (Eds.) (2020) Bananas and Plantains – Leading Edge Research and Developments; Vol.1: Diversity, Improvement and Protection. Angkor Publishers, Noida.

Giribabu, P., Nagesh, M. and Uma, S. 2020. Recent advances in banana nematode management. *Ibid.*

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10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

S.No.	Date	Name of the Technology	Address of the Client	Revenue (Rs. in Lakhs)
I	**Consultancy Services / Contract Research**			
1	3 September, 2020	Development of Sea Protocol for the Export of Nendran Banana to European Market in PPP Mode	VFPCK, Kerala	9.15
2	February, 2020	Study on the efficacy of an automated irrigation and fertigation solution using Internet of Things (IoT) enabled sensors and satellite imaging to optimize yield and quality of Grand Naine banana in Karnataka	M/s. Digite Infotech Pvt. Ltd, Mumbai, Maharastra	13.25
3	7-8 January, 2020	Fact finding survey with special emphasis on the identification of yield limiting factors in banana plantations around the tailing pond of M/s. Uranium Corporation of India Ltd., Thummalapalli, Kadapa, Andhra Pradesh.	Andhra Pradesh Pollution Control Board, Hyderabad	1.10
4		Virus Indexing		25.0
II	**Commercialisation of Technologies**			
1	16 December, 2020	Banana Fig	Mr. Ashif,Kerala- 673 573	0.1
III	**Other Services**			
1.		Sale of polyclonal antiserum for CMV, BBrMV, BBTV and BSMYV		0.27

Signing of MoUs / MoCs / MoAs

ICAR-NRCB signed MoUs / MoCs / MoAs with the following State Governments / institutes / organizations.

* Andhra Pradesh Food Processing Society (APFS, Govt. of Andhra Pradesh)

* Indian Institute of Information Technology Design and Manufacturing (IIITDM), Kancheepuram, India

* National Design And Research Forum, Bangalore, India

* Dr. YSR Horticultural University (Dr. YSRHU), Andhra Pradesh

* K. Ramakrishnan College of Technology, Tiruchirappalli, Tamil Nadu

Patents filed by ICAR-NRCB

Patent	202041012384	Ready-to-Serve Basil Seed Suspended Banana Juice and Preparation Method thereof	21 March, 2020
Plant Variety	DL1712190001	Kaveri Sugantham	12 January, 2020

Genetic Fidelity testing

About 20 batches of tissue culture plants of cvs. Grand Naine, Nendran, Karpuravalli, Red Banana, etc. have been tested for their genetic fidelity using ISSR markers and reports issued.

Virus indexing

During 2020, 1817 TC banana samples from the TCPUs were tested against four viruses 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 banana viruses.

Supply of planting material

Around 6,722 tissue cultured plants and 8725 suckers of banana varieties have been supplied to banana growers.

Scientists of ICAR-NRCB with the Chief Minister, Andhra Pradesh, during signing of MoA

11. RAC/ IRC / IMC MEETS

QRT meet

The second sitting of the Quinquennial Review Meet of ICAR–NRCB was held through video conference on 1 June, 2020 under the chairmanship of Dr. K.V. Peter, Former Vice-Chancellor, KAU and it was attended by the other members: 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, presented the salient research achievements of the centre for 2019-20. Heads of Crop Improvement, Crop Production and Post-Harvest Technology and Crop Protection made presentations of research findings for the reporting period. Dr. R. Selvarajan, Member Secretary, QRT, presented the vote of thanks.

QRT meet of ICAR-NRCB

RAC meet

The 21st Research Advisory Committee (RAC)meet of ICAR-NRCB was held on 24 October, 2020 on virtual platform. The meet was held under the chairmanship of Dr. V.A. Parthasarathy, Retd. Director, ICAR-IISR, Calicut, with the members: 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; and Dr. S.C. Dubey, Head Quarantine, ICAR-NBPGR, New Delhi. Dr. S. Uma, Director, ICAR-NRCB presented the salient achievements of the centre during 2019-20. Research work carried out during 2019-20in Crop Improvement, Crop Production and Post-Harvest Technology, and Crop Protection sections were presented by the selected scientists of the respective section. The recommendations made by the team were prepared and submitted to the SMD for approval.

21st RAC meet of ICAR-NRCB

IRC meet

The 24thInstitute Research Council Meet was held on 8 and 9 December, 2020. The Member Secretary welcomed the chairman and the scientist members. The scientists presented the salient achievements during 2019-20 and the technical program for 2020-21. New project proposals were also presented and discussed.

Director and scientists at the 24th IRC meet of ICAR-NRCB

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

Human Resource Development

12.1. Trainings / Refresher courses attended by staff of ICAR – NRCB during 2020

Name of the Staff	Name of the program and organizers	Venue	Date
All Staff of ICAR- NRCB	International training programme on 'Epidemiology and management of Fusarium wilt – Tropical Race 4 in Banana', jointly organized by ICAR-NRCB and Bioversity International-CIAT	Hotel Breeze Residency, Trichy	24 February
Trainings on virtual platform			
M. Mayil Vaganan	Online workshop on 'Training Management Information System for HRD Nodal Officers of ICAR' organized by Human Resource Management Unit, ICAR, New Delhi		8 May
C. Anuradha	JCR South Asia training and certification program-2020 organized online by Web of science group		3 June
K.N. Shiva	Processing and Value Addition of Seasonal Fruits, organized by IIFPT, Thanjavur, Tamil Nadu		11 June
V. Kumar K.N. Shiva	Training on "e-Office" organized by ICAR-IASRI, New Delhi		22 June
S. Backiyarani	Online Training Programme on "Stress Management" organized by ICAR-NAARM, Hyderabad		7-10 July
J. Poorani	Online Training Workshop for Vigilance Officers organized by ICAR-NAARM, Hyderabad		5–7 August
K.N. Shiva	'Orientation Workshop and Training Program for ABI units', organized by ICAR-NAARM, Hyderabad along with IP&TM Unit of ICAR, New Delhi		17-19 August
V. Kumar	Training on India Good Agricultural Practices (IndGAP) organized by Quality Council of India, New Delhi		7-8 September
K.N. Shiva M.S. Saraswathi P. Suresh Kumar	IPR in Agricultural Research and Education in India organized by NAHEP and IP&TM unit, New Delhi		12-18 September
M.S. Saraswathi	International Webinar & training on 'DUS Data Management/ Automation/ Image Analysis in crops'organized by PPV&FRA, New Delhi; Ministry of Agriculture & Farmers' Welfare, Govt. of India and Federal Ministry of Food & Agriculture (BMEL), Germany		6-7 October
P. Suresh Kumar	Online training on MDP on Implementation of Access and Benefit Sharing Regulations in Agriculture Research: Awareness cum Sensitization Workshop organized by ICAR-NAARM, Hyderabad		9-10 October
R. Selvarajan	MDP on Priority Setting Monitoring and Evaluation (PME) of Agricultural Research Projects organized by ICAR-NAARM, Hyderabad		12-17 October

I. Ravi	Training Program on Analysis of Experimental Data using SAS organized by ICAR-NAARM, Hyderabad	9-17 November
P. Ravichamy	Awareness & Use of CeRA Resources through J-Gate Discovery Platform by Nehru Library, CCSHAU, Hisar, e-Resources in Agriculture (CeRA) – DKMA-ICAR, New Delhi and Informatics Publishing Limited, Bangalore	25 June

12.2 Workshop / Seminar / Conference / Symposia / Scientific meet etc. attended by the Staff of ICAR – NRCB during 2020

Name of the Staff	Event and organizers	Venue	Date(s)
All staff of ICAR-NRCB	International Banana Conference 2020 -Innovations in Sustainable Production and Value Chain Management in Banana organized by ICAR-NRCB and SPH, ICAR-IIHR	Hotel Breeze Residency, Tiruchirappalli	23-25 February
S. Uma B. Padmanaban R. Thangavelu V. Kumar K.J. Jeyabaskaran K.N. Shiva S. Backiyarani P. Suresh Kumar	7th Group Discussion of ICAR-AICRP (Fruits)	Punjab Agricultural University, Ludhiana	16-19 January
S. Uma	Women's Science Congress	UAS, Bengaluru	5-6 January
	Meeting with MD and Dy. Director, Ministry of Agri., Govt. of Kerala on Establishment of Banana Park	Thiruvananthapuram, Kerala	10 March
S. Uma V. Kumar P. Suresh Kumar C. Karpagam	Inauguration of Green chillrefrigeration systems	TNBGF, Thottiyam, Tamil Nadu	4 December
R. Selvarajan	Project review meet 'CRP vaccinesand diagnostics'	ICAR-CTCRI, Kerala	29-30 January
	Invited lecture	North Maharashtra University, Jalgaon	5 March
V. Kumar	VII Scientific Advisory Committee Meeting of ICAR-KVK, Krishnagiri	ICAR-KVK, Krishnagiri	5 March
V. Kumar C. Karpagam	42nd Scientific Advisory Committee Meeting of ICAR-KVK, Tiruchirappalli	ICAR-KVK, Sirugamani	26 November
	XXIII Scientific Advisory Committee Meeting of ICAR-KVK, Karur	ICAR-KVK, Puzhutheri	15 December
V. Kumar P. Suresh Kumar	Consultancy Project Review meeting on "Development of Sea Protocol for the Export of Nendran Banana to European Market in PPP Mode"	Thrissur, Kerala	22 December

K.J. Jeyabaskaran	Lecture in the Workshop cum seminar on Soil Health Management organized by ICAR-KVK, Karur	ICAR-KVK, Karur	5 December
	Lecture in the seminar cum workshop organized under ICAR & IMD sponsored District Agromet Unit (DAMU) Scheme by ICAR-KVK, Karur	Thaliyapatti, Karur Dist., Tamil Nadu	22 December
K.N. Shiva	International Workshop on Value Addition for Income Generation in Agriculture (VAIGA-2020), organized by Dept. of Agriculture Development & Farmers' Welfare, Govt. of Kerala	Thrissur, Kerala	4 January
	ICAR-NRCB Commercialization of Technologies in the Dream–Big Kalpa Workshop, organized by ICAR-CPCRI	ICAR-CPCRI, Kasaragod, Kerala	2 March
	Onsite Farmers Training on Export Opportunities in Organic Banana, organized by Irrigation Management Training Institute (IMTI), Thuvakudi, Tiruchirappalli	Gopichettipalayam, Tamil Nadu	29 December
D. Ramajayam	9th Scientific Advisory Committee meeting	ICAR-KVK, Needamangalam	7 March
Events on virtual platform			
All staff of ICAR-NRCB	27th ICAR-NRCB's Foundation Day and Kisan Mela	21 August	
	Meeting on 'ISO Certification' Audit	26 August	
	ICAR-NRCB Webinar Series 1-8	3, 18, 22, 25, 29 July; 4, 7, 21 August	
S. Uma, Director			
Director's Conference, ICAR, New Delhi			4 April
Plenary Session of Institute Research Committee meet, ICAR-CPCRI, Kasaragod			2 May
CGIAR Centres' Review Meeting, ICAR, New Delhi			4 May
1st Meeting of APEDA Export Promotion Forum (EPF)			20 May
QRT Review Meet of ICAR-NRCB			1 June
CII TN State Agri. & Food Processing Panel –2020-21 meet, organized by CII, Tamil Nadu			1 June
Musa Net Executive Committee Meeting – Bioversity International			3 June
Governing Body Meeting of IIFPT, MOFPI, Thanjavur			9 June
Endowment Lecture on 'Biotechnological Approaches for Banana and Plantain improvement' organised by TNAU, Coimbatore			15 June
Review Meeting of externally funded projects organized by SMD, ICAR, New Delhi			27 June
Project Review Meeting of DBT-NER, New Delhi			29 June
National webinar on '*Foc* Race 4 – An invasive threat for banana production' organized by BRS, Kannara (ICAR-AICRP on Fruits) under KAU, Kerala			30 June

CII – Regional Agri Show-Special lecture on 'Value addition opportunities and strategies in banana'	1 August
Video Conference Meeting with Banana Stakeholders organized by APEDA, Hyderabad	5 August
TNAU Admissions Monitoring Committee Meeting	12 August
ASRB Assessment Committee Meeting of scientists of ICAR-NRCB at ASRBm New Delhi	19 August
Governing Body Meeting of IIFPT, MoFPI, Thanjavur	20 August
Dept. of Food Processing, Govt. of AP – MoU signing Ceremony in the presence of Hon. CM, Andhra Pradesh	4 September
Meeting on Precision Farming – organized by ADG-ICT, ICAR, New Delhi	7 September
Meeting on One District – One Crop organized by ADG (AE), ICAR, New Delhi	9 September
3rd Party Evaluation of Schemes – organized by SMD, ICAR, New Delhi	16 September
IITA –Annual meeting of the Melinda Gates funded project on 'Accelerated Breeding of Better Bananas'	21-25 September
Horticulture Division Review Meeting by Hon'ble MoS, AFW Ministry, GoI – Virtual Platform – organized by SMD, ICAR, New Delhi	22-23 & 30 September
Webinar on DUS Testing Data Management – organized by PPV&FRA, New Delhi	6 October
Chief Guest for the Webinar on Value addition in Banana organized by APEDA, Mumbai	7 October
IIFPT, Thanjavur – Incubation Facility Committee Meeting	20 October
Presentation of Country report on 'Update of Foc TR4 in India in Virtual Workshop series on 'Safeguarding the banana industry from Fusarium wilt : Research updates and opportunities in the Asia Pacific – organized by TFNet, Malaysia	20 October
EFC-SFC Meeting organized by SMD, ICAR, New Delhi	22 October
21st RAC Meeting of ICAR-NRCB, Trichy	24 October
MusaNet Executive Committee Meeting	26 October
CVRC Meeting organized by DAC, DARE, New Delhi	28 October
Invited Lecture given in ENP-01 Program organized by Fac. Of Tech. &Engg., MS University of Baroda, Vadodara	28 October
Special Address given in CII-Virtual Conference on Refrigeration Technology – organized by CII, Tamil Nadu	30 October
Invited lecture on ' Breeding initiatives for resistance against Foc TR-4 in India' in Virtual Workshop series on 'Safeguarding the banana industry from Fusarium wilt : Research updates and opportunities in the Asia Pacific' – organized by TFNet, Malaysia	3 November
PMFME Committee Meeting organised by IIFPT, MoFPI, Thanjavur	4 November
Project Extension Proposal Review Meeting of DBT-NER, New Delhi	16 November
PMFME Committee Meeting organised by IIFPT, Thanjavur	20 November
Technology Commercialization Proposal Meeting – AgriInnovate, ICAR, New Delhi	23 November
Invited Lecture given in National Webinar on Food Production organized by Bishop Heber College, Trichy	27 November

Keynote speech on 'Developing Climate Resilient banana Industry' at the 6th International Conference on Dry Zone Agriculture hosted by the Faculty of Agriculture, University of Jaffna, Sri Lanka	3 December
Chief Guest – Opening of Green Chill – Cold Storage Facility Unit at TN Banana Growers Federation, Thottiam, Trichy	4 December
Annual Director's Conference, ICAR, New Delhi	5 December
J. Poorani, Principal Scientist	
National Webinar on "Beetle (Insecta: Coleoptera) Diversity of India" organised by Zoological Survey of India, Kolkata	1 October
R. Thangavelu, Principal Scientist	
International webinar on 'Stakeholder Advisory Board Meeting- Looking for banana pest and diseases solutions' organized by INIBAP	26 June
National webinar on '*Foc* Race 4 – An invasive threat for banana production' organized by BRS, Kannara (ICAR-AICRP on Fruits) under KAU, Kerala	30 June
National Webinar on 'Advances in Disease and Pest Management for Sustainable Banana Industry' organized by ICAR-AICRP (Fruits), AAU, Jorhat, Assam	4 July
International Plant Health Event-2020-Webinar lectures organized by IPS	14 July
National webinar on "Current scenario of biopesticides in India, regulatory requirements and commercialization" organized by IPS, New Delhi	7 August
National web conference on "Sustainable pest management of organic banana: Need of climate smart Agriculture" organized by Bihar Agricultural University, Sabour, Bihar	31 August
International web conference on 'Perspective on Agricultural and Applied Sciences in COVID-19 Scenario (PAAS-2020)' Organized by the Agricultural & Environmental Technology Development Society (AETDS), U.S. Nagar, Uttarakhand, India	4-6 October
11th International conference on 'Agriculture, Horticulture and Plant Sciences' organised by The Society of Tropical Agriculture, New Delhi	19-20 December
National webinar on "Management of Root rot Disease in Horticultural Crops"	24 November
International virtual mini-symposium – 'Towards the Integrated Management of Fusarium Wilt of Banana" organized in the framework of the CGIAR Research Program on Roots, Tubers and Bananas (RTB)	16-17 December
National webinar on 'Prospective, Priorities and Preparedness of Sustainable Agriculture Development in India organized by Dr. Ram Avatar Shiksha Samiti (DRASS), U.P.	28-29 December
R. Selvarajan, Principal Scientist	
Department of Biotechnology, Bishop Heber College, Tiruchirappalli	26 June
Advisory committee meeting on DBT Certificate Programme organized by VAIAL, VIT	10 July
Lead talk in IPS webinar of south zone organized by IPS (South Zone).	14 July
Invited lecture in the webinar organized by ICAR-NBAIR, Bangalore	24 July
International E-Conference organized by UHS, Bagalkot	6-9 October
Lead lecture in National Symposium organized by IPS (South Zone) and ICAR-IARI, Wellington (RS)	1-2 December

Lead lecture in the National Conference organized by Dr. B. Vasantharaj David Foundation, Chennai	5 December
Online National Seminar on "Big Data Analytics in Agriculture" by ICAR-NAARM, Hyderabad	10-11 December
International Colloquium on 'Crop Physiology (ICCP-2020) organized by TNAU, Coimbatore	
M. Mayil Vaganan, Principal Scientist	
Webinar on NABL Accreditation of ICAR Labs organized by National Accreditation Board for Testing Calibration Laboratories, Gurugram, Haryana	22 July
Webinar on Nutrition, Immunity and Covid-19 organized by Society for Plant Biochemistry and Biotechnology & Division of Biochemistry, ICAR-IARI, New Delhi	30 September
National Virtual Conference on Current trends and challenges in plant biochemistry and biotechnology organized by Society for Plant Biochemistry and Biotechnology, New Delhi & Birla Institute of Technology and Science, Goa	20-21 November
I. Ravi, Principal Scientist	
Lecture delivered at National Seminar on "Climate Smart Agriculture for Sustaining Crop Productivity and Improving Livelihood Security" organised by Annamalai University, Chidambaram	27 February
Lecture delivered at National seminar on "Frontiers in Biological Innovations for Resource Management, Patents and Entrepreneur Development" organised by Jamal Mohammed College, Trichy	11 March
Lecture delivered at National webinar on "Abiotic Stress Management of Horticultural Crops: a Serious Issue of Food and Nutritional Security Under Challenging Environmental Conditions" organised by SKUAST-Kashmir	11-17 September
Webinar on "Genomics Strategies for Improvement of Abiotic Stress Tolerance in Crop Plants" organized by ICAR-NIASM, Baramati, Maharashtra	27 November
V. Kumar, Principal Scientist	
Webinar on 'Indian Banana Industry: Challenges, Opportunities and Scope of Value addition' organized by Media Today Group, New Delhi	11 May
Webinar on "Export Challenges and Mitigation Strategies for Fresh and Processed F & V in COVID-19 Times" organized by NIFTEM, Sonipat, Haryana	8 August
Webex Conference on 'Cluster Development Program on Banana' in Trichy with officials of APEDA and State Dept., T.N. organized by APEDA	10 August
Virtual Meeting on 'Cluster Development Programme on Banana' in Jalgaon, MH and APEDA Officials and Its Representatives organized by APEDA, New Delhi	14 August
Webinar on "Soil and Climate" by World Food Prize 2020 winner Prof. Rattan Lal organized by Amity University, Noida, U.P.	21 August
Zoom Project proposal meeting on 'Development of low-cost portable optical instrument for pre- and post-harvest quality detection of vegetation through smart phone using IoT' organized by NIT, Trichy and ICAR-NRCB	9 September
Consultancy Project Review meeting on "Development of Sea Protocol for the Export of Nendran Banana to European Market in PPP Mode"	16-17 September
Zoom Meeting with officials of TRACEX and VFPCK Officials under Consultancy project on "Development of Sea protocol for export of Nendran bananas to Europe (UK) organized by VFPCK, Kerala	25 September

Video Conference with VFPCK Officials under Consultancy project on "Development of Sea protocol for export of Nendran bananas to Europe (UK) organized by VFPCK, Kerala	13 October
Online Training on "Traceability of Nendran banana for Export Market to VFPCK Officials, Kerala organized by VFPCK, Kerala	27-28 October
Virtual Meeting on "Restructured Weather based Banana Crop Insurance Scheme term-sheet (Rabi / AmbiyaBahar 2020-21) organized by DDA, Pune	3 December
K.J. Jeyabaskaran, Principal Scientist	
CHAMAN Phase-II review meeting cum workshop organized by the MNCFC, IARI, New Delhi	9 April
Attended and delivered lecture in the webinar "Quality banana production" organized by the 'Kisan Samvad (Kisan.com)	5 August
Online International Symposium on "The Practice and Benefits of Circular Agriculture in Waste Reducing and Recycling" organized by FFTC and Council of Agriculture, Taiwan, in collaboration with APAARI, Bangkok, Thailand	5-6 November
K.N. Shiva, Principal Scientist	
Webinar on 'Indian Banana Industry: Challenges, Opportunities and Scope of Value addition' organized by Media Today Group, New Delhi	11 May
Webinar on "Approaches of Public Funded Research Organizations in Agri-Technology Generation and Its Transfer In New Normal Situation", organised by a-IDEA, Technology Business Incubator of ICAR-NAARM, Hyderabad	28 May
Virtual Session on 'Processing and Value Addition Opportunities in Nodal Crops', organized by CII, Tamil Nadu	1 August
Fruit Care and Value Addition in Banana in the Video Conference for 'Cluster Development Programme on Banana', organized by APEDA, Hyderabad	5 August
Webinar on 'Technology Driven Agri-Business Interaction with Incubators", organized by Kalpa Green Web Chat Series, ICAR-CPCRI, Kasaragod, Kerala	22 August
National Webinar on "Entrepreneurship through value addition of banana and its by-products", organized by Department of Agricultural Processing and Food Engineering, College of Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odisha	19 December
Webinar on 'Horticulture Schemes and Crop Insurance; Integrated (organic) Farming & Farmer Producer Company/Organization (FPC/FPO) – Guidelines and Schemes' by ICICI Foundation	12 & 19 July
Webinar on 'Banana Cultivation and Value Addition – New Technologies' by Agricultural Information, Bengaluru, Karnataka	13 August
Webinar on 'Technology Driven Agri-Business Interaction with Incubators" by Kalpa Green Web Chat Series, ICAR-CPCRI, Kasaragod, Kerala	22 August
Webinar on 'Cluster Development for Horticulture Export' (12 Clusters in 7 Crops) by MIDH (MoA& FW), New Delhi with ICAR and Dept. of Horticulture Officials of the states	9 September
Webinar on 'Value Addition in Banana' by APEDA, Mumbai	7 October
Webinar on 'Agri-Business Incubator: Models and Prospects under NARES' by NaaViC ABI, ICAR-NIVEDI, Bengaluru	21October
Webinar on 'Recent Developments in Food Processing Sector' by MSME Development Institute, Thrissur, Kerala	28 October

Video Conference / 1st Banana Export Promotion Forum Meeting on 'Pre-harvest, Post-harvest, Market Access and Promotion of Banana' by APEDA, New Delhi	20 May
Digital Conference on Food Processing' under Digital Indo-Italian Business Mission by CII in association with the Italian Trade Agency (ITA)	15 & 16 July
Virtual Session on 'Processing and Value Addition Opportunities in Nodal Crops' English & Tamil by CII, Tamil Nadu	1 August
Video Conference with VFPCK Officials under Consultancy project on "Development of Sea protocol for export of Nendran bananas to Europe (UK) by VFPCK, Trivandrum, Kerala	13 October
Online Training on Traceability of 'Nendran' banana for Export Market to VFPCK Officials, Kerala and ICAR-NRCB Scientist under Consultancy project by VFPCK, Trivandrum, Kerala	27 & 28 October
Virtual Meeting of "Restructured Weather based Banana Crop Insurance Scheme term-sheet (Rabi / Ambiya Bahar 2020-21)" (through MS-Team) by Deputy Director of Agriculture, Pune	3 December
Virtual Business Meet on "Post-Harvest and Value Addition Technologies Developed at ICAR-CIPHET, Ludhiana" (through Zoom platform) by ICAR-CIPHET, Ludhiana, Punjab	10 December
S. Backiyarani, Principal Scientist	
Board of studies meeting on Bioinformatics held by Department of Biotechnology & Bioinformatics, Bishop Heber College, Tiruchirappalli	25 June
Sub Committee Meeting for Group-I of DBT's NER Banana Programme	29 June
Review meeting of 'Network project on functional genomics and genetic modification'	18-19 & 21 August
M.S. Saraswathi, Principal Scientist	
MDP on Implementation of Access and Benefit sharing regulations in Agriculture Research: Awareness cum Sensitization workshop organized by ICAR-NAARM, Hyderabad	8-9 June
Endowment lecture on Biotechnological Approaches for Banana and Plantain improvement organized by TNAU, Coimbatore	15 June
DBT Review meeting (Group 1) by DBT- NER-BPMC, New Delhi	29 June
Fusarium wilt Tropical Race 4 organized by BRS, Kannara, KAU Kerala	30 June
International e-conference on Advances and Future Outlook in Biotechnology and Crop Improvement for Sustainable Productivity organized by UHS, Bagalkot	24-27 November
Virtual mini-symposium -Towards Integrated Management of Fusarium Wilt of Banana organized by CGIAR Research Program on Roots, Tubers and Bananas (RTB)	16-17 December
M. Loganathan, Principal Scientist	
National webinar on '*Foc* Race 4 – An invasive threat for banana production' organized by BRS, Kannara (ICAR-AICRP on Fruits) under KAU, Kerala	30 June
National webinar on "Current scenario of biopesticides in India, regulatory requirements and commercialization" organized by IPS, New Delhi	7 August
International Symposium on 'The Practice and Benefits of Circular Agriculture in Waste Reducing and Recycling' Organized by Taiwan Livestock Research Institute (TLRI) and Food and Fertilizer Technology Center (FFTC), Taipei, Taiwan	5-6 November

Virtual workshops on 'Safeguarding the Banana Industry from Fusarium Wilt: Research Updates and Opportunities in Asia Pacific' organised by International Tropical Fruit Network along with Bioversity International-CIAT	20 & 27 October; 3 & 10 November
IPS South Zone Virtual Symposium-2020 - Advances in Crop Health Management organized by Indian Phytopathological Society (South Zone Chapter) and ICAR-IARI, Wellington (R.S.)	1-2 December
D. Ramajayam, Principal Scientist	
Review meeting of CHAMAN	29 July
P. Suresh Kumar, Principal Scientist	
Project initiative for various schemes under NABARD by ICAR-NRCB, Trichy	5 March
Webinar on 'Future strategies during COVID lockdown' by ICAR-AICRP on Fruits	29 May
Presentation in Webinar 'Agrobiodiversity of Indian Himalayan Region (with the special emphasis on traditional food)' by G.B. Pant National Institute of Himalayan Environment and Sustainable Development	5 June
Talk on 'Biotechnology in the Food Industry: Challenges and Prospect' at Cauvery college for women, Trichy	7 August
Talk on 'Innovative Future Products from Banana for New markets' in the Virtual meeting on 'Value addition in Banana' hosted by APEDA, Mumbai	7 October
Nendran Banana Export: Pack house operations, Issues, strategies by VFPCK, Kerala	20 October
Project proposal presentation on 'Banana fibre: Utilization in secondary agriculture' in collaboration with IIITM, Kancheepuram	22 October
Talk on 'Innovative Future Products from Banana for New markets' in virtual meeting on ENP01: Women Entrepreneurship and New Enterprise management	12-29 October
Lecture delivered at virtual meet organized by The Maharaja Sayajirao University of Baroda, Gujarat	29 October
Online International Symposium on 'The Practice and Benefits of Circular Agriculture in Waste Reducing and Recycling' organized by Taiwan Livestock Research Institute (TLRI) and Food and Fertilizer Technology Center (FFTC)	4-6 November
Talk on 'Business strategies and market opportunities in Banana' organized by HC&RI, Periyakulam, TNAU, Tamil Nadu	6 November
ICAR-AICRP on Fruits - Nodal Officers & Officers in-Charge Meeting	3 December
Establishment of Common Incubation Centre under PM FME Scheme by IIFPT, MoFPI, Thanjavur	18 December
Webinar meeting on 'Strategies for enhancing Banana export trade' by APEDA, New Delhi	
KAU ABI Webinar series - Resurgence- Life rising above the COVID 19 - Market Innovations for Agripreneurs	18 June
Online International Students and Faculty Development Programme on "Innovative Food Processing Technologies: Value addition, food safety and security" by Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior	29 June – 1 July
Agriculture Startups - Opportunities & Challenges by Agrovision foundation	10 July
Launch of IFPRI South Asia Global Food Policy Report-2020 by Planning commission, GoI, New Delhi	6 July
Digital Indo-Italian Business Mission on Food Processing to India by CII, India	15-16 July

TR4 - Strategies to prevent and management by Dr. YSRHU, Andhra Pradesh	25 July
'Export Challenges and Mitigation Strategies for Fresh and Processed F&V in COVID-19 by NIFTEM	8 August
Development of horticulture export clusters by MIDH	9 September
One district one product by NRM, New Delhi	9 September
Innovative Business Models emerging through COVID19 by CII, New Delhi	10 September
Boosting Immunity through Horticulture by Society for Horticulture Research & Development, Ghaziabad, Uttar Pradesh	1-9 September
Traceability of Nendran banana for Export market by TraceX, Bengaluru	27-28 October
P. Giribabu, Senior Scientist	
Webinar on 'Plant Parasitic Nematodes, The Hidden Enemy For Perennial Crops' organized by ADAMA	30 October
National webinar on '*Foc* Race 4 – An invasive threat for banana production' organized by BRS, Kannara (ICAR-AICRP on Fruits) under KAU, Kerala	30 June
Virtual workshops on 'Safeguarding the Banana Industry from Fusarium Wilt: Research Updates and Opportunities in Asia Pacific' organised by International Tropical Fruit Network along with Bioversity International-CIAT	20 & 27 October; 3 & 10 November
C. Anuradha, Senior Scientist	
International e-conference on 'Genetics and Plant Breeding Research in Post Covid-19 Era' organised by Dept. of Genetics and Plant Breeding, CCSU, Meerut, U. P.	13-14 June
International e-conference on 'Advances and Future Outlook in Biotechnology & Crop Improvement for Sustainable Productivity' organised by Dept. of Biotechnology and Crop Improvement, College of Horticulture, Bengaluru	24-27 November
Virtual workshops on 'Safeguarding the Banana Industry from Fusarium Wilt: Research Updates and Opportunities in Asia Pacific' organised by International Tropical Fruit Network along with Bioversity International-CIAT	20 & 27 October; 3 & 10 November
Web of Science Advanced Series workshop - JCR Training & Certification Program organised by Web of Science group online workshop	5, 7 & 29 March
U.C. Davis Plant Sciences e-Symposium	6 May
IPS South Zone Virtual Symposium-2020 - Advances in Crop Health Management organized by Indian Phytopathological Society (South Zone Chapter) and ICAR-IARI, Wellington (R.S.)	1-2 December
CRISPR/Cas tools in plant disease management organized by IPS, Delhi	30 July
National Webinar on 'Trans-boundary and Emerging Infectious Disease: Challenges in Diagnosis and Control' organised by IVS	18 November
'Take it to the Farmer: Reflections on Delivering Genetic Gain in Wheat - A New Era for Food and Climate' organised by Borlaug Global Rust Initiative	18 & 25 June
National webinar on '*Foc* Race 4 – An invasive threat for banana production' organized by BRS, Kannara (ICAR-AICRP on Fruits) under KAU, Kerala	30 June

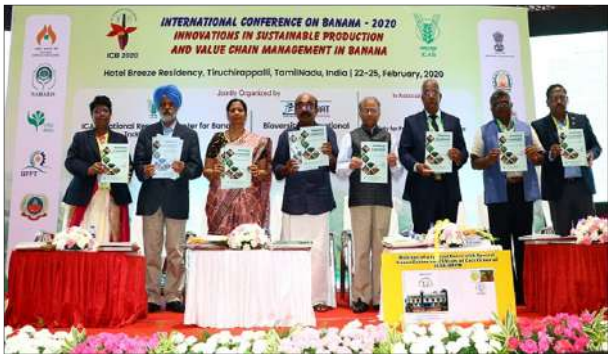
Gene Editing for Agriculture, Society & Sustainable Development: Prospects and Perspectives (Science Serving Society webinar series)	15 December
P. Ravichamy, Senior Technical Officer	
'Mechanization in Value Addition of Banana Pseudostem waste' by ICAR-CIAE, Regional Centre, Coimbatore	18 September
'Automation in Agricultural Mechanization: An overview' by ICAR-CIAE, Regional Centre, Coimbatore	23 October
Library Technology Conclave (LTC-2020): Curtain-Raiser Lecture e-Science and the Fourth Paradigm in Research by Informatics (I) Limited, Bangalore and CSIR, Bangalore	6 November
LTC-2020: Digital Libraries and Research Data Management by Informatics (I) Limited, Bangalore, NIAS, Bangalore and CSIR, Bangalore	27 November
LTC-2020: Data Science: The Good, the Bad and the Ugly by Informatics (I) Limited, NIAS, and CSIR, Bangalore	11 December
International Web Conference on Global Research Initiatives for Sustainable Agriculture & Allied Sciences (GRISAAS-2020) by Astha Foundation and Society for Scientific Development in Agriculture and Technology (SSDAT), Meerut, U. P.	28-30 December
Workshop on ABC of Scientific Writing (Publications and Library Management) by ICAR-NRRI, Cuttack	18 August – 2 September

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

International Conference on Banana (ICB – 2020)

The "International Conference on Banana 2020 - Innovations in Sustainable Production and Value Chain Management in Banana" jointly organized by the ICAR-National Research Centre for Banana, Tiruchirappalli; Society for Promotion of Horticulture, Bangalore; and Alliance Bioversity International-CIAT, was held at Tiruchirappalli, Tamil Nadu, during 22-25 February, 2020. Dr. A.K. Singh, DDG (Hort. Sci.), ICAR, New Delhi was the Chief Guest of the inaugural ceremony. Other dignitaries were Dr. Alagusundaram, DDG (Agrl. Engi.), ICAR, New Delhi; Dr. W.S. Dhillon, ADG (Hort. Sci.), ICAR, New Delhi; Dr. S. Uma, Director, ICAR-NRCB, Tiruchirappalli; Dr. N.K. Krishnakumar, Regional Representative of Bioversity International for South and Central Asia; Dr. N. Kumar, Vice Chancellor, TNAU, Coimbatore; Mr. Sivarasu, Collector, Tiruchirappalli District and Ms. Sumathi Ramachandran, Post Master General, Tiruchirappalli. During the inauguration, a 'Banana Expo', showcasing the vast diversity of bananas in India and other banana related enterprises was inaugurated by Mr. Sivarasu, Collector, Tiruchirappalli District. A special postage cover marking the Silver Jubilee Year of establishment of ICAR-NRCB was released by Ms. Sumathi Ramachandran. Awards were distributed and publications were released on the occasion. Mobile apps on banana information, banana cultivation, export and value addition, and pest and disease management, an ELISA kit for virus detection and a liquid formulation of Banana Sakthi (a micronutrient mix) were also released for the benefit of banana farmers.

The conference was conducted in 11 Technical Sessions on identified theme areas and a Satellite Workshop on Tropical Race 4 of Fusarium wilt, a dreaded disease of banana in many countries including India, was held as part of the ICB 2020. Many international collaborators such as IITA, Alliance Bioversity International-CIAT, FAO and QUT participated. Over 500 delegates including international delegates from Australia, Belgium, France, Czech Republic, Turkey, South Africa, Zambia, Kenya, Uganda, Nigeria, Philippines and Indonesia took part in ICB-2020. A 'Banana Expo' displaying fruits of 180 banana cultivars and 60 stalls related to banana industry was visited by more than 15,000 farmers, students and the public. A training on Foc TR4 was conducted by ICAR-NRCB in collaboration with the Alliance Bioversity-CIAT and it was attended by 45 people including scientists, plant quarantine officials and students.



Release of publications by delegates during the inaugural ceremony of ICB-2020

27th Foundation Day & Kisan Mela

ICAR-NRCB celebrated its 27th Foundation Day and Kisan Mela in virtual mode due to the restrictions imposed by Covid-19. Dr. Trilochan Mohapatra, Secretary, DARE & DG, ICAR was the Chief Guest and Dr. A. K. Singh, DDG (Hort. Science), ICAR was the Guest of Honour. The event was felicitated by Drs. N. Kumar, Vice Chancellor, TNAU; Rony Swennen, IITA, Uganda; James Dale, QUT, Australia; Nicholas Roux, Bioversity Interanational-CIAT and K.B. Patil, JISL. During the event, the Chief Guest virtually inaugurated the new facilities at NRCB, *viz*. transgenic net-house, rain-out shelter, gamma chamber and bioreactor facility. The Chief Guest also released ICAR-NRCB publications and gave away awards to banana farmers and entrepreneurs. A webinar on 'Approaches and

Strategies for Augmenting Export of Bananas from India' was also held with the following panellists: Dr. S. Uma, Director, ICAR-NRCB; Mr. R. Ravindra, Regional Head, DGM, APEDA, Mumbai; Dr.Azhar Pathan, Business Head, Mahindra Agri Solutions ltd., Mumbai; Dr. K.B. Patil, Vice President (TC & Agri Services), JISL, Jalgaon and Dr. K.N. Shiva, Principal Scientist, ICAR-NRCB.

Training programme for Meghalaya farmers

ICAR-NRCB organized a five-day (28 January–1 February, 2020) entrepreneurship training programme on 'Value addition and marketing of banana' to farmers and entrepreneurs belonging to Meghalaya state. The training was sponsored by Meghalaya Basin Development Authority, Shillong, Meghalaya. A total of 15 participants took part in the hands-on training programme. The programme was focussed on cultivation, production and marketing of value-added products from green unripe and ripe bananas and other parts of banana and plantains and it was aimed at skill development for the least developed states for wealth generation from waste and doubling the farmers' income. The trainees were trained on value addition and marketing of more than 30 different value-added products.

ICAR- NRCB signs MOA with Government of Andhra Pradesh for developing banana value chain

ICAR-NRCB signed a Memorandum of Agreement (MoA) with the Government of Andhra Pradesh for providing new innovative technologies on banana processing and value addition. This agreement ensures development of a knowledge centre at Pulivendala under the AP Food Processing Society (APFPS) and promotion of new micro food processing centre besides imparting capacity building to the entrepreneurs. Dr. A.K. Singh, DDG (Hort. Science), ICAR, New Delhi, and Dr. S. Uma, Director, ICAR-NRCB also participated in the event through virtual platform. State Minister of Agriculture, Mr. K. KannaBabu; Vice Chairman of AP Agriculture mission, Mr. M.V.S. Nagi Reddy; Special Secretary Food Processing, Mrs. Poonam Malakondiah; Chief Executive Officer, APFPS, Mr. Sridhar Reddy; and officials from the state agriculture and horticulture departments also attended the ceremony.

Trainees from Meghalaya with the Director and course co-ordinators of ICAR-NRCB

ICAR-NRCB signs MoU with YSRHU

ICAR-NRCB signed a memorandum of understanding with Dr. YSR Horticultural University, West Godavari District, Andhra Pradesh, in the presence of Dr. A.K. Singh, DDG (Hort. Science) during a webinar 'Horticulture Ability – Favourable Conditions' organised by the university on 7 November, 2020. Through the MoU, ICAR-NRCB and YSRHU will be able to work together on various aspects of banana cultivation and provide an opportunity

to students to learn effectively.

ICAR-NRCB inaugurates Green Chill™ - Novel cold chain technology made for India

Dr.S.Uma, Director, ICAR-NRCB inaugurated'Green Chill™', anovel and innovative cold chain / refrigeration technology developed by New Leaf (off-grid refrigeration) for Indian agri supply chain and established one such unit in the premises of Thottiyam Banana Growers' Association with the financial assistance of the United Nations Industrial Development Organization (GEE-BEE-UNIDO) on 4 December, 2020. Mr. Ravichandran Purushothaman, President, Danfoss, India and Mr. Anurag Agarwal, New leaf Dynamics, New Delhi also attended the ceremony. Mr. A.P. Karuppaiah, President, TNBGF, Mr. G. Ajeethan, Director, TNBGF, other directors, functionaries and farmers also attended the event. This model refrigeration unit operates with solid adsorption-based refrigeration system powered by farm waste and biomass. This will establish end-to-end cold chain infrastructure for enhancing the shelf life of commodities like banana. It emits no smoke due to its efficient blower-based combustion using gasification principles and thus emits no carbon into the environment, the company claims.

Director, ICAR-NRCB inaugurates Green Chill™ - Novel cold chain technology

14. DISTINGUISHED VISITORS

Name	Date
Dr. M. Kalidurai, Commissioner, Horticulture and Farm Forestry, Govt. of Madhya Pradesh	27 January, 2020
Mr. T. Ramesh, General Manager, NABARD	5 March, 2020
Dr. Bhimaraya Metri, Director, IIM, Tiruchirappalli	10 March, 2020
Mrs. Snehalatha Johnson, DGM, Canara Bank	
Smt. T. Banumathi, Senior Advocate	
Dr. K. Uma Maheswari, Dean SASH, SASTRA, Thanjavur	
Dr.Vanathi, Department of Microbiology, Govt KAPV Medical College, Tiruchirappalli	24 July, 2020
Dr. S. Palaniappan, ENT Surgeon, KAPV Govt. Medical College, Tiruchirappalli	15 August, 2020
Dr. Rajesh, DNB orthopaedics, KMC Hospital, Tiruchirappalli	
Mr. Vinod Sonkar, Member of Parliament, Kausambi, Uttar Pradesh	26 September, 2020
Mr. Vijay Prakash, General Manager (BD-NV), NSIC Ltd., Uttar Pradesh	

DISTINGUISHED VISITORS AT ICB-2020 (22 - 25 February, 2020)

Name
Rony Swennen, International Institute of Tropical Agriculture, Uganda
B. Uwimana, International Institute of Tropical Agriculture, Uganda
James Dale, Queensland University of Technology, Brisbane, Australia
Nicolas Roux, The Alliance of Bioversity and CIAT, France
E. Hřibová, Institute of Experimental Botany, Czech Academy of Sciences, Centre of the Region Hana for Biotechnological and Agricultural Research, Olomouc, Czech Republic
J. Kubiriba, National Agricultural Research Organisation, Entebbe, Uganda
Sebastien Carpentier, Bioversity International, Leuven, University of Leuven, Belgium
Leena Tripathi, East Africa Hub, International Institute of Tropical Agriculture, Nairobi, Kenya
Guy Blomme, Alliance of Bioversity and CIAT, Addis Ababa, Ethiopia
F. Dusunceli, FAO, Plant Protection Division, Viale terme di Caracalla, Rome, Italy
A. Viljoen,Department of Plant Pathology, Stellenbosch University, Matieland, South Africa
John E. Thomas, Queensland Alliance for Agriculture and Food Innovation, The University of Queensland, Brisbane, Australia
Lavernee S. Gueco, Institute of Plant Breeding, University of the Philippines, Los Baños, Philippines
Agus Sutanto, Indonesian Agency for Agricultural Research and Development, Indonesia
Prakash Patil, Project Coordinator, ICAR-AICRP on Fruits, ICAR-IIIHR, Bengaluru
C. Anandharamakrishnan, Indian Institute of Food Processing Technology, Ministry of Food Processing Industries, Government of India, Thanjavur
N. Kumar, Vice Chancellor, Tamil Nadu Agricultural University, Coimbatore
R. Kalpana Sastry, Tata Institute of Social Sciences, Hyderabad
K.B. Patil, Jain Irrigation Systems Ltd, Jalgaon

Name
C.K. Narayana, ICAR-IIHR, Bangalore
P.D. Kamala Jayanthi, ICAR-IIHR, Bangalore
P.G. Patil, ICAR-CIRCOT, Mumbai
V. K. Baranwal, Advanced Centre for Plant Virology, ICAR-IARI, New Delhi
M. Maheswari, ICAR-CRIDA, Hyderabad
M. Nagesh, ICAR-NBAIR,Bangalore
C.A. Jayaprakas, ICAR-CTCRI, Thiruvananthapuram
Shibendu S. Ray, Mahalanobis National Crop Forecast Centre, Ministry of Agriculture & Farmers' Welfare, Pusa, New Delhi
Saravanan Raj, National Institute of Agricultural Extension Management (MANAGE),Hyderabad
T.N. Balamohan, Department of Horticulture, AC&RI (TNAU), Madurai, Tamil Nadu, India
K.S. Subramanian, Department of Nano Science & Technology, TNAU, Coimbatore
Shiv Kant Shukla, Biotech Consortium India Limited, New Delhi
C. Ruckmani, Centre for Excellence in Nanobio Translational Research (CENTRe), Department of Pharmaceutical Technology, University College of Engineering,Anna University - BIT Campus, Triuchirappalli
S. Radha, SSN College of Engineering, Kalavakkam, Tamil Nadu
P. Sathiyarajeswaran, Siddha Central Research Institute, Chennai, Tamil Nadu, India

ICAR-NRCB felicitate to Dr. B. Padmanaban, Principal Scientist, on his superannuation on 30 April, 2020

15. PERSONNEL

15.1 Staff News

Name	Event	Date
Dr. B. Padmanaban, Principal Scientist	Superannuation	30 April, 2020
Dr. Dinesh Kumar Agarwal, Principal Scientist	Joined ICAR-NRCB on transfer from ICAR–Indian Institute of Seed Science, Mau	3 August, 2020
Dr. C. Karpagam, Senior Scientist	Joined ICAR-NRCB on transfer from ICAR – Central Institute of Cotton Research, Regional Station, Coimbatore	6 November, 2020
Mr. Arjun Singh, Scientist	Posted at ICAR–NRCB	4 April, 2020
Dr. P. Suresh Kumar, Principal Scientist	Promoted from the post of Senior Scientist (Level 13A) to the post of Principal Scientist (Level 14)	w.e.f. 25 June, 2018
Mrs. C. Gomathi, Finance & Accounts Officer	Promoted from the post of Assistant Finance & Accounts Officer to the post of Finance & Accounts Officer	w.e.f. 6 March, 2020
Mr. R. Kandamani, Administrative Officer	Promoted from Assistant Administrative Officer, to Administrative Officer	w.e.f. 7 August, 2020
Mrs. A. V. Suja, Upper Division Clerk	Promoted from Lower Division Clerk to Upper Division Clerk	w.e.f. 1 January, 2020
Mr. V. Thangaraju, Lower Division Clerk	Promoted from Skilled Supporting Staff to Lower Division Clerk	w.e.f. 16 December, 2020

15.2 Staff position

Scientific Staff

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

15	Dr. P. Suresh Kumar	Principal Scientist (Horticulture)
16	Dr. C. Karpagam	Senior Scientist (Agricultural Extension)
17	Dr. P. Giribabu	Senior Scientist (Nematology)
18	Dr. C. Anuradha	Senior Scientist (Biotechnology)
19	Mr. Arjun Singh	Scientist (Agronomy)

Technical Staff

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

16. OTHER INFORMATION

Republic Day celebrations

The 71st Republic Day was celebrated at ICAR-NRCB on 26 January,2020 with flag hoisting and distribution of sweets by Dr. S. Uma, Director. All staff of the Centre, students and public from the nearby villages took active participation in the festivities.

Staff of ICAR-NRCB during Republic Day celebration

International Women's day celebrations

The International Women's Day was celebrated at ICAR-NRCB on 10 March, 2020. Staff of the institute and students from the HC & RI for Women, Tiruchirappalli (TNAU) took part in the activities with enthusiasm. Dr. S. Uma, Director, ICAR-NRCB addressed the gathering and emphasized that women should be empowered, bold enough to face the problems and should have equal opportunities in all spheres of life. Dr. Bhimaraya Metri, Director, IIM, Trichy, was the Chief Guest and other guests included, Mrs. Snehalatha Johnson, DGM, Canara Bank; Smt. T. Banumathi, Senior Advocate; and Dr. K. Uma Maheswari, Dean SASH, SASTRA, Thanjavur.

Director, ICAR-NRCB addressing the audience during International Women's Day celebrations

ICAR-NRCB's contributions to mitigate the impact of COVID-19

During the COVID-19 crisis, ICAR-NRCB actively took part in social service and contributed to mitigate its impact on the vulnerable sections by distributing relief material. A total of 300kg of banana fruits, 200 bottles of stem juice and 300 banana figs were handed over to the district authorities by Dr. S. Uma, Director, ICAR-NRCB in the presence of scientists and staff. The staff of ICAR-NRCB contributed a day's salary to the PM-CARES fund. The NRCB distributed 10 kg of rice, vegetables, fruits and banana stems to 200 families at the Poolangudi Narikorava Colony near Trichy. Rations were also distributed to stranded North Indian labourers in Kumbakudi area near Mathur and to a home for visually impaired and senior citizens. The institute also distributed around 7000 banana fruits to 2700 sanitary workers in Trichy Corporation which was inaugurated by Mr. Sivasubramaniyan, Commissioner, Trichy Corporation. In order to facilitate rapid testing of COVID-19 samples in Tiruchirappalli, ICAR-NRCB handed over an advanced version of RT-PCR machine to Dr. Vanathi, Department of Microbiology, Govt KAPV Medical College, Tiruchirappalli, on 24 July, 2020. Shri Sivarasu, District Collector, Trichy, appreciated the cooperation extended by the Ministry of Agriculture and Farmers' Welfare, Govt. of India, New Delhi.

Handing over of RT-PCR machine by ICAR-NRCB for COVID-19 diagnosis

Independence Day celebrations

During the Independence Day celebration on 15 August, 2020, ICAR-NRCB appreciated the doctors who worked tirelessly during COVID-19 crisis and honoured Dr. S. Palaniappan, KAPV Govt. Medical College and Dr. Rajesh, KMC Hospital, Tiruchirappalli.

Director, ICAR-NRCB honours doctors of COVID pandemic during Independence Day celebrations

Celebration of 150th birth anniversary of Mahatma Gandhi

The staff of ICAR-NRCB celebrated the 150th birth anniversary of Mahatma Gandhi by planting tree saplings in the premises of the institute on 1October, 2020. On Gandhi Jayanthi day (2 October, 2020), the staff of ICAR-NRCB took a 'Swachtha Pledge' in virtual mode followed by recitation of poems and songs on Gandhian values and principles.

Vigilance Awareness Week

ICAR-NRCB observed the Vigilance Awareness Week during 27October–2 November, 2020. Staff of the institute took the integrity pledge and elocution and on-spot slogan competitions were held on the theme - "SATARK BHARAT, SAMRIDDH BHARAT (Vigilant India, Prosperous India)".

Observance of Vigilance Awareness Week in virtual platform

Constitution Day celebrations

The Constitution Day was celebrated on 26 November, 2020 at ICAR–NRCB and the staff of the institute read out the preamble to the constitution.

Staff of ICAR-NRCB reading the preamble of the Constitution during Constitution day

17. Success Stories

Increased yield of banana achieved by using Banana Shakti, a micronutrient mixture for banana

Name of the farmer : Mr. T. Linganatham

Location : Odhiyadikkuppam, Cuddalore district,Tamil Nadu

Banana Variety : Ney Poovan (3 acres)

The farmer used the micronutrient mixture "Banana Shakti" as 2% foliar spray at 3rd, 5th and 7th months after planting along with other fertiliser management practices as per the recommendations of this Centre, during 2019-20. By using Banana Shakti, he got a bumper yield of 40 t/ha in Ney Poovan with a gross profit of Rs. 14,00,000/-, which is 60% more than what he used to get (Rs.8,75,000/-) previously from his farm without using Banana Shakti. He rejoiced that his plantation was healthy and its vegetative growth was at satisfactory level with the usage of Banana Shakti. He invested only Rs. 4000/- as additional input cost for Banana Shakti and its spray charges in one hectare of Ney Poovan plantation. His Ney Poovan bunches fetched very good price in the market (Rs.35/kg) because of their appealing appearance and enhanced quality due to Banana Shakti usage. Here, the impact of Banana Shakti in increasing yield has been worked out with a leveraged gross profit at the rate of Rs. 131.25 per one rupee investment as Banana Shakti. The farmer is very much satisfied with Banana Shakti.

Processing and Value Addition in Banana at Bihar

A five-day training programme on 'Production of value-added products from banana' sponsored by ATMA, Vaishali Dist., Bihar, was held at ICAR-NRCB during 12–16 March, 2018. There were ten trainees and they got hands on training on production of 13 value added products (banana fig, jam, RTS fruit juice, sweet chutney from ripened fruits, chips, sauce, flour, baby food, health drink and soup mix from unripe fruits, flower pickle, candy from central core stem and fibre from pseudostem sheath). The trainees visited Solar dryer system, Thottiyam, Tamil Nadu and banana fibre based handicraft making unit.

Trainees with the Director and scientists of ICAR-NRCB

Off-campus training at Vaishali, Bihar

A follow-up was done on the participants from self-help groups who attended the off-campus training imparted during 4-8April, 2018, under ATMA, Vaishali. One thousand farmers were added in different Farmers Interested Groups (FIGs) and Farmers Producers Organizations (FPOs).Atotal of 15 FIGs were formed by ATMA, Vaishali in which banana fibre, fibre-based paper, compost from scutcher waste, and allied products were produced with a turnover of Rs. 15 lakhs in the

last year. By banana fibre extraction units 240 persons are benefitted directly and 600 persons indirectly. Two banana-based processing units were initiated by two SHGs and one FPO. Food products dealt in the SHGs were banana sauce, jam, pickle and handicrafts like wall hangings, yoga mats, table mats, bags, etc. with an annual turnover of Rs. 7.5 lakh in the last year. One Whats App Group in the name of 'Banana Fiber Association' is also functioning with 45 members (manufacturers, farmers, traders, ICAR-NRCB Scientists, etc.) to exchange the latest information among members, trade their products and establish marketing linkage.

In Bihar, banana is cultivated in 22 districts with an area of 32,000 ha and production of 14 lakh MT. The major banana growing areas of Bihar are Vaishali and Bhagalpur and Naugachhia. Wealth generation from waste is taken up on priority in Bihar in which Vaishali is having 10 banana fiber extraction units and similar units were set up in the other Districts such as Purnea, Khagaria, Medhepura, Motihari (East Champaran), Samastipur, Saran, and West Champaran (Next year).

Training on banana fiber extraction to rural women

ANNEXURE – I

I. Institute projects

Name of the Project	Principal Investigator
Crop Improvement	
1.Improvement and management of banana genetic resources in the Indian subcontinent	S. Uma
2.Improvement of banana through conventional breeding	S. Backiyarani
3.Development of trait specific markers for *Fusarium* wilt resistance through association mapping studies in banana (*Musa* spp.)	M.S. Saraswathi
4.Improvement of cv. Grande 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.Pest mapping in bananas and plantains of India	J. Poorani
16.Integrated management of Tropical race 4 of *Fusarium* wilt disease in banana	R. Thangavelu
17.Survey, etiology and management of rhizome rot of banana	M. Loganathan
18.Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan
19.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 Transgenics 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. Development of banana sucker paring equipment, pseudostem injector, bunch harvester and pseudo-stem outer sheath plate making equipment (collaborating institute : ICAR-CIAE, RS, Coimbatore)	V. Kumar K.N. Shiva P. Suresh Kumar

III. Other agencies funded projects

Name of the Project	Funding Source	Principal and Co-Investigator(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. Biofortification 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)		
Consortium for managing Indian banana genetic resources		S. Uma M.S. Saraswathi S. Backiyarani

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
Whole genome and transcriptome study to stress tolerant banana cultivars	S. Backiyarani S. Uma I. Ravi
Collection, evaluation, documentation and conservation of banana genetic resources from NE region	M.S. Saraswathi M. Mayil Vaganan S. Uma
In vitro mass multiplication of high value hill area bananas of the North Eastern region	M.S. Saraswathi R. Thangavelu I. Ravi
Diversity assessment, germplasm conservation and database development on banana resources in NE India	M.S. Saraswathi S. Backiyarani
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
Management of low temperature and soil moisture deficit stresses in banana growth in NE India	I. Ravi M. Mayil Vaganan M.S. Saraswathi
Development of pre & postharvest bunch care management methods for fresh banana	P. Suresh Kumar K.N. Shiva
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
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
Exploring diversity, genomic and transcriptome profiling and phytosemiochemicals of banana pest complex in NE Region	J. Poorani S. Backiyarani
Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	R. Thangavelu
Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	R. Thangavelu M. Loganathan
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
Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	R. Selvarajan C. Anuradha
6. DST sponsored projects	
A whole genome based reduced representation approach for identification of seedless phenotype in banana (*Musa* spp.) (DST-SERB)	C. Anuradha

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

VI Contract research projects

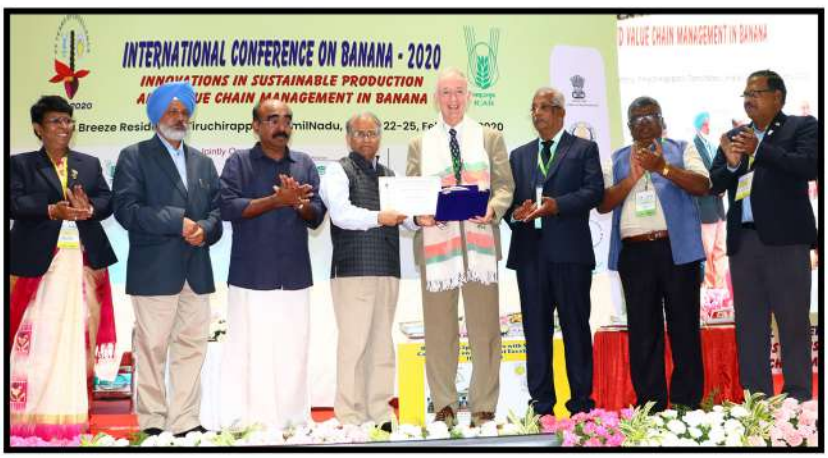
Name of the Project	Funding Source	Principal Investigator
National certification system for tissue culture raised plants		R. Selvarajan M.S. Saraswathi S. Uma
Study on the efficacy of an automated irrigation solution using Internet of Things (IoT) enabled sensors and satellite imaging to optimize the yield and quality of Grand Naine banana in Karnataka	M/s. Digite International, Mumbai	I. Ravi
Fact finding survey with special emphasis on the identification of yield limiting factors in banana plantations around the tailing pond of M/s. Uranium Corporation of India Ltd., Thummalapalli, Kadapa, Andhra Pradesh.	Andhra Pradesh Pollution Control Board, Hyderabad	K.J. Jeyabaskarn

ANNEXURE – II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
January, 2020	31.64	22.22	74.64	21.8
February, 2020	33.89	22.41	68.82	-
March, 2020	36.64	25.0	65.19	-
April, 2020	38.46	27.06	62.2	13.4
May, 2020	39.22	28.09	60.90	25.0
June, 2020	37.96	27.46	58.33	62.9
July, 2020	35.64	26.09	66.22	205.4
August, 2020	35.70	26.19	63.29	191.4
September, 2020	34.16	25.33	71.43	128.8
October, 2020	34.41	25.58	68.41	79.0
November, 2020	31.7	24.33	80.16	195.1
December, 2020	28.83	22.22	83.06	203.2
Total				1126.0

GLIMPSES OF ICB - 2020



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