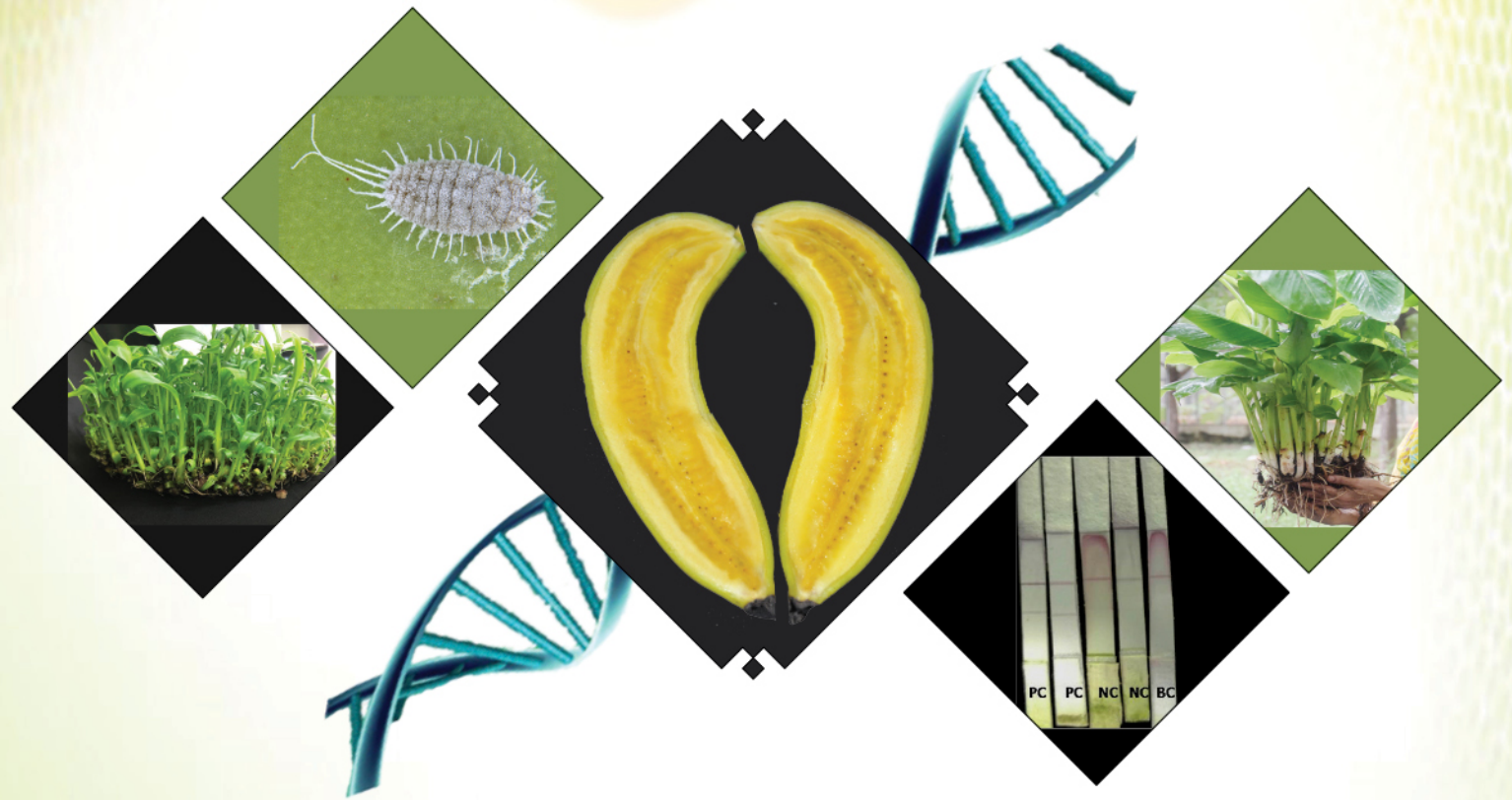
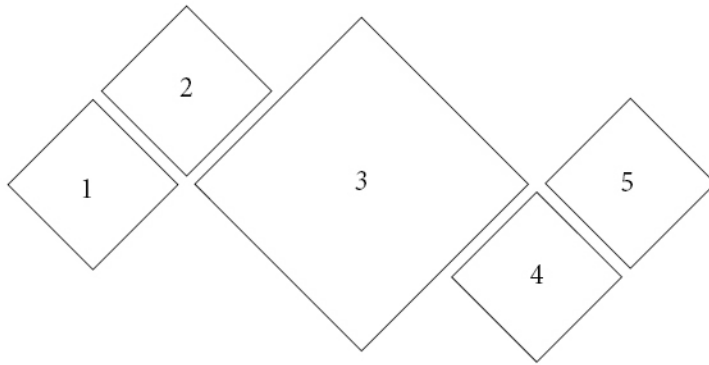


वार्षिक प्रतिवेदन
ANNUAL REPORT
2018-19



ICAR-NRCB
भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र
ICAR - NATIONAL RESEARCH CENTRE FOR BANANA
(ISO - 9001:2015 Certified Institute)





1. Next generation tissue culture technology using bioreactors
2. *Pseudococcus jackbeardsleyi* – an invasive alien species on banana
3. Transgenic banana cv. Grand Naine enriched with provitamin A
4. Dipstick technology developed for detection of Cucumber mosaic virus (CMV)
5. 'Khela vruddhi' – A farmers' friendly banana multiplication technology



Kaveri Saba



Kaveri Kalki



Kaveri Sugantham

वार्षिक प्रतिवेदन ANNUAL REPORT 2018-19



भारतीय - राष्ट्रीय केला अनुसंधान केंद्र
(भारतीय कृषि अनुसंधान परिषद)

थायनूर पोस्ट, तोगमलै रोड, तिरुच्चिरापल्लि - ६२० १०२, तमिल नाडु, भारत



ICAR-NATIONAL RESEARCH CENTRE FOR BANANA

(Indian Council of Agricultural Research)

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



Citation

ICAR – NRCB. 2019. Annual Report 2018-19.

ICAR – National Research Centre for Banana, Tiruchirappalli

Editors

Dr. P. Giribabu

Dr. B. Padmanaban

Dr. K. N. Shiva

Dr. M. S. Saraswathi

Dr. P. Ravichamy

Published by

Dr. S. Uma

Director

ICAR - National Research Centre for Banana

Thayanur Post, Thogamalai Road

Tiruchirappalli - 620 102

Tamil Nadu, India

Printed at

CNU Graphic Printers

No. 35/1, South End Road, Malleswaram, Bengaluru - 560 020

Mob. : 9880 888 399 | E-mail : cnu@cnu.net.in

CONTENTS

1	Preface	
2	Introduction	1
3	Executive Summary	4
4	Research Achievements	
4.1	Crop Improvement	13
4.2	Crop Production and Post-Harvest Technology	27
4.3	Physiology and Biochemistry	33
4.4	Crop Protection	35
4.5	Externally Funded Projects	44
5	Technology Assessed and Transferred	58
6	Education and Training	60
7	Awards and Recognitions	63
8	Linkages and Collaborations	70
9	Publications	72
10	Consultancy Services and Commercialization of Technologies	80
11	RAC / IRC / IMC Meets	82
12	Training / Refresher Course / Summer / Winter Institutes / Seminar / Conference / Symposia / Workshop attended by the Scientists and other Staff	83
13	Workshops, Seminars, Farmers Day <i>etc.</i> organized at the Centre	90
14	Distinguished Visitors	92
15	Empowerment of Women	94
16	Personnel	95
17	Other Information	97
	Annexure I	99
	Annexure II	103





PREFACE

The ICAR-National Research Centre for Banana, Tiruchirappalli, established in 1993, has grown into a nationally and internationally recognized centre of excellence on banana research. I take immense pleasure in presenting the Annual Report of ICAR-NRCB for the year 2018-19. During 2018-19, the centre has made significant progress in research on banana addressing key problems faced by banana farmers.

The centre has collected and added 34 wild and 33 exotic accessions including *Musa thomsonii*, a first report from Arunachal Pradesh to the field gene bank at ICAR-NRCB. Three varieties – Kaveri Saba, Kaveri Kalki and Kaveri Sugantham have been released by SVRC, Tamil Nadu. Sixteen elite clones of cvs. Grand Naine, Ney Poovan and Nendran were collected for further improvement. The centre has identified 35 out of 310 *Musa* germplasm accessions as resistant to Fusarium wilt (Tropical Race 4), an emerging problem in banana cultivation and also identified few high yielding 'carotenoid rich', nematode resistant, Nendran-based hybrids. Inter-specific crosses among ornamental *Musa* have given hybrids with interesting colour patterns on bracts and leaves. Vitamin A (10 fold higher) and iron rich (3 fold higher) transgenic banana lines of cv. Grand Naine have been successfully raised in newly erected transgenic nethouse and evaluated for the first time in ICAR history.

In crop production, significant research strides were made in working out nutrient dynamics in banana cvs. Ney Poovan and Rasthali; identifying best combination of treatments under clump management; optimizing storage temperature for extending shelf-life of banana leaves and identification of few drought tolerant banana genotypes. The centre has identified a solution to banana finger drop and attempted micro-encapsulation of anthocyanin. Varieties with low glycemic index have been identified. Estimation of post-harvest losses across 4 states and 5 varieties was done. Research on banana starch and fibre was another front where significant achievements were made.

In crop protection, nematode and weevil resistant *Musa* genotypes were identified. Volatiles of banana weevils were investigated. New banana insect pests and their natural enemies were documented. Intensive surveys were carried out for Fusarium wilt incidence in different banana growing states of India. Biocontrol agents were identified and evaluated against Fusarium wilt and other banana diseases. Molecular characterization was done for major fungal and viral diseases of banana. In a public-private partnership mode, ICAR-NRCB, as a technical partner to TNBGF launched a sea protocol for export of Cavendish bananas to Europe (Italy), which was flagged off by DDG (Hort. Science), Agriculture Minister (Tamil Nadu), APC (Tamil Nadu) and others.

The centre has successfully conducted one National symposium, one brainstorming meet and two workshops. During 2018-19, a total of 28 research articles were published by the centre in various journals of National and International repute and 46 presentations in various National and International conferences/

seminars etc. were made by the researchers of the centre. Consultancy services were provided to Tripura Biotech Council and Tamil Nadu Banana Growers Federation (TNBGF). Trainings were given to farmers and stakeholders on banana cultivation and post harvest value addition. Virus indexing, genetic fidelity testing, soil nutrient analysis, supply of planting materials and supply of antisera were other services provided by the centre.

The Centre has signed MoU's with Andhra Pradesh and premier institutions like NIT, Tiruchirappalli and KNCET, Thottiyam. The centre has research linkages with international institutes like Bioversity International, France; QUT, Australia; IITA-Nigeria; NARO-Uganda and more than 30 National institutions.

The Centre has been accredited with ISO 9001:2015 certification for its quality standard services. The Centre mainly focuses on farmers' empowerment through Kisan Melas, exhibitions, on-campus and off-campus training programmes during this year. The Government of India's farmers' welfare programmes and other initiatives like *Mera Gaon Mera Gaurav* (MGMG) and *Swachh Bharat* and other events like Hindi Pakwada, International yoga day, Vigilance awareness week, Communal harmony campaign, National science day were successfully organized during the year in a befitting manner.

I sincerely thank Dr. T. Mohapatra, Secretary-DARE and Director General, ICAR for his valuable guidance and support. I profusely thank Dr. A. K. Singh, Dy. Director General (Hort. Science), ICAR, New Delhi for his inspiring and constant encouragement. Thanks are also due to Dr. W. S. Dhillon and Dr. T. Janakiram, Assistant Director Generals (Hort. Science), ICAR for their untiring support and guidance. Sincere thanks are due to the staff members of SMD (Hort. Science) for their continuous support and cooperation extended to ICAR-NRCB. I am also thankful to the Chairman and members of QRT, RAC and IMC for their guidance. I record my heartfelt thanks to all the Scientists, Technical, Administrative and Supporting staff of ICAR-NRCB for having stood by me in various institute activities. Finally, my earnest thanks to the Publication Committee for shaping this document and bringing it in time.



(S.Uma)

2. Introduction

ICAR-National Research Centre for Banana is celebrating its silver jubilee year after it was established on 21st August 1993 at Tiruchirappalli, Tamil Nadu by ICAR, New Delhi with an aim to increase the production and productivity of banana and plantains through mission mode basic and strategic research approaches. ICAR-NRCB has contributed immensely for the present production estimate of 30.2 MT from an area of 8.47 lakh hectares keeping India in the first place in terms of production since last three decades. The crop has transformed from its status as a backyard crop to a high value crop in the last 25 years. The Centre has a research farm of 36.5 ha and a laboratory complex in 3.23 ha. ICAR-NRCB also has an area of 0.80 ha under residential complex in the main city. This Centre is located at 11.50°N latitude and 74.50°E longitude, 90 m above MSL and receives 800mm rain annually. The climate is warm and humid and the average minimum and maximum temperature are 25 and 35°C, respectively.

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

The Institute harbors one of the largest and best kept *Musa* field gene banks apart from DNA and cell line banks. Three varieties, Kaveri Saba, Kaveri Kalki and Kaveri Sugantham were released by SVRC, Tamil Nadu and four more hybrids, two each in cooking and plantain types exhibiting tolerance to root-knot nematodes are under advanced yield trials. For the first time in ICAR history, ICAR-NRCB has successfully developed biofortified bananas with ten times higher pro-vitamin A and three times higher iron contents. For quality planting material, the centre has developed a high throughput technology of mass production using embryogenic cell suspension in bioreactors. Mutation breeding has led to the identification of putative mutants with resistance / tolerance to Fusarium wilt - Race 1 and Tropical Race 4 (TR4). More than 300 accessions

have been screened for Race 1 and TR4 in hotspots of Theni, Tamil Nadu and Kathihar, Bihar, leading to the identification of disease resistant sources. Consultative meetings on TR4 disease sensitization have brought awareness across the country. Geo-mapping of TR4 has confirmed its spread in Uttar Pradesh, while occurrence of Subtropical Race 4 has been reported for the first time in India in Maharashtra and Madhya Pradesh. In a public – private partnership mode, ICAR-NRCB, as a technical partner to TNBGF launched a sea protocol for export of Cavendish bananas to Europe (Italy), which was flagged off by DDG (Hort. Science), Agriculture Minister (Tamil Nadu), APC (Tamil Nadu) and others. The eco-friendly low cost dipstick developed for on-site detection of banana bract mosaic virus disease has been globally acknowledged and development of a dipstick for multiple virus detection is in progress.

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

The Centre has 23 in-house research projects and 27 externally funded projects funded by various agencies like ICAR, DBT, PPV& FRA, DAE, DST, Bioversity International, etc. Four contract research projects have been completed and consultancy has been provided to TNBGF in PPP mode to ship indigenous banana to Europe and to establish tissue culture laboratories for mass multiplication of banana. The Perspective Plan and Vision 2030 and 2050 documents on the research priorities and inputs from the QRT and RAC were published. The Centre has conducted Institute Research Council meet and Research Advisory Council meet to review the ongoing research projects and also monitor the progress made on the RAC and QRT recommendations. 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.

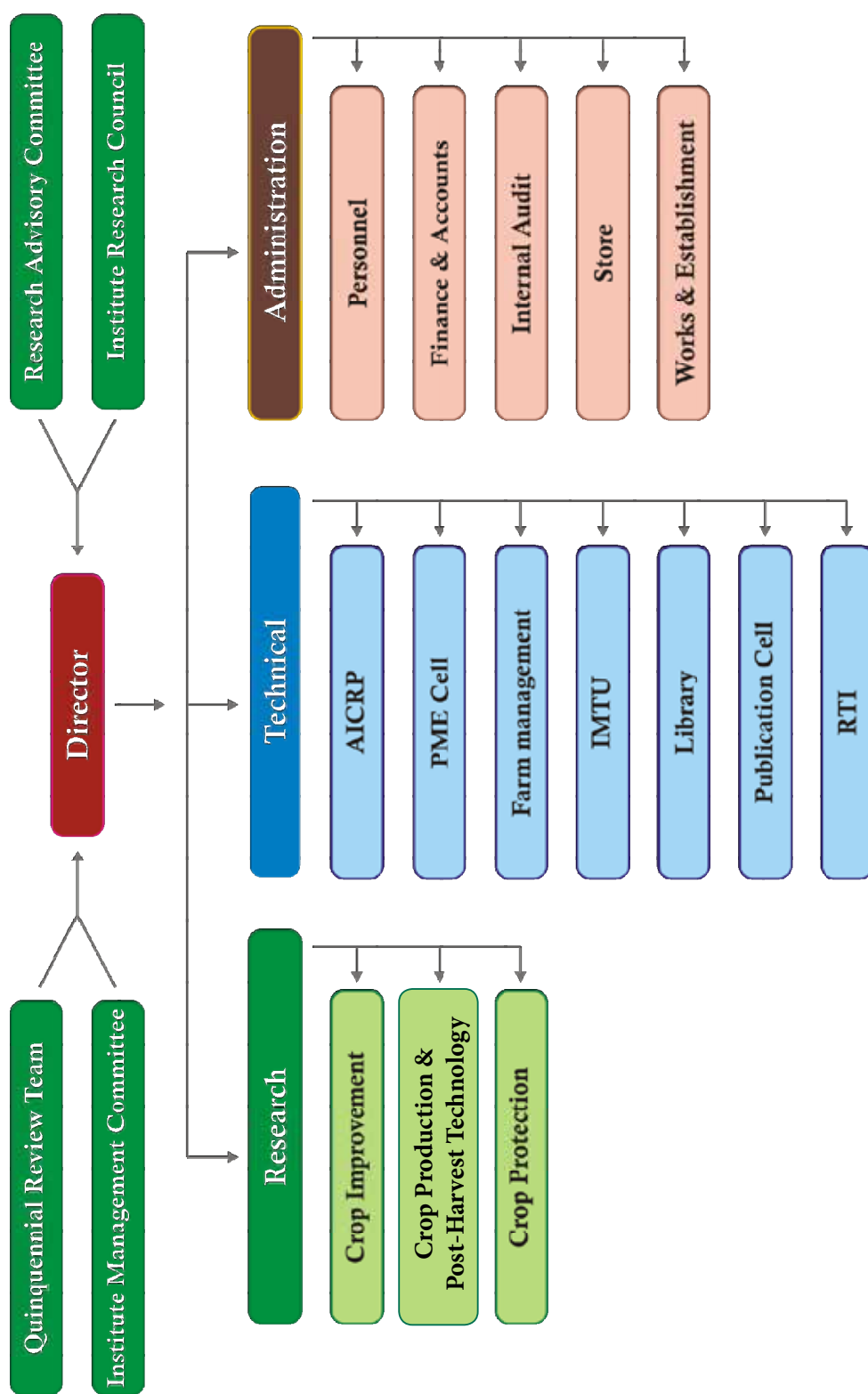
- ✦ Transfer of technology and capacity building of stakeholders for enhanced and sustained production of banana.
- ✦ Referral laboratory for monitoring the quality of micro-propagated banana plants.

Budget details for the year 2018 - 19 (Rs. in lakhs)

Head of account	Expenditure (Rs. in lakhs)
Works	53.11
Equipment	12.89
Establishment	817.93
TA	15.00
Research Exp.	49.99
Operational Exp.	66.99
Infrastructure	132.77
Communication	22.68
Repair of equipment, Vehicle	22.31
Office building	44.27
Residential building	0.77
Other Admin	12.64
Publicity & Exhibition	1.00
Miscellaneous Exp.	5.00
Pension & Retirement Benefits	62.02
Total	1319.37
SCSP-Capital	5.00
SCSP-General	79.90
P Loans & Advances	1.00
Grand Total	1405.27

A sum of Rs. 97.65 Lakhs was generated by the centre during the financial year 2018-19.

Organizational Setup of ICAR-NRC for Banana



3. EXECUTIVE SUMMARY

Crop Improvement

Survey in the North Eastern parts of India covering lower and upper Dibang districts of Arunachal Pradesh led to the collection of 14 *Musa* accessions including *M. thomsonii*, a first report by ICAR-NRCB from Arunachal Pradesh. A total of 20 accessions have been collected from secondary sources, including a somaclonal variant of Nendran with green pseudostem and 33 exotic accessions from ITC, Belgium. Surveys in Tamil Nadu and Karnataka resulted in collection of 16 elite clones viz., 3 high yielding Grand Naine, 2 ultra dwarf and 3 dwarf Grand Naine, 6 high yielding Ney Poovan with one shy suckering (without side suckers) and 2 high yielding Nendran having green pseudostem. Morpho-taxonomic characterization of 21 accessions revealed seven new types which have been added to the core collection. IC nos. have been obtained for 32 unique germplasm accessions (IC 0627968 to IC 062799) from ICAR-NBPGR, New Delhi. Results of the field evaluation of cv. Rasthali derived from three different explants, namely, shoot tip, cormlet and male flower bud along with suckers as control indicated that the crop duration was higher (20 days more) in sucker and shoot tip derived plants compared to male bud and cormlet derived plants (263 days). The yield was maximum in male bud (22 kg) followed by sucker (20 kg) both of which were on par. Sick plot screening of 313 germplasm accessions against Fusarium wilt Tropical Race 4 (Foc-TR 4) led to the identification of 35 accessions which were found to be either resistant or tolerant to TR4. This included one *Rhodochlamys*, one progeny, 15-AA, 4-BB, 11-AAB, and 3-AAA genotypes. Out of 72 accessions screened for Fusarium wilt resistance under pot culture conditions, 15 belonging to different genomes (AAA – 5, AA – 1, AB – 2 and AAB – 7 Nos.) were found to be resistant.

Modified embryo culture media enhanced the germination by upto 116% over control and 62 % of the embryos produced multiple shoots. Five progenies of the cross Poovan x Pisang Lilin have been successfully developed into plantlets. Among the 18 Nendran based progenies which were evaluated in a farmers' field at Malliyampathu, it was found that NCR-2, NCR-8, NCR-17, NCR-21, NPL-33 and NOP-45 were high yielding, NCR-17 had best consumer acceptability. Saba based Progenies No.

684 (Saba x Pisang Lilin) and No. 690 (Saba x Pisang Lilin) performed well with a stable and consistent yield. Hybrid progenies of the cross *Musa ornata* × *M. laterita* had more intense bract colour than the female parent while those of the cross *M. ornata* × *M. acuminata* ssp. *zebrina* had variegated leaves with purplish brown blotches on the upper surface of the leaves and continuous pigmentation on the lower surface of the leaves.

Screening of hybrid progenies for various pests and diseases indicated that NCR-5, 8, 10, 18, 21; NPL-28 and 33 were promising with lesser population of root-lesion nematode (*Pratylenchus coffeae*) while hybrids NCR-2, 10, 18 and 19; NPL-30; NOP-44 and 45 were promising with lesser population of root-knot nematode (*Meloidogyne incognita*). Among the seven synthetic diploid progenies evaluated for their reaction against nematodes under pot conditions, only two, namely, progeny no. 134 (Anaikomban x Matti) and 148 (Pisang Jajee x Lairawk), were found to be resistant and moderately resistant to root-knot nematode (*M. incognita*), respectively.

Pot screening of the EMS treated population of ECS derived cv. Grand Naine has resulted in the identification of 11 putative resistant mutants (NRCBGN – 1 to 11) of which three showed resistance to race 1 and eight to race 4 and the same have been initiated under *in vitro* for mass multiplication purpose. Sick plot screening of 15 putative mutants of ECS derived cv. Rasthali at Muthalapuram, Theni indicated that 6 lines (RM 3, RM 4, RM 10, RM 11, RM 12 & RM 15) yielded normally without any external symptoms.

Anthers containing highly vacuolated uninucleate stage responded better for the induction of embryogenic calli and their germination towards the production of androgenic haploids. LRR-RLP and LRR-RLK genes have been cloned and sequenced from banana roots.

Genetic fidelity testing of tissue cultured bananas of various commercial varieties has generated revenue to the tune of Rs.14.10 lakhs to the Institute. A total of 8100 plants of Udhayam have been supplied to banana growers of various districts of Tamil Nadu through M/s. Shaanti Agro-Tech, Bengaluru. Mother cultures of cvs. Udhayam and Grand Naine have

been supplied to M/s. MAHYCO, Faizabad. Disease free healthy suckers of 10-15 germplasm accessions have been distributed to Sirugamani KVK, Trichy and Thiruvannamalai College of Agriculture for evaluation purpose.

Crop Production and Post-Harvest Technology

Under nutrient dynamics in banana, the average N-P-K and Cu-Mn-Zn-Fe concentrations (%) of different parts, total dry weight, nutrient uptake and total uptake of 5- and 10-leaved stage in Nendran and Grand Naine were studied. In organic treatment combination (M_2S_2) including poultry manure, groundnut cake, rural compost, wood ash recorded the highest yield and quality parameters with optimum soil colony forming units of actinomycetes, fungi and bacteria. The benefit-cost ratio of this best treatment was 1.9 against 2.8 with inorganic fertiliser alone. In the second ratoon crop of cv. Ney Poovan, mother plant with four suckers per clump and applied with highest dose of fertilizers (175% recommended dose of fertilizer) produced improved growth, production and quality attributes.

Mother plants of Poovan, Naadu and Karpuravalli produced 8, 7.66 and 8 leaves, respectively. However, side suckers of Poovan produced more leaves, compared to the other two varieties. In a storage study, both at room temperature and at 13.5°C, the shelf-life of banana leaves in three varieties was extended. Use of ethylene gas as ripening agent is found to be the best with improved quality parameters. Proportion of 20:80 (banana flour: rice flour) was the best for the preparation of banana flour based snack food.

Out of 67 ABB banana genotypes, a few drought tolerant genotypes at flowering stages have been identified, viz., 'Sakkai', 'Ney Vannan', 'Nepali China' and 'Vennutu Mannan' along with their physiological traits. The Membrane stability index was recorded higher in Kallumonthan and Karibale genotypes.

Grand Naine and Rasthali are highly susceptible to finger drop. Treating with 500 ppm gibberellic acid (GA_3) and 6% calcium chloride ($CaCl_2$) delayed the onset of finger drop. The treatment extended the shelf life of fingers and 100% drop occurred on 5th day after ripening. Anthocyanin pigments in banana varieties were estimated and micro-encapsulated anthocyanin was characterized. Best spray drying procedure was standardised. Glycemic indices (GI) of traditional

varieties like Pachanadan, Hill Banana and exotic variety, Saba at stage 5 and North Eastern banana cultivars at full ripe stage were analysed. Fruit pulp of Rigatchi and Malbhog possessed highest fructans content of 138 and 125 mg/100 g, respectively.

The inulin type-fructans content in peel and pulp of ripe and unripe of nine banana cultivars was quantified. The ripe fruit peel and pulp had accumulated higher levels of inulins with Nendran containing the highest quantity of 556 and 1199 mg/100g respectively. The oil contents in ripe fruit peel of 12 commercial banana cultivars were estimated, the highest being in Red Banana, followed by Grand Naine. One each of Grand Naine and Rasthali lines are promising with 3.06 and 2.73 mg of iron per 100 g fruit pulp against control of 0.85 mg.

The post-harvest losses estimated by ICAR-NRCB were 10.83% and 11.39% in Theni and Erode districts, respectively for 'Grand Naine' variety, while it was 17.39% and 6.41% in Tiruchirappalli and Tuticorin districts, respectively in 'Poovan' variety. With varying maturity, the green life of the banana varied significantly in Red Banana and Ney Poovan by adopting improved post-harvest handling practices. Use of carbendazim enhanced the green life of banana irrespective of the temperature. Minimal processing of ripe Monthan banana was standardised.

Extraction of starch without addition of enzymes and treatment with KMS (0.5 g/l) gave higher starch recovery with the purity of above 90%. Characteristics like light transmittance and microscopic structure of the starches were studied. Protein enriched prebiotic pasta from banana modified starch was developed by incorporating banana flour and channa powder, respectively with maida flour. Ripe banana powder could be used as a functional replacement for refined wheat flour (in the ratio of 60:40) for the preparation of doughnut. Production of Xylo-oligosaccharide using banana peel was standardised. Karpuravalli fiber had higher water absorption characteristics (892%), followed by Grand Naine (816%).

Characteristics of banana fiber were analysed by using X-ray diffraction. Adsorption of lead [Pb (II)] by banana fiber was reached at 140 minute and after that it was maintained. Maximum removal was at 1.5 g of adsorbent dosage. Extraction of nano fibrillated cellulose from banana fibre was carried out

from cellulase enzyme and softness was obtained by sodium hydroxide and sodium hypochlorite.

Crop Protection

Two accessions resistant to corm weevil and 16 accessions less susceptible to stem weevil were identified from *Musa* germplasm. 337 isolates of endophytes isolated and identified from *Musa* germplasm which belong to *Beauveria* spp., *Metarhizium* spp. and *Lecanicillium* spp. Volatile semiochemicals were isolated from male and female stem weevils. A volatile blend showing 77.5% attraction to stem weevil has been identified. Azadirachtin gave good repellent property in preventing stem weevil infestation in plants under field evaluation. Banana fruit scarring beetle and host released volatiles were collected and identified using NIST library. The leaf and fruit scarring beetle populations from Assam were identified as belonging to the morphospecies, *Basilepta subcostata* (Jacoby). COX1 gene of three colour morphs of the beetle from Assam was sequenced and the sequence data indicated the presence of more than one species.

Evaluation of *Fusarium* wilt suppressive biocontrol agents against root-lesion nematode (*Pratylenchus coffeae*) and root-knot nematode (*Meloidogyne incognita*) under *in vitro* conditions showed that *Bacillus flexus* (Tvpr1) was superior followed by *Trichoderma asperellum* (Prr-2). Species identity of native isolate of entomopathogenic nematode was deciphered through amplification and sequencing of ITS1-5.8S-ITS2 region of rDNA using primer TW81- AB28. It was identified as *Heterorhabditis indica* (NCBI accession no. MH 299879). Virulence of two native isolates of entomopathogenic nematodes (*Steinernema siamkayai* and *Heterorhabditis indica*) was compared by dose response assay, one-on-one assay and probit analysis using waxmoth larvae. *S. siamkayai* was found more virulent than *H. indica* based on insect mortality and LD50 values.

Incidence of *Fusarium* wilt (Foc) in banana cv. Grand Naine was recorded in Maharashtra (Muktainagar, Besalvadi taluk, Jalgaon district), Madhya Pradesh (Nanchenkhera, Burhanpur district) and Gujarat (Kholeshwar village, Kamrej taluk, Surat district) states. Molecular diagnostics and VCG analysis were carried out for Foc isolates obtained from Gujarat, Madhya Pradesh, Uttar

Pradesh, Bihar, Kerala and Tamil Nadu. Foc isolates of Uttar Pradesh and Bihar belonged to tropical race 4 (VCGs 01213/16) and Foc isolates of Gujarat and Madhya Pradesh belonged to subtropical race 4, whereas, Foc isolates from Kerala and Tamil Nadu belonged to race 1. A simple and cost effective diagnostics, Loop mediated isothermal amplification (LAMP) method for Foc tropical race 4 (TR4) of banana was developed. The mass production technology of Foc TR4 effective *Trichoderma* sp. was standardized by using rice chaffy grain. A total of 14 banana cultivars belonging to AA, BB, ABB genome were explored and totally 132 bacterial isolates and six isolates of *Trichoderma* sp. were obtained.

Survey was conducted for rhizome rot in Andhra Pradesh, Bihar and Tamil Nadu and rot infected samples were collected from different banana cultivars. In total, 154 bacterial isolates were isolated and purified from the infected samples. In total, 52 PGPR isolates were obtained from rhizosphere soil samples collected from different places. Seven isolates out of 34 isolates significantly increased the banana (cv. Grand Naine) growth characters.

Screening of 50 diploid banana germplasm accessions for resistance against banana bunchy top virus (BBTV) was done using sucker grown plants and the virus transmitted into the plants using viruliferous aphids. Twelve diploid accessions of AA genomic groups and Hill banana and Grand Naine plants expressed the BBTV symptoms but not the accessions having BB genome. The BB genome containing accessions were re-inoculated again with 20 viruliferous aphids in each plant and none expressed symptoms except susceptible Hill banana and Grand Naine. The result indicated that a single aphid was able to acquire 861.04 copies of the virus after 24hrs of AAP from the infected banana plant and transmitted the virus to 16.6% tissue culture plants, whereas 50 viruliferous aphids (15066.94 viral copies) were necessary to achieve 100% transmission in a shortest time of 21.6 days. Mother cultures of Tissue culture (TC) banana plant received from TC production units (TCPU) were tested for banana viruses under contract service. Totally 19114 TC samples were tested for the presence of four viruses.

The LFIA developed for banana bract mosaic virus (BBBrMV) was further validated with 114 samples of commercial banana cultivars collected from different farmers' fields and also tissue culture

banana production units located in six banana growing states of India. Twenty Eight differentially expressed spots (> 2.5 fold) during BBTV time course study were subjected to peptide mass fingerprinting.

Transfer of Technology

Around 4800 visitors including farmers, agricultural & horticultural officers, entrepreneurs, students and other stakeholders visited ICAR-NRCB and they were explained about institutes' activities / technologies. Ten radio talks, 10 television talks and 25 press notes in various dailies and magazines were published by ICAR-NRCB. The institute participated in / organized seven exhibitions at State / National levels and a total of eight on-campus and two off-campus trainings were conducted to farmers and entrepreneurs. One National symposium, three workshops and one brainstorming meet were conducted by the centre. The institute has signed MoU with Tripura Biotechnology Council for supply of quality tissue cultured planting material of banana cv. Sabri and with Tamil Nadu banana growers federation, Greeners' Agro, Tiruppur and SMV Exports, Theni for export of banana fruits to Europe.

Linkages and Collaborations

ICAR-NRCB has research collaborations with International institutes which include IITA, Nigeria; Bioversity International, France; KUL, Belgium and University of Queensland, Australia. The institute has linkages with National institutes, namely, 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 namely, 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 being associated with ICAR-NRCB. ICAR-NRCB also coordinates with ICAR-AICRP (Fruits) centers (11 Nos.) working on banana. Tissue culture industries involved in banana mass propagation, farmers, exporters, State Horticulture and Agriculture departments and self-help groups are linked with the centre for various research and developmental activities.

HRD and Education

Under human resource development a total of 17 seminars / conferences / symposia / workshops / meets were attended by the scientists and technical staff of the center at Regional / National / International levels. The centre has published 28 research papers in various journals of International and National repute and 46 research papers were presented in various conferences / symposia / seminars, etc. held across the country. More than 15 students are pursuing B. Tech., M. Tech., M. Sc., Ph. D. and post doctoral research at the centre.

Revenue Generated

A sum of Rs. 97,65,881/- was generated by the centre during the financial year 2018-19.

विशिष्ट सारांश

फसल सुधार

अरुणाचल प्रदेश के निचले तथा ऊपरी दिबांग जिलों को लेते हुए भारत के उत्तर पूर्वी भागों में किए गए सर्वेक्षण के परिणामस्वरूप एम. थोम्सनी सहित म्यूसा की 18 प्रविष्टियाँ एकत्र की गईं। यह अरुणाचल प्रदेश से भा.कृ.अ.प. - एनआरसीबी द्वारा पहली बार रिपोर्ट की गई है। द्वितीयक स्रोतों से कुल 20 प्रविष्टियाँ एकत्रित की गई हैं जिनमें हरे छद्म तने सहित नेन्द्रन का एक कायक्लोनी वैविध्य तथा आईटीसी, बैल्लियम से प्राप्त की गई 33 विदेशी प्रविष्टियाँ शामिल हैं। तमिल नाडु और कर्नाटक में किए गए सर्वेक्षणों के परिणामस्वरूप 16 श्रेष्ठ क्लोन नामतः, 3-उच्च उपजशील ग्रैंड नयने, 2-अल्ट्रा ड्वार्फ और 3-ड्वार्फ गेर्ड नयने, 6-उच्च उपजशील नेय पूवन और एक भीरू (शाई) भूस्तार करने वाला (पार्श्व भूस्तारियों के बिना) तथा 2-उच्च उपजशील नेन्द्रन प्राप्त किए गए जिनमें हरा छद्म तना था। कुल 21 प्रविष्टियों के आकृति-वर्गीकरणविज्ञानी लक्षण-वर्णन से सात नए प्रकारों का पता चला और इन्हें मुख्य संकलन में जोड़ा गया। कुल 32 अनोखी जननद्रव्य प्रविष्टियों (आईसी 0627968 से आईसी 062799 तक) की आईसी संख्याएं भा.कृ.अ.प.-एनबीपीजीआर, नई दिल्ली से प्राप्त की गई हैं। विभिन्न कर्तातकों (एक्सप्लान्ट), नामतः प्ररोह की नोक, उप भूस्तारियों और नर पुष्प कलिकाओं से व्युत्पन्न रसथली किस्म के भूस्तारियों के साथ-साथ तुलनीय के रूप में नर पुष्प कलिकाओं के प्रक्षेत्र मूल्यांकन के परिणामों की नर कलिका तथा उप भूस्तारियों से व्युत्पन्न पौधों (263 दिन) से की गई। सर्वाधिक उपज नर कलिका (22.00 कि.ग्रा.) थी जिसके पश्चात् भूस्तारियों से होने वाली उपज (20 कि.ग्रा.) का स्थान था और ये दोनों ही लगभग बराबर थीं। फ्यूजेरियम मुर्झान की उष्णकटिबंधीय प्रजाति 4 (एफओसी-टीआर 4) के विरुद्ध 313 जननद्रव्य प्रविष्टियों की रोगी प्लॉट में छंटाई करने के परिणामस्वरूप 35 ऐसी प्रविष्टियों की पहचान की गई जो टीआर 4 के विरुद्ध या तो प्रतिरोध या सहिष्णु पाई गई। इनमें से एक रोडोक्लेमाइस, एक संतति, 15-एए, 4-बीबी, 11-एएबी और 3-एएए हैं। गमले में उगाई गई दशाओं के अंतर्गत फ्यूजेरियम मुर्झान प्रतिरोध के लिए जिन 72 प्रविष्टियों की छंटाई की गई उनमें से विभिन्न जीनोम (एएए-5, एए-1, एबी-2 और एएबी-7 संख्याएं) के अंतर्गत आने वाली 15 प्रतिरोधी पाई गई।

रूपांतरित भ्रूण संवर्धन माध्यमों से तुलनीयों में होने वाले 62: अंकुरण की तुलना में 116: की वृद्धि हुई तथा अनेक प्ररोह वाले भ्रूण उत्पन्न हुए। पूवन ग पिसांग लिनन संकर की पांच संततियों में पौधे सफलतापूर्वक विकसित हुए हैं। नेन्द्रन आधारित जिन 18 संततियों का मूल्यांकन मल्लियामपत्तु में किसानों के खेत में किया गया उनमें यह पाया गया कि एनसीआर-2, एनसीआर-8, एनसीआर-17, आरसीआर-21, एनपीएल-33 और एनओपी-45 उच्च उपजशील थी तथा एनसीआर-17 में सर्वश्रेष्ठ उपभोक्ता स्वीकार्यता थी। साबा आधारित संतति संख्या 684 (साबा ग पिसांग लिनन) और संख्या 690 (साबा ग पिसांग लिनन) ने भी स्थिर और निरंतर उपज देते हुए अच्छा निष्पादन दिया। म्यूसा ओर्नाटा ग म्यूसा लेटेरिता के संकरण से प्राप्त की गई संकर संततियों में मादा जनक की तुलना में सहपत्र का रंग अधिक गहन होता है तथा जो म्यूसा ओर्नाटा ग म्यूसा एक्व्यूमिनेटा उपजाति जेब्रिना के संकरीकरण से प्राप्त किए गए थे उनमें चित्तीदार पत्तियाँ थीं और इन पत्तियों की ऊपरी सतह पर बैंगनीपन लिए हुए भूरे रंग के धब्बे थे। इसके साथ ही पत्तियों की निचली सतह पर निरंतर रंजकता विद्यमान थी।

विभिन्न पीड़कों और रोगों के लिए संकर संततियों की छंटाई से यह संकेत मिला कि एनसीआर-5, 8, 10, 18, 21; एनपीएल - 28 और 33 जड़ में घाव उत्पन्न करने वाले सूत्रकृमि (प्रेटिलैकस कॉफीई) की समष्टि को कम करने की दृष्टि से आशाजनक थीं जबकि संकर एनसीआर - 2, 10, 18 और 19; एनपीएल - 30; एनओपी - 44 व 45 जड़-गांठ सूत्रकृमि (मेलाइडोगाइने इन्कोग्रीटा) की समष्टि को कम करने की दृष्टि से आशाजनक पाए गए। जिन सात कृत्रिम द्विगुणित संततियों का मूल्यांकन गमला दशाओं के अंतर्गत सूत्रकृमियों के विरुद्ध उनकी प्रतिक्रिया के लिए किया गया उनमें से केवल दो संततियाँ संख्या 134 (एनेकोम्बन ग मत्ती) और 148 (पिसांग जाजी ग लैरावक) जड़-गांठ सूत्रकृमि (मेलाइडोगाइने इन्कोग्रीटा) के विरुद्ध क्रमशः प्रतिरोधी और हल्की प्रतिरोधी पाई गई।

ग्रैंड नयने किस्म से व्युत्पन्न ईसीएस की ईएमएस से उपचारित समष्टि की गमला छंटाई के परिणामस्वरूप 11 प्यूटेटिव प्रतिरोधी उत्परिवर्तकों (एनआरसीबीजीएन-1 से 11) की पहचान की गई जिनमें से तीन में प्रजाति 1 के

विरुद्ध प्रतिरोध तथा आठ में प्रजाति 4 के विरुद्ध प्रतिरोध प्रदर्शित हुआ और इनका बड़ी संख्या में प्रगुणन करने के उद्देश्य से स्वपात्रे प्रगुणन का कार्य आरंभ कर दिया गया है। मुथालापुरम, थेन्नी में रसथली किस्म से व्युत्पन्न ईसीएस के 15 प्यूटेटिव उत्परिवर्तकों की रोगी प्लांटों में छंटाई से यह संकेत मिला कि छह वंशक्रमों (आरएम 3, आरएम 4, आरएम 10, आरएम 11, आरएम 12 और आरएम 15) से सामान्य उपज प्राप्त हुई और कोई बाहरी लक्षण भी नहीं दिखाई दिए।

अत्यधिक रसधानी युक्त एक केन्द्रकीय अवस्था से युक्त परागकोषों ने भूरणजनित कैलस के प्रेरित होने की दृष्टि से बेहतर अनुक्रिया प्रदर्शित की तथा एंड्रोजेनिक अगुणित के उत्पादन की दृष्टि से उनका अंकुरण भी बेहतर था। एलआरआर - आरएलपी और एलआरआर-आरएलके जीन केले की जड़ों से क्लोन किए गए हैं तथा उनका अनुक्रमण भी किया गया है।

केले की विभिन्न वाणिज्यिक किस्मों के ऊतक संवर्धन से प्राप्त किए गए केलों के आनुवंशिक फिडेलिटी परीक्षण से संस्थान को 14.10 लाख रुपये का राजस्व प्राप्त हुआ है। मेसर्स शांति एग्रोटेक, बंगलुरु के माध्यम से तमिल नाडु के विभिन्न जिलों के केला उगाने वालों को उद्यम किस्म के 8100 पौधे आपूर्त किए गए हैं। मेसर्स मायको, फैजाबाद को उद्यम तथा ग्रांड नयने किस्मों के मातृ संवर्धन आपूर्त किए गए हैं। कुल 10-15 जननद्रव्य प्रविष्टियों के रोग मुक्त व स्वस्थ भूस्तारी सिरूगामिनी कृषि विज्ञान केन्द्र, त्रिची तथा तिरुवनमलय कृषि महाविद्यालय को मूल्यांकन के उद्देश्य से वितरित किए गए हैं।

फसलोत्पादन और फसलोत्तर प्रौद्योगिकी

नेन्द्रन तथा ग्रेंड नयने में केले में 5- तथा 10-पत्ती की अवस्था पर पोषक तत्वों की गतिकी के अंतर्गत पौधे के विभिन्न भागों में औसत छ.व्.ज्ञ और ब्र.डद.द.थम की सांद्रताओं (:), कुल शुष्क भार, पोषक तत्वों के अंतर्ग्रहण और अध्ययन किया गया। कुक्कुट खाद, मूंगफली की खली, ग्रामीण कम्पोस्ट, काष्ठ भस्म सहित जैविक उपचार संयोगों (ड22) से सर्वोच्च उपज रिकॉर्ड की गई तथा गुणवत्ता संबंधी प्राचल भी सर्वश्रेष्ठ रहे। एक्टिनोमाइसिटीस, कवकों तथा जीवाणुओं की मृदा में कालोनी बनाने वाली इकाइयों की संख्या भी इस उपचार में उपयुक्ततम पाई गई। इस सर्वश्रेष्ठ उपचार का लाभ

लागत अनुपात 1.9 था जबकि केवल अकार्बनिक उर्वरक उपयोग करने पर यह अनुपात 2.8 था। नेई पूवन किस्म की दूसरी पेड़ी की फसल में प्रति क्लम्प चार भूस्तारी युक्त मातृ पौधे प्राप्त हुए तथा उर्वरकों की सर्वोच्च खुराक (उर्वरकों की 175: अनुशंसित खुराक) का उपयोग करने से वृद्धि, उत्पादन तथा गुणवत्ता संबंधी गुणों में सुधार हुआ।

पूवन, नादू और करपूरावल्ली के मातृ पौधों में क्रमशः 8, 7.66 और 8 पत्तियां उत्पन्न हुईं। तथापि, पूवन के पार्श्व भूस्तारियों में अन्य दो किस्मों की तुलना में अपेक्षाकृत अधिक पत्तियां उत्पन्न हुईं। भंडारण संबंधी अध्ययनों में कक्ष तापमान और 13.50 से. तापमान पर तीन किस्मों में केले की बढ़ी हुई निधानी आयु देखी गई। पकाने के लिए प्रयुक्त होने वाले पदार्थों में से इथिलीन का उपयोग केले को पकाने की दृष्टि से सर्वश्रेष्ठ पाया गया जिससे इसके गुणवत्ता संबंधी प्राचलों में सुधार हुआ। केले के आटे पर आधारित स्वल्पाहार तैयार करने की दृष्टि से 20:80 (केले का आटा : चावल का आटा) का अनुपात सर्वश्रेष्ठ पाया गया।

केले के 67 एबीबी जीनप्ररूपों में से फसल की पुष्पन अवस्थाओं पर कुछ सूखा सहिष्णु जीनप्ररूपों की पहचान की गई है। ये हैं : सक्कई, नेई वन्ना, नेपाली चिनिया और वेन्नतू मन्नान। इनके कार्यिकी गुण भी पहचाने गए हैं। काल्लूमॉथन और कारीबेले जीनप्ररूपों में झिल्ली स्थिरता सूचकांक अपेक्षाकृत उच्चतर रिकॉर्ड किया गया।

ग्रांड नयने तथा रसथली किस्मों को केले के फल के झड़ जाने वाले विकार के प्रति उच्च संवेदी पाया गया। इस विकार को नियंत्रित करने के लिए 500 पीपीएम जिब्रेलिक अम्ल (ळ।3) और 6: कैल्सियम क्लोराइड (बूँस2) उपचारों से गुच्छे से केलों का गिरना विलंबित हुआ। इस उपचार से केले की निधानी आयु में वृद्धि हुई तथा परिपक्वन के पांचवें दिन बाद 100: पतन हुआ। केले की किस्मों में एंथोसियानिन रंजकों का आकलन किया गया और सूक्ष्म-कवचीकृत एंथोसियानिन का लक्षण-वर्णन किया गया। सर्वश्रेष्ठ छिड़काव शुष्कन क्रियाविधि का मानकीकरण किया गया। पचनंदन, हिल बनाना और विदेशी किस्म साबा जैसी परंपरागत किस्मों के ग्लाइसेमिक सूचकांकों (जीआई) तथा अवस्था 5 पर और केले की उत्तरी पूर्वी किस्मों का फलों के पूरी तरह पकी हुई अवस्था पर विश्लेषण किया गया। रिगत्यी और मालभोग के

फल के गूदे में फ्रक्टांस अंश की मात्रा सर्वोच्च थी जो क्रमशः 138 व 125 मि.ग्रा./100 ग्रा. पाई गई।

केले की नौ किस्मों के पके और अनपके फलों के छिलके और गूदे में इनुलिन प्रकार के फ्रक्टांस का मात्रात्मक निर्धारण किया गया। पके हुए फल के छिलके और गूदे में इनुलिन की उच्च मात्रा संचयित हुई, विशेष रूप से नेन्ड्रन में इसकी सर्वोच्च मात्रा थी जो क्रमशः 556 और 1199 मि.ग्रा./100 ग्रा. थी। केले की 12 वाणिज्यिक किस्मों के पके हुए फल के छिलके में तेल अंश का आकलन किया गया तथा यह रेड बनाना के छिलके में सर्वाधिक पाया गया जिसके बाद ग्रेंड नयने के छिलके का स्थान था। ग्रेंड नयने और रसथली वंशक्रम, प्रत्येक को आशाजनक पाया गया क्योंकि इनमें प्रति 100 ग्रा. फल के गूदे में क्रमशः 3.06 और 2.73 मि.ग्रा. लौह तत्व था जबकि तुलनीय सर्वश्रेष्ठ में यह मात्रा मात्र 0.85 मि.ग्रा. थी।

भा.कृ.अ.प.-एनआरसीबी में थेन्नी और इरोड जिलों में ग्रांड नयने किस्म में आंकी गई फसलोत्तर हानियां क्रमशः 10.83: और 11.39 प्रतिशत थीं, जबकि तिरुचिरापल्ली और टूटीकोरिन जिलों में ये पूवन किस्म के मामले में क्रमशः 17.39: और 6.41: थी। विभिन्न परिपक्वताओं के साथ केले का हरा जीवन काल रेड बनाना और नेई पूवन में उल्लेखनीय रूप से भिन्न पाया गया। ऐसा फसलोत्तर साज-संभाल की उन्नत विधियां अपनाने से संभव हुआ। कार्बोन्डेज़िम के उपयोग से केले के हरित जीवन काल में वृद्धि हुई, तापमान चाहे कितना भी क्यों न हो। पके हुए मॉथन केले के न्यूनतम प्रसंस्करण की विधि मानकीकृत की गई।

एंजाइमों को मिलाए बिना और ज़डै (0.5 ग्रा./लि.) के उपचार से स्टार्च निकालने की विधि से स्टार्च की अधिक प्राप्ति हुई जिसकी शुद्धता 90: से अधिक थी। स्टार्च के प्रकाश संचारणशीलता जैसे गुणों का सूक्ष्मदर्शी द्वारा अध्ययन किया गया। केले के रूपांतरित स्टार्च से प्रोटीन से समृद्ध प्रीकायोटिक पास्ता तैयार किया गया। इसके लिए केले के आटे में बेसन और मैदा मिलाए गए। पके हुए केले के चूर्ण का उपयोग मैदा या गेहूं के महीन आटे के स्थान पर (60:40 के अनुपात में) किया जा सकता है और इससे अच्छा गुथा हुआ आटा तैयार होता है। केले के छिलके का उपयोग करके ज़ाइलो-ओलिगोसेक्राइड उत्पादन की विधि मानकीकृत की गई। केले की करपूरवल्ली किस्म के रेशे में उच्च जल

अवशोषण गुण (892:) होता है जिसके बाद ग्रांड नयने में यह 816: होता है।

केले के रेशे के गुणों का विश्लेषण एक्स-किरण आवर्तनांक का उपयोग करके किया गया। केले के रेशे के द्वारा लैड ख्वूइ ;प्ड्र, का अवशोषण 140 मिनट में हो गया और इसके पश्चात् यह वैसा ही बना रहा। सर्वाधिक हटाव अवशोषक की 1.5 ग्रा. खुराक से हुआ। केले के रेशे से नैनो फाइब्रिलेटिड सेल्यूलोज को सेल्यूलोज एंजाइम से निकाला गया तथा सोडियम हाइड्रोक्साइड और सोडियम हाइपोक्लोराइड द्वारा मृदुलता प्राप्त की गई।

फसल सुरक्षा

प्रकंद घुन की प्रतिरोधी दो प्रविष्टियों की पहचान की गई तथा 16 प्रविष्टियों को म्यूसा जननद्रव्य के तना घुन के प्रति अपेक्षाकृत कम संवेदनशील पाया गया। अंतः पादपों के 337 विलगक अलग किए गए तथा म्यूसा जननद्रव्य से इनकी पहचान की गई। ये बीयूवेरिया जातियाँ, मेटार्हिजियम जातियाँ और लेकासिलियम जातियों के अंतर्गत आते हैं। नर तथा मादा तना घुनों से वाष्पशील सेमियोकेमिकल विलगित किए गए। तना घुन के प्रति 77.5: आकर्षण प्रदर्शित करने वाले वाष्पशील मिश्रण की पहचान की गई। खेत मूल्यांकन के अंतर्गत पौधों को तना घुन के संक्रमण से बचाने के लिए एंजाइरेक्टिन में अच्छा प्रतिकर्षी गुण देखा गया। केले के फल को छितराने वाले भृंग तथा उसके परपोषी ने जो वाष्पशील यौगिक विमोचित किए उन्हें एकत्र किया गया तथा एनआईएसटी लाइब्रेरी का उपयोग करके उनकी पहचान की गई। असम से पत्ती और फल को छितराने वाली भृंग समष्टियों की पहचान की गई और उन्हें मोर्फास्पीसीज, बैसिलेष्टा सब्कोस्टाटा (जैकोबी) के अंतर्गत आने वाली जाति के रूप में पहचाना गया। असम से प्राप्त किए गए भृंग के तीन रंग आकृतियों के सीओएक्स1 जीन का अनुक्रमण किया गया तथा इनके क्रम आंकड़ों से इनकी एक से अधिक जाति की उपस्थिति का संकेत मिला।

स्वपात्रे दशाओं के अंतर्गत जड़ में घाव करने वाले सूत्रकृमि (पैरिटिलैकस कोफीई) और जड़-गांठ सूत्रकृमि (मेलाइडोगाइने इन्काग्रिटा) के विरुद्ध फ्यूजेरियम मुर्झाने के शमनकारी जैव नियंत्रण एजेंटों के मूल्यांकन से बैसिलस

फ्लेक्सस (जुअचत1) को श्रेष्ठ पाया गया और इसके पश्चात् ट्राइकोडर्मा एस्पेरैलम (चतत-2) का स्थान था। कीटरोगजनक सूत्रकृमि के देशी विलगक की जाति की पहचान प्राइमर टीडब्ल्यू 81- एबी28 का उपयोग करते हुए तक्छ। के आईटीएस1-5.8 एस-आईटीएस2 के आवर्धन और अनुक्रमण के माध्यम से की गई। इसे हेटरोरैब्डिटिस इंडिका के रूप में पहचाना गया (एनसीबीआई प्रविष्टि संख्या एमएच 299879)। कीटरोगजनक सूत्रकृमियों के दो देशी विलगकों (स्टेइननेमा सियामकायाई और हेटरोरैब्डिटिस इंडिका) की उग्रता की तुलना खुराक अनुक्रिया मूल्यांकन के द्वारा की गई, एक बनाम एक मूल्यांकन तथा प्रोबिट विश्लेषण के लिए वैक्समोथ लावों का उपयोग किया गया। इसमें एस. सियामकायाई को कीट की मृत्यु दर तथा एलडी50 मानों के आधार पर एच. इंडिका की तुलना में अधिक उग्र पाया गया।

महाराष्ट्र (मुक्तैनगर, बेसलवाड़ी ताल्लुक, जलगांव जिला), मध्य प्रदेश (नानचैनखादा, बुरहानपुर जिला) और गुजरात (खोलेश्वर गांव, कामरेज ताल्लुक, सूरज जिला) राज्यों में केले की ग्रांड नेयने किस्म में फ्यूजेरियम मुझान (एफओसी) का संक्रमण पाया गया। गुजरात, मध्य प्रदेश, उत्तर प्रदेश, बिहार, केरल और तमिल नाडु से प्राप्त किए गए एफओसी विलगकों के लिए आण्विक नैदानिकी और वीसीजी विश्लेषण किया गया। उत्तर प्रदेश और बिहार के एफओसी विलगक उष्ण कटिबंधी प्रजाति 4 (वीसीजी 01213/16) और गुजरात व मध्य प्रदेश के एफओसी विलगक उप उष्णकटिबंधी जाति 4 के अंतर्गत आते हैं, जबकि केरल और तमिल नाडु से प्राप्त किए गए विलगक प्रजाति 1 के अंतर्गत आते हैं। केले की एफओसी उष्ण कटिबंधी प्रजाति 4 (टीआर 4) के लिए एक सरल तथा सस्ती नैदानिक विधि, लूप मध्यित समतापीय आवर्धन (लैम्प) विकसित की गई। ट्राइकोडर्मा जाति के एफओसी के प्रति प्रभावी टीआर4 की वृहत उत्पादन प्रौद्योगिकी चावल के टूटे हुए टुकड़ों के दानों का उपयोग करते हुए मानकीकृत की गई। एए, बीबी और एबीबी के अंतर्गत आने वाले केले की कुल 14 किस्मों को खोजा गया तथा कुल 132 जीवाण्विक विलगक और ट्राइकोडर्मा जाति के छह विलगक प्राप्त किए गए।

आंध्र प्रदेश, बिहार और तमिल नाडु में प्रकंद सड़न के लिए एक सर्वेक्षण किया गया तथा केले की विभिन्न किस्मों

के इस सड़न से संक्रमित नमूने एकत्र किए गए। कुल 154 जीवाण्विक विलगक विलगित किए गए तथा संक्रमित नमूनों से उन्हें शुद्ध किया गया। विभिन्न स्थानों से एकत्र किए गए व जड़ क्षेत्र से प्राप्त किए गए मृदा नमूने प्राप्त किए गए जिनमें कुल 52 पीजीपीआर विलगक उपस्थित थे। कुल 34 विलगकों में से सात विलगकों से केले (किस्म ग्रेंड नेयने) के वृद्धि संबंधी गुणों में सुधार हुआ।

केले के गुच्छित चूर्ण विषाणु (बीबीटीवी) के विरुद्ध प्रतिरोध के लिए केले के कुल 50 द्विगुणित प्रविष्टियों की छंटाई भूस्तारी से उगाए गए पौधों का उपयोग करके की गई तथा उग्र माहुओं का उपयोग करके इन विषाणुओं को पौधों में पहुंचाकर उन्हें संक्रमित किया गया। एए जीनोमी समूहों की 12 द्विगुणित प्रविष्टियों तथा हिल बनाना और ग्रांड नेयने के पौधों में बीबीटीवी के लक्षण व्यक्त हुए हैं लेकिन किसी भी प्रविष्टि में बीबी जीनोम नहीं था। बीबी जीनोम से युक्त प्रविष्टियों को प्रत्येक पौधे में 20 उग्र माहुओं से एक बार पुनः संरोपित किया गया तथा संवेदनशील हिल बनाना और ग्रांड नेयने के अलावा किसी ने भी लक्षण व्यक्त नहीं हुए। परिणामों से यह संकेत मिला कि एक माहु केले के संक्रमित पौधे से एएपी के 24 घंटे बाद विषाणुओं की 861.04 प्रतियां ग्रहण करने में सक्षम था और यह 16.6: ऊतक संवर्धित पौधों तक विषाणुओं को फैलाने में भी सक्षम था, जबकि 21.6 दिनों के सबसे कम समय में 100 प्रतिशत विषाणुओं के फैलाव के लिए 50 उग्र माहुओं (15066.94 विषाण्विक प्रतियां) का होना आवश्यक है। टीसी उत्पादन इकाई (टीसीपीयू) से प्राप्त किए गए ऊतक संवर्धित (टीसी) केले के पौधों के मातृ संवर्धनों का निविदा सेवा के अंतर्गत केले के विषाणुओं के लिए परीक्षण किया गया। चार विषाणुओं की उपस्थिति के लिए कुल 19114 टीसी नमूनों की जांच की गई।

केले के सह-पत्र चित्ती विषाणु (बीबीआरएमवी) के लिए विकसित एलएफआईए का विभिन्न किसानों के खेतों तथा भारत के केला उगाने वाले 6 विभिन्न राज्यों में स्थित ऊतक संवर्धन केला उत्पादन इकाइयों से एकत्र की गई केले की वाणिज्यिक किस्मों के 114 नमूनों से और अधिक सत्यापन किया गया। बीबीटीवी समय पाठ्यक्रम अध्ययन के दौरान 28 भिन्न रूप से व्यक्त स्पॉट (झ25 गुनी) की पेष्टाइड मास फिंगरप्रिंटिंग की गई।

प्रौद्योगिकी हस्तांतरण

लगभग 4800 आगंतुकों जिनमें किसान, कृषि एवं बागवानी अधिकारी, उद्यमी, छात्र तथा अन्य हितधारक शामिल थे, ने भा.कृ.अ.प.-एनआरसीबी का दौरा किया तथा उन्हें संस्थान की गतिविधियों/प्रौद्योगिकियों के बारे में बताया गया। दस रेडियो वार्ताएं और दस टेलीविजन वार्ताएं प्रसारित हुईं तथा विभिन्न दैनिक समाचार-पत्रों व पत्रिकाओं में भा.कृ.अ.प.-एनआरसीबी द्वारा 25 प्रेस नोट प्रकाशित किए गए। संस्थान में राज्य/राष्ट्रीय स्तर की सात प्रदर्शनियों में भाग लिया तथा किसानों और उद्यमियों के लिए कुल आठ परिसर में तथा दो परिसर से इतर प्रशिक्षण कार्यक्रम आयोजित किए। केन्द्र द्वारा एक राष्ट्रीय सिम्पोज़ियम, तीन कार्यशालाएं और एक विचार मंथन बैठक आयोजित किए गए। संस्थान द्वारा केले की साबरी किस्म की गुणवत्तापूर्ण ऊतक संवर्धित रोपण सामग्री की आपूर्ति के लिए त्रिपुरा जैवप्रौद्योगिकी परिषद के साथ समझौता ज्ञापन पर हस्ताक्षर किए गए तथा तमिल नाडु बनना ग्रीनर्स फेडरेशन, ग्रीनर्स एग्री, तिरुपुर व एसएमवी एक्सपोर्ट, थेन्नी के साथ यूरोप को केला फलों के निर्यात के लिए भी समझौता ज्ञापन पर हस्ताक्षर हुए।

सम्पर्क एवं सहयोग

भा.कृ.अ.प.-एनआरसीबी के अनेक अंतरराष्ट्रीय संस्थानों के साथ अनुसंधान सहयोग के कार्यक्रम चल रहे हैं जिनमें शामिल हैं - आईआईटीए, नाइजीरिया; बायोवर्सिटी इंटरनेशनल, फ्रांस; केयूएल, बेल्जियम; क्वींसलैंड विश्वविद्यालय, आस्ट्रेलिया। संस्थान के कई राष्ट्रीय संस्थानों के साथ भी संबंध हैं जैसे बीएआरसी, मुम्बई; विज्ञान एवं प्रौद्योगिकी विभाग तथा जैवप्रौद्योगिकी विभाग, नई दिल्ली; एपीडा; तमिल नाडु कृषि विश्वविद्यालय, कोयम्बतूर;

एनआईटी, तिरुचिरापल्ली और केएनसीआईटी, थोडियम, तमिल नाडु। इस केन्द्र के भा.कृ.अ.प. के अन्य संस्थानों के साथ भी अनुसंधान सहयोग हैं जैसे भा.कृ.अ.प.-एनबीपीजीआर, नई दिल्ली; भा.कृ.अ.प.-आईआईएचआर, बंगलुरु, भा.कृ.अ.प.-सीआईए (अनुसंधान केन्द्र), कोयम्बतूर। इसके अलावा डीबीटी-एनईआर के अंतर्गत देश के विभिन्न भागों में स्थित 50 से अधिक संस्थान भा.कृ.अ.प.-एनआरसीबी से संबंधित हैं। यह संस्थान भा.कृ.अ.प.-एआईसीआरपी (फल) के उन 11 केन्द्रों के साथ भी समन्वयन कर रहा है जो केले पर कार्य कर रहे हैं। केले के बड़े पैमाने पर प्रवर्धन में शामिल ऊतक संवर्धन उद्योग, किसान, निर्यातक, राज्य बागवानी और कृषि विभाग तथा स्वयं सहायता समूह भी विभिन्न अनुसंधान एवं विकास संबंधी गतिविधियों के लिए इस केन्द्र के साथ सम्पर्क स्थापित किए हुए हैं।

मानव संसाधन विकास एवं शिक्षा

मानव संसाधन विकास के अंतर्गत केन्द्र के वैज्ञानिकों व तकनीकी स्टाफ ने क्षेत्रीय/राष्ट्रीय/अंतरराष्ट्रीय स्तरों पर कुल 17 सेमिनारों/सम्मेलनों/सिम्पोजिया/कार्यशालाओं/बैठकों में भाग लिया। इस केन्द्र ने अंतरराष्ट्रीय और राष्ट्रीय प्रतिष्ठा प्राप्त विभिन्न जर्नलों में 28 अनुसंधान पत्र प्रकाशित किए हैं तथा देशभर में आयोजित विभिन्न सम्मेलनों/सिम्पोजिया/सेमिनार आदि में 46 अनुसंधान पत्र प्रस्तुत किए हैं। कुल 15 से अधिक छात्र केन्द्र में बी.टेक., एम.टेक, एम.एससी., पीएच.डी. तथा डॉक्टरेट उपरांत अनुसंधान कर रहे हैं।

राजस्व का सृजन

वित्त वर्ष 2018-19 के दौरान केन्द्र द्वारा कुल 97,65,881/-रुपये का राजस्व सृजित किया गया है।

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

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

A total of three and 20 accessions have been

collected from primary and secondary sources respectively, all of which have been added to the genebank including a somaclonal variant of Nendran with green pseudostem. The details of the accessions collected from various sources are provided in Table 1.

Table 1. List of accessions collected during 2018-19

S. No.	Source	Accessions collected
1.	Central Agriculture University, Lembucherra, Agartala	Local cultivars of Tripura (11 Nos.)
2.	Munu, Tripura	<i>Musa ochracea</i> , <i>M. flaviflora</i> and <i>M. balbisiana</i>
3.	B. R. Hills, Karnataka	Chandrabale, Madhuranga, Naatu Elakki, Durga, Udhiran and Anaibale
4.	ICAR-IIHR, Hirehalli, Karnataka	Pachabale and Rajabale
5.	Coimbatore, Tamil Nadu	Nendran variant (Green colored pseudostem)

Morpho-molecular characterization

Morpho-taxonomic characterization has been completed for 21 *Musa* accessions using IPGRI *Musa* descriptor, leading to the identification of their genomic and sub-groups (Table 2).

Table 2. List of accessions subjected to morphotaxonomic characterization

S.No	Acc. No.	Name	Assigned genome	Identified sub group
1	2328	Gera	ABB	Pisang Awak
2	2329	Wild banana	BB	Similar to Khungsong wild (1168) – BB type
3	2330	Wild Kela	BB	- “ -
4	2331	Jahaji	AAA	Cavendish
5	2332	Bhimkol	BB	<i>M. balbisiana</i> type Bhimkol
6	2333	Jatikal	ABB	Monthan
7	2334	Amrit Sagar	AAA	Unique
8	2335	Kashkol	ABB	Monthan
9	2336	Red Banana	AAA	Red Banana
10	2433	Chaou	ABB	Borkal Baista
11	2435	Borjahaji	AAA	Cavendish
12	2436	Modan	ABB/ABBB	Pisang Awak
13	2437	Sobokgire	ABB	Karthobiumtham
14	2438	Ibok therek	BB	Unique
15	2439	Sodogol	ABB/ABBB	Pisang Awak
16	2440	Wild form (<i>M. flaviflora</i>)	<i>M. flaviflora</i>	Unique in section <i>Eumusa</i>
17	2441	Kechulepa	ABB	Unique
18	2442	Reshing	<i>Ensete glaucum</i>	Unique
19	2443	Jahaji Mutant	AAA	Cavendish
20	2444	Chaou	ABB	Borkal Baista
21	2445	Monishal	ABB/ABBB	Pisang Awak

Out of the 21 banana accessions characterized, seven accessions which were identified as new types have been added to the core collection and the remaining 14 accessions which were identified as synonyms/ duplicates of the already existing germplasm and have been removed.

Morpho-taxonomic characterization has been completed for 231 banana accessions belonging to different AICRP centers using IPGRI *Musa* descriptor leading to the identification of duplicates and synonyms except four unique types.

DNA fingerprints have been developed for the newly released Kaveri Kalki (Fig.1) and Kaveri Sugantham (Fig.2) using ISSR 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.

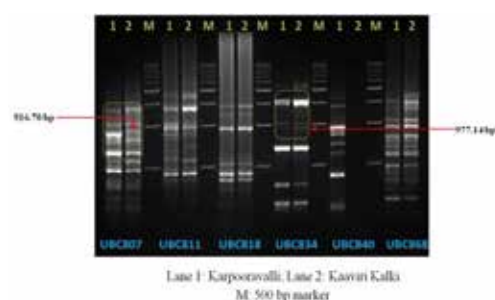


Fig. 1. DNA fingerprinting for Kaveri Kalki using ISSR markers

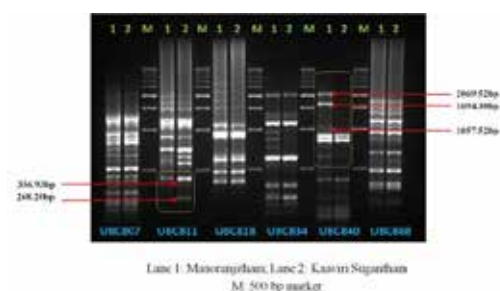


Fig. 2. DNA fingerprinting for Kaveri Sugantham using ISSR markers

Introduction

About 33 exotic accessions have been introduced from ITC, Belgium through ICAR-NBPGR, New Delhi in two batches (Table 3).

Table 3. List of accessions introduced

S. No.	Alternate ID	Name of Cultivar	<i>In vitro</i>	Secondary hardening	Field planted
1.	ITC0266	Sowmuk	√	3	-
2.	ITC0365	Williams	-	2	2
3.	ITC0539	<i>Musa textilis</i>	√	2	-
4.	ITC0588	<i>M. jackeyi</i>	√	2	-
5.	ITC0609	Pahang	-	4	-
6.	ITC1002	<i>Schizocarpa</i>	-	-	-
7.	ITC0962	Prata Ana	-	-	-
8.	ITC1297	BITA 3	√	3	-
9.	ITC1318	SH-3436-9	-	5	-
10.	ITC1344	CRBP 39	-	1	-
11.	ITC0081	Igitsiri (Intuntu)	-	1	-
12.	ITC0084	Mbwazirume	-	1	3
13.	ITC0093	Long Tavoy	-	5	2
14.	ITC0250	<i>Malaccensis</i>	√	5	-
15.	ITC0340	Pisang Masal' Hijau	-	2	-
16.	ITC0341	<i>Banksii</i>	-	-	-
17.	ITC0357	Vudi wai wai	-	3	-

S. No.	Alternate ID	Name of Cultivar	<i>In vitro</i>	Secondary hardening	Field planted
18.	ITC0393	Truncate	√	3	-
19.	ITC0471	Bebek	-	5	2
20.	ITC0479	Diploide Basilan	-	5	1
21.	ITC0504	FHIA -01	-	-	-
22.	ITC0662	KhAI –Thong Ruang	√	5	1
23.	ITC0672	Pa (Rayong)	-	3	-
24.	ITC0712	AA cv. Rose	-	6	4
25.	ITC0805	God Mun	-	3	-
26.	ITC1261	PA03-22	√	1	-
27.	ITC1264	FHIA -17	-	5	-
28.	ITC1265	FHIA-23	√	2	-
29.	ITC1307	SH-3640	-	-	-
30.	ITC1588	Lal velchi	-	-	-
31.	ITC0506	FHIA -3	-	2	-
32.	ITC0974	Bata Bata	-	-	-
33.	ITC1207	<i>M. macclayii</i>	-	-	-

Registration

IC numbers (IC 0627968 to IC 0627999) have been obtained from ICAR-NBPGR, New Delhi for 32 banana germplasm including four unique collections of BCKVV, Kalyani by submitting complete passport information along with their unique features.

Evaluation

Performance evaluation of the elite cooking bananas

Eight elite types of cooking bananas were planted in a randomized block design and recommended package of practices were adopted. Observations on growth and yield parameters were recorded at regular intervals and the final data are presented in Table 4.

Table 4. Growth and yield parameters of the elite cooking bananas

Characteristics	Ash Mon	Ashy Bath	PBB	Bainsa	Nute-pong	Kachkel	Kothia	Cuba
Pseudostem Height (cm)	340.5	320.3	325.5	350.2	321.2	360.7	319.5	296.1
Pseudostem Girth (cm)	78.5	71.2	70.42	77.5	73.3	72.7	76.6	75.3
No. of leaves at shooting	17.5	17.2	16.8	17.4	17.8	18.7	18.2	16.8
No. of leaves at harvest	7.5	6.8	7.2	7.3	7.2	7.8	7.5	7.5
Bunch weight (kg)	21.5	24.5	25.2	22.5	22.5	21.9	24.5	20.4
No. of hands	7.3	17.2	16.8	8.7	7.3	8.7	10.5	9.2
No. of fingers/hand	13.4	16.4	16.2	14.5	14.2	14.2	16.3	14.2
Days for taken shooting (Days)	265.5	272.5	265.5	270.2	280.2	284.6	269.5	278.0
Days taken for fruit maturation (Days)	105.5	116.2	115.2	106.5	112.2	115.1	98.2	113.7
Crop duration	380.5	388.7	380.7	376.7	392.4	399.7	367.7	381.7
PBB - Pacha Bontha Batheesa; Ash Mon – Ash Monthan; Ashy Bath – Ashy Batheesa								

Results indicated that maximum yield was recorded in Kachkel (ABB) with 27 kgs, 9 hands and 14 fruits per bunch. Minimum yield was recorded in Pacha Bontha Batheesa and Ashy Batheesa with an average 21 kgs with 16 hands of fruits. Cuba recorded 23.kgs bunch with 9 hands of fruits with an average of 16 fruits per hand. Ash Monthan recorded a yield of 21.5 kgs with 7 hands and 13 fruits per hand. With respect to crop duration, all the varieties recorded 380 to 400 days.

Performance evaluation of the exotic introduction, Popoulu

Exotic introduction, Popoulu was evaluated at higher altitudes of Semmedu, Kolli Hills and Nadukombai, foot hills of Kolli Hills, Tamil Nadu and the data are in Table 5. The field trials were not properly irrigated because of water shortage and monsoon failure. Its performance was on par for all traits irrespective of altitudes. But the trial will be repeated to study the performance stability.

Table 5. Performance evaluation of Popoulu in banana growing areas of Tamil Nadu

Traits /trial	Districts					
	Namakal	Kanniyakumari	Villupuram	Cuddalur	Krishnagiri	Tiruchirappalli
No. of trials	2	6	3	1	1	2
Height (cm)	285.5±18.3	290.5±10.6	288.2±20.2	282.0±15.6	289.0±12.3	280.5±10.5
Girth (cm)	63.5±5.2	65.5±1.6	65.3±3.8	65.5±3.6	65.4±2.3	64.2±5.2
Duration(days)	275.5±18.6	280.5±26.9	286.3±30.5	287.0±22.8	290.2±25.9	275.5±18.9
Bunch weight (kg)	12.5±1.8	15.0±2.2	13.5±3.1	14.0±2.8	13.5±1.6	14.5±1.2
Number of Hands	6.7±1.2	7.3±0.5	6.6±1.0	6.9 ±1.3	6.7±1.2	7.2±0.8
Fruits per hand	12.5±2.3	13.4±1.5	13.2±1.2	13.5±1.0	12.9±2.2	11.3±2.8
TSS(Bricks)	23.2 ±0.8	23.5 ±1.2	23.1±0.5	23.6±1.6	23.8±1.7	23.4 ±1.5
Acidity	0.32±0.02	0.34±0.08	0.32±0.06	0.33±0.08	0.34±0.09	0.32±0.05

Evaluation of ITC accessions

A separate block has been established for the evaluation of ITC accessions imported from Belgium

through ICAR-NBPGR, New Delhi where almost forty accessions have been planted and 33 have been characterized and seven have not been established (Table 6).

Table 6. Morpho-taxonomic characterization of the ITC accessions

S. No.	ITC No.	Name	Genome	Sub group	Evaluation (Yes/No)	Yield (Kgs)	Other traits	Similar to
1	5	Guineo	AAA	Unique	Yes	8.5	Medium statured	Unique
2	69	Type 2x	AA	Unique	Yes	1.2	Slender, ill filled fruits	Unique
3	81	Kayinja	ABB	Pisang Awak	Yes	20.5	Tal and robust statured	Karpuravalli
4	95	Pelipita	ABB	Bluggoe	Yes	14.5	Tall, persistent male flowers and bracts on the whole male axis	Unique
5	101	Fogamou	ABB	Pisang Awak	Yes	13.5	Tall and robust stature	Karpuravalli
6	123	Simili Radjah	ABB	Bluggoe	Yes	17.5	Tall and robust stature	Kothia
7	180	Grand Naine	AAA	Cavendish	Yes	10.5	Dwarf stature	Grand Naine
8	200	Kelong Mekintu	AAB	Plantain	Yes	6.5	Plantain type fruits but not developed	Nendran
9	217	Akpakpak	AAB	Plantain	Yes	12.5	Very tall and has persistent male flowers on the whole male axis.	Swar-namukhi
10	279	Biyang	AA	Plantain	Yes	2.5	Diploid , just 3 to 4 hands, very small fruits	Unique
11	280	Rajapuri India	AAB	Pome	Yes	10.2	Pome, small fruits	Hill ba-nana
12	294	Pitu	AA	Unique	Yes	4.5	Small fruits	Unique
13	304	Palang*	AAA	Dead	No	D	-	-

S. No.	ITC No.	Name	Genome	Sub group	Evaluation (Yes/No)	Yield (Kgs)	Other traits	Similar to
14	319	Biuketip	AAA	Unique	Yes	8.5	Lengthy fruits, dark green, change to yellow upon ripening	Unique
15	322	Maiden Plantain	AAB	Plantain	No		Not flowered	
16	393	Truncata**	AA	<i>M.ac.</i> subspecies	Yes	19.5	**	Pome (AAB)
17	395	Lidi	AA	Dead	No	D	-	-
18	415	Pisang Cici Alas	AA	Unique	Yes	2.2	Small fruits , no pulp , almost rounded Male flower bud	
19	433	Pisang Mulik	AA	Berlin	Yes	6.5	Medium size bunch with 8-10 hands of fruits, fruits are smaller with range coloured pulp	Pisang Berlin
20	446	Pu-te La-Bum	AA	Dead	No	D		
21	448	Pisang Keling	AAB	Pome	Yes	10.9	Pome sub group Ladan type	Ladan
22	451	Cocos	AAA	Plantain (AAB)	Yes	4.5	***	
23	471	Bebek	AA	Dead	No	D		
24	480	Pisang Buntal	AA	P Mas	Yes	3.5	Small fruits like Pisang Mas	
25	513	Plantain No-2	AAB	Plantain	Yes	7.5	French plantain type	Nendran
26	519	Obit Natnga Green Mutant	AAB	Biuketip	Yes	15.5	Lengthy fruits like Biuketip	Biuketip
27	530	A3617/9	AA	Unique seeded	Yes	4.5	Green yellow male flower bud , seeded	Unique
28	533	Klui Lep Mu Nang	AA	Like cv. Rose	Yes	4.5	Fruits are similar to cv. Rose	Cv.Rose
29	547	Chinese Cavendish	AAA	Cavendish	Yes	20.5	Huge bunch, high yielder	Madhukar
30	647	Lep chang Kut	BBB	<i>M.balbisiana</i>	Yes	13.0	****	Ash Mon-than
31	659	Namwakhom	ABB	Pisang Awak	Yes	19.5	Dwarf statured Pisang Awak	Pisang Awak Unique
32	724	Cocos	AAA	Gros Michel	Yes	8.5	Gros Michel	Unique
33	727	Phang	AA	Dead	No	D		
34	766	Paliama	AA	Dead	No	D		
35	823	Ambiri	AAA	Unique	Yes	9.5	Like Cavendish	Robusta
36	825	Uzhakan	AAB	Plantain	Yes	7.4	Plantain type	Nendran
37	1016	<i>Musa balbisiana</i> ***	BB	Unique	Yes		Yet to flower	
38	1067	THA -018*	AA	Like cv.Rose	Yes	2.5	Like cv. Rose	Cv.Rose
39	1120	Tani	BBB	Unique	Yes	19.5	Erect leaves, robust stature	Unique
40	1177	Zebrina	AA	Unique	Yes	1.5	Diploid, variegated leaves	Unique
41	1287	Pisang Berangan	AAA	Berlin	Yes	8.5	Medium statured plant, like Pisang Berlin.	Pisang Berlin

** Actual *M. acuminata* ssp. *truncata* is a AA diploid, but here the plants were characterized and classified as AAB Pome type.

*** There were two Cocos viz., ITC no. 451 and 0724, actually both the accessions belongs to AAA and Gros Michel sub group respectively, but results of present characterization of ITC 451 has classified it into Plantain type and 0724 expressed its original characteristics like Gros Michel.

**** ITC 0647 - Lep Chang Kut belongs to BBB, however the present characterization reveals that the same is not BBB but it belongs to ABB and Bontha sub group. This might have happened by mixed / mislabeled during acquisition from ITC.

Performance evaluation of some of the ITC accessions indicated that ITC accession 0547 Chinese Cavendish recorded highest yield with 20.5 kgs, which is on par with Local Madhukar (AAA). Similarly, Akpapak (0217), a plantain type recorded 12.5 kgs with 7 hands of fruits. But this has to be evaluated for nematode resistance. Grand Naine (ITC 0180) was found to be dwarf even in Ratoon I with 205 cm plant height as against normal (280-290 cm) and 16-20 kgs yield.

Evaluation of tissue cultured bananas derived from different explants of cv. Rasthali

Field evaluation of cv. Rasthali derived from three different explants namely shoot tip, cormlet and male flower bud along with suckers as control was conducted at farmers field, Malliyampathu, Tiruchirappalli. Results indicated that the crop duration was higher (20 days more) in sucker and shoot tip derived plants compared to male bud and cormlet derived plants (263 days). The yield was maximum in male bud derived plants (22 kgs) followed by sucker (20 kgs) which were statistically non significant. The minimum yield was observed in plants derived from shoot tip (11.25 kgs) followed by cormlet (16.80 kgs) (Fig. 3 & 4).

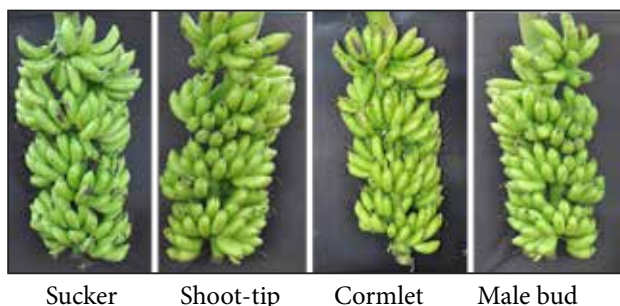


Fig. 3. Field evaluation of cv. Rasthali derived from various explants

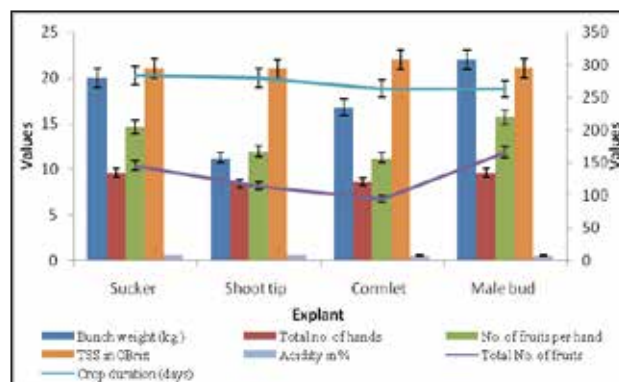


Fig. 4. Yield parameters recorded in cv. Rasthali derived from various explants

Evaluation of tissue cultured banana cv. Udhayam (ABB) derived from different gelling agents

Field evaluation of cv. Udhayam derived from different gelling agents like agar, clerigel (Hi Media) and carrageenan indicated that maximum yield of 28 kgs was obtained in a minimum duration of 406 days in carrageenan derived plants followed by clerigel (26 kgs in 433 days) and agar derived plants (20 kgs in 457 days) (Fig. 5 & Table 7).

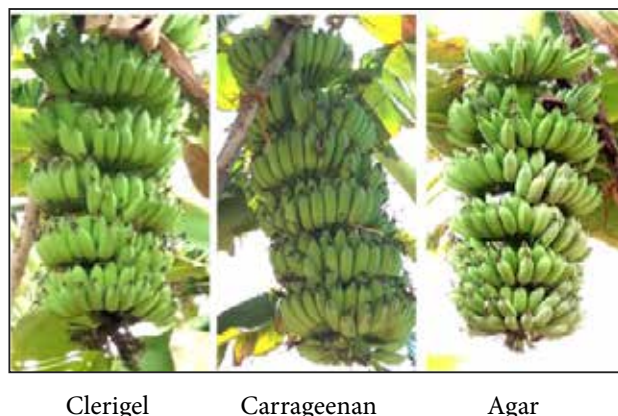


Fig. 5. Field evaluation of cv. Udhayam derived from three different gelling agents

Table 7. Yield parameters recorded in cv. Udhayam derived from different gelling agents

Explant	Bunch weight	Total no. of hands	No. of fruits per hand	Total no. of fruits	Crop duration	TSS (Brix)	Acidity (%)
Clerigel	26b	14.40	17	212b	433b	29.00b	0.58c
Carrageenan	28a	15.60	18	226a	406a	30.00a	0.60a
Agar	20b	14.40	17	202c	457c	29.00b	0.59b
SEd	0.55	21.63	0.48	0.68	0.56	0.34	0.003
CD (0.05)	1.20	47.14	1.06	1.48	1.23	0.75	0.007
Level of significance	**	NS	NS	**	**	*	**

Evaluation of macropropagated banana cvs. Rasthali and Ney Poovan under field conditions

Field evaluation of cvs. Rasthali and Ney Poovan derived from macropropagated plants in farmer's field at Koppu, Tiruchirappalli indicated that their performance was on par with sucker derived plants with respect to bunch weight and crop duration. This is quite evident from the yield parameters presented in Fig. 6, 7, 8 & 9.

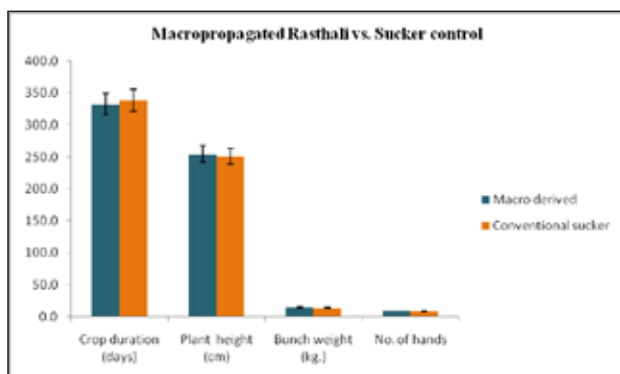


Fig. 6. Comparison of plant growth parameters of banana cv. Rasthali derived from macropropagation and sucker



a) Macropropagated b) Control

Fig. 7. Bunch derived from a) Macropropagated plants of cv. Rasthali; b) Control (Sucker derived)

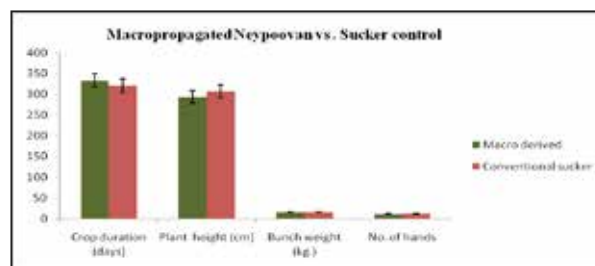


Fig. 8. Comparison of plant growth parameters of banana cv. Ney Poovan derived from macropropagation and sucker



a) Macropropagated b) Control

Fig. 9. Bunch derived from a) Macropropagated plants of cv. Ney Poovan; b) Control (Sucker derived)

Performance evaluation of the first ratoon of ECS derived Rasthali at ICAR-NRCB, Tiruchirappalli

Performance evaluation of the first ratoon of embryogenic cell suspension (ECS) derived Rasthali was carried out at ICAR-NRCB, Tiruchirappalli, using shoot tip derived plantlets and conventional suckers as checks. The results of the first ratoon are presented in Table 8.

Table 8. Growth and yield parameters recorded in ECS derived Rasthali (first ratoon)

Characters	Sucker	TC	ECS	SEd	CD	Level of significance
Pseudostem height (cm)	345.10a	299.10b	272.50c	1.67	3.65	HS
Pseudostem girth (cm)	84.70a	78.06b	64.04c	0.64	1.39	HS
No. of Leaves at shooting	14.84a	12.90b	10.56c	0.43	0.95	HS
No. of leaves at harvest	8.36a	7.36b	6.92b	0.4	0.88	HS

Characters	Sucker	TC	ECS	SEd	CD	Level of significance
Bunch weight (kg)	5.10a	8.52b	7.50c	0.3	0.65	HS
No. of hands	9.30a	7.76b	7.42b	0.29	0.65	HS
No. of fingers/hand	15.66a	14.42b	13.50c	0.34	0.75	HS
Total no. of fruits	145.70a	111.90b	99.26b	5.28	11.51	HS
Finger length(cm)	13.74a	12.44b	8.76c	0.29	0.63	HS
Finger girth	12.25a	11.48b	8.32c	0.3	0.66	HS
Finger weight (g)	96.56a	77.22b	77.90b	0.77	1.68	HS
Days for shooting	263.60a	264.20a	275.00b	1.06	2.31	HS
Days for harvest	106.50a	114.70b	118.10c	0.51	1.11	HS
Crop duration	370.10a	378.90b	393.90c	1.45	3.17	HS
TSS (Brix)	25.30a	25.00a	26.28b	0.28	0.61	HS
Acidity	0.518b	0.524b	0.40a	0.02	0.04	HS
HS – Highly significant						

The performance of suckers surpassed the other two explants with respect to growth and yield parameters. However the performance of shoot tip and ECS derived plantlets were on par with each other in the first ratoon.

Nutrient analysis in the germplasm accessions

About 182 accessions were analyzed for the 10 different mineral elements contents. The highest

coefficient of variation (%) was observed for Copper (403.8) followed by Calcium (101.6), Boron (90.5), Iron (83.9) and lowest for Potassium (32.9). The values for fruit pulp Iron contents ranged from 0.7 to 36.5 mg / Kg fresh weight (ppm) with an average of 7.3 mg / Kg fresh weight. Majority of the genotypes (81%) recorded <10 ppm Iron and only 5% of genotypes recorded >20 ppm Iron contents (Table 9. & Fig. 10).

Table 9. Mineral contents of 182 banana genotypes

Mineral content (mg/kg fresh weight)	Minimum	Maximum	Mean	Std. Dev.	Coefficient of variation (%)
Boron	0.0	11.9	2.0	1.8	90.5
Calcium	7.6	2552.4	403.5	409.9	101.6
Copper	0.0	2.1	0.1	0.2	403.8
Iron	0.7	36.5	7.3	6.2	83.9
Potassium	76.9	987.2	513.7	169	32.9
Magnesium	1.5	764.5	254.7	103	40.4
Manganese	0.1	22.4	4.0	3.0	75.1
Sodium	5.0	372.7	155.2	72.3	46.6
Phosphorus	0.2	6.3	2.9	1.3	44.4
Zinc	0.1	9.6	2.0	1.4	72.3

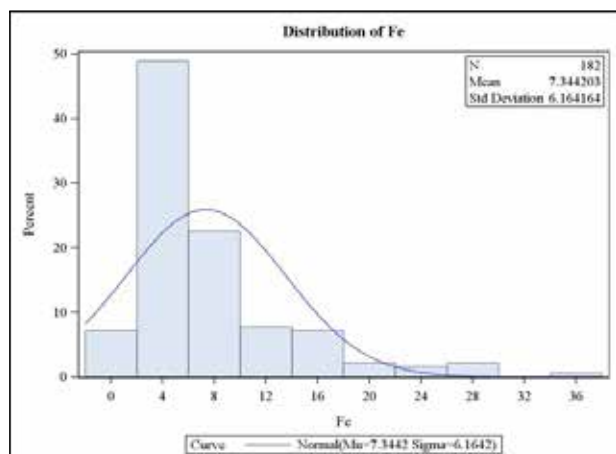


Fig. 10. Univariate distribution of Fe contents mg/Kgfw (ppm) in 182 banana genotypes

Sick plot screening of germplasm accessions for resistance to Fusarium wilt (Foc) Race 1 and Tropical Race 4

The core collection comprising of 311 accessions have been planted in two phases in the sick plot at Muthalapuram, Theni District of Tamil Nadu for screening against Fusarium wilt race 1 (Theni Foc VCG 0124). Internal scoring on the disease scale (0-5) has been completed for the first batch of 232 accessions. 19 accessions were found to be either highly resistant or resistant to Foc race 1. This included 6-AA, 4-BB, 6-AAB, and 3-AAA genotypes.

Similar trial was conducted at Bihar for screening against Fusarium wilt Tropical Race 4 (Foc-TR 4). Out of 313 accessions screened, a total of 35 accessions were found to be either resistant or tolerant to TR4. This included one *Rhodochlamys*, one hybrid progeny, 15-AA, 4-BB, 11-AAB, and 3-AAA genotypes.

Documentation

Complete descriptions of 15 banana varieties including origin, morphological description, agronomic traits, distribution pattern and good photographs have been uploaded in ICAR-NRCB website for the benefit of the banana community.

4.1.2 Improvement of banana through conventional breeding

Evaluation of hybrid progenies

A total of 68 progenies have been developed from 15 different cross combinations using various female parents such as Calcutta 4 (18), Poovan (12), Nendran (9), cv. Rose (7), Karpuravalli (6) Kothia (5), Attikol (5), Saba (3), each one from Udhayam, Chinia, SH

3436-9. Similarly 42 open pollinated progenies were developed from 8 triploid, two diploid germplasm accessions and five hybrid progenies of various cross combinations and they were field planted for further evaluation of yield and their resistance to various biotic and abiotic stresses.

Development of Sigatoka leaf spot (*Pseudocercospora eumusae*) resistance in Poovan

To develop Sigatoka leaf spot resistance, cv. Poovan (AAB) was crossed with Calcutta 4 (AA), Microcarpa (AA), cv. Rose, Pisang Lilin and SH 3436-9. None of the embryos of Poovan crossed with Calcutta 4 and Microcarpa germinated though it recorded high percentage of seed set and viable embryos. Out of 110 crossed seeds of Poovan x Pisang Lilin, the germination percentage was 71.4%, but only five progenies could be successfully regenerated into plantlets.

Improvement of cv. Saba based progenies and improved diploids

Embryos of open pollinated seeds of four high yielding Saba based progenies were cultured *in vitro*. Only nine embryos obtained from three progenies namely P 183 (5), P-686 (3) and P-688 (1) germinated while P-733 embryos failed to germinate. Similarly embryos of open pollinated seeds of three improved diploids were cultured, but only seven embryos germinated from P-59 (Pisang Jajee x Calcutta 4) and no embryos could be regenerated from other improved diploids namely P-207 (Matti x cv. Rose) and P-122 (Pisang Jajee x cv. Rose).

Pyramiding of resistance genes through three way crosses

For developing improved diploids through pyramiding of resistant genes, a total of 11 three way crosses and 3 four way crosses were made and seeds were obtained in all the cross combinations. But embryos were obtained from only 5 crosses and none of the four way cross combinations produced embryos. Out of five three way crosses, ten progenies could be developed from four crosses namely P-793(Karpooravalli x Pisang Jajee) x Pisang Lilin (4), P-95 (Udhayam x Chengdawt) x Chengdawt (3), P-821 (Udhayam x Pisang Lilin) x Pisang Lilin (1), and P-814 (Ban Kela x Pisang Jajee) x Pisang Jajee. Towards the improvement of progenies of Pisang Awak group, a total of 41 bunches were crossed with 16 cross combinations, and bunches are yet to be harvested.

Evaluation of Nendran and Saba based hybrids at farmers' field.

All the 18 Nendran based progenies were evaluated in a farmers field at Malliyampathu, Tiruchirappalli and yield parameters were recorded. It was found that NCR-2, NCR-8, NCR-17, NCR-21,

NPL-33 and NOP-45 were high yielding. Observations on the organoleptic parameters indicated that, NCR-17 had best consumer acceptability followed by NCR-2, NCR-21, NCR-8, NOP-45 and NPL-33. (Fig. 11). Saba based progenies, No. 684 (Saba x Pisang Lilin) and No. 690 (Saba x Pisang Lilin) performed well with a stable and consistent yield.

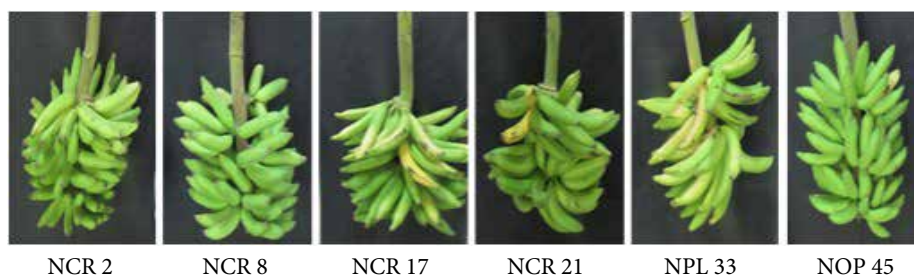


Fig. 11. Bunches of elite Nendran based hybrid progenies

Evaluation of progenies

Morphotaxonomic characters and the ploidy levels were assessed for Karpuravalli based progenies. Fourteen out of 25 Karpuravalli x Pisang Jajee progenies were found to be tetraploid in nature and the rest were diploid and none of the progenies were triploid. Whereas, all the four Karpuravalli x Pisang Lilin progenies were triploid in nature. This revealed that possibility of developing unreduced gametes are more in wild type Pisang Jajee than the parthenocarpic Pisang Lilin. Drastic variation in bunch characters was observed among the 16 Udhayam based progenies obtained from various cross combinations such as Udhayam x Pisang Lilin (7), Udhayam x Pisang Jajee (3), Udhayam x Calcutta - 4 (2) and Udhayam x Chengdawat (2). (Fig. 12).

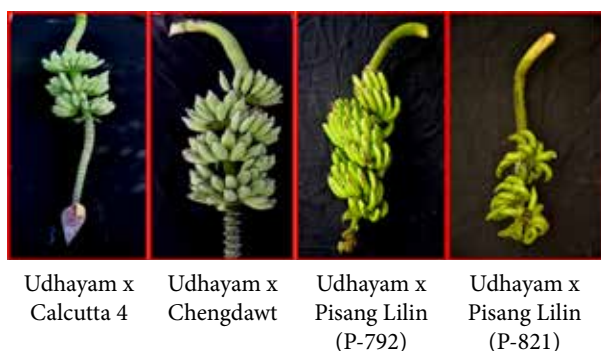


Fig. 12. Bunch variation in Udhayam based progenies

Development of root-lesion nematode (*Pratylenchus coffeae*) resistance in cv. Nendran

Nendran based hybrids and their parental lines (Nendran, Pisang Lilin and cv. Rose) were evaluated for their reaction to nematodes by sampling roots in progeny block at NRCB farm. Among the 21 progeny

lines sampled, hybrids NCR - 5, 8, 10, 18, 21; NPL - 28 and 33 were found promising with lesser population (< 10 nematodes / g root) of root-lesion nematode (*Pratylenchus coffeae*) than susceptible parent, Nendran. Hybrids NCR - 2, 10, 18 and 19; NPL - 30; NOP- 44 and 45 were found promising with lesser population of root-knot nematode (*Meloidogyne incognita*).

Screening of diploid hybrids of banana for resistance to root-knot nematode, *Meloidogyne incognita*

Seven diploid hybrids viz., 15 (Sannachenkadali x Lairawk), 97 (Pisang Jajee x Matti), 115 (Karpuravalli x Pisang Lilin), 134 (Anaikomban x Matti), 148 (Pisang Jajee x Lairawk), 207 (Matti x cv.Rose), 429 (cv. Rose x Pisang Lilin) were evaluated for their reaction against root-knot nematode (*Meloidogyne incognita*) under pot conditions. Based on root-knot index and nematode reproduction, progenies 134 and 148 were found resistant and moderately resistant respectively.

Development of multiple shoots in zygotic embryos Protocol for the induction of multiple shoots from zygotic embryos

Attempts to enhance the germination percentage and to produce more number of plantlets from a single embryo, indicated that modified embryo culture media enhanced the germination upto 116% over control and 62 % of the embryos produced multiple shoots. The remaining (38%) single plantlets were subjected to shoot tip culture and at the time of third subculture multiple shoots were formed (Fig. 13). Thus multiple shoot could be regenerated from 100% of the germinated hybrid embryos.

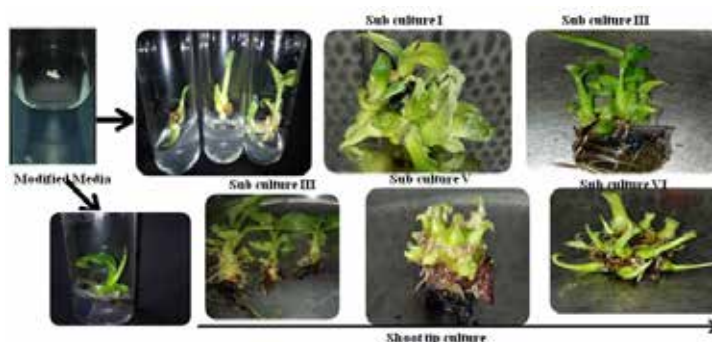


Fig. 13. Multiple shoot formation from single zygotic embryo

Breeding of ornamental bananas

Eleven different crosses were made among *Musa ornata*, *M. laterita*, *M. velutina*, *M. velutina* ssp. *markkuana*, *M. rubra*, *M. flaviflora* and *M. acuminata* ssp. *zebrina*. In addition, Calcutta-4 and Pisang Lilin were also used as male parents to impart tolerance to biotic and abiotic stresses in ornamental hybrids.

The average number of seeds extracted per

crossed bunch varied from 99 (Calcutta 4 x *M. ornata*) to 1110 (*M. velutina* ssp. *markkuana* X *M. ornata*). The percent sunken seeds varied from 4.5 (*M. rubra* X *M. velutina*) to 99.6 (*M. velutina* X *M. acuminata* ssp. *zebrina*), while the germination per cent varied from as low as 0.4 (*M. velutina* ssp. *markkuana* X *M. ornata*) to 59.2% (*M. laterita* X *M. acuminata* ssp. *zebrina*) as shown in the Table 10.

Table 10. Average seed set and germination in different ornamental cross combinations

S. No.	Ornamental crosses	Average No. of seeds extracted per bunch	Floating seeds	Sunken seeds	Germination of sunken seeds
1	<i>Musa velutina</i> (Naturally self pollinated)	320	78 (24.4)	242 (75.6)	45 (18.6)
2	<i>M. velutina</i> X <i>M. acuminata</i> ssp. <i>zebrina</i>	474	2 (0.4)	472 (99.6)	276 (58.5)
3	<i>M. velutina</i> ssp. <i>markkuana</i> X <i>M. ornata</i>	1110	30 (2.7)	1080 (97.3)	4 (0.4)
4	<i>M. ornata</i> X <i>M. ornata</i>	288	72 (25.0)	216 (75.0)	106 (49.1)
5	<i>M. ornata</i> X <i>M. laterita</i>	466	66 (14.8)	400 (85.2)	201 (54.9)
6	<i>M. ornata</i> X <i>M. acuminata</i> ssp. <i>zebrina</i>	298	29.4 (9.9)	268.6 (90.1)	149.2 (55.5)
7	<i>M. ornata</i> X <i>M. velutina</i>	808	51 (6.3)	757 (93.7)	241 (31.8)
8	<i>M. ornata</i> X Pisang Lilin	447	23 (5.1)	424 (94.9)	190 (44.8)
9	<i>M. rubra</i> X <i>M. velutina</i>	537	513 (95.5)	24 (4.5)	1 (4.2)
10	<i>M. laterita</i> X <i>M. acuminata</i> ssp. <i>zebrina</i>	938	578 (61.6)	360 (38.4)	213 (59.2)
11	Calcutta-4 X <i>M. ornata</i>	99	33 (33.3)	66 (66.7)	16 (24.2)
Figures in parenthesis are values in %					

Ornamental banana hybrids were produced with significantly darker bract colour than its female parent (*M. ornata*) after crossing with *M. laterita* (Fig. 14 & 15).



Fig. 14. Ornamental banana hybrids between *M. ornata* X *M. laterita* with intense bract colour than its female parent in the open field



Fig. 15. Abaxial and adaxial sides of bracts (L to R): *M. laterita*, hybrid (*M. ornata* X *M. laterita*) and *M. ornata*

Ornamental banana hybrids were produced with pigmented / coloured leaves between *M. ornata* X *M. acuminata* ssp. *zebrina* (Fig. 16).



Fig. 16. Ornamental banana hybrids with pigmented/coloured leaves between *M. ornata* X *M. acuminata* ssp. *zebrina*

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

A total of 56 core collection accessions representing various genomic groups namely AAB (3), ABB (49), AAA (1), AB (3) were established in pots with five replications each. Out of 72 accessions screened for Fusarium wilt resistance under pot culture conditions, 15 belonging to different genomes (AAA – 5, AA – 1, AB – 2 and AAB – 7 Nos.) were found to be resistant with disease score of '0'. (Table 11). About 29 accessions have been inoculated with spores of Fusarium wilt (VCG 0124) after five months of establishment and awaited disease scoring. Genotyping of 153 germplasm accessions has been completed for 33 primers using automated electrophoresis system (Table 12; Fig. 17 & 18).

Table 11. Phenotyping data of Fusarium wilt resistant genotypes

S. No.	Accession No.	Variety	Genome
1.	0165	Dwarf Cavendish	AAA
2.	0174	Kodapanilla Kunnan	AB
3.	0188	Njalipoovan	AB
4.	0100	Ladies finger	AAB
5.	0519	Hoobale	AAB
6.	0012	Jahaji	AAA
7.	0608	Williams	AAA
8.	0009	Borjahaji	AAA
9.	0618	Nanjangud Rasabale	AAB
10.	0497	Atrusingan	AAB
11.	0957	Imbogo	AA
12.	0498	Highgate	AAA
13.	0735	H3	AAB
14.	0703	Kalieathen	AAB
15.	0731	Nijokhom	AAB

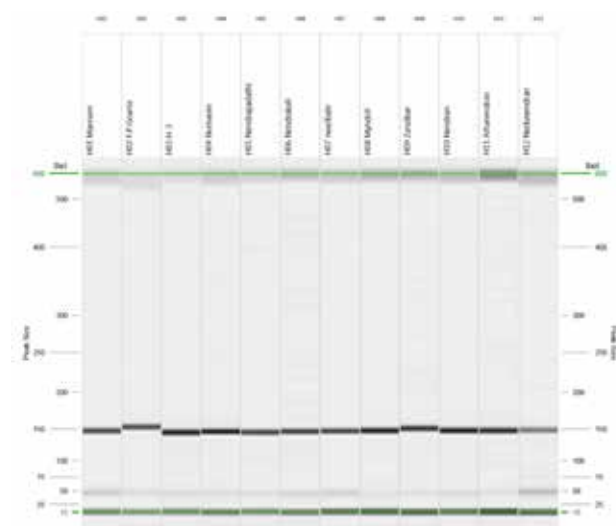


Fig. 17. DNA profile for Primer 64 - *Musa acuminata* ssp. *malaccensis* AP2-like ethylene-responsive transcription factor At1g79700

Expected product size for primer 64 - 144 bp

Variation in product size observed in the gel picture

H01- 146bp; H02-152bp; H03-143bp; H04-145bp; H05-144bp; H06-144bp; H07-146bp

H08-147bp; H09-149bp; H10-146bp; H11-146bp; H12-147bp

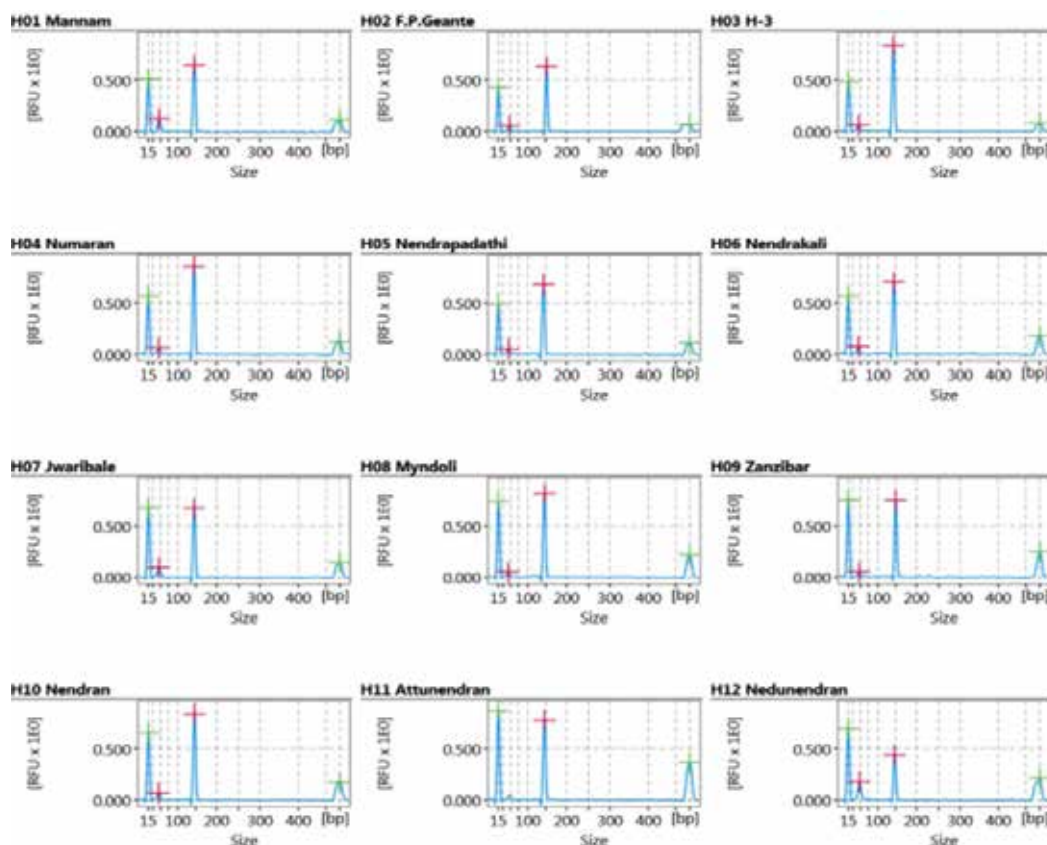


Fig. 18. Electrophoregram for the primer 64 - *Musa acuminata* ssp. *malaccensis*
AP2-like ethylene-responsive transcription factor At1g79700

Table 12. Table showing the product concentration and size observed in the electrophoregram

Sample name	Product size in base pair	Concentration (ng/μl)
H1	146	0.78
H2	152	0.74
H3	143	0.98
H4	145	1.00
H5	144	0.79
H6	144	0.81
H7	146	0.77
H8	147	0.95
H9	149	0.90
H10	146	0.99
H11	146	0.91
H12	147	0.54

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

Totally 50 numbers of male flower buds have been

initiated in callus induction medium towards the establishment of ECS and two cell lines (NGFB1001 and NGFB1002) with good regeneration efficiency have been developed. LD₅₀ has been determined for Sodium azide (0.005% for 1 hr) and gamma irradiation (20 Gy) using ECS explants of cv. Grand Naine. The secondary hardened plants of the mutated population were challenge inoculated with spores of Foc races 1 and 4 under pot culture conditions and the screening studies were conducted under glass conditions. After three months of inoculation, the plants were uprooted and observed for vascular discoloration and they were scored as per INIBAP's technical guidelines No. 6 (Carlier et al. 2002) and the descriptions (Ploetz et al. 1999). This has resulted in the identification of 11 putative resistant mutants (NRCBGN –1 to 11) which are free from both external and internal symptoms. Among the 11 putative mutants (all EMS derived) three showed resistance to race 1 and eight to race 4 and the same have been initiated under *in vitro* for mass multiplication purpose.

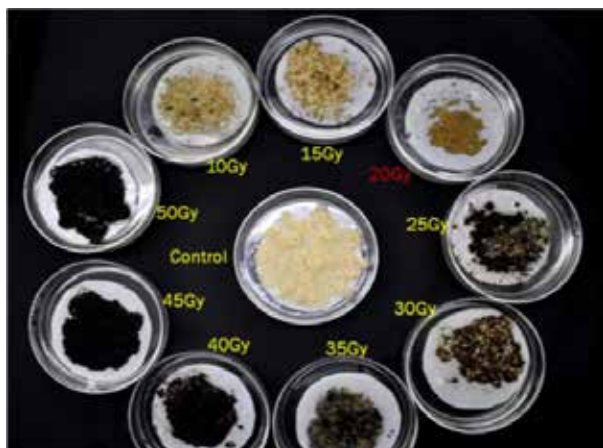


Fig. 19. Effect of Gamma irradiation on regeneration of ECS cv. Grand Naine



Fig. 20. Pot screening of mutated and ECS derived Grand Naine against Fusarium wilt TR-4

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

Induction of embryogenic calli in anthers containing highly vacuolated uninucleate stage was achieved in modified MS media containing 2,4-D, IAA and NAA and their germination was observed in modified MS media containing PGRs of NAA, IAA, BAP and GA3 resulting in the *in vitro* production of androgenic haploids. (Fig. 21a and b).



Fig.21. (a) Callus induction and embryogenic callus from anthers containing highly vacuolated uninucleate stage; (b) Germination of somatic embryos

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

Three explorations were made in different parts of Tamil Nadu and Karnataka and collected 16 elite clones *viz.*, 3-high yielding Grand Naine, 2-ultra dwarf and 3-dwarf Grand Naine, 6-high yielding Ney Poovan with one shy suckering (without side suckers) and 2-high yielding Nendran having green pseudostem (Fig. 22 & 23).



Fig. 22. Ultra dwarf Cavendish type (80 cm height; 8.5 Kg yield; 60 cm girth; 78cm length and 55 cm width of 3rd leaf; 15 cm petiole length)

Fig. 23. Green stemmed Nendran

Elite Grand Naine clones collected during the previous years were evaluated during 2017-2019 and their plant height ranged from 109 to 186 cm and only 16% of clones *i.e.* 25 out of 158 clones recorded < 125 cm and majority of clones (76%) recorded a plant height of ≤ 150 cm (Fig. 24).

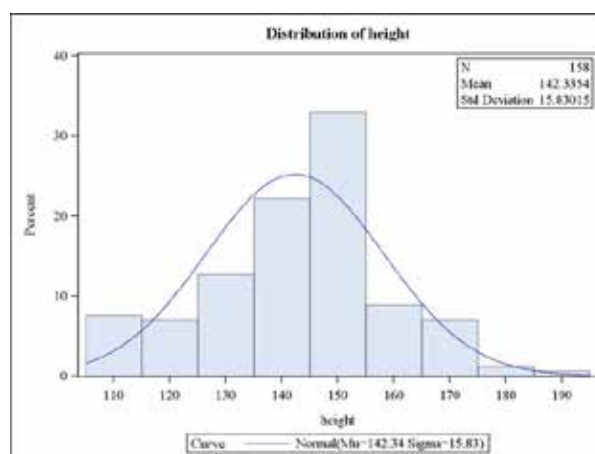


Fig. 24. Univariate distribution of Grand Naine clones based on plant height(cm).

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

Cloning and sequencing of expressed LRR-RLPs and LRR-RLKs from roots of hardened plants

RNA was isolated from *in-vitro* plants of cv. Calcutta-4, Grand Naine, Williams, Gros Michel and Lady Finger. cDNA was synthesised and PCR reaction was carried out with 11 sets of primer pairs for amplification of LRR-RLPs. The amplicon size of 3, 2.8 and 2.3 kb were excised from all the cultivars, purified, cloned in pTZ57 R/T vector. Similarly, LRR-RLK specific primers were used for amplification of the kinase gene from all the above mentioned cultivars and an amplicon size of 3.0 kb was excised, cloned in pTZ57 R/T vector. Four colonies each amplified by different primer pair were sequenced from all the cultivars for both the genes.

In-silico analysis

In-silico analysis of full length LRR-RLP genes showed the presence of all the characterised motifs and domains pertaining to these genes i.e., LRR region (24-28 LRR repeats) with an N-terminal signal peptide, transmembrane domain and short cytoplasmic tail. Difference in amino acid sequence was observed in LRR region between the resistant and susceptible cavendish cultivars. In case of LRR-RLKs, LRR region (24-28 LRR repeats) with an N-terminal signal peptide, a single transmembrane-spanning region, and a kinase domain were observed.

Isolation, cloning of RGA2 gene against *Foc* TR4

RGA2 gene (3.78 kb), which is the only reported gene showing resistance against *Foc* TR4 when over expressed was amplified from six resistant and susceptible cultivars against *Foc* TR4.

4.2 CROP PRODUCTION AND POST-HARVEST TECHNOLOGY

Crop Production

4.2.1 Studies on nutrient dynamics in banana

Under nutrient dynamics studies in banana, at planting, the average Nitrogen (N) – Phosphorus (P) – Potassium (K) concentrations (%) of pseudostem were 1.57 - 0.38 - 6.30 and 1.49 - 0.29 - 5.91 and that of corm were 0.64 - 0.15 - 3.90 and 0.75 - 0.19 - 4.28 in cvs. Grand Naine and Nendran, respectively. The total dry weight of five leaved Grand

Naine and Nendran were 800g and 730g and that of ten leaved plants were 1774g and 1892g, respectively. Nutrient uptake (g/plant) of five leaved Grand Naine were N - 8.40, P - 2.34, K - 38.96, Copper (Cu) - 0.47, Manganese (Mn) - 0.83, Zinc (Zn) - 0.14, Iron (Fe) - 0.69 and that of Nendran were N - 6.88, P - 1.92, K - 33.05, Cu - 0.39, Mn - 0.73, Zn - 0.11, Fe - 0.50. Nutrient uptake (g/plant) of ten leaved Grand Naine were N - 18.25, P - 5.74, K - 82.96, Cu - 0.97, Mn - 1.64, Zn - 0.33, Fe - 1.07 and that of Nendran were N - 20.57, P - 6.73, K - 86.41, Cu - 0.96, Mn - 1.52, Zn - 0.30, Fe - 1.55. In twenty leaved Nendran, dry matter production (DMP) was 3069g (leaf - 770g, petiole - 92g, stem - 1111g, corm - 973g, root - 124g) with percent fraction of leaf - 25%, petiole - 3%, stem - 36%, corm - 32%, root - 4% while in Grand Naine, DMP was 3231g (leaf - 931g, petiole - 82g, stem - 1080g, corm - 1019g, root - 119g) with percent fraction of leaf - 29%, petiole - 3%, stem - 33%, corm - 31%, root - 4%. In Nendran, the N - P - K concentrations (%) were leaf (2.63, 0.34, 3.16), petiole (0.35, 0.37, 6.65), stem (1.00, 0.38, 7.32), corm (0.62, 0.25, 4.64), root (0.66, 0.24, 7.00), while that of Grand Naine leaf (2.27, 0.39, 3.19), petiole (0.30, 0.41, 6.61), stem (0.87, 0.42, 7.38), corm (0.53, 0.28, 4.68), root (0.57, 0.27, 7.05). In Nendran, the Cu - Mn - Zn - Fe concentrations (ppm) were: leaf (410, 788, 120, 2028), petiole (428, 600, 148, 1626), stem (529, 726, 137, 1445), corm (488, 795, 154, 1206), root (467, 621, 185, 1806), while that of Grand Naine leaf (450, 858, 136, 1923), petiole (470, 653, 168, 1542), stem (581, 790, 156, 1370), corm (536, 865, 175, 1143), root (513, 676, 210, 1712). The total uptake (g/plant) of N - P - K in Nendran were 38-9-165 while that of Grand Naine were 37-11-170. The total uptake (g/plant) of Cu - Mn - Zn - Fe were 1.47 - 2.32 - 0.44 - 4.72 while that of Grand Naine were 1.69-2.67-0.52-4.77. In Nendran the root length density (RLD) (mm/cm³) were 0.51, 0.10, 0.04 and SRL (cm/g) were 6.1, 6.0, 8.9 at 0-30, 30-60, 60-90 cm away from the base of the plant while in Grand Naine RLD were 0.44, 0.14, 0.10 and SRL were 5.4, 5.6, 5.6, respectively. Unfortunately, the whole experimental field was devastated by Gaja Cyclone on 16 November, 2018.

4.2.2 Organic banana farming for sustainable soil health and nutritional security

In organic treatment combination (M₂S₂) including poultry manure, groundnut cake, rural com-

post, wood ash recorded the highest bunch weight of 23.5 kg, which was on a par with that (23.20kg) with inorganic fertiliser alone (Fig. 25). It also recorded the highest pulp peel ratio (2.72), total soluble solids (TSS) (21.20°Brix), TSS acidity ratio (64.2), optimum soil colony forming units (CFUs) of actinomycetes (713×10^1), fungi (45×10^2) and bacteria (153×10^3). The same treatment recorded the highest leaf nutrient concentrations (%) viz., N-2.78, P-0.29, K-3.12, Ca-0.65, Mg-0.39, at 20 leaf stage, while at shooting, they were N-2.65, P-0.29, K-3.21, Ca-0.72, Mg-0.34. The highest nutrient uptakes (g/plant) were recorded with same treatment combination viz., N-96.3, P-14.4, K-196.6, Ca-75.1, Mg-36.1, at 20 leaf stage, while at shooting, they were N-174.9, P-28.7, K-317.8, Ca-142.6, Mg-67.3, which were on a par with that of 100% inorganically fertilised. Higher r-values between soil nutrient contents Vs plant uptake in successive plant growth stages confirmed matching of nutrient releasing pattern with uptake pattern. The 'r' values for Soil Available Nutrients (SAN) at 10 leaf stage Vs Nutrient Uptakes (NU) at 20 leaf stage were $N=0.86^{**}$, $P=0.77^{**}$, $K=0.67^*$, $Ca=0.64^*$, $Mg=0.51^*$, while that of SAN at 20 leaf stage Vs NU at shooting were $N=0.84^{**}$, $P=0.68^*$, $K=0.76^{**}$, $Ca=0.77^{**}$, $Mg=0.74^{**}$, indicating significant matching of nutrient releasing and uptake patterns in organic banana farming. The same treatment declined soil pH from 8.2 to 7.2, increased electrical conductivity (EC) from 0.21 to 0.23 dS/m and Organic carbon from 0.12 to 0.72%, at harvesting stage. The benefit cost ratio (B/C) of this best treatment was 1.9 against 2.8 that of inorganic fertiliser alone.



Fig. 25. Effect of organic manures on Grand Naine banana bunches

4.2.3 Development of clump management technology for enhanced productivity in banana

In the second ratoon crop of cv. Ney Poovan,

results revealed that treatment T12 (S4N3) took the least time for flowering to fruit maturity (104.5 days) and produced the highest fingers/bunch (161.0). Bunch weight ranged from 10.3 kg (T11) to 13.7 kg (T13).

Banana cvs. Ney Poovan and Poovan were planted in modified field layout and the observations recorded at the vegetative stage of the plant crop of cv. Ney Poovan, revealed that treatment T12 (S4N3) recorded the highest plant height (249.0 cm) and plant girth (67.8 cm) followed by T9 (S3N3) (Fig. 26). Among the treatments, these parameters were found to be the lowest in T13 (Control). Similarly, the treatment T12 (S4N3) recorded more number of healthy leaves (19.1), mean leaf area (0.97 m^2), total leaf area (19.01 m^2) as well as leaf area index (3.30) followed by T9 (S3N3) with regard to all these growth parameters (Fig. 27 & 28).

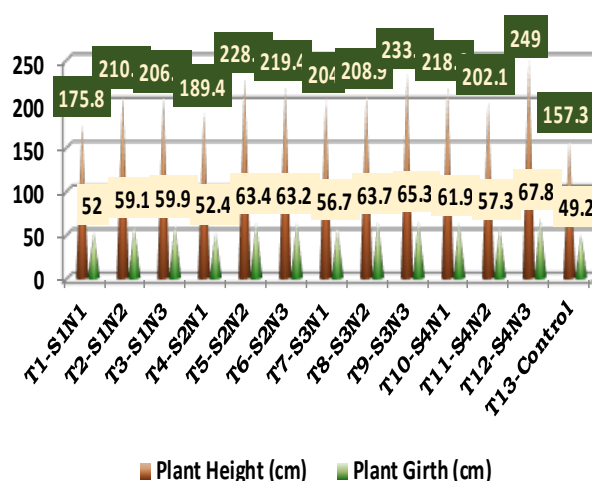


Fig. 26. Effect of numbers of suckers and nutrient dosage per clump on plant height and plant girth

S1 - Mother Plant + allowing one daughter sucker at 4th month after planting (MAP) i.e.,

Mother plant + 1 Sucker

S2 - Mother Plant + one daughter sucker each at 4rd and 6th MAP (Mother plant +2 Suckers)

S3 - Mother Plant + one daughter sucker each at 5th, 7th and 8th MAP (Mother plant +3 Suckers)

S4 - Mother Plant + one daughter sucker each at 5th, 6th, 7th and 8th MAP (Mother plant + 4 Suckers)

S5 - Traditional farmer's practice of planting single sucker per pit at 2.0m X 2.0m spacing and

allowing one sucker per plant after flowering of mother plant with 100% RDF (Control)

N1 - Application of 125% RDF per clump in five split doses

N2 - Application of 150% RDF per clump in five split doses

N3 - Application of 175% RDF per clump in five split doses

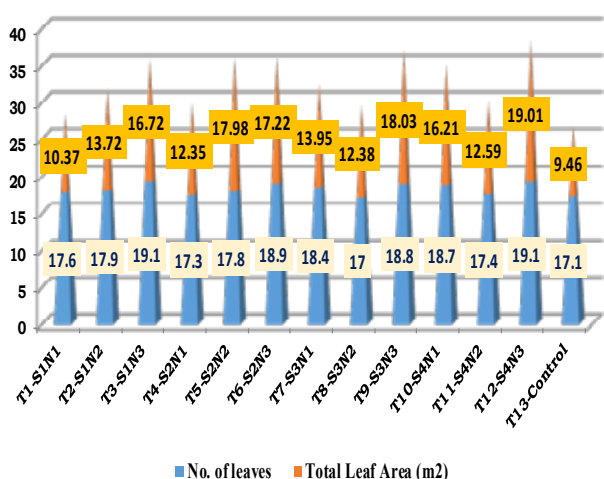


Fig. 27. Effect of numbers of suckers and nutrient dosage per clump on healthy leaves and total leaf area

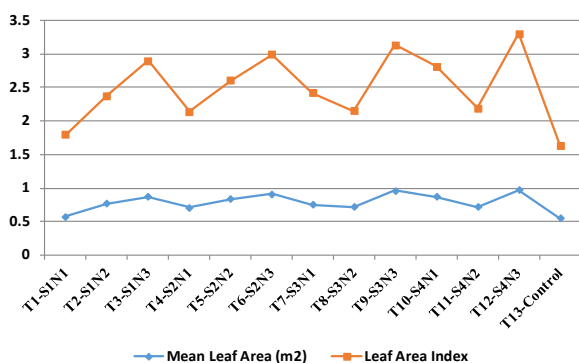


Fig. 28. Effect of numbers of suckers and nutrient dosage per clump on mean leaf area and leaf area index

With regard to the leaf biochemical analyses, the leaf chlorophyll 'a', chlorophyll 'b' and total chlorophyll contents showed non-significant differences among the treatments. However, the control treatment of T13, recorded the highest leaf carotenoid content of 0.81 mg g⁻¹ while T10-S4N1 recorded the least carotenoid content (0.46 mg g⁻¹) (Fig. 29).

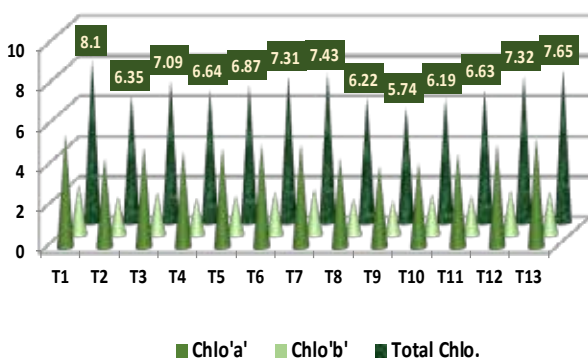


Fig. 29. Effect of numbers of suckers and nutrient dosage per clump leaf chlorophyll contents in cv. Ney Poovan

Post-Harvest Technology

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

Number of suckers on leaf production of banana

A trial was laid out to study the effect of number of suckers on leaf production by retaining three to five suckers per hill. Observations were taken after five months i.e., July to September (for 2 months) during which 'Poovan' mother plant alone produced eight leaves, while three suckers per hill produced 20.33 leaves and four sucker per hill produced 22.9 leaves. 'Naadu' mother plant alone produced 7.66 leaves per hill and 'Karpuravalli' mother plant alone produced 8.00 leaves per hill. With respect to leaf area, 'Poovan' produced 0.896 m², while 'Naadu' produced 1.057 m² and 'Karpuravalli' 0.865 m². The leaf thickness varied among the varieties from 0.188 mm to 0.255 mm. 'Poovan' produced 0.255 mm, while 'Naadu' produced 0.242 mm and 'Karpuravalli' 0.188 mm. With respect to leaf chlorophyll content, 'Poovan' recorded with 8.013 mg/g fresh weight basis, while 'Naadu' produced 5.746 mg/g and 'Karpuravalli' produced 3.247 mg/g.

Extension of shelf life of banana

Storage study to extend the shelf-life of banana leaves was taken up in three varieties, 4.22 days of shelf-life was recorded with 'Poovan', 8.00 days with 'Naadu' and 4.00 days with 'Karpuravalli' at room temperature. At 13.5°C, shelf-life of 13.22 days was recorded with 'Poovan', 15.00 days with 'Naadu' and 10.00 days with 'Karpuravalli'. Freshness the leaf without yellowing and curling/breakage was associated with shelf-life. In a long-term storage trial with Poovan leaves, maximum shelf-life of 92.66 days was observed with -20°C storage, followed by 21.77 days at 6-8°C refrigeration, 14 days at 13.5°C cold storage and 10 days at 20°C storage.

4.2.5 Studies on active packaging in extending the shelf-life of banana

Ripening agents on quality and sensory parameters

Quality and sensory parameters affected by various ripening agents were studied in 80-85% maturity of 'Udhayam' and 'Grand Naine' varieties of banana at full ripe stage. In 'Udhayam' banana, maximum pulp peel ratio (2.60), total soluble solids (26.5°B), total sugars (13.46%) and the minimum acidity (0.30%),

starch (0.66%), firmness (5.06 N) were obtained with ethylene gas at 100 ppm at room temperature. Similarly at cold storage also maximum pulp peel ratio (2.04), TSS (23.63°B), total sugars (9.73%) and minimum starch (4.38%) and firmness (9.10 N) were obtained with ethylene gas at 100 ppm and the lowest acidity with ethylene spray at 500 ppm. In the case of 'Grand Naine' banana, maximum total soluble solids (22.22°B), total sugars (10.53%), and minimum acidity (0.30%), starch (0.38%) and firmness (2.66 N) was recorded for ethylene gas as ripening agent at 100 ppm in room temperature. However, the highest pulp peel ratio (2.21) was reported for ethylene dip at 500 ppm. Similar results were also reported for 'Grand Naine' at cold storage. The maximum pulp peel ratio of 1.86, total soluble solids of 20.19°B, total sugars of 15.20%, and minimum acidity of 0.20%, starch of 4.38% and firmness of 5.93N was registered for ethylene gas at 100 ppm treatment.

With respect to sensory evaluation, the fruits ripened with ethylene gas scored overall highest value under hedonic scale supported by individual sensory character (color, flavor, texture and taste) in both the varieties of banana at room temperature as well as cold storage, followed by ethylene spray at 500 ppm. It is proved that use of ethylene gas as ripening agent is found to be the best among the ripening agents for ripening of banana with improved quality parameters at acceptable level.

Development of banana flour based snack foods

Banana flour based snack food – Murukku was standardized and developed by using five varieties of banana namely Saba, Nendran, Ash Monthan, Bangrier and Monthan and their quality parameters or nutritive values were evaluated or estimated. Significant differences in the physico-chemical characters of raw (unripe/green) banana and its flour were recorded. High protein content was recorded with Bangrier flour (2.04%), while starch and total carbohydrate content recorded high with Nendran flour (66.73% and 67.73%). Bangrier flour was found to have higher energy (270.07 Kcal) along with high content of crude fibre (1.44%). The ratio/combination of 20:80 (Banana flour: Rice flour) for snack food (Murukku) was found to be the best in 'Saba' banana with the support of its physico-chemical analysis of protein

content (1.60%), starch content (39.54%), crude fibre (1.73%) and energy (525.87 Kcal), whereas in 'Nendran', the combination of 50:50 (Banana flour: Rice flour) was found the best for snack food (Murukku) supported by its physico-chemical analysis of high starch content (40.20%), total carbohydrate (64.84%) and crude fibre (2.04%). The proportion of 20:80 (Banana flour: Rice flour) in Ash Monthan was proved to be the best for snack food (Murukku) preparation with high protein (2.98%), total carbohydrate (62.73%) and crude fibre (2.19%), while it was 'Bangrier' with combination of 50:50 (Banana flour: Rice flour) for snack food (Murukku) supported by its physico-chemical characters mainly high protein content (2.62%), starch content (40.76%), total carbohydrate (61.99%) and crude fibre (2.30%). For snack food (Murukku) preparation, 'Monthan' was found best with the combination of 20:80 (Banana flour: Rice flour) with high protein content (1.93%), starch content (39.57%), total carbohydrate (63.11%) and crude fibre (2.08%).

Sensory evaluation revealed that the proportion of 20:80 (Banana flour: Rice flour) was the best for the preparation of banana flour based snack food (Murukku) with highly accepted level. Nendran flour based snack food – Murukku scored the highest overall acceptability, followed by Bangrier, Monthan, Ash Monthan and Saba.

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

Standardization of driers for dehydration of banana slices

Physicochemical characterization of banana flour

To get the clear value on colour indices, green banana flour colour index (GBFCI) was calculated. GBFCI recorded higher with Saba (77.7 ± 0.15), on par with Monthan whereas Popoulu recorded the least GBFCI value (59.70). Yellowness index (YI) and whiteness index (WI) were also calculated to know the variation among the flours. Nendran and Popoulu recorded significantly ($p < 0.05$) higher yellowness (YI) due to the inherent presence of higher carotenoids than other banana and wheat flour. Correspondingly the WI was recorded more with plantain varieties like Monthan and Saba (Fig. 30 & 31.).

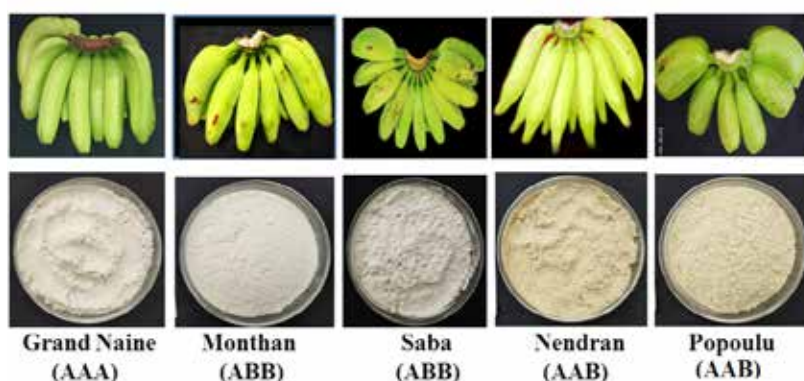


Fig. 30. Flour of different banana varieties

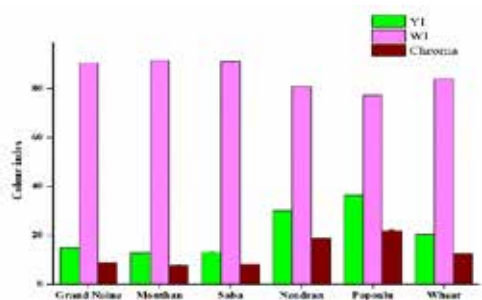


Fig. 31. Colour indices of green banana flour of different varieties

XRD of green banana flour

The crystalline structure of sample was analyzed using X ray diffraction (XRD). Generally, starches displays three types of patterns namely, A (cereal starches), B (tuber, amylo-maize, and retrograded starch) and C (root and seed starches- pea and bean). It is illustrated that varietal difference of banana led to the different crystallinity pattern. The appearance of diffraction peak at the angle of $2\theta = 15.4^\circ$ and 17.19° , 18.06° and 23.566° indicates the mixture of A and B-type crystallinity. However, Monthan did not show any typical spectra at a 2θ angle of 18.06° , which indicated the presence of C-type (Fig. 32).

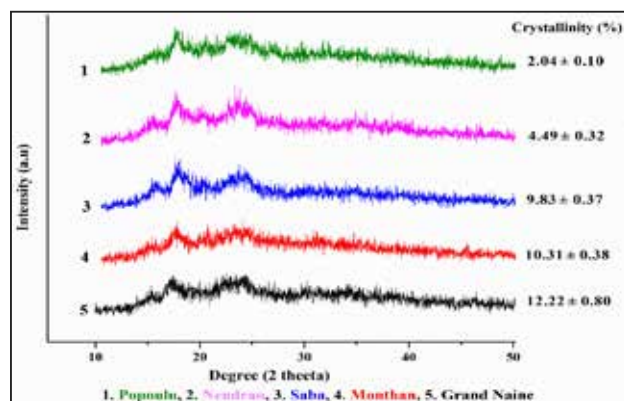


Fig. 32. Crystalline pattern of banana flours

Process standardization for the extraction of starch and functional studies

Starch from banana was extracted with three different methods. It was observed that use of alkali (0.1 M NaOH) for the washing of the suspension resulted into the browning of the powder. Extraction of starch without addition of enzymes and treatment with KMS (0.5 g/l) is sufficient to get the higher starch recovery with the purity of above 90%. Light transmittance of the starches expressed that Monthan and Saba starches were compared with the corn starch in terms of stability after storage at low temperature with lesser disintegration. Microscopic studies revealed the difference in structure, shape and morphology of starches of different varieties (Fig. 33 & 34).

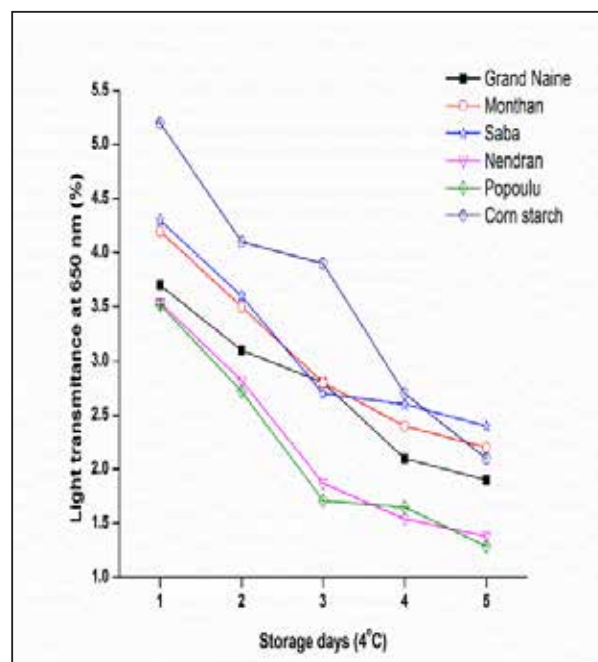


Fig. 33. Light transmittance studies with green banana flour



Fig. 34. Microscopic structure and shape of starches of different varieties

Development of low glycemic, gluten free pasta using banana flour and modified starch

Pasta was prepared with different proportional replacement of white flour with banana flour and modified starch. Addition of modified starches in the product led to higher resistant starch content (19-22%) compared to control (1.23%). Replacement with 15: 15 Banana flour and Modified starch resulted in to the pasta which had the textural properties as that of control pasta with the hardness and resilience value compared to that of control (Table 13).

Table 13. Texture profile analysis of pasta prepared from banana flour, starch and modified starch

Treatments	Hardness (kg)	Cohesiveness	Gumminess	Chewiness	Resilience
T1: Control (WF)	0.761 ± 0.01	0.438 ± 0.07	331.84 ± 28.88	262.62 ± 40.80	0.265 ± 0.06
T2: WF + GBF (70:30)	0.109 ± 0.02	0.831 ± 0.06	91.71 ± 17.00	79.52 ± 13.69	0.632 ± 0.06
T3: WF + GBF (50:50)	0.106 ± 0.05	0.799 ± 0.10	85.82 ± 21.21	73.12 ± 44.26	0.600 ± 0.09
T4: WF + GBF (30:70)	0.081 ± 0.01	0.678 ± 0.14	56.02 ± 12.84	45.65 ± 12.15	0.486 ± 0.05
T5: WF + MS (70:30)	0.422 ± 0.12	0.679 ± 0.15	271.82 ± 39.71	233.45 ± 34.11	0.483 ± 0.13
T6: WF + GBF + MS (70:15:15)	0.418 ± 0.13	0.435 ± 0.13	174.92 ± 47.71	137.39 ± 16.14	0.295 ± 0.09
WF: White flour; GBF: Green Banana Flour; MS: Modified starch					

Protein enriched prebiotic pasta from modified banana starch

The study was designed to develop nutrient enriched pasta by incorporating banana flour (5% to 10%) and *channa* powder (10%) white flour. The cooking loss of the pasta with added banana flour, and *channa* powder ranged up to 5.96%, water uptake –

212%, cooking time 10-13 min. with higher swelling index (2.7). The nutrient content of the standardized nutrient enriched pasta were ranged up to moisture (4.07%), total ash (6.05%), total sugar (2.96%), total starch (35.2%), protein (12.53g), crude fibre (4.13%), fat (0.23g), phenol (83.33mg) and flavonoids (357.40 µm) per 100g (Table 14).

Table 14. Physical characteristics of fortified pasta

Sample	Color index			Cooking loss (%)	Water uptake (%)	Optimal cooking time (min)	Swelling index
	L	a*	b*				
T ₁ : RF	77.41	-5.56	16.29	3.54	164	10	1.94
T ₂ : RF + GBF (70:30)	63.03	-2.32	12.65	4.09	181	12	2.19
T ₃ : RF+ GBF + MS (70:20:10)	59.34	-1.92	11.84	5.52	202	12	2.36
T ₄ : RF+ GBF + MS + CF (65:20:5:10)	52.78	-0.77	14.58	5.83	207	13	2.52
T ₅ : RF+ GBF + MS + CF (65:15:5:15)	59.23	-1.77	12.07	5.96	212	13	2.73
RF: Refined flour; GBF: Green Banana flour; MS: Modified starch CF: <i>Channa</i> flour							

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

Sixty seven ABB banana genotypes have been field evaluated for the soil moisture deficit stress tolerance with 'Saba' as drought tolerant check. The stress was imposed at flowering stage and the irrigation was stopped in the drought treatment till it reached the threshold moisture stress of -0.7 to -0.8 MPa. After soil moisture deficit stress, yield of ABB genotypes have been recorded. A few drought tolerant genotypes at flowering stages were identified, viz., 'Sakkai', 'Ney Vannan', 'Nepali China' and 'Vennutu Mannan'. Their bunch weight was recorded in the range of 16.50 - 21.25 kg under drought stress conditions and their yield reduction was less compared to all other genotypes. The epicuticular wax of ABB genotypes was in the range of 140-190 $\mu\text{g}/\text{cm}^2$. The chlorophyll content varied from 7.16 - 8.32 $\mu\text{g}/\text{g}$ of leaf. The gas exchange properties of ABB banana genotypes and North Eastern region banana were characterized and cultivars Kothia, Kachkel, Pacha Bontha Batheesa were recorded Pn, gs, E on par with Saba (drought tolerant) whereas the Sabri and Borjahaji were observed with lower values for gas exchange parameters. The high temperature tolerance traits of PSII activity in terms of Y (II) recorded significantly lower in Rasthali and Nendran compared to Saba. The drought stress did not affect the fruit length during development in ABB banana genotypes viz., Erode Kai, Karibale, Manjavazal & Kanthali. The fruit lengths at harvest on par with irrigated control. The drought stress induced significantly higher epicuticular wax production (1.82 to 2.47 $\mu\text{g}/\text{cm}^2$) in Kaitshjeng, Napali China & Vennutu Mannan. The Membrane stability index was recorded higher in Kallu Monthan and Karibale genotypes.

The peel gave more of protection to the ripening pulp from the microbes. The banana pulp loses its membrane integrity, which was assessed through membrane leakage, when it dehydrates its moisture content around 30-34%. Grand Naine banana fruit slices (3 cm thickness) dehydrated through hot air oven at 60°C at different time intervals. The rehydration of dried fruit slices property was lost when it losses 30-35 % of its original fresh weight after

16-20 hrs of oven dry drying at 60°C. The resorption materials may lose its properties of its rehydration at this set of dehydration conditions.

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

Management of finger drop in bananas

Fruit shattering or finger drop is a post-harvest disorder during ripening of some of the banana varieties. It is a phenomenon of weakening and softening at the pedicel region causing dislodging of individual fingers from the crown. Among the commercial banana cultivars, Grand Naine (AAA) and Rasthali (AAB) are highly susceptible to finger drop. For management of the disorder, Rasthali hands at harvest maturity stage were first treated with 500 ppm of ethylene for uniform ripening of the fingers. Then the hands were target-treated at the rupture developing pedicel region of fingers by spraying with 100, 200, 500, 750 and 1000 ppm of gibberellic acid (GA_3) and 2, 4, 6, 8, 10% of calcium chloride (CaCl_2) and stored at controlled conditions of 25°C and 85% relative humidity (RH) for ripening. Monitoring of the ripening behaviour, particularly the occurrence of finger drop during storage showed full yellow stage of fingers reached on fourth and fifth day. The 500 ppm GA_3 and 6% CaCl_2 treatments delayed the onset of finger drop i.e., initiation of pedicel region rupturing by two and three days after ripening and the 6% CaCl_2 reduced finger drop by 40% while 100% fruit drop was observed within three days after ripening. The treatment extended shelf-life of fingers and 100% droppings occurred on fifth day after ripening (Fig. 35a & b).

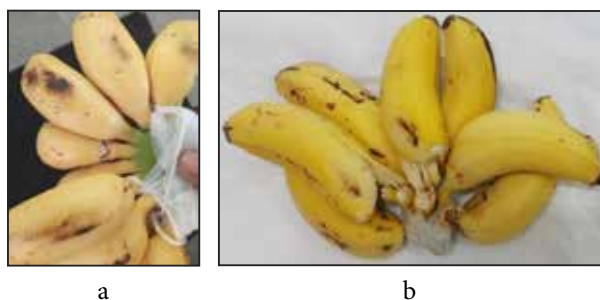


Fig. 35. Finger drop in cv. Rasthali (AAB); (a) CaCl_2 treated fingers at third day and (b) control fingers at third day after ripening

Analysis of respiration and ethylene evolution in pedicel tissues of treated and control fingers of CaCl_2 treated and control fingers showed lower rate of respiration and ethylene evolution. The enzyme

activities especially the polygalacturonase (PG), which is the main depolymerising enzyme, was lower in CaCl_2 treated fingers compared to controls during the incidence of finger drop (Fig. 36). The ethylene evolution and PG activity in peel tissue of the pedicel region of GA_3 treated bananas were lower than the controls. The PG activity was 3.86 unit activity/ g fresh peel tissue against the 2.55 unit activity in 6% CaCl_2 treated fingers. The quality parameters and sensory attributes did not vary between CaCl_2 treated and control fruit.

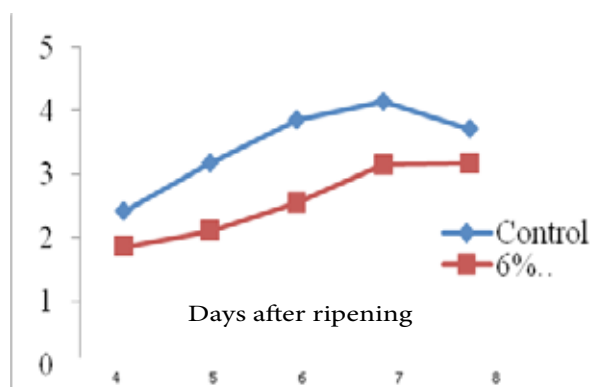


Fig. 36. Polygalacturonase activity (U activity/ g fruit weight) in finger pedicel peel tissues

Screening of banana germplasm for anthocyanins (in flower bracts)

Anthocyanin pigments contents 52 accessions were quantified. Monthan II and Bhat Manohar contained 345 and 268mg of anthocyanin pigments/100g flower bract respectively, followed by Kallu Monthan (198) and Calcutta 4 (142). Vennettu Mannan, Cheeni Champa, Safed Velchi, Beula and Rasakadali contained more than 100 mg (Fig.37). The accessions like *Musa laterita* and *M. flaviflora* contained low anthocyanins in flower bracts (around 12 mg).

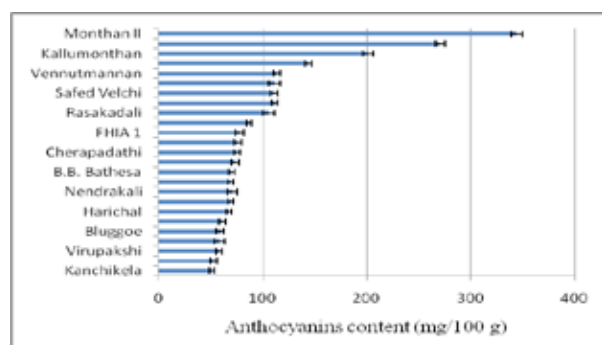


Fig. 37. Anthocyanins content in flower bracts of *Musa* germplasm accessions

Characterisation of macro-encapsulated anthocyanins

Anthocyanins extracted in aqueous solution from flower bracts of Nendran were concentrated and freeze dried at CFTRI, Mysuru (Fig. 38a & b) and macro-encapsulated with wall material, maltodextrin (~20 DE) at a concentration of 20%, and spray-dried to use as 'nutraceutical' (Fig. 38c). The micro-encapsulated anthocyanin was characterized for total anthocyanins content, solubility and encapsulation efficiency and by scanning electron microscope (SEM). The best spray dried product was obtained at 140°C with solubility of 96.51%, retention of 72.35 mg and the encapsulation efficiency of 76.49%. The encapsulated particle was sphere in shape (Fig.38d).

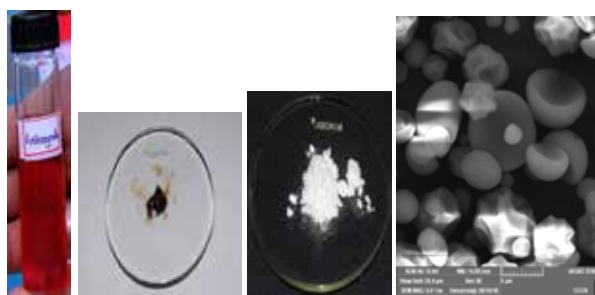


Fig. 38. Macro-encapsulation of banana flower bract anthocyanins; (a) extracted pigments; (b) freeze-dried anthocyanins; (c) micro-encapsulated with maltodextrin and (d) micrograph of encapsulated particles

Glycemic index of bananas

Glycemic indices (GI) of two ripening stages (green at the tips - stage 5 and full yellow - stage 6) of fruits of three banana cultivars namely, Pachanadan (AAB), Hill Banana (AAB) and Saba (ABB) were worked out by *in vitro* starch hydrolysis. The GIs of Pachanadan, Hill Banana and Saba at stage 5 were 41.6, 49.1 and 34.6 respectively which were 14 points lesser than the fruits at stage 6.

Inulin-Fructans in bananas

The inulin type-fructans content in peel and pulp of ripe and unripe fruits of nine banana cultivars was quantified. In unripe fruit peel of the bananas, the inulin contents varied between 10 and 47 mg/ 100 g in peel 10 mg in Karpooravalli and 47 mg in Poovan. In unripe pulp, the contents were in the range of 13-50 mg/100 g. The ripe fruit peel and pulp had accumulated higher levels of inulins of with Nendran

(AAB) containing highest quantity of 556 and 1199 mg/100 g followed by Karpooravalli (ABB) with 234 and 1034 mg. Lowest amounts were found in Grand Naine, Monthan and Ney Poovan (Fig.39).

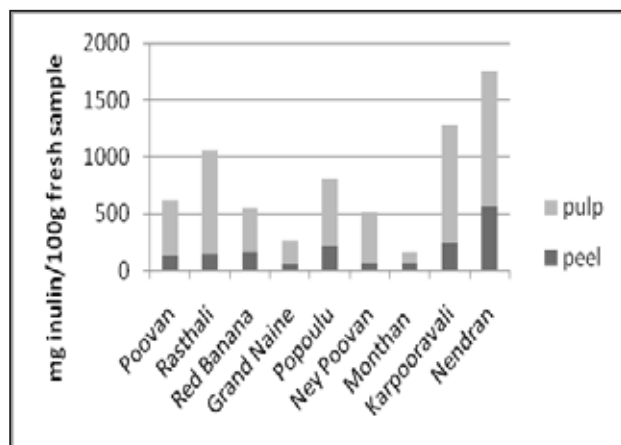


Fig. 39. Inulin type-fructans contents in peel and pulp of banana fruits at ripe stage

Estimation of banana peel oil in commercial varieties

The oil contents in ripe fruit peel of 12 commercial banana cultivars were estimated. Red Banana peel contained 6.15g/100 g fruit weight in both ripe and unripe peel followed by Grand Naine peel, which contained 3.06g. Fruit peel of other cultivars like Poovan, Ney Poovan, Udhayam, Saba and Karpooravalli ranged between 2.0-2.5 mg. Among Red Banana collected from four geographical locations, the Red Banana from Theni, Tamil Nadu contained highest quantity. Palmitic, linoleic and linolenic were predominant fatty acids in peel oil of Red Banana and the essential fatty acids of linoleic and linolenic acids constituted 50%.

4.4 CROP PROTECTION

4.4.1 Isolation and identification of banana stem weevil pheromone for the management of the pest

Isolation and identification of banana stem weevil pheromone components

Out of the fourteen volatile semiochemicals identified from banana stem weevil, six recorded from male and eight from female weevils. Eight chemicals were commonly recorded on both male and female weevils.

Identification of banana leaf sheath volatiles as attractant (Kairomones) for stem weevil

Banana leaf sheath volatiles from cv. Poovan was tested using GC-EAD and identified ten volatile components found attractive to male and female weevils. These semiochemicals were tested in different combinations and among them 77.5% weevil attraction was recorded to the banana stem volatile, tetradecenoic acid.

In vitro screening of bio-pesticides/botanical extracts

Seven bio-pesticides / botanical extracts (*Pongamia* soap (ICAR-IIHR), Neem soap (ICAR-IIHR), Nanma (ICAR-CTCRI), bio-formulation, zimmu leaf extract, bio-pesticide (Nimbecidine), 3,4,5-trihydroxybenzoic acid), Insecticide (Chloropyrifos) were screened against banana stem weevil, *Odoiporus longicollis* under *in vitro* condition. Maximum mortality (100%) was recorded in the treatment chloropyrifos and bio-formulation on third day. Other chemicals were less effective in terms of weevil mortality.

Field evaluation of bio-pesticides / plant extract against banana stem weevil, *Odoiporus longicollis*

Bio-pesticides (Nimbecidine, *Pongamia* soap, Neem soap) botanical extracts (Zimmu, Nanma), insecticide (standard check - Chloropyrifos), 3, 4, 5-trihydroxybenzoic acid were tested under field condition against banana stem weevil. Spray was given from 5th month at 20 days interval. Observations recorded after 4th spray on 8 months old plants. Among the treatments minimum damage due to stem weevil was recorded in the treatment Nimbecidine followed by Zimmu. Maximum damage was recorded in control and no infestation was recorded in Chlorpyrifos.

Screening of *Musa* germplasm against banana corm weevil, *Cosmopolites sordidus* and banana stem weevil, *Odoiporus longicollis*

Out of the 313 *Musa* germplasm accessions screened against banana corm weevil, three accessions were recorded as resistant to banana corm weevil and rest were susceptible. All the 313 accessions were susceptible to stem weevil and no accession indicated resistance. Fifteen *Musa* germplasm accessions were recorded as less susceptible to the pest (Table 15). 210 *Musa* hybrids were screened under field conditions of which 100 progenies were free from banana stem weevil (Table 16).

Table 15. Screening of *Musa* germplasm for resistance to banana weevils

S. No.	IC No.	Name of the accession	Ge- nome	Reac- tion
Corm weevil, <i>Cosmopolites sordidus</i>				
1	250532	Kanthali	ABB	R
2	250903	Sambal Neyvannan	ABB	R
3	250460	Bhimkol	BB	R
Stem weevil, <i>Odoiporus longicollis</i>				
4	250964	Somai	AB	MT
5	250687	Valiya Kunnan	AB	MT
6	251086	GCTCV-215	AAA	MT
7	250534	Harichal	AAA	MT
8	250951	Highgate	AAA	MT

S. No.	IC No.	Name of the accession	Ge- nome	Reac- tion
9	251071	Shrimanti	AAA	MT
10	250820	Soniyal	AAB	MT
11	250588	Kallar Ladan	AAB	MT
12	250581	Neyvazhai	AAB	MT
13	250946	Ashy Batheesa	ABB	MT
14	250856	Bainsa	ABB	MT
15	250699	Batheesa ash	ABB	MT
16	251037	Boothibale	ABB	MT
17	250883	Rigatchi	ABB	MT
18	250903	Sambal Neyvannan	ABB	MT

R – Resistant; MT – Moderately Tolerant

Table 16. *Musa* progenies tolerant to stem weevil under field conditions

Progeny Number	Parents
0031	Namarai x Pisang Lilin
0052	Pisang Jajee x Matti
0057	Lairawk x Namarai
0122	Piang Jajee x Lairawk
0401	Ankur-II x Calcutta-4
0017	Anaikomban x Lairawk
0134	Anaikomban x Matti
0014	Anaikomban x Pisang Jajee
0455	Anaikomban x Matti
0036	Anaikomban x Namarai
0703	Attikol x Calcutta-4
0704	Attikol x Calcutta-4
0160	Bankela x Lairawk
0813	Bankela x Pisang Jajee
0814	Bankela x Pisang Jajee
0815	Bankela x Pisang Jajee
0816	Bankela x Pisang Jajee
0787	Bankela x (Kothia x C4)
0789	Bankela x (Kothia x C4)
0790	Bankela x (Kothia x C4)
0187	Bhat Manohar x Udhayam

Progeny Number	Parents
0099	<i>Musa laterita</i> x Chengdawat
0091	<i>M. laterita</i> x Pisang Jajee
0440	Marabale x Pisang Jajee
0447	Marabale x Pisang Jajee
0424	<i>M. ornata</i> x <i>M. a. ssp. burmanica</i>
0425	<i>M. ornata</i> x <i>M. a. ssp. burmannica</i>
0426	<i>M. ornata</i> x <i>M. a. ssp. burmannica</i>
0422	<i>M. ornata</i> x <i>M. a. ssp. burmannica</i>
0011	Matti x Anaikomban
0207	Matti x cv. Rose
0200	Matti x cv. Rose
0201	Matti x cv. Rose
0213	Matti x cv. Rose
0001	Matti x Pisang Jajee
0693	Microcarpa
0694	Microcarpa
0033	Namarai x Pisang Lilin
0055	Namarai x Pisang Lilin
0100	Pagalapahad wild x <i>M. a. burmannica</i>
0714	Phirma wild x Pisang Lilin
0720	Phirma wild x Pisang Lilin

Progeny Number	Parents
0764	Bhat x Pisang Jajee
0768	Bhat x Pisang Jajee
0667	Bhat Manohar -OP
0669	Bhat Manohar -OP
0182	Calcutta 4 x Lairawk
0105	Calcutta 4 x Pisang Jajee
0082	Calcutta 4 x Lairawk
0776	Chinia x Pisang Jajee
0398	cv. Rose x Lairawk
0429	cv. Rose x Pisang Lilin
0427	cv. Rose x Pisang Lilin
0428	cv. Rose x Pisang Lilin
0020	H-3 x Pisang Jajee
0021	H-3 x Pisang Jajee
0793	Karpuravalli x Pisang Lilin
0755	Karpuravalli x Pisang Jajee
0756	Karpuravalli x Pisang Jajee
0757	Karpuravalli x Pisang Jajee
0783	Karpuravalli x Pisang Jajee
0817	Karpuravalli x Pisang Jajee
0115	Karpuravalli x Pisang Jajee
0002	Karpuravalli x Pisang Jajee
0109	Karpuravalli x Pisang Jajee
0110	Karpuravalli x Pisang Jajee
0111	Karpuravalli x Pisang Jajee
0113	Karpuravalli x Pisang Jajee
0117	Karpuravalli x Pisang Jajee
0056	Lairawk x Namarai
0022	<i>M. laterita</i> x Pisang Jajee
0023	<i>M. laterita</i> x Pisang Jajee

Progeny Number	Parents
0722	Phirma wild x Pisang Lilin
0460	Pisang Jajee x Calcutta 4
0059	Pisang Jajee x cv. Rose
0171	Pisang Jajee x cv. Rose
0172	Pisang Jajee x cv. Rose
0174	Pisang Jajee x cv. Rose
0121	Pisang Jajee x Lairawk
0151	Pisang Jajee x Lairawk
0049	Pisang Jajee x Matti
0047	Pisang Jajee x Imbogo
0148	Pisang Jajee x Lairawk
0096	Pisang Jajee x Matti
0651	Saba x Chengdawn
0684	Saba x Pisang Lilin
0686	Saba x Pisang Lilin
0687	Saba x Pisang Lilin
0688	Saba x Pisang Lilin
0689	Saba x Pisang Lilin
0691	Saba x Pisang Lilin
0685	Saba x Pisang –(Kothia)
0818	Udhayam x Calcutta 4
0819	Udhayam x Calcutta 4
0791	Udhayam x Pisang lilin
0189	Udhayam X Pisang Jajee
0734	Udhaym x Pisang Lilin
0820	Udhaym x Pisang Lilin
0821	Udhaym x Pisang Lilin
0098	<i>M. laterita</i> x Chengdawn
0099	<i>M. laterita</i> x Chengdawn

Isolation of endophytic fungi from *Musa* accessions for the management of banana insect pests

Three hundred and thirty seven strains of entomopathogenic fungi belong to *Beauveria* spp. (167

Nos.), *Metarhizium* spp. (132Nos.), *Verticillium lecanii* (46 Nos.) were isolated from 313 *Musa* germplasm accessions belong to eight different genomic groups viz., AB, AA, BB, AAB, AAA, ABB, ABBB and *Rhodochlamys* and 44 sub-groups (Table 17).

Table 17. Distribution of endophytic fungi from *Musa* germplasm

Genome	No. of accessions	Type of fungus		
		<i>Beauveria</i> spp.	<i>Metarhizium</i> spp.	<i>Lecanicillium</i> spp.
ABB	104	47	58	25
AAB	99	63	25	0
AAA	27	10	15	6
AB	23	16	8	0
BB	22	14	10	3
AA	26	5	16	10
ABBB	8	8	0	2
<i>Rhodochlamys</i>	4	4	0	0

Nine species of *Beauveria* was recorded from the collections: *Beauveria bassiana*, *B. amorpha* sp. nov., *B. asiatica* sp. nov., *B. australis* sp. nov., *B. brongniartii*, *B. caledonica*, *B. malawiensis*, *B. sungii* sp. nov. and *B. pseudobassiana* sp. nov.

The isolated *Metarhizium* species belong to six species and they were *M. anisopliae*, *M. majus*, *M. robertsii* nov., *M. frigidum* sp. nov., *M. acridium* nov. and *M. flavoviride*.

More than one fungal isolate was recorded in 16 accessions in the combination of species of *Beauveria*, *Metarhizium* and *Lecanicillium lecanii*. Three fungi (*B. bassiana*, *M. anisopliae* and *L. lecanii*) in a single accession were recorded in 2 accessions and two fungi (*B. bassiana* and *M. anisopliae*) were recorded in 6 accessions (Fig.1a, b and c).



Fig. 36a. *B. brongniartii* + *M. flavoviride*



Fig. 36b. *B. brongniartii* + *L. lecanii*



Fig. 36c. *B. bassiana* + *M. anisopliae* + *L. lecanii*

4.4.2 Pest mapping in bananas and plantains in India

Studies on leaf and fruit scarring beetles (*Basilepta* spp.)

Surveys were carried out for banana leaf and fruit scarring beetles (*Basilepta* spp.) in Assam, Meghalaya and Uttar Pradesh states showed that the beetle population was very high in Assam (25-45/plant) on banana cv. Grande Naine in Dergaon, Assam, during September, 2018. Damage symptoms were observed on turmeric besides banana. Extensive leaf and fruit damage symptoms were observed in Bahraich and Faridabad districts of Uttar Pradesh during November, 2018.

COX1 sequencing of banana leaf and fruit scarring beetles (*Basilepta* spp.) from four states, namely, Assam, Bihar, Uttar Pradesh, and West Bengal was done. The populations from Bihar, Assam and Uttar Pradesh were found to be distinct though morphological differences were insignificant.

Species complex of banana skippers (*Erionota* spp.)

In a survey at Jorabad, Meghalaya, *Erionota torus* was found to be more predominant than *E. thrax* during October, 2018. Out of 60 larvae of *Erionota* spp. collected, only two adults belong to *E. thrax*, the rest being *E. torus*.

New records of thrips on banana

Asprothrips navsariensis was recorded as a pest of banana foliage for the first time from peninsular India (Fig. 37). Cv. Grande Naine was found to harbour significant numbers of the thrips (10-50/leaf), the infested leaves showing small, irregular patches of characteristic streaks. Three more species of thrips were recorded on cv. Grande Naine, namely, *Scirtothrips dorsalis*, *Anascirtothrips arorai* and *Pseudodendrothrips mori*. The last two are recorded for the first time on banana. Foliage of banana cvs. Grande Naine, Ash Monthan, Rasthali and Pisang Lilin were found to be affected by *Helionothrips kadaliphilus* during August-October, 2018 with cv. Grande Naine suffering greater degree of damage on leaves as well as on fruits.



Fig. 37. *Asprothrips navsariensis*

Fig. 38. *Pseudococcus jackbeardsleyi*

Mealybug pests of banana

Dysmicoccus neobrevipes, an emerging pest of banana in parts of Karnataka was recorded on bunches and pseudostem of cv. Ney Poovan from Kattuputhur, Tiruchirappalli, Tamil Nadu. Extensive infestation by *Pseudococcus jackbeardsleyi*, an alien invasive pest, was recorded on banana fruits and bunches of cvs. Poovan, Grande Naine, Karpuravalli, Pisang Lilin, Monthan, NamwaKhom in Tiruchirappalli, Tamil Nadu (Fig. 38). *Phenacoccus solenopsis*, its parasitoid, *Aenasius arizonensis* and the coccinellid predators, *Brumoides suturalis* and *Hyperaspis maindroni* were recorded from banana. *Dysmicoccus brevipes* was found feeding on the roots, sheath and rhizome of cvs. Udhayam, Bhimkol, Beejkela, and Boothi Bale.

Natural enemies of banana pests

Two species of earwigs, *Euborellia* and *Chaetospila* sp. were found to be predominant predators on pseudostem weevil (*Odoiporus longicollis*) infested banana plants. *Brachymeria lasus* (Hymenoptera: Chalcididae) was recorded as a common pupal parasitoid of banana skipper (*Erionota* spp.) and *Amata passalis*. Three coccinellid predators on banana, *Stethorus pauperculus*, *S. keralicus* and *Parastethorus indira*, were found to be host-specific to *Oligonychus indicus*, *Raoiella indica* and *Eutetranychus orientalis*. Heavy egg parasitism by *Ooencyrtus pallidipes* was observed on *E. torus*. One pupal parasitoid, *Brachymeria lasus* (Chalcididae) and two tachinid pupal parasitoids were recorded.

Web-based identification aid to banana pests

A web-based identification aid of about 50 insect and mite pests of bananas and plantains in different parts of India was constructed and hosted in ICAR-NRCB's website (URL: nrcb.res.in/album). This identification aid features over 1000 high res-

olution photos of the life stages and symptoms of damage of major banana pests and their natural enemies and enables easy field identification of banana pests by farmers and extension workers.

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

Survey in Madhya Pradesh, Maharashtra and Gujarat

Incidence of *Fusarium* wilt (Foc) in banana cv. Grand Naine was recorded in Maharashtra (Muktainagar, Besalvadi taluk, Jalgaon district), Madhya Pradesh (Nanchenkhed, Burhanpur district) and Gujarat (Kholeshwar village, Kamrej taluk, Surat district) states. Awareness campaigns were conducted to farmers, officials of state agricultural department on importance and impact of the *Fusarium* wilt disease, its prevention and management. Foc race identification is in progress.



Fig. 39. *Fusarium* wilt disease and its damage symptoms

Molecular detection of *Fusarium oxysporum* f. sp. *cubense* (Foc) from different parts of India

Molecular diagnostics and VCG analysis were carried out for Foc isolates obtained from Gujarat, Madhya Pradesh, Uttar Pradesh, Bihar, Kerala and Tamil Nadu. Foc isolates of Uttar Pradesh and Bihar belonged to tropical race 4 (VCGs 01213/16) and Foc isolates of Gujarat and Madhya Pradesh belonged to be sub tropical race 4. Whereas, Foc isolates from Kerala and Tamil Nadu belonged to race 1. A phylogenetic tree constructed using the sequences of TEF α -1 gene of various Foc isolates of India also confirmed the results and the Foc isolates from India grouped with known VCGs of 01213/16, 0124 & 0120. The tree was rooted with *Fusarium commune* and *Fusarium circinatum* which served as outgroup. A maximum parsimony tree inferred from the translation elongation factor-1 α (TEF) gene of isolates representing all vegetative compatibility groups of Foc (Fig. 40).

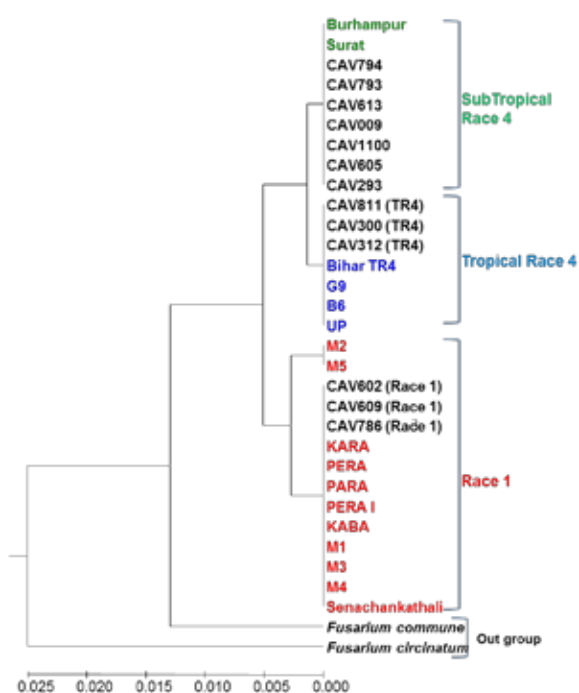


Fig. 40. Phylogenetic analysis of Foc isolates from different banana growing regions of India

Detection of *Fusarium oxysporum* f. sp. *cubense* (Foc) pathogen by Loop mediated isothermal amplification (LAMP) method

A simple and cost effective diagnostics for Foc tropical race 4 (TR4) of banana, Loop mediated isothermal amplification (LAMP) method was attempted by exploiting the sequences of Foc TR4 specific effectors' genes. A total of five different sets of LAMP primers were designed and tested and the results showed that only two sets (1 and 5) out of five primers set specifically amplified the target DNA of Foc TR4. The PCR reaction mixture and conditions were optimized for an accurate detection of the target DNA (Fig. 41).

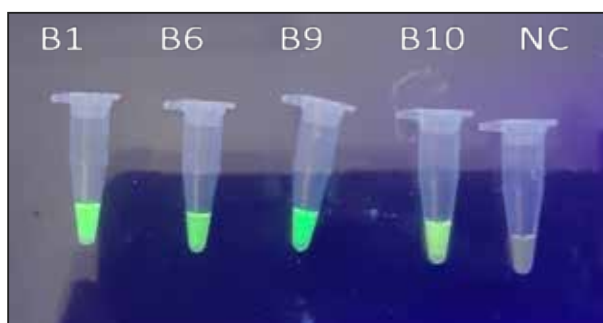


Fig. 41. Specificity test of the LAMP assay for the detection of Foc TR4

Designing and development of mass production technology for the management of Foc TR4 effective *Trichoderma* sp.

The mass production technology of Foc TR4 effective *Trichoderma* sp. was standardized by using rice chaffy grain with 10 per cent molasses at excess moisture level in layering method which yielded maximum production of *Trichoderma* (5×10^{15} cfu g^{-1}) at 7 days of inoculation at room temperature conditions.

Evaluation of native endophytic bacterial and fungal bioagents against Foc TR4

Nine bacterial endophytic isolates obtained from *Fusarium* wilt resistant banana germplasm and four other fungal isolates were tested as individual treatments and in combinations to identify the effective combination against Foc TR4.

Evaluation of Foc race 1 effective biocontrol agents combination against Foc TR4

The native endophytic and rhizospheric biocontrol agents (*Trichoderma* sp. - NRCB3, *Penicillium pinophilum*, *Trichoderma asperellum* - prr2 and *Bacillus flexus*) which were found effective against Foc race 1 were evaluated against Foc TR4 under pot culture condition in cv. Grand Naine. Maximum disease suppression (1.12 disease score) and increased plant growth were observed in combined application of *Trichoderma* sp. NRCB3 + *Penicillium pinophilum* followed by *Trichoderma* sp. NRCB3 + *Penicillium pinophilum* (1.58 disease score).

Study of infection and spread of Foc TR4 in banana cv. Grand Naine

Scanning electron microscopy (SEM) analysis indicated that the presence of mycelial structure of Foc TR4 was observed on second day of inoculation in the root, corm and stem, whereas, in the leaf it was observed on seventh day of inoculation (Fig. 42).



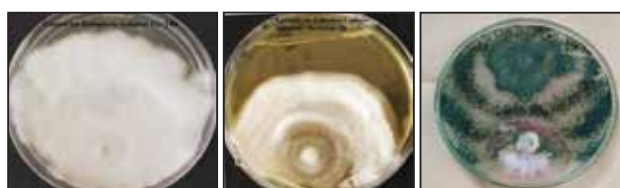
Fig. 42. SEM image showing the presence of Foc TR4 mycelium on seventh day of inoculation in the banana leaf

Isolation and evaluation of endophytic microbes from banana accessions against Foc TR4

A total of 14 banana cultivars belong to AA, BB, ABB genome were explored and totally 132 bacterial isolates and six isolates of *Trichoderma* sp. were obtained. Nine bacterial isolates and one isolate of *Trichoderma* sp. inhibit mycelial and spore germination of Foc TR4 under *in vitro* condition.

Evaluation of effective endophytic bacterial and fungal isolates for the production of lytic enzymes

Analysis of lytic enzymes and plant growth promoting compounds of Foc TR4 effective bacterial and fungal isolates indicated that two bacterial isolates (from stem of cv. Attikol and root of cv. Manohar) have shown maximum mycelial inhibition (up to 54.29) and maximum spore germination inhibition (up to 98.0%) respectively. These isolates also shown maximum cellulolytic (0.56 Uml^{-1}), protease (0.12 Uml^{-1}) and chitinolytic activity (0.10 Uml^{-1}), IAA production ($19 \mu\text{g ml}^{-1}$) and phosphate solubilisation.



Control

Bacterial endophyte

Trichoderma spp. endophyte

Fig.43. Plates showing Foc TR 4 mycelial inhibition by the isolates of endophytic bacteria and *Trichoderma* sp.

4.4.4 Survey, etiology and management of rhizome rot of banana

Survey, isolation and characterisation of rhizome rot pathogen

A total of 154 bacterial isolates were isolated and purified from the rhizome rot infected samples collected from banana cultivars viz., Grand Naine, Thelachakrakeli, Red Banana, Ney Poovan, Saba, Bangrier, Popolou and Myndoli from Andhra Pradesh, Bihar and Tamil Nadu states. Different types of bacterial cultures were obtained and most of them were able to utilize pectin as they formed depression or cavity on crystal violet pectate medium (Fig. 44). The isolates produced characteristic soft rot upon inoculation on potato (Fig. 45).



Fig. 44. Cavity formation on crystal violet pectate medium by rhizome rot isolate



Fig 45. Soft rot symptom produced on potato by rhizome rot isolate (tubers inoculated on left and un-inoculated on right)

Pathogenicity of rhizome rot pathogen

The bacterial isolates produced characteristic rhizome rot symptoms on cv. Grand Naine after one month of inoculation. Initially the inoculated plants showed yellowing and later they produced typical rotting (Fig.46). Affected plants showed internal symptoms such as rotting in rhizome and pseudostem especially inner core region besides formation of cavity in advanced stages (Fig.47).

Isolation and bioassay of plant growth promoting rhizobacteria (PGPR)

In total 52 PGPR isolates were obtained from rhizospheric soil samples collected from different places. Seven out of 34 isolates significantly increased plant growth characters of cv. Grand Naine (Fig. 48 & 49).



Fig. 46. Rhizome rot symptoms produced on cv. Grand Naine by the pathogenic isolate (Control on left extreme and inoculated plants on right)



Fig. 47. Typical rhizome and pseudostem rot, and cavity symptoms seen in split opened plant (control on left and inoculated plant on right)



Fig.48. Growth of cv Grand Naine plant treated with PGPR isolate 4-1 (right) and untreated (left)



Fig.49. Growth of cv Grand Naine plant treated with PGPR isolate 5-3 (right) and untreated (left)

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

Partial reverse transcriptase and ribonuclease H (RT/RNase H) region of a banana streak virus (BSV) species infecting wild banana was cloned, sequenced and the sequence analysis confirmed that the BSV species might be a variant. Dimers of three genomic components of banana bunchy top virus (BBTV) clones were constructed and using RCA based approach the infectivity of BBTV was attempted on to tissue culture and embryogenic cell suspension (ECS) derived embryos of cv. Rasthali. One of seven plants expressed the disease symptoms.

Distribution of banana bract mosaic virus (BBBrMV) in various parts of the seeds, flower and leaf tissues of banana seedlings of a synthetic diploid, H-201, naturally infected in the field was determined by DAC-ELISA (Fig.50). In a seed - growth test, ex-

pression of typical symptoms of bract mosaic virus disease was confirmed using RT-PCR (Fig.51).

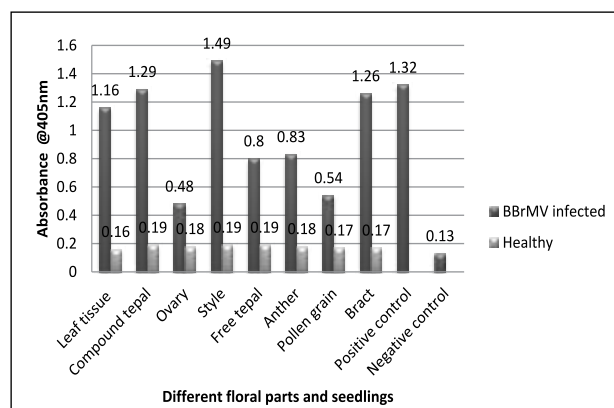


Fig. 50. Analysis of different floral parts and seedlings assayed for BBrMV using DAC-ELISA



Fig.51. Testing seedlings of banana for the presence of BBrMV in RT-PCR. (a) Lane M: 1kb DNA ladder plus (Thermo fishers, USA); Lanes 1-13: seedlings from infected seeds; Lanes 14-20: Healthy seedlings; Lane 21-Healthy control; Lane 22: Positive control.

Screening of fifty diploid banana germplasm accessions for resistance against BBTV using viruliferous aphids showed that twelve diploid accessions of AA genomic groups and Hill banana and Grand Naine plants have expressed the BBTV symptoms. No symptom expression in 20 accessions with BB genome.

To study the vector-virus-host relationship, the viral copies in a single to group of aphids with different acquisition access period (AAP) were quantified using SYBR green-based quantitative polymerase chain reaction (qPCR). The result indicated that a single aphid was able to acquire 861.04 copies of the virus after 24 hrs of AAP from the infected banana plant and transmitted the virus to 16.6 % tissue culture plants, whereas 50 viruliferous aphids were required to achieve 100% transmission in a shortest time of 21.6 days (Table 18). Tissue culture banana plants are highly prone or vulnerable to BBTV infection compared to sucker grown plants (Fig.52). It is concluded that higher the number of viral copies in the vector increase the per cent transmission and induce early expression of symptoms

Table 18. Absolute quantification of BBTV titre in distinct number of viruliferous aphids based on SYBR green Real-time PCR and transmission rate

Number of aphids	Virus titer (viral copies)	C _T (Mean)	BBTD incidence (%)	Time taken for BBTD Symptom expression (Days) (Mean)
1	861.04±207.04	28.76±0.32	16.6 (5/30)	102.8±20.06
5	2384.24±164.89	27.01±0.10	26.6 (8/30)	80.6±16.07
10	3868.48±937.75	26.79±0.38	36.6 (11/30)	67.5±7.01
20	4897.98±736.48	26.56±0.22	83.3 (25/30)	54.2±6.76
30	6922.45±1042.62	26.41±1.03	100 (30/30)	49.8±6.45
40	7378.40±3839.18	25.97±1.92	100 (30/30)	23.3±3.62
50	15066.94±2280.54	24.71±0.24	100 (30/30)	21.6±3.87
Non-viruliferous	-	36.42±1.11	-	-

BBTD – Banana bunchy top disease

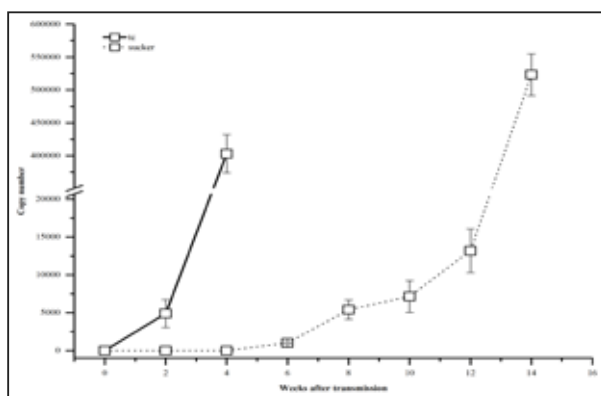


Fig.52. Comparison of viral titre in both tissue culture and sucker grown plants on bi-weekly intervals after transmission with Banana bunchy top virus by SYBR green based qPCR assay. In X-axis, the different number of weeks after the transmission and in Y-axis, the viral titre values are plotted as copy number

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

28 differentially expressed spots (> 2.5 fold) during BBTV time course study were subjected to peptide mass fingerprinting.

Screening of germplasm for variation in eIF4E gene

eIF4E gene (a candidate resistant gene against banana bract mosaic virus) from 20 different cultivars were amplified, sequenced and compared with resistant genes from other crops as well as with se-

quence from other banana cultivars for identification of SNP in the VPg-eIF4E interacting domain. 3D structure was predicted for eIF4E through homology based modelling and the structure was evaluated. Further, *in-silico* analysis was carried out to study the changes corresponding to non-conservative amino acid substitution in the cap binding pocket and at the surface of the protein in 3D structure of eIF4E.

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

Evaluation of promising biocontrol agents against banana nematodes

Evaluation of *Fusarium* wilt suppressive biocontrol agents against root-lesion nematode (*Pratylenchus coffeae*) and root-knot nematode (*Meloidogyne incognita*) under *in vitro* conditions showed that *Bacillus flexus* (Tvpr1) was found superior followed by *Trichoderma asperellum* (Prr-2).

Evaluation of promising biocontrol agents against root-knot nematode, *Meloidogyne incognita* infecting banana cv. Grand Naine

Evaluation of *Fusarium* wilt suppressive biocontrol agents against root-knot nematode (*Meloidogyne incognita*) infecting banana cv. Grand Naine under shadenet conditions showed that application of endophytic *Trichoderma asperellum* (Prr-2) was found

better over other treatments in reducing root-knot nematode population and improving plant growth.

Molecular diversity studies on banana nematodes

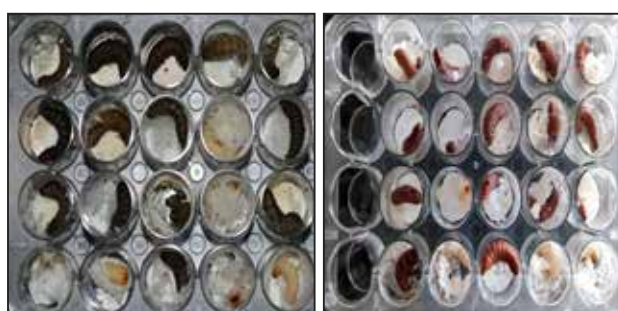
Species identity of native isolate of entomopathogenic nematode was deciphered through amplification and sequencing of ITS1-5.8S-ITS2 region of rDNA using primer TW81- AB28. It was identified as *Heterorhabditis indica* (NCBI accession no. MH 299879).

Survey and sampling of banana for nematodes

Sampling at Sathyamangalam, Mettupalayam, Sirumugai and Coimbatore areas of Tamil Nadu revealed higher population of root-lesion nematode, *Pratylenchus coffeae* in banana cv. Ney Poovan. Sampling at Cumbam and Theni, Tamil Nadu showed higher population of spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode (*Meloidogyne incognita*) in banana cultivars Red banana and Sakakai respectively.

Virulence studies of native entomopathogenic nematode isolates

Virulence of the two native isolates of entomopathogenic nematodes (*Steinernema siamkayai* and *Heterorhabditis indica*) was compared by dose response assay, one-on-one assay and probit analysis using waxmoth larvae. *S. siamkayai* was found more virulent than *H. indica* based on insect mortality and LD50 values (Fig.53).



Steinernema siamkayai *Heterorhabditis indica*

Fig.53. Dose response assay of native entomopathogenic nematode isolates using larvae of greater waxmoth, *Galleria mellonella*

Efficacy of native entomopathogenic nematodes (*Steinernema siamkayai* and *Heterorhabditis indica*) were evaluated against banana stem weevil, *Odoiporus longicollis* by inoculating different concentrations (1000, 2500, 5000, 10000 and 20000) of infective ju-

veniles in pseudostem pieces kept in plastic container. Maximum weevil mortality caused by *H. indica* and *S. siamkayai* were 100% and 80% respectively at 120hrs of exposure at 20000 nematodes / weevil concentration.

4.5 EXTERNALLY FUNDED PROJECTS

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

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

Chromosome doubling of BB, AA and AB diploids through *in vitro* polyploidization was initiated using different explants namely shoot tips (Kunnan), ECS (Ney Poovan) and embryos and male buds (BB accessions). The experiment was designed with varying concentrations of Oryzalin and time intervals. A population was 350 Ney Poovan, 40 Kunnan and 2 BB (Phirima wild) are in primary and secondary hardening stages. Few are in callus stage, when the explants is male bud. (Fig.54 & 55).



Fig.54. Oryzalin treated
Ney Poovan

Fig.55. Oryzalin treated
Kunnan

Detection of Fusarium wilt Tropical Race 4 (Foc TR4) resistant marker

Out of 100 *in silico* SSR primers tested against contrasting cultivars for Foc TR4, of which – primers showed polymorphism among the contrasting parents. Interestingly it was observed that A RGA leucine-rich repeat receptor-like protein kinase which is located on chromosome 9 showed polymorphism between Foc TR 4 susceptible (Kadali, Matti and Namarai) and resistant (Calcutta 4 and cv. Rose) cultivars but monomorphic banding pattern was obtained within the susceptible and within resistant cultivars (Fig.56). Validation of mapping population obtained from the contrasting parents for Foc TR 4 resistance is in progress.

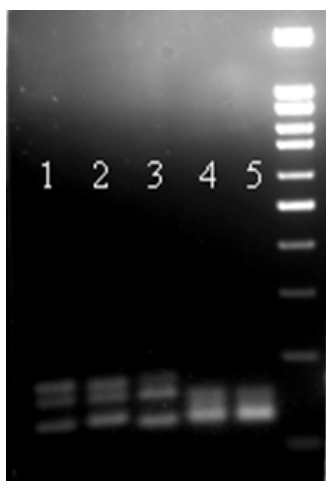


Fig. 56. Polymorphism among the contrasting parents of Foc TR4

Resistant - 1. Kadali, 2. Namarai, 3. Matti,
Susceptible - 4. Calcutta 4, 5. cv. Rose

DBT-QUT Project

4.5.2 Biofortification and development of disease resistance in banana

Component I: Transfer and evaluation of Indian bananas with PVA constructs (S. Backiyarani and S. Uma)

No yield reduction was observed in the Grand Naine transgenic events (20kg) developed using the construct DC 49 when compared to wild type Grand Naine but the β -carotenoid content of all the events (only two – three fold) was less. Among the DC 32 transgenic events, only 5 events recorded lesser yield than wild type and two events recorded maximum of 28kg with 2-5 fold enhanced the β carotenoid content. But among the four constructs DC 34 recorded the maximum yield of 40kg and only 5 events recorded lesser yield than wild type (Fig.57 & 58) and also recorded 4 to 9 fold enhanced β carotenoid in mostly all the events. Thus among the five constructs used DC 34 which is having the Asupina phytoene synthase gene under the control of AOC promoter was found to be the best construct in terms of yield as well as β carotenoid.

To confirm the copy number, southern analysis has been carried out in six DC 34 transgenic plants using the probe of APsy2a developed from the PCR product (732bp) of Ubilnt as a forward primer & Apsy2a as a reverse primers. Of which five plants showed positive results and found that only four are independent events. In that two events namely 14-4, and 14-7 are having two copies whereas 13-8, 13-9 and 14-6 are having single copy. It is assumed that 13-8 and 14-6 might be the same event.



DC 34 14/7

DC 34 13/9

Fig. 57. Comparison within the DC 34 transgenic events



DC 34

DC 49

Fig. 58. Comparison between the transgenic events of DC 34 and DC 49

For large scale multiplication of elite transgenic events the immature male flower buds of were initiated (Fig. 59) for direct regeneration as per the standardized protocol of ICAR-NRCB.

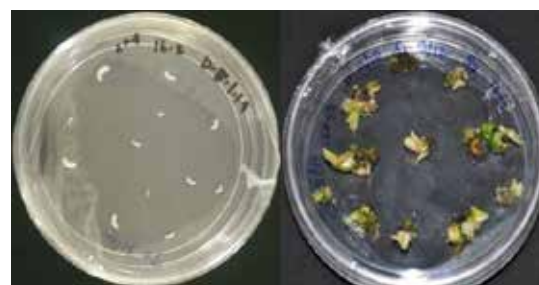


Fig. 59. Direct regeneration of immature male flower buds of elite transgenic events

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

Thirty one Grand Naine and 24 Rasthali *OsNAS1* transgenic event plants were harvested, of which 22 Grand Naine and 17 Rasthali lines were analyzed for iron content in pulp of both unripe and ripe fruits. One each of Grand Naine and Rasthali lines is promising with 3.06 and 2.73 mg of iron per 100 g fruit pulp against control of 0.85 mg (Fig.60). Other Grand Naine lines showed iron contents in the range of 0.926-1.83 mg and Rasthali lines in the range of

0.738-2.178. The DUS characterization of promising lines was found to be true to type. Remaining *OsNAS1* plants are in bunch-maturing stage.



Fig.60. Bunches of Grand Naine plant transformed with *OsNAS1* (left) and untransformed plant

Fifty numbers each of PCR-confirmed Grand Naine and Rasthali *OsNAS2* transgenic event plants were field-planted in July 2018. Leaf iron content analysis in randomly selected ten lines each of Grand Naine and Rasthali showed four and two lines of Grand Naine and Rasthali promising with iron contents of 26-34 mg/100g DW against control of 11-12 mg. Two Grand Naine *OsNAS2* bunches have been harvested and processed for iron quantification in fruit pulp and remaining Grand Naine transgenics are in bunch-maturing stage or in shooting stage (Fig.61) and Rasthali plants are in late vegetative stage.

The *OsNAS1* and *OsNAS2* event plants of BARC were planted in July 2018 and Jan. 2019 respectively. Around 60 *OsNAS1* lines are in bunch-maturing stage and *OsNAS2* plants are in early vegetative stage.



Fig. 61. Flower shooting of Grand Naine plants transformed with *OsNAS2* in transgenic net house under confined field trials

Component III - Development of efficient ECS of cv. Rasthali and providing to Indian partners (S. Uma, S. Backiyarani and M. S. Saraswathi)

A total of three ml of Grand Naine and two ml of Rasthali ECS have been distributed to TNAU, Coimbatore and one ml of Grand Naine and five ml Rasthali ECS have been distributed to ICAR-IIHR, Bangalore.

DUS characterization have been done for transgenic plants using forty one DUS traits for the Iron and PVA enriched transgenic plants of cv. Rasthali and Grand Naine during vegetative, flowering and fruiting stages. Out of 165 plants characterized, 5 plants showed variation for plant height, 4 for bunch position, 7 for bunch shape, 3 for peduncle length, 3 for leaf arrangements. Altogether 13.3% somaclonal variation was observed for the PVA transgenic plants of both cv. Rasthali and Grand naine. Similarly, A total of 50 plants were DUS characterized for the Iron transgenic plants of cv. Rasthali and Grand Naine and found variation in two plants for plant height, 1 for bunch position, 2 for bunch shape. Altogether 10.0% somaclonal variation was observed for the Iron transgenic plants of both cv. Rasthali and Grand Naine.



Fig. 61a. Transgenic net house at ICAR-NRCB farm

DAE Project

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

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

Pot screening against Fusarium wilt (Foc) race 1(VCG 0124/5) has resulted in the identification of 20 putative resistant mutants (NRCBRM -1 to 20) which are free from both external and internal

symptoms of Fusarium wilt disease. The first batch of 15 lines out of 20 resistant mutants were multiplied in vitro and planted in the sick plot at Theni district, Tamil Nadu for further evaluation (Fig. 62).



Fig.62. Pot screening of Rasthali mutants
Treatment – EMS – 0.1% for 2 hrs; No. of plants – 300; Foc @ 20g/plant
A) Before inoculation of Foc;
B) 8 weeks after inoculation
C) NC – Negative control; PC – Positive control;
1 to 15 – Resistant lines

Sick plot evaluation

To confirm their resistance, the mutant lines (RM 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14 & 15), along with five non-mutated plants of cv. Rasthali (control) were planted in the sick plot at Theni, TN. Planting was taken up in 2018. The trial was regularly inspected for external symptoms such as wilting and/or leaf yellowing. The phenotypic data was recorded at monthly intervals until harvest. The bunches were harvested and the plants were uprooted and examined for the internal symptoms by adopting the INIBAP's technical guidelines No. 6 Carlier *et al.* and the descriptions of Ploetz *et al.* Among 15 Rasthali mutants planted in sick plot, 6 lines (RM 3, RM 4, RM 10, RM 11, RM 12 & RM 15) yielded normally (12 – 14.5 kg bunch) without any external symptoms. From those plants, only one clone (RM 15) showed no vascular discoloration for Race 1. The other 5 lines had minimal vascular discoloration. The identified RM15 had been carried forward (Table 19 & Fig. 63).

Table 19. Yield parameters of mutant lines and resistant levels

Line No.	Bunch weight (kg)	No. of hands	No. of fingers	Remarks
RM15	14.5	8	88	Resistant
RM 3	12	7	76	Tolerant
RM4	13	8	82	Tolerant
RM10	14	8	80	Tolerant
RM11	12.5	7	79	Tolerant
RM12	13.5	8	84	Tolerant

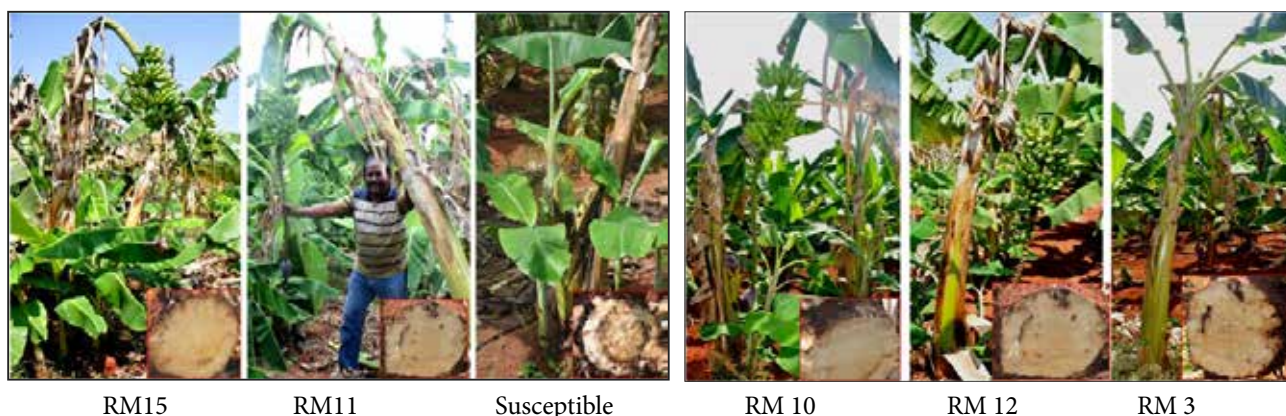


Fig. 63. Identified resistant mutant lines Cv. Rasthali in wilt sickplot

PPV & FRA project

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

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

Out of 39 accessions (which included 28 reference accessions, 5 new accession and 6 farmers' varieties) planted, DUS characterization has been completed for 18 reference accessions and three

farmers' varieties.

Kamal Vikas A1

It was observed that the variety Kamal Vikas (AAA) very closer to the famous Grand Naine variety. However, it shows its unique features like fruit orientation, shape and bunch shape. The unique features/distinguishable are presented in the Table 20 & 21.

Table 20. DUS characterization

Character No. as in DUS guidelines	Character	Grand Naine	Kamal Vikas
2. QL	Pseudostem colour	Green with black brown blotches	Green with brown black blotches
6. (+) QL	Petiole canal	Open with margins	Straight with erect margins
14. PQ	Bunch - Compactness	Medium	Loose/lax
15. (+) QL	Rachis orientation male phase	Curved with vertical end	Hanging vertically downward
16. (*) QL	Rachis appearance	Male flowers / bracts above the male bud (but the stalk is bare above flowers / bracts)	Neutral/male flowers and presence of withered bracts (on the whole stalk)
26. (*) QL	Fruit orientation	Curved towards stalk/ peduncle	Curved upward
29. (*) (+) PQ	Transverse section of fruit	Slight ridges	Pronounced ridges
30. (*) (+) QL	Fruit apex	Bottle necked	Blunt tipped
32. QL	Fruit pedicel attachment at ripeness	Medium	Medium
34. (*) QN	Pedicel length(cm)	Long (> 1.5)	Very short (< 0.6)

Table 21. Yield parameters recorded in KVA 1 and Grand Naine

Variety	Crop duration (days)	Bunch weight (kg)	No. of hands	No. of fingers	TSS (°Brix)	Acidity (%)
KVA1	260	27.0	14	226	14.5	0.38
Grand Naine	304	37.6	14	238	14.5	0.32

DBT-ATL Project

4.5.5 Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants (R. Selvarajan and C. Anuradha; M. S. Saraswathi and S. uma)

During the reporting period, as expertise of the 'Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants' 797 batches of tissue culture plants (Grand Naine, Williams, Robusta, Ney Poovan, Red Banana,

Quintal Nendran, Sabri etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports issued. This generated an income of Rs.14.10 lakhs to the Institute.

Mother cultures of tissue culture (TC) banana plant received from tissue culture production units (TCPU) were tested for banana viruses under contract service. Totally 19114 TC samples were tested for the presence of four viruses. Banana germplasm accessions conserved in the field gene

bank at different locations (AICRP-TF- Arabhavi, Coimbatore, Gandevi and Tiruchirappalli) and mother plants used for embryogenic cell suspension (ECS) development were tested for presence of banana viruses. Totally 55 samples were tested.

ICAR-AICRP Project

4.5.6 Assessment of post-harvest losses in banana under AICRP on Fruits (K. N. Shiva)

A survey was conducted in Theni and Erode districts (cv. Grand Naine) and in Tiruchirappalli and Tuticorin districts (cv. Poovan) of Tamil Nadu, to estimate the post-harvest losses in banana at various levels viz., field, transport, assembly/wholesale market, storage and ripening. The results showed that the post-harvest losses were 10.83% and 11.39% in Theni and Erode districts, respectively for cv. Grand Naine, while it was 17.39% and 6.41% in Tiruchirappalli and Tuticorin districts, respectively for cv. Poovan. In Jalgaon center, the post-harvest losses estimated were 30.34% in Jalgaon district, Maharashtra in cv. Grand Naine. Surveys carried out at different AICRP (Fruits) centers revealed that the average post-harvest losses of banana were 21.97, 25.09, 16.83 and 31.25% at Kerala, Andhra Pradesh, Tamil Nadu and Maharashtra centers, respectively. Among the centers, Tamil Nadu recorded the least post-harvest losses (11.50%), while Maharashtra recorded the highest losses (30.34%), followed by Andhra Pradesh (24.61%).

The causes observed for the post-harvest losses in banana for each stage/level were: small or undersized fruits, malformed fruits, over maturity and ripe fruits, splitting and cracking of fruits, sun

scorching (blackened fruit skin), damaged fruits, cigar end rot (*Verticillium theobromae*), rust spots (thrips - *Chaetanaphothrips signipennis*), bird (peacock - *Pavo cristatus*) and wild boar (*Sus scrofa*) damage at farm level; bruises, damaged/compressed fruits during transportation; bruises, ripe and damaged/compressed fruits at wholesale /assembly market level; damage of bottom of hands/fruits during ripening in the smoking room, cracking and splitting of fruits in cold cum ripening chamber; over ripe, damaged or rotten fruits and shattering of fruits at retail level.

DBT-NER Projects

4.5.7 Consortium for managing Indian banana genetic resources

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

Efforts were taken to identify the SNPs from the available transcriptome data. Among the seeded and seedless accessions, it was found that 3 genes namely Mitochondrial di/tri carboxylated (MDC), pentatricopeptide protein (PPRT), Terpenesynthase (TS) had SNPs. MDC gene are showing polymorphic banding pattern between seeded and seedless accessions. In another study, genes involved in parthenocarpy trait were identified through literature survey and subjected to protein-protein interaction network analysis to identify candidate genes for parthenocarpy. From this, 15 genes were listed as candidate genes such as Floral homeotic protein, DELLA protein, gibberellin receptor A and transcription factors such as (WRKY family domain, ARF 7 & MYB) etc.

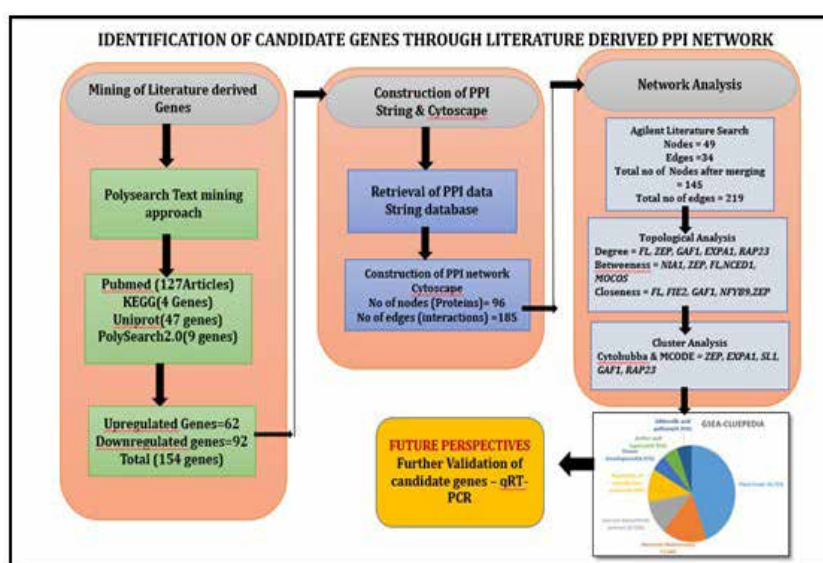


Fig. 64. Identification of candidate genes through literature derived PPI network

4.5.8 Whole genome and transcriptome study of stress-tolerant banana cultivars (S. Backiyarani)

It was confirmed the chances of occurrence of variation is less among the Bhimkol clones as these Bhimkol seeds do not have embryos unlike its very close relative Attikol.

The transcriptome data available on drought tolerant genotypes available at ICAR-NRCB has been analysed for annotating the uncharacterized genes. The integrated analysis performed in this work resulted in the assignment of precise or general function(s) to ~85% total of the uncharacterized genes, which would be further used to predict the new features to that protein that might be important for further attempts in deciphering the molecular mechanism of drought tolerance.

4.5.9 Collection, evaluation, documentation and conservation of banana genetic resources from North Eastern region

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

Tissue culture multiplication has been initiated and standardization is in progress for traditional varieties of North Eastern region, Cheeni Champa and Malbhog.

Nutrient and biochemical parameters of the North Eastern accessions are being evaluated in the fruit samples. The nutrient analysis for peel and pulp samples at unripe and ripe stages of eight accessions viz., Attikol, Bhat Manohar, Borkal Baista, Kanai Bansi, Manjahaji, Phirima Wild, Pagalapahad I and Pagalapahad II have been completed. Similarly, the biochemical analysis of the peel and pulp samples at unripe stage of seven accessions Attikol, Bhat Manohar, Kanai Bansi, Manjahaji, Phirima Wild, Pagalapahad I and Pagalapahad II have been completed.

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

(M. S. Saraswathi and S. Backiyarani)

Molecular characterization of the 17 North Eastern cultivars have already been characterized using six IRAP primer pairs under the Institute project. In this project, the study has been extended using 14 ISSR markers and another 4 IRAP markers. The selected ISSR & IRAP markers have produced numerous discrete and reproducible amplicons which will be helpful to find out the genetic variability

among the 17 North Eastern cultivars available in ICAR-NRCB field gene bank. The data analysis and dendrogram construction for both markers are in progress. Shoot tips of *Musa laterita* have been initiated *in vitro* for the production of tissue cultured plants for use in transcriptomic studies against Fusarium wilt (Foc) resistance. The most specific genes for both Foc race 1 and TR4 resistance have been selected and primers for the respective genes (Unigene15980_BXA-1: Somatic embryogenesis receptor kinase 2, CL1173.Contig1_BXA-1: LRR receptor-like serine/threonine-protein kinase FLS2, Unigene22999_BXA-1: Serine/threonine-protein kinase PBS1, Unigene4893_BXA-1: Putative RPM1-interacting protein 4) were synthesized for use in gene expression studies. PCR conditions have been standardized to amplify the full length genes responsible for Foc race1 & TR4 resistance and they will be cloned to sequence and characterize. Similarly, the genes for other biotic stresses viz., nematode and Sigatoka leaf spot resistance will be identified and primers will be designed and synthesized.

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

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

Characterization of wild species of North Eastern origin (26 Nos.) has been completed using ISSR markers, data analysis is in progress. IRAP characterization is in progress. List of wild North Eastern cultivars used for molecular characterization are as follows. 1. *Musa sikkimensis* Type I (627968), 2. *M. nagensium* Type I (627969), 3. *M. itinerans* Type I (627970), 4. *M. nagensium* Type I (627871), 5. *M. acuminata* wild / Khungsong wild (627974), 6. *M. itinerans* Type III (627972), 7. *M. rosaceae* (627976), 8. *M. velutina* variant I (627977), 9. *M. aurantiaca* (627978), 10. *M. velutina* variant II (627979), 11. *M. sikkimensis* Type II (627980), 12. *M. cheesmanii* (627981), 13. *M. ochracea* (627982), 14. Bhimkol (251050), 15. Athiakol (250464), 16. Attikol (250897), 17. *M. ornata* (251137), 18. *M. laterita* (623556), 19. Lairawk, 20. *M. acuminata* Assam (623560), 21. *M. acuminata* Arunachal Pradesh, 22. *M. flaviflora*, 23. Phirima wild, 24. Manohar (250472), 25. Pagalapahad wild I, 26. Pagalapahad wild I.

Shoot tips of Sabri and Amrit sagar have been initiated towards the development of variety specific tissue culture protocols. Pot screening for Fusarium wilt resistance (Race 1) has been initiated for 10 North Eastern wild accessions.

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

(M. S. Saraswathi and S. Uma)

Macropropagation trial for North Eastern cultivars like Bhimkol, Cheeni Champa, Jahaji and Malbhog has been completed and same is in progress for other varieties Kungsong Wild, Manohar, Desi Kadali and Jatikol.

Standardisation of low cost protocol for *in vivo* seed propagation is in progress for North Eastern wild varieties using different media and sowing depths.

The duration of priming has been determined based on the water uptake% for each of the wild species.

4.5.13 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)

Two sets of banana genotypes with 13 genotypes (Chenichampa, Athiakol, Karthobiumtham, Dudhsagar, Agnimalbhog, Jahaji, Nutepong, Kachkel, Honda, Borjahji, Bhimkol, Kechulepa and Digjowa) from ICAR-NRCB gene bank and 20 genotypes (Gobin Tulchi, Suti Jahaji, Honda, Athia, Savari, Balha Kual, Jatikal, Cheni Champa, Simolu Manohar, Grand Nine, Banria, Amrit Sagar, Agni Sagar, Boji Manohar, Digjona, Kachkal, Doodh Sagar, Borjahaji, Bhimkhal and Assamese Malbhog) have been collected from North Eastern region and planted for drought stress evaluation.

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

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

The glycemic index (GI) of seven North Eastern

banana cultivars were worked out and the GIs at full ripe stage were 68 for Champa, 73 for Jahaji, 71 for Malbhog (Fig.65), 67 for Rigitchi, 68 for Kartchikela, 62 for Reybok and 68 for Monaranchi. The fructans contents in fruit pulp of seven cultivars were quantified and among the seven, Rigitchi and Malbhog possessed highest amount of 138 and 125 mg/100 g respectively. Champa, Jahaji, Malbhog and Katchikela contained 116, 113, 112 and 85 mg and Monaranchi contained low amount of 57 mg.

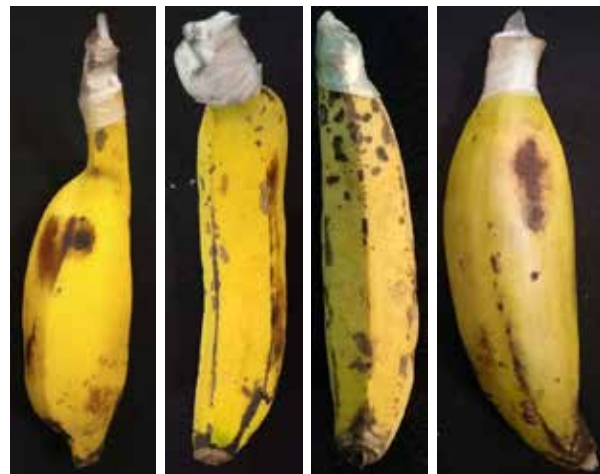


Fig.65. Fruits of some of the North Eastern region banana cvs. at ripe stage; Champa, Jahaji, Malbhog and Monaranchi

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

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

Effect of post-harvest handling on shelf life of Red banana at different maturity level

Red banana of varying maturity viz., 70%, 80% and 90% maturity hands were treated with carbendazim coupled with ethylene absorber and vacuum packaging. With the varying maturity the green life of the banana varied significantly. Higher pulp to peel ratio was observed with the increased maturity. The green life of banana was more than 50 days even with 90% maturity (Table 22 & Fig. 66).



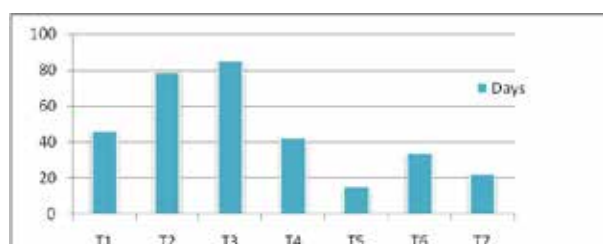
Fig. 66. Red banana with various maturity levels

Table 22. Influence of maturity level on the physico-chemical characteristics of Red banana

Maturity	Pulp Peel Ratio	Caliper (mm)	TSS (°Brix)	Total Sugar (%)	Starch (%)	Green Life (days)
70%	1.43 ± 0.51	40.72 ± 0.52	11.4 ± 0.15	2.68 ± 0.01	19.65 ± 2.17	68 ± 1
80%	1.92 ± 0.03	44.67 ± 1.03	13.3 ± 0.20	2.76 ± 0.01	18.23 ± 2.38	61 ± 1.5
90%	2.27 ± 0.1	51.27 ± 0.89	13.5 ± 0.10	2.71 ± 0.10	18.71 ± 2.24	57 ± 1
S.E±	0.12	0.43	0.38	0.21	0.271	1.65

Evaluation of new molecules and process development for the shelf life of cv. Ney Poovan

Ney Poovan (90% maturity, (Caliper: 28 - 30mm) hands, were treated with NF1, NF 2 and Carbendazim by dipping for 5 -10 mins, coupled with using ethylene, CO₂ and O₂ absorber and packed by vacuum packaging and stored at 13.5°C and room temperature. Use of carbendazim enhanced the green life of banana irrespective of temperature. Low temperature storage exerted enormous influence on the keeping quality of the fruits. Being the green chemical, NF2 has the greater potential to be used in the processing line of fresh banana (Fig. 67).



T1 – NF1 (13.5°C); T2 –NF2 (13.5°C); T3 – Carbendezim (13.5°C); T4 – Control(13.5°C); T5 – NF1 (RT); T6 – Carbendezim (RT); T7 – Control (RT)

Fig.67. Influence of treatments on the shelf life of banana cv. Ney Poovan

Development of colour charts for traditional banana varieties

Colour charts for ripening stages of the traditional varieties (in cold room) were developed. The varieties such as Nendran, Red Banana, Rasthali were good for consumption in the 7th stage of ripening compared to Grand Naine which lose its firmness after 6th stage, whereas, Hill banana, Karpuravalli and Ney Poovan were edible even in the 9th stage in cold room. Unlike Grand Naine where the change of skin colour corroborated with the textural changes in the pulp firmness, the traditional varieties tend to retain the firmness of the pulp in spite of the skin turning its colour.



Fig. 68. Colour chart of ripening stages of banana cultivars

4.5.16 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)

Characterization of North eastern varieties

North Eastern banana cultivars namely Kanai Bans, Ash Monthan, Beeji Kela, Bharat Moni, Attikol (seed), Man Jahaji, Desi Kadali were characterized at mature and ripe conditions. Kanai Bans had highest pulp to peel ratio (2.10 before ripening and 3.10 after ripening), Kanai Bans recorded higher total

starch content (28.54%) compared with other North Eastern banana varieties (Fig. 69).

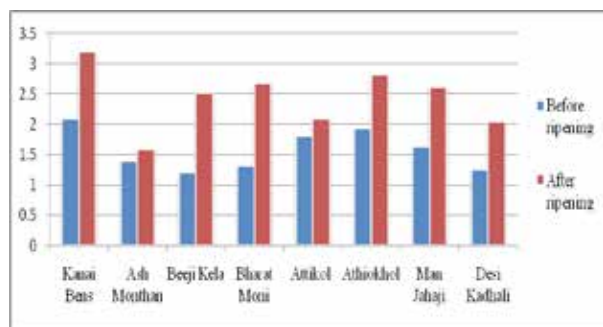
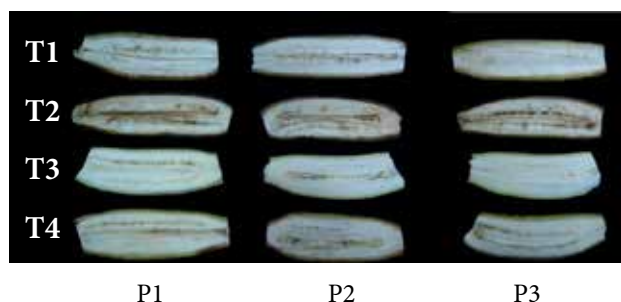


Fig.69. Difference in pulp peel ratio of North Eastern cultivars of banana

Minimal processing of fresh banana

The raw banana (cv. Monthan) was sliced and treated with different treatments. The pre-treatment of the slice with potassium metabisulphite (KMS) at the concentration of 0.5 % was found to be the most effective treatment by for colour retention (whiteness) in all the three different packaging materials at refrigeration ($7\pm1^{\circ}\text{C}$) temperature (Fig.70).



T1-Control (without any treatment);
T2-blanching(60°C to 80°C for 1 to 2mins);
T3-potassium metabisulphite(KMS) (0.5 per cent);
T4-Citric acid (0.5 per cent)

P1-Polyethylene; P2-High-density polyethylene(HDPE); P3-Metallised Polypropylene(MPP)

Fig. 70. Minimal processing of cut banana slices with varying conditions

Utilization of ripe banana powder as functional replacement in doughnut preparation

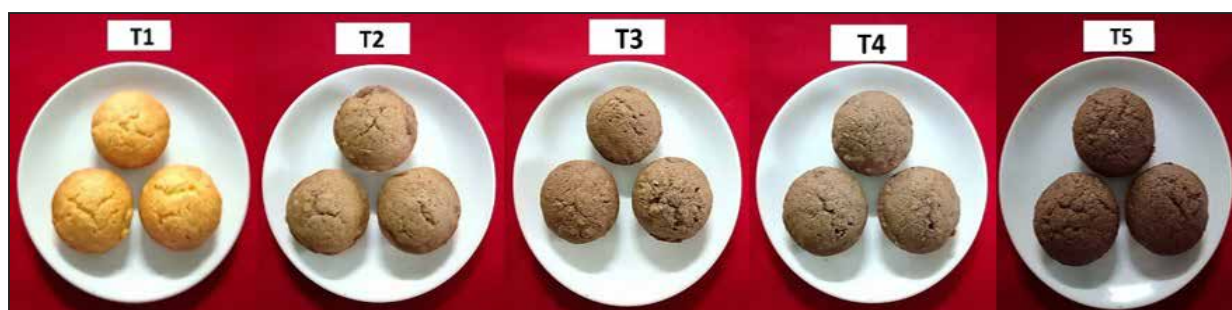
Doughnut is a fermented, fried snack which is characterized by a golden-brown exterior color, a crisp crust, and an inner core that resembles a baked product more than a fried food. Different combinations of banana flour was tried with maida (100:0, 80:20, 70:30 and 60:40). Ripe banana powder could be used as a functional replacement for refined wheat flour (in the ratio of 60:40) for the preparation of doughnut due to the reduction in fat content and calorific value.

Extraction of xylo oligosaccharides from banana peel

14% NaOH extraction along with steam application had superior recovery of xylan (1.65%) from banana peel of cv. Nendran. Further the enzymatic hydrolysis of xylan using commercial endoxylanase enzyme enabled production of Xylo-oligosaccharide.

Dietary fibre rich muffin by incorporating banana peel powder

The specific volume of baked products is considered as one of the most important quality criteria because it provides quantitative measurements of baking performance. The specific volume of the muffins made from addition of 5-7 g of Nendran peel powder with 20 g of banana pulp was the lowest (1.93 and $1.96\text{ cm}^3/\text{g}$). The incorporation of different ratio in NPF improved the specific volume of the muffins.



T1 – Refined flour ; T2 – Refined flour + Nendran peel flour (90:10);
T3 - Refined flour + Nendran peel flour (80:20); T4 – Refined flour + Nendran peel flour (70:30);
T5 – Refined flour + Nendran peel flour(60:40)

Fig. 71. Muffin with varying combinations of peel flour

4.5.17 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)

Water absorbing characteristics of banana fibre

Water absorption is more during initial 24 hours. Karpuravalli (892 %) had higher water absorption characteristics, followed by Grand Naine (816 %) and least was found in Popoulu (685 %). The water absorption capacity of fibers got saturated after 96h (Fig. 72).

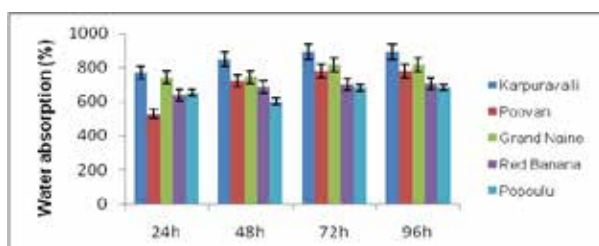


Fig.72. Water absorbing characteristics of banana fibre

X-Ray diffraction studies on banana fibre

X-ray diffraction (XRD) concerning to the different varieties showed that they are similar to other vegetable fibre, which mainly exhibit cellulosic structure. Samples showed peaks related to the characteristic crystal planes of lignocellulosic materials in $2\theta = 22^\circ$ coordinate plane of reflection corresponding to the amorphous portion in microfibrils (Fig.73).

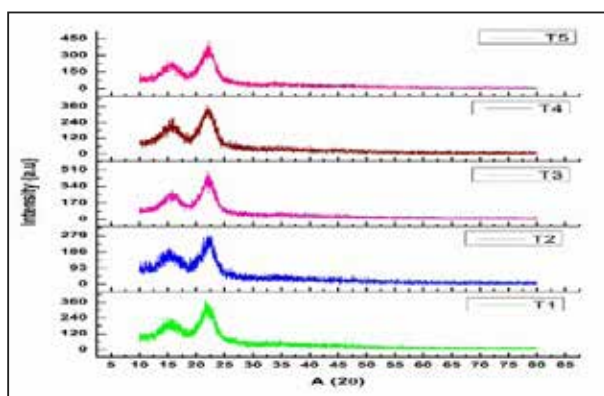


Fig.73. XRD Pattern of treated banana fibre

Adsorptive removal of lead (Pb (II)) using pseudostem fibre of banana

Adsorption of Pb (II) showed a moderate increase in percentage removal up to 90 minutes. At 100 minutes it showed rapid increase and the optimum contact time was reached at 140 minute. After 140 minutes the removal efficiency is maintained. The effect of adsorbent dosage on

adsorption of lead was studied at different dosage rates. 0.5, 1, 1.5, 2 g/0.3 L⁻¹. Maximum removal was at 1.5 g of adsorbent dosage (Fig. 74).

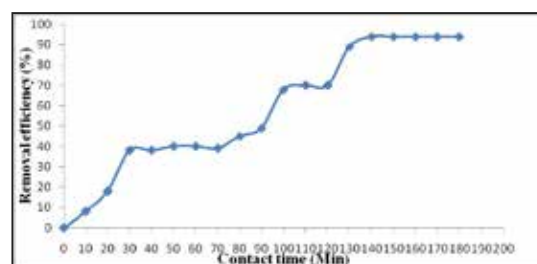


Fig.74. Effect of contact time on Lead(Pb (II)) removal

Model fitting for heavy metal removal using fibres

The maximum removal efficiency data were taken for isotherm studies. Langmuir, Freundlich, Temkin isotherm models were evaluated for equilibrium data. Temkin isotherm fits well with the system with highest correlation coefficient ($R^2 = 0.9942$) (Fig.75).

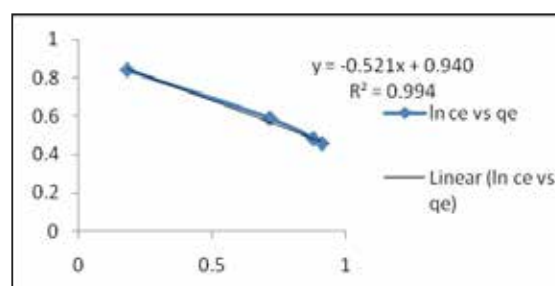


Fig.75. Temkin isotherm adsorption of lead

Extraction of Nano fibrillated cellulose from banana fibre

Nanocellulose being a potential material for medical and cosmetic industries can be obtained from cellulase enzyme. Banana fibre was cut in to small pieces and treated with 5 % NaOH solution. The treated fibre was bleached using sodium hypochlorite and hydrogen peroxide. The nanocellulose was produced using cellulase enzyme.

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

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

Survey undertaken during the period

Survey was conducted in banana growing areas of North Eastern Hill region and collected Banana fruit scarring beetle from Assam (Jorhat), Kamrup District (Kahikuchi, Barthari, Boko, Golaghat Baruahgoan), Goalpara Dt. (Madang), Meghalaya (Riboi (Nongpoh), West Garo Hills (Tura) and East Garo Hills (Umiam).

Collection and identification of volatiles of banana fruit scarring beetle (BFSB) by GC-MS and electrophysiology by GC-EAD

Collected volatiles of BFSB by air-Entrainment out of the 21 compounds identified five compounds belong to attractant volatile chemicals. Fifteen volatile chemicals were recorded from midrib and flag leaf volatiles of cv. Jahaji one compound was recorded as an attractant to insects.

In-vitro screening of Entomopathogenic fungi fungal isolates

Twenty six isolates (with 2 commercial formulations and one control) of Entomopathogenic fungi (*B. bassiana* and *M. anisopliae*) was screened against BFSB under *in vitro* at Jorhat. One potential isolate with 98.0 % mortality has been identified.

In-vitro screening of insecticides / bio-pesticides against BFSB

Nine commercial insecticides were screened against BFSB under *in vitro* at Jorhat. Out of the nine chemicals maximum mortality was recorded in

Chlorpyrifos followed by Fipronil. Three non-edible vegetable oils and one botanical powder (aaviya) were screened against BFSB under *in vitro* at Jorhat; Maximum beetle mortality of 93.33% was recorded in azadirachtin, Neem oil and botanical powder, where as karanj oil and madhuca oil recorded only 33.0 percent mortality.

4.5.19 Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRISPR – Cas9 system

(R. Selvarajan and C. Anuradha)

In silico analysis of whole genomes of banana available in public domain to identify the structure of integrated badna viral sequences

Phylogenetic analysis of conserved RT/RNase H region of banana streak MY virus was done to identify the genomic region to be targeted by CRISPR/Cas-9 approach. By comparison of the conserved genomic regions the potential target of CRISPR/Cas-9 was identified (Fig.76).

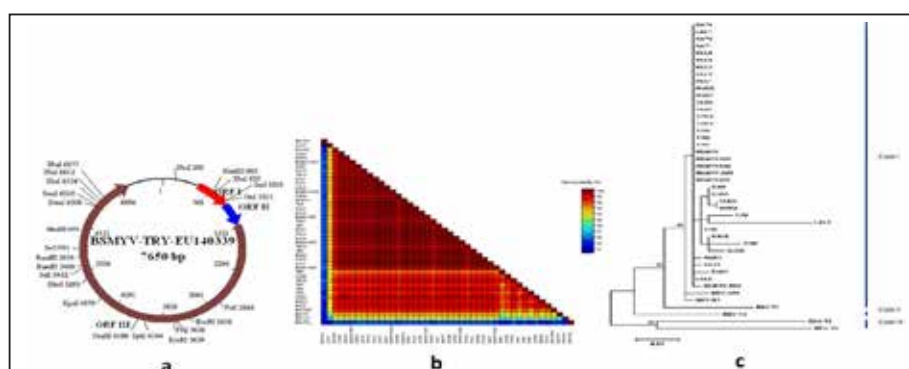


Fig.76. (a) Sequence map of banana streak MY virus and ORF3 genomic region to be targeted by CRISPR/Cas-9 system, (b) Graphical representation of pair wise nucleotide identity (with percentage identity scale) of partial RT/RNase H region of BSMYV isolates, (c) Phylogenetic analysis of the partial RT/RNase H region of amino acid sequences of BSMYV isolates using Maximum Likelihood method

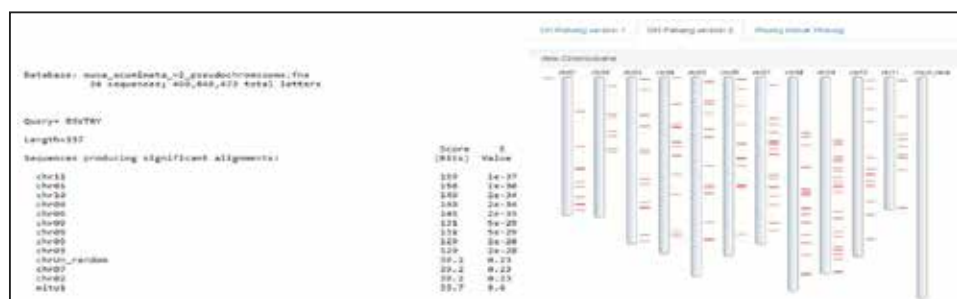


Fig.77. Chromosomal location of integrant BSV in DH Pahang banana genome

The vital 337 bp conserved reverse transcriptase and RNase H region of the banana streak viruses were blasted in the banana genome hub (<https://banana-genome-hub.southgreen.fr/organism/Musa>)

with the whole genome of DH-Pahang (AA) as well as Pisang KlutukWulung (BB). Since the DH Pahang contain only dead sequences of the virus, it may not form live viral genome upon homologous

recombination whereas PKW, a B genome containing clone is an opt target to choose for the *in-silico* analysis as Cheeni Champa (AAB) variety has one B genome in its genomic constitution. The 337bp RT/RNase H region which is being targeted to be mutated lies in four chromosomes (1, 3, 5, 6) in cultivar DH Pahang (Fig.77). In case of PKW, 100 cent homological sequence of RT-RNase H region was located in chromosomes 1, 3, 7 and 10. Further motif-based blast has also been done to choose short genomic RNA for knock out study in Cheeni Champa.

Initiation of Embryogenic cell suspension of banana cv. Poovan (Syn: Cheeni Champa)

In order to develop embryogenic cell suspension of cv. Cheeni Champa (Syn: Poovan) totally 255 virus free Poovan banana male buds (30 per week) were collected, surface disinfected and under a sterile hood, immature male flowers were isolated and used as explants. After two to three months on M1 (MS basal medium and supplemented with 4mg/l 2,4-D, 1mg/l BAP and 1mg/l NAA) medium, yellow nodular callus formed, most frequently on flower rows 5 to 10. A few of embryogenic calli were transferred cell suspension culture medium (M2) (Fig.78).

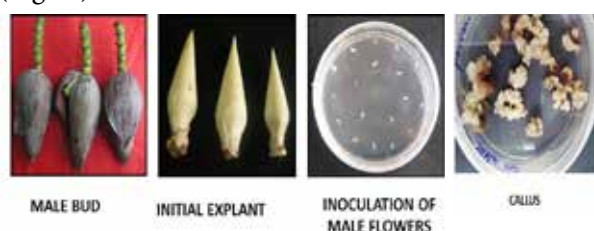


Fig.78. Preparation of embryogenic calli

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

(R. Selvarajan and C. Anuradha)

Hairpin RNAi construct for replicase gene has been developed without any intron and primers were designed for developing RNAi gene constructs targeting three important genes (DNA-R (Master Rep), DNA-M (movement protein) and DNA-N (nuclear shuttle protein) of banana bunchy top virus and developed two strategies, one in cloning using pHannibal vector and the other to clone in pGreen vector.

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

(R. Thangavelu and M. Loganathan)

Leaf spot samples were collected from Jorhat, Assam from banana cv. Malbhog (Silk-AAB) and

the pathogen was isolated and purified. The major pathogen isolated was identified as *Pseudocercospora eumusae*. The other pathogens isolated and characterized were *Veronea musae* and *Cladosporium musae* (Fig.79).

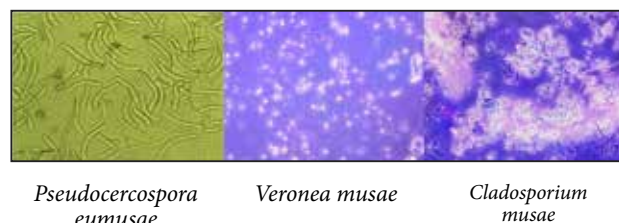


Fig. 79. Leaf spot pathogen isolated from North Eastern region

4.5.21 CRP on vaccines and diagnostics (R. Selvarajan and C. Anuradha)

The Lateral flow immuno assay (LFIA) developed for detection of banana bract mosaic virus (BBrMV) was further validated with 114 samples of commercial banana cultivars collected from different banana growing states of India. The LFIA strip detected BBrMV in bract, young leaf, leaf sheath, flower, seed coat, endosperm and embryo of infected plant. LFIA was also developed for detection of cucumber mosaic virus (CMV) (Fig.80). Multiple pathogens of banana (FocTR-4, BSMYV, CMV, BBrMV) were detected through Nanopore sequencer simultaneously by spiking the Pathogen DNA with DNA from healthy banana. Improvement of dipstick-based detection with a new antiserum of CMV was prepared. Multiplex reverse transcription-recombinase polymerase amplification-based detection system for DNA and RNA viruses, banana bunchy top virus (BBTV) and CMV was standardized. Probes and primers were designed for Nucleic acid based lateral flow kit development of BBTV. Seven thousand five hundred virus free banana tissue culture plants of cultivar Nendran and Hill banana supplied to banana farmers under SC-Sub-Plan.

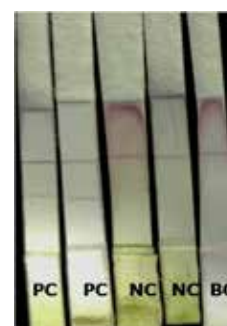


Fig.80. Lateral flow immuno assay developed for detection of CMV: PC; Positive samples, NC; Negative samples, BC; Buffer control

Ready to use indirect ELISA kit for detection of banana bract mosaic virus (BBrMV) and cucumber mosaic virus (CMV)

Indirect ELISA kit was developed by cloning the coat protein of BBrMV and CMV and expressed in bacterial expression vector system and produced polyclonal antiserum. DAC-ELISA was performed using both BBrMV and CMV antibodies. The healthy samples were negative for virus. The indirect ELISA detection kit has been developed for the qualitative detection of BBrMV and CMV in banana samples.



Fig.81. Dr. N. Kumar, Vice Chancellor, TNAU released two ready-to-use ELISA kits for the detection of CMV and BBrMV during National symposium on “Cutting edge approaches for sustainable plant disease management and ensuring farmers’ profit”, organized by IPS (South Zone) and ICAR-NRCB, during 21 – 23 December, 2018

Duplex detection of BBrMV and CMV with a single dipstick

For simultaneous detection of BBrMV and CMV, Lateral flow immunostrip was developed with the gold nanoparticle (GNP) - antibody conjugates. The test zone was formed by the antibodies against the BBrMV and CMV, and the control zone comprised the goat antirabbit immunoglobulins, both of which were dispensed at concentrations. The results were not consistent. Hence, further standardisation of the technology is in progress.

Attempts were made to construct dual expression vector for the expression of coat protein genes of BBrMV and CMV using Gibson Assembly. For the assembly of dual construct, two set of primers were designated to amplify two coat protein gene with a 20–22 nucleotides (nt) overlap region between BBrMV and CMV, and 20 nt overlap between coat protein segments and plasmid. Primer pairs BBrMVFP/BBrMV-RP and CMVFP/CMVRP were used to amplify coat protein gene of BBrMV

and CMV (Fig. 82), respectively, while primer pair pET-28 a (+) FP and pET-28 a (+) RP was used to amplify the pET-28 a (+) expression vector. Coat protein gene of BBrMV and CMV fragments were individually amplified using the Q5 High-Fidelity DNA Polymerase (New England BioLabs, Ipswich, USA). Amplified fragments were analyzed by electrophoresis using agarose gels (1%), individually purified using the GenElute™ Gel Extraction Kit (Sigma, USA), and treated with DpnI restriction enzyme for degradation of methylated plasmid DNA used as template. Coat protein gene of BBrMV and CMV were assembled using Gibson Assembly Cloning Master Mix (New England BioLabs) following the manufacturer’s protocol. Finally, GA products were used to transform chemical competent cells of *Escherichia coli* DH5α strain. Colonies of transformed *E. coli* DH5α were grown on Luria-Bertani (LB) medium at 37 °C for 18 h, and plasmid DNA was extract using the Wizard Plus SV Miniprep DNA Purification System (Promega, Madison, USA). The recombinant clones were confirmed with restriction enzyme digestion analysis. Antibodies will be raised for this dual CP and attempt will be made to develop LFIA in the ensuing year.

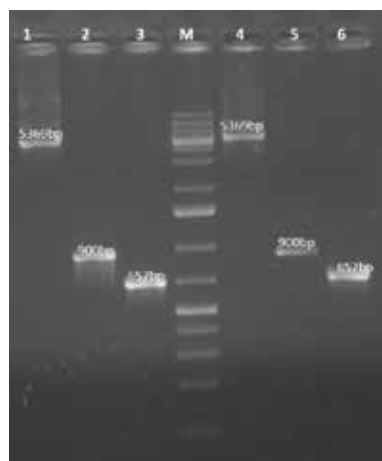


Fig.82. Agarose gel showing PCR products of pET-28 a (+) expression vector, coat protein gens of BBrMV and CMV using Gibson assembly primers for making dual construct. Lane M-1kb DNA ladder plus (Thermofisher); Lanes 1-3: Primer Set I, Lane 1- pET-28 a (+) expression vector primer; Lane 2- BBrMV primer; Lane-3: CMV primer ; Lanes 4-6: Primer Set II, Lane-4: ET-28 a (+) expression vector primer; Lane 5- BBrMV primer ; Lane-6: CMV primer

4.5.22 CHAMAN-Coordinated Horticulture Assessment And Management Using Geoinformatics (Phase-II) – Banana Yield Estimation

(K. J. Jeyabaskaran and D. Ramajayam)

The data on plant growth parameter (height, pseudostem girth, number of functional leaves, *etc.*) and yield parameters (number of hands per bunch, number of fingers per bunch, peduncle girth, bunch weight *etc.*) were collected from 406 banana plants of different banana cultivars grown in ten districts of Tamil Nadu by adopting the guidelines given by the MNCFC. The production and productivity of banana were estimated and the correlation coefficients (*r*) values were worked out among different parameters and different linear regression equations were derived. Using all these equations, a common multi-regression equation was derived as banana yield prediction model. $Y = 0.004 X_1 + 0.046 X_2 + 0.016 X_3 + 0.230 X_4 + 0.012 X_5 + 7.70$, where X_1 -plant height, X_2 -pseudostem girth, X_3 -number of leaves, X_4 -number of hands and X_5 -number of fingers and Y -bunch weight.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Radio talk

Name of the Scientist	Topic	Date of broadcast	Channel
K. N. Shiva	Scientific aspects on value added products of banana	12 April, 2018	All India Radio, Tiruchirappalli
S. Uma	Banana industries in India – An overview	24 April, 2018	
V. Kumar	Live Phone in program on 'Advanced banana cultivation techniques'	27 April, 2018	
R. Selvarajan	Live phone in program on 'Disease free tissue culture banana plants'	12 June, 2018	
D. Ramajayam	Salient findings of ICAR-NRCB	23 May, 2018	
K. J. Jeyabaskaran	Live phone in program on 'Role of soil fertility in banana cultivation'	3 July, 2018	
S. Backiyarani	Live phone in program on 'Novel banana varieties from ICAR-NRCB'	7 August, 2018	
P. Suresh Kumar	Live phone in program on 'Value added products of banana and their utility'	4 September, 2018	
V. Kumar	Live phone in Program on 'Management of banana plantations in <i>Gaja</i> cyclone affected areas'	22 November, 2018	
I. Ravi	Abiotic stresses and their management in banana	29 November, 2018	
M. Mayil Vaganan	Nutritive values and health benefits of banana flower	29 February, 2019	

5.2 Television talk

Name of the Staff	Topic	Date of broadcast	Channel
S. Uma	Varietal wealth of banana	8 June, 2018	Jaya News
S. Uma	Importance of value added products of banana developed at ICAR-NRCB	9 June, 2018	Door Dharshan, Chennai
K. N. Shiva	Value added products from unripe banana / plantain	9 June, 2018	
S. Uma	ICAR-NRCB and activities towards value added products from banana	16 June, 2018	
K.N. Shiva	Value added products from ripe banana	16 June, 2018	
P. Suresh Kumar	Utilization of banana fibre: Market potential	4 August, 2018	
S. Uma	Role of ICAR-NRCB in banana waste utilization	18 August, 2018	
K. N. Shiva	Value added products from waste materials of banana (Wealth generation from waste)	18 August, 2018	
P. Ravichamy	Importance of banana industries	25 August, 2018	Polimer TV
P. Ravichamy	Varieties and value added products of banana	8 January, 2019	ETV

5.3 Exhibitions conducted / participated

Name of the event	Organizer & Venue	Date	Name of the staff participated
Krishi Kalyan Kariyashala	ATMA, Dept. of Agri., Govt. of Pondicherry	2 May, 2018	S. Uma V. Kumar
7 th SICCI Agri Expo and Summit 2018	SICCI in association with ICAR-NRCB, Tiruchirappalli and TNAU, Coimbatore at Tiruchirappalli, Tamil Nadu	8 - 10 June, 2018	V. Kumar P. Durai P. Ravichamy T. Anitha Sree N. Marimuthu V. Selvaraj
Seminar on banana cultivation and marketing	Dept. of Agriculture, Pondicherry	26 July, 2018	V. Kumar K. N. Shiva P. Sureshkumar
ICAR-NRCB's Foundation Day and Kisan Mela	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	31 August, 2018	V. Kumar P. Ravichamy K. Kamaraju
'Kisan Samrudhi Mela	ICAR-SBI & TNAU at Codissia Complex, Coimbatore, Tamil Nadu	24 - 26 August, 2018	V. Kumar P. Ravichamy K. Kamaraju
Agri Expo & Golden jubilee celebration and exhibition	HRS (Dr. YSUHS), Kovvur, Andhra Pradesh at HRS, Kovvur, Andhra Pradesh	8 January, 2019	P. Ravichamy
National Horticultural Fair – 2019	ICAR-IIHR, Bengaluru	23 - 25 January, 2019	V. Kumar P. Ravichamy P. Durai

5.4. Publicity

A total of twenty five press notes on ICAR-NRCB activities and technological information were published in different national and local newspapers and magazines for the benefit of the banana farmers and stakeholders.



District Collector, Tiruchirappalli visits ICAR-NRCB stall during Agri Expo at Tiruchirappalli

6. EDUCATION AND TRAINING

6.1 Students guided

Student Name	Degree	Project title	Chairperson
M. Kannan	National Post Doctoral Fellow (SERB-DST)	Identification of host plant volatiles and odorant binding proteins of antennae of banana stem weevil, <i>Odoiporus longicollis</i>	B. Padmanaban
R. Vinita	M. Sc. (Biotechnology)	Isolation and characterization of entomopathogenic fungi from <i>Musa</i> germplasm	
R. Kavinila	“ “	Characterization of host plant volatiles on the behaviour of banana stem weevil, <i>Odoiporus longicollis</i>	
K. T. Muhammed Aboobacker	“ “	Isolation and characterization of endophytic microorganisms from insect tolerant cultivars	
M. Kalpana	“ “	Gene expression analysis and iron quantification in leaf tissue of Grand Naine and Rasthali banana plants genetically transformed with OsNAS1 gene	M. Mayil Vaganan
G. Anitha	M. Sc. (Biochemistry)	Analysis of flavonoids and their antioxidant activities and inulin-fructans in commercial banana fruits	
D. Naveen	M. Sc. (Food Processing)	Characterization of pectin from banana peel and development of banana peel powder based product (cookies)	K. N. Shiva
B. Pavithra	B. Tech. (Bioinformatics)	Genome-wide analysis of DIR gene and its expression in biotic and abiotic stress in banana through <i>in-silico</i> approach	S. Backiyarani
M. Rajeshwari	“ “	Identification of parthenocarpic candidate genes through literature Derived Protein	
S. Sindhuja	“ “	Identification of parthenocarpic candidate Genes through literature derived protein	
M. Bathrinath	M. Sc. (Biotechnology)	Determination of LD ₅₀ for EMS using ECS explants of banana cv. Ney Poovan	M. S. Saraswathi
K. S. Jasmin	M. Sc. (Food Technology and Quality Assurance)	Standardization of thickness and studying the Influence of hydrcolloids on the preparation of low fat banana chips from different varieties	P. Suresh Kumar
Sherlin Saji	“ “	Nutritional and functional properties of banana center core stem powder and preparation of designer cookies	

Student Name	Degree	Project title	Chairperson
Keerthana Roop	“ “	Preparation of gluten free and dietary fibre rich pizza base with banana flour and modified banana starch	P. Suresh Kumar
P. P. Ribu Dilshad	“ “	Studies on the utilisation of banana waste (peel) for the preparation of biodegradable polymeric film	
T. Arul Pandian	M. Sc. (Food Processing)	Characterization and functional enrichment of muffin with banana peel flour	

6.2 Trainings

6.2.1. On-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Use of banana fibre for making handcrafts	P. Suresh Kumar	55	6 April, 2018
Training on 'Improved production and post-harvest technologies in Nendran banana' to the officials of VFPC, Kerala	V. Kumar K. N. Shiva	10	3 - 7 July, 2018
Training on 'Banana chips, flour and flour based soup mix, biscuits and extraction of fiber'	K. N. Shiva	1	3 - 7 September, 2018
Training cum exposure program on 'Improved production and post-harvest technologies in banana' to farmers from Akola	K. N. Shiva V. Kumar	30	24 - 26 September, 2018
Training on 'Post-harvest handling, packing, storage and ripening in banana for domestic and export markets'	K. N. Shiva	1	5 - 7 December, 2018
Training on 'Practices for the production of innovative banana chips'	K. N. Shiva	1	28 - 29 January, 2019
Training on 'Banana fruit and central core (stem) juice / RTS beverage and stem pickle'	K. N. Shiva	1	27 February - 2 March, 2019
Hands on training on 'Banana micropropagation'	M. S. Saraswathi	5	7 - 9 May, 2018, 9 - 10 July, 2018 17 - 24 December, 2018
Internship program on 'Application of molecular techniques in crop improvement'	S. Backiyarani	2	5 June - 4 July, 2018
Internship program on 'Tissue culture and molecular techniques'	S. Backiyarani	1	6 - 21 June, 2018

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	No. of participants	Date
Production of quality planting material through 'Macropropagation' in banana to officials of State dept. of Horticulture, Tripura	M. S. Saraswathi	35	24 April, 2018
Training cum workshop for 'Banana fruit crop' to farmers, organized by ATMA, Solapur Dt., Maharashtra at Sri Guruseva Mangal Karyasala, Kandar village, Karmala Taluk, Solapur, Maharashtra	B. Padmanaban R. Thangavelu V. Kumar K. N. Shiva	100	7 - 8 February, 2019



Scientists of ICAR-NRCB with VFPC (Kerala) trainees of training on 'Improved production and post-harvest technologies in Nendran banana'



Trainees from Akola, Maharashtra under ATMA scheme at ICAR-NRCB

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
ICAR - NRCB	'Special appreciation certificate' from ICAR, New Delhi for the effective management of data repository in KRISHI portal
R. Selvarajan	'Jeersannidhi Award' by Indian Phytopathological Society at National symposium on 'Recent challenges and opportunities in sustainable plant health management' held at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi on 28 February, 2019
	'Fellow of Horticultural Society of India' (FHSI) at 8 th Indian Horticulture Congress-2018, IGKV, Raipur during 17 - 21 January, 2019
	'Best poster award' at National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21- 23 December, 2018
I. Ravi	'J C Bose best scientist award' from Bose Science Society under the Charter of TNSRO (Tamil Nadu Scientific Research Organisation, TNSRO), Affiliated with Vigyan Prasar, Department of Science and Technology, Government of India, New Delhi
K. N. Shiva	'Best poster award' at 'XIV Agricultural science congress' held at National Agricultural Science Complex, New Delhi during 20 - 23 February, 2019
M. S. Saraswathi	'CHAI fellow' at CHAI meet held at Pusa, New Delhi during 28 - 31 May, 2019
	'Fellow of Horticultural Society of India' (FHSI) at 8 th Indian Horticulture Congress-2018, IGKV, Raipur during 17 - 21 January, 2019
P. Suresh Kumar	'Best poster award' at National conference cum Krishi Unnati Mela held at KVK, Namsai, Arunachal Pradesh during 17-18 November, 2018
C. Anuradha	'Best oral presentation award' at National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21- 23 December, 2018
	'Post doctoral research fellow' at CTCB, Queensland University of Technology, Brisbane, Australia
	'Endeavour Fellowship – 2018' by Department of Education and Training, Australian Government
M. Kumaravel S. Uma M. S. Saraswathi	'ISHS Young Minds Award' for best poster presentation at ISHS - Promusa symposium held at Istanbul, Turkey during 12-16 August, 2018
P. Ravichamy	'Excellence in communication award' for outstanding contribution in the field of Journalism at National conference on 'Promoting & reinvigorating Agri - Horti technological innovations' held at Jaipur, Rajasthan during 15 -16 December, 2018
	'Best poster award' at National conference on 'Farmers orientation towards climate change & upgrading to sustainable agriculture' (FOCUS-2019) held at National college, Tiruchirappalli during 23 - 24 February, 2019



R. Selvarajan, Principal Scientist, ICAR-NRCB receiving 'Jeersannidhi Award'



R. Selvarajan, Principal Scientist, ICAR-NRCB receiving 'Fellow of Horticultural Society of India' Award



R. Thangavelu, Principal Scientist, ICAR-NRCB at 11th International Congress of Plant Pathology (ICPP) 2018



M. S. Saraswathi, Principal Scientist, ICAR-NRCB receiving 'Fellow of Horticultural Society of India' Award



M. Kumaravel, Research Scholar, ICAR - NRCB receiving ISHS Young Minds Award'



ICAR-NRCB receiving Best Poster Award at ISHS - Promusa symposium held at Istanbul, Turkey

7.2 Recognitions

Name of the Scientist	Details
S. Uma	Selected as steering committee member of World Banana Forum, a program of FAO
	Local consultant for EU funded banana project to be operative at KUL, Leuven, Belgium
	India's representative & presented lead paper at International society for horticultural science (ISHS)- Promusa symposium held at Istanbul, Turkey during 12-16 August, 2018
	Country representative for BAPNET, Philippines
	SCM – Investor consultative Meeting on 'Agri. marketing and agri. Business' held at Chennai on 20 September, 2018
	Panel Member – CII – Tamil Nadu state council for Agri. food processing and millet panel (2018-19)
	Expert member in the selection committee meeting held at CREED-KVK, Ariyalur on 29 May, 2018
	Organizer, Brainstorming discussion on banana fiber at ICAR-NRCB, Tiruchirappalli on 10 May, 2018
	Presided over the meet on 'Banana export to EU' with Tamil Nadu Banana Federaiton at ICAR-NRCB on 24 July, 2018
	Lead lecture, International conference on 'Recent Advances in Food Processing Technology (ICRFPT-18)' held at IIFPT, Thanjavur on 19 August, 2018
	Expert member, IBSC meet at Bharathidasan University, Tiruchirappalli on 15 October, 2018
	Board member, IIFPT, MoFP &I, Thanjavur
	Member, DBT project monitoring team on tissue culture banana in Tripura
	Team leader, Export expert team of ICAR-NRCB to undertake banana export to Europe via sea route
	Organizer, 'Sensitization meet on Fusarium wilt TR-4 in Banana' at ICAR-NRCB, Tiruchirappalli on 26 November, 2018
	Organizer, National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
	Expert member, Dean & Registrar (TNAU) selection committee meet at TNAU, Coimbatore during 9 – 10 January, 2019
	Lead talk at 8 th Indian Horticulture Congress-2019 held at IGKVV, Raipur, Chhattisgarh during 17-21 January, 2019
	Chief guest at 'Pre-rabi season campaign' for Karur organized by SKVK, Karur, Tamil Nadu on 22 January, 2019
	Chairperson, technical session and Co-Chairperson for one session at 6 th group discussion meet of ICAR-AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Chief guest, National conference on 'Farmers orientation towards climate change & upgrading to sustainable agriculture' (FOCUS-2019) held at National college, Tiruchirappalli on 23 February, 2019
	Organizer, one day workshop on 'Arabi to Banana : Potential & fruitful research project' at ICAR-NRCB, Tiruchirappalli on 13 March, 2019
	Member, NABARD project review meet held at KNCET, Thottiam, Tamil Nadu on 14 March, 2019
	Guest lecture on 'Women in Agriculture' at NIT, Tiruchirappalli on 20 March, 2019
	Chief guest, Inauguration of Dinamani's (Tamil daily) 'Higher Education Fair' held at Tiruchirappalli on 23 March, 2019
	Organizer, workshop on 'Krishi Portal' at ICAR-NRCB, Tiruchirappalli on 26 March, 2019

Name of the Scientist	Details
B. Padmanaban	Convener for session at 6 th group discussion meet of ICAR-AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Member Secretary, RAC & QRT, ICAR-NRCB, Tiruchirappalli
	Co-Chairman for one session at International conference on 'Recent Advances in Food Processing Technology (ICRFPT-18)' held at IIFPT, Thanjavur during 17 - 19 August, 2018
	Co-Chairman for one session at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
J. Poorani	Convener for one session at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
	Co-chairman one session at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
R. Thangavelu	India's representative to attend satellite meeting on Tropical race 4 of <i>Fusarium</i> wilt disease of banana in the 11 th International Congress of Plant Pathology (ICPP) 2018, held at Boston, USA from July 28 to August 3, 2018
	Chairman, one session at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
	Organizing Secretary for National workshop on 'Sensitization of tissue culture industries in preventing the spread of newly emerging disease – <i>Fusarium</i> wilt (Tropical Race 4) of banana' held at ICAR-NRCB, Tiruchirappalli on 26 November, 2018
	Co-Organizing secretary, National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit', organized by IPS (South Zone) and ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018
	Councillor, (Southern Zone) - Indian Phytopathological Society - 2018
	Lead lecture on 'Fusarium wilt – Tropical Race 4 – A threat to banana production in India' at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
R. Selvarajan	President (Southern Zone) - Indian Phytopathological Society - 2018
	Organizing secretary, National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit', organized by IPS (South Zone) and ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018
	Lead lecture on 'Virus diagnostics and impact of certification for banana and plantains' at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
	Organizing Secretary, Careers in plant pathology – A special interactive workshop held at ICAR-NRCB on 22 December, 2018
	Member, program committee, INTERVIROCON 2018: International Conference on "Global Viral Epidemics: A Challenging Threat" held at PGIMER Chandigarh during 10 - 14 November, 2018
	Chairperson, Viruses and small RNAs in INTERVIROCON 2018: International Conference on "Global Viral Epidemics: A Challenging Threat" held at PGIMER Chandigarh from 10-14 th November 2018
	Lead lecture on 'A critical appraisal on the virus indexing method adopted for Banana streak viruses' at INTERVIROCON 2018: International Conference on "Global Viral Epidemics: A Challenging Threat" held at PGIMER Chandigarh during 10 - 14 November, 2018
	Jury member for award of young scientist contest in International Virology conference (INTERVIROCON, 2018) held at PGIMER, Chandigarh during 12- 14 November, 2018

Name of the Scientist	Details
R. Selvarajan	Co-Chairman, one technical session at 6 th group discussion meet of ICAR-AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Chief guest to inaugurate the function and deliver Inaugural address in Biofest' 2K19 on the future prospectus of Life Sciences held at Department of Biotechnology, Bioinformatics and Nutrition and Dietetics, Bishop Heber College, Trichy on 25 January, 2019
	Invited lecture at CAFT training on 'Frontier technology for future profitable and sustainable agriculture' at Dept of Agronomy, TNAU on 8 December, 2018
	Co-organizer, Regional krishi portal workshop held at ICAR-NRCB, Trichy on 25 March, 2018
	Doctoral committee member, Department of genetic engineering, SRM University, Kattankulattur, Chennai and Faculty of Agriculture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur
	External examiner, ICAR-CTCRI, Sreekariyam, Thiruvananthapuram and Sri Ramachandra Medical College and Research Institute, Chennai
M. Mayil Vaganan	Delivered key note lecture at the International conference on 'New vistas in biological sciences' at Holy Cross College, Tiruchirappalli, Tamil Nadu on 11 September, 2018
	Delivered talk on 'Biofortification of iron in bananas by expression of <i>Oryza sativa</i> nicotianamine synthase genes' at International Conference on 'Next generation plant production and bioresources utilisation technologies' at the Indian Institute of Technology, Guwahati, Assam during 11 - 13 February, 2019
	Convener, workshop on 'Arabi to banana: Potential and fruitful research projects' held at ICAR-NRCB, Tiruchirappalli on 13 March, 2019
I. Ravi	Moderator during Entrepreneurs & Technocrats session on the occasion of brainstorming meeting on "Banana fiber: Research needs for commercial exploitation" held at ICAR-NRCB on 18 May, 2018
	Judge, best poster presentation at International conference on climate change, biodiversity and sustainable agriculture (ICCBSA-2018) held at AAU, Jorhat during 13 - 16 December, 2018
	Co-chair, one technical session at International conference on climate change, biodiversity and sustainable agriculture (ICCBSA-2018) held at AAU, Jorhat during 13 - 16 December, 2018
	Rapporteur, National seminar on 'Abiotic stress management: Challenges and opportunities' during 25 - 26 October, 2018 at TNAU, Coimbatore
	ICAR representative, recruitment of subject matter specialist, RVS-KVK, Tenkasi on 15 May, 2018
	ICAR representative, recruitment of driver posts for ICAR-KVK, Saraswathi on 3 July, 2018
K. J. Jeyabaskaran	Lead paper presentation at National conference on 'Strategies & challenges in doubling farmers' income through horticultural technologies in Subtropics' held at ICAR-CISH, Lucknow during 21-22 June, 2018
K. N. Shiva	Member, organizing committee, Brainstorming meet on 'Banana fibre: Research needs for commercial exploitation' held at ICAR-NRCB, Trichy on 10 May, 2018
	Moderator for one session at Brainstorming meet on 'Banana fibre: Research needs for commercial exploitation' held at ICAR-NRCB, Trichy on 10 May, 2018
	Expert - Export of 'Grand Naine' Bananas to Europe (Italy)
	Convener for a technical session during the National symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit", organized by IPS (South Zone) and ICAR-NRCB, Tiruchirappalli, Tamil Nadu, India during 21 - 23 December, 2018
	Member, organizing committee, Brainstorming meet on 'Banana fibre: Research needs for commercial exploitation' held at ICAR-NRCB, Trichy on 10 May, 2018
	Moderator for one session at Brainstorming meet on 'Banana fibre: Research needs for commercial exploitation' held at ICAR-NRCB, Trichy on 10 May, 2018

Name of the Scientist	Details
K. N. Shiva	Expert - Export of 'Grand Naine' Bananas to Europe (Italy)
	Convener for a technical session during the National symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit", organized by IPS (South Zone) and ICAR-NRCB, Tiruchirappalli, Tamil Nadu, India during 21 - 23 December, 2018
	Nominated as crop expert (Banana) for facilitating and supporting the production and export banana in Puducherry.
	Lead presenter at 6 th group discussion of ICAR-AICRP on Fruits held at AAU, Jorhat, Assam on 15 February, 2019
	Served as a reviewer for Indian Journal of Horticulture
	Evaluated one Ph. D. thesis of Calicut University, Kerala
S. Backiyarani	Lead talk at 8 th Indian Horticulture Congress-2019 held at IGKV, Raipur, Chhattisgarh during 17-21 January, 2019
	Delivered a lecture on "Development of genome specific and parthenocarpic markers in banana" for the training program on "Application of molecular markers in crop breeding" under CAFT in PBG held at TNAU on 3 December, 2018
	Delivered lecture on "Biotechnological interventions in enhancing the production of horticulture crops" at the National seminar cum workshop on 'Innovations and implementation of modern technologies in Agriculture & Horticulture' held at Department of Biotechnology, Selvam Arts and Science College, Namakkal on 23 November, 2018
	Member, Board of Studies in bioinformatics for M.Sc., (Biotechnology) - An integrated course of Bishop Heber College, Tiruchirappalli
	Served as external examiner two M. Sc. theses from TNAU, Coimbatore
S. Uma S. Backiyarani M. S. Saraswathi	Technical consultants - Tripura Biotechnology Council, Tripura
M. S. Saraswathi	Covenor for one session at National symposium on 'Cutting edge technologies for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21-23 December, 2018
	Reviewed research paper submitted to PLoS; South African Journal of Botany; Indian Journal of Horticulture
	External examiner one Ph. D. thesis from TNAU, Coimbatore
	Evaluated six M. Sc. and two Ph. D. theses from UAS, Dharwad and TNAU, Coimbatore
M. Loganathan	Convener in organizing National Symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit, held during December 21-23, 2018 at ICAR- NRCB, Tiruchirappalli.
	Co-organizing Secretary for organizing one day workshop on "Careers in Plant Pathology – A special Interactive workshop" conducted at ICAR-NRCB, Tiruchirappalli on 22 December, 2018.
	Co-organizing Secretary for National workshop on 'Sensitization of tissue culture industries in preventing the spread of newly emerging disease – <i>Fusarium</i> wilt (Tropical Race 4) of banana' held at ICAR-NRCB, Tiruchirappalli on 26 November, 2018.
P. Suresh Kumar	Reviewer - <i>Scientia Horticulturae</i> , Journal of Food Science & Technology; Indian Journal of Horticulture; International Journal of Food Properties; Innovative Food Science and Emerging Technologies; Journal of Food processing and preservation
	Thesis evaluation to one Ph.D. and one M.Sc. from KAU, Thrissur, Kerala External examiner to one Ph.D. student from KAU, Thrissur, Kerala
	Rapporteur at Section on Action taken Report in the 6th Group Discussion of AICRP Fruits at AAU, Jorhat from 14-16th February, 2019

Name of the Scientist	Details
P. Suresh Kumar	Convenor, one session at 6th Group discussion of AICRP (Fruits) held at AAU, Jorhat during 14-16 February, 2019
	Management representative ISO 9001: 2015
	Technical expert for the Export of Grand Naine Banana from Theni to Italy
	Associate editor - 5 th Group Discussion on ICAR-AICRP (Fruits), Research report -2017. ICAR-IIHR, Bengaluru, Tech Doc. No. 120. Pp. 283
	Associate editor - Annual Report 2017-18 ICAR-AICRP (Fruits), ICAR-IIHR, Bengaluru, Tech Doc. 122. Pp 128.
	Member - Organizing committee ICAR- Krishi Portal a central research data repository on 25 March 2019.
P. Giribabu	Rapporteur for a session at workshop on 'Appraisal of QRT team on ICAR-AICRP on fruits held at ICAR-NRCB, Tiruchirappalli on 20 December, 2018
	Rapporteur at consultative meeting on 'Quarantine and biosafety issues relating to Fusarium wilt Tropical race - 4: An emerging threat to banana cultivation in India' held at ICAR-NRCB, Tiruchirappalli on 21 December, 2018
	Rapporteur for one session at National Symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit" held at ICAR-NRCB, Tiruchirappalli on 21 December, 2018.
	Rapporteur, QRT meet, ICAR-NRCB on 25 February, 2019
C. Anuradha	Reviewer - Journal of Plant Pathology, Virus Disease, The Open Virology Journal
	Member, organizing committee at National symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit" held at ICAR-NRCB, Tiruchirappalli on 21 December, 2018
	Convener for one session at National symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit" held at ICAR-NRCB, Tiruchirappalli on 21 December, 2018
	Rapporteur for a session during National Symposium on "Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit" held at ICAR-NRCB, Tiruchirappalli on 21 December, 2018
	Rapporteur, QRT meet, ICAR-NRCB on 25 February, 2019
	Rapporteur, workshop on "Sensitization of TC Industries in preventing the spread of newly emerged disease – Fusarium wilt TR-4" held at ICAR-NRCB, Trichy on 26 November, 2018
P. Ravichamy	'Certificate for life membership awarded by Madhumitha Foundation (Hyderabad, Telangana State) and Academy of Environment & Life Science Society (Agra, U.P.) during National conference on "Promoting & Reinvigorating Agri-Horti, Technological Innovations" (PRAGTI-2018) at Jaipur, Rajasthan during 15 - 16 December, 2018

8. LINKAGES AND COLLABORATIONS

Project Title	Collaborating Institute(s)
'Knowledge Partner' in developing technologies towards value chain management, supporting banana export, organic production and waste utilization	Government of Andhra Pradesh
Developing imaging systems, electronic devices, solar energy applications in agriculture, nanotechnology and other fields by enlisting the students for internship and post graduate research programmes	NIT, Tiruchirappalli, Tamil Nadu
Developing various instruments for banana production and value addition	ICAR-CIAE (Regional Centre), Coimbatore, Tamil Nadu
Developing biosensors and imaging technology for pest detection, portable cable car conveyor system for the transportation of harvested bunches and to promote green technology through utilization of solar power and other fields	KNCET, Thottiyam, Tamil Nadu
Development of protocol for sea shipment of banana to Gulf countries	APEDA, Bengaluru & M/s. Fair Exports India Ltd., Kochi
Development of non chimera mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	DAE, Mumbai, Maharashtra
Assessment of post-harvest losses in banana	ICAR-AICRP on Fruits centers viz., Jalgaon, Kannara and Kovvur
Improvement of banana for smallholder farmers in the great lakes region of Africa - Enhancing banana production by developing fusarium wilt-resistant varieties and benefit sharing with african smallholder	IITA, Nigeria; Bioversity International, France; NARO, Tanzania; University of Malaya; SLU, Sweden; Stellenbosch University, South Africa; Cornell University, USA; KUL, Belgium; University of Queensland, Australia; Nelson Mandela African Institution of Science and Technology, Tanzania; Institute of Experimental Botany, Czech Republic and EMBRAPA, Brazil

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, Aizwal, Mizoram Assam Agricultural University, Jorhat, Assam
Collection, evaluation, documentation and conservation of banana genetic resources from NE region	Indian Institute of Technology, Guwahati, Assam Tamil Nadu Agricultural University, Coimbatore ICAR-Indian Institute of Horticulture Research, Bengaluru
Diversity assessment, germplasm conservation and database development on banana resources in NE India	Institute of Advanced Study in Science and Technology (IASST), Guwahati, Assam ICAR Research Complex for NEH region, Umiam, Meghalaya
Whole genome and transcriptome study to stress tolerant banana cultivars	N.V.Patel College of Pure and Applied Science, Gujarat Utkal University, Bhubaneswar, Odisha
Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRISPR – Cas9 system	Tripura University, Suryamaninagar, Tripura National Botanical Research Institute, Lucknow Jawaharlal Nehru Tropical Botanic Garden & Research Instt., Thiruvananthapuram
Molecular dissection of defense against Sigatoka infection in banana - Exploitation of <i>Musa</i> germplasm of NE for development of Sigatoka resistant hybrid	Kohima Science College, Jotsoma, Nagaland Nagaland University, Medzhiphema, Nagaland Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal
Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	Patkai Christian College, Dimapur, Nagaland North Eastern Regional Instt. Of Science and Technology, Nirjuli, Arunachal Pradesh
Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	Nagaland University, Lumami, Nagaland Gauhati University, Guwahati, Assam TERI School of Advanced Studies, New Delhi
Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	The Energy and Resource Institute, New Delhi ICAR – National Bureau of Plant Genetic Resources, New Delhi
<i>In vitro</i> mass propagation of high value hill area banana	PSG College of Technology, Coimbatore College of Agriculture, Lembucherra, Tripura Regional Plant Resource Centre, Bhubaneswar, Odisha
Characterization of high value phyto-chemicals of anti diabetic and immune-modulatory properties in NE banana varieties	ICAR- Research Complex for NEH Regional, Nagaland Centre – Dimapur, Nagaland Jawaharlal Nehru University, New Delhi West Bengal State University, Kolkata
Development of pre & post harvest bunch care management methods for fresh banana	ICAR Research Complex for NEH Regional, Manipur Centre, Imphal, Manipur Sikkim University, Gangtok, Sikkim
Genetic resource assessment, <i>in-situ</i> conservation and impact of banana waste as a feed for animals in NE region of India	Guru Nanak Dev University, Amritsar, Punjab North East Hill University, Tura Campus, Meghalaya Translational Health Science and Technology Institute, Faridabad
Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	Assam down Town University, Guwahati, Assam Institute of Life Science, Bhubaneswar, Odisha Indian Institute of Technology, Kharagpur
Management of low temperature and soil moisture deficit stresses in banana growth in NE India	Tezpur University, Naapam, Assam College of Veterinary Science, Khanapara, Guwahati National Bureau of Plant Genetic Resources – Regional Station, Shillong
Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	National Bureau of Plant Genetic Resources – Regional Station - Hyderabad

9. PUBLICATIONS

9.1 Research Papers

International

- Anuradha, C. and Selvarajan, R. 2018. Molecular characterization of banana bract mosaic virus from India reveals recombination and positive selection in the VPg gene. *Journal of Plant Pathology*. **100**: 523–531.
- Backiyarani, S., Chandrasekar, A., Uma, S. and Saraswathi, M. S. 2019. Musatrans SSRDB (a transcriptome derived SSR database) – An advanced tool for banana improvement. *Journal of Biosciences*. **44**: 4. <https://doi.org/10.1007/s12038-018-9819-5>.
- Ganga Devi, P. and Thangavelu, R. 2019. Development of species specific SCAR based molecular marker for the detection of *Pseudocercospora eumusae*, the causal agent of eumusae leaf spot disease in banana. *Journal of Plant Pathology*. **101**(2): 295 - 305. <https://doi.org/10.1007/s42161-018-00204-3>.
- Kumaravel, M., Uma, S., Backiyarani, S., Saraswathi, M. S. and Mayil Vaganan, M. 2019. Molecular analysis of somatic embryogenesis through proteomic approach and optimization of protocol in recalcitrant *Musa* spp. *Physiologia Plantarum*. DOI:10.1111/ppl.12966.
- Manohar Jebakumar, R. and Selvarajan, R. 2018. Biopriming of micropropagated banana plants at pre- or post-BBTV inoculation stage with rhizosphere and endophytic bacteria determines their ability to induce systemic resistance against BBTV in cultivar Grand Naine. *Biocontrol science and technology*. **28**(11): 1074–1090.
- Muthusamy, M., Uma, S., Backiyarani, S., Saraswathi, M. S. and Chandrasekar, A. 2018. Genome-wide identification of novel, long non-coding RNAs responsive to *Mycosphaerella eumusae* and *Pratylenchus coffeae* infections and their differential expression patterns in disease resistant and sensitive banana cultivars. *Plant Biotechnology Reports*. **13**(1): 73 – 83. <https://doi.org/10.1007/s11816-018-00514-z>.
- Muthuswamy, M., Uma, S., Backiyarani, S., Saraswathi, M. S. and Chandrasekar, A. 2018. Drought stress modulated alternative splicing landscapes in drought tolerant and sensitive banana cultivars. *Current Analysis on Biotechnology*. **1**: 1-7.
- Neethi Baruah, Ashok Bhattacharyya, Thangavelu, R. and Puzari, K. C. 2018. *In vitro* screening of native banana rhizospheric microbes and endophytes of Assam against *Fusarium oxysporum* f. sp. *cubense*. *International Journal of Current Microbiology and Applied Sciences*. **7**(6): 1575-1583.
- Poorani, J., Padmanaban, B. and Thanigairaj, R. 2019. Natural enemies of banana lacewing bug, *Stephanitis typica* (Distant) in India, including first report of *Anagrus* sp. (Hymenoptera: Mymaridae) as its egg parasitoid. *Munis Entomology & Zoology*, **14**(1): 83-87.
- Saraswathi, M. S., Uma, S., Sharmila Gayatri, D., Soundaryan, R., Jithu, G., Bahrudeen, S. H., Durai, P. and Backiyarani, S. 2019. Comparison of two different electrophoretic methods in studying the genetic diversity among plantains (*Musa* spp.) using ISSR markers. *Electrophoresis*. **40**: 1265-1275. DOI: 10.1002/elps.201800456.
- Shiva, K. N., Adiyaman, P., Ravindra Naik and Marimuthu, N. 2018. Development and standardization of banana pseudostem based novel functional blended ready to drink (RTD) beverages and studies on nutritional changes during storage. *International Journal of Life Sciences*. **7**(3): 151-158.
- Suman, R., Kalaimathi, K., Palanichamy, S., Sowmiya, R., Mayil Vaganan, M., Ravi, I. and Uma, S. 2018. Anti-cancerous activities of anthocyanins of banana cv. Nendran (*Musa* sp.) flower bracts against human colon and cervical cancer cell lines. *International Journal of Current Microbiology and Applied Sciences*. **7**(12): 2786-2793.
- Suresh Kumar, P., Eyarkai Nambi, V., Shiva, K. N., Mayil Vaganan, M., Ravi, I., Jeyabaskaran, K. J. and Uma, S. 2019. Thin layer drying kinetics of banana var. Monthan (ABB): Influence of convective drying on nutritional quality, microstructure, thermal properties, colour and sensory characteristics. *Journal of Food Process Engineering*. DOI: 10.1111/JFPE.13020.
- Thangavelu, R. and Ganga Devi, P. 2018. Rapid and sensitive detection of *Pseudocercospora eumusae* pathogen causing eumusae leaf spot disease of banana by loop-mediated isothermal amplification (LAMP) method. *Biotech*. **8**: 442-852. <https://doi.org/10.1007/s13205-018-1468-8>.

Thangavelu, R., Mostert, D., Gopi, M., Ganga Devi, P., Padmanaban, B., Molina, A. B., Viljoen, A. 2019. First detection of *Fusarium oxysporum* f. sp. *cubense* tropical race 4 (TR4) on Cavendish banana in India. *European Journal of Plant Pathology*. <https://doi.org/10.1007/s10658-019-01701-6>.

National

Alagesan, A., Tharani, G., Padmanaban, B., Sivaramakrishnan, S. Manivannan. 2018 . Kairomones from highly susceptible host to control banana pseudostem weevil, *Odoiporus longicollis* (Olivier). *Journal of Biocatalysis and Agricultural Biotechnology*. **16**: 655 – 662.

Aruna, R., Srinivasan, M. R., Balasubramanian, V. and Selvarajan, R. 2018. Complete genome sequence of sacbrood virus isolated from Asiatic honey bee, *Apis cerana indica* in India. *Virus Disease*, **29**(4): 453-460.

Bisane, K. D., Patil, N. M., Padmanaban, B., Saxena, S. P. and Prakash Patil. 2018. Technique for management of banana red rust thrips, *Chaetanophothrips signipennis* (Bagnall). *Journal of Entomology and Zoology studies*. **6**(5): 1964-67.

Jeyabaskaran, K. J., Pitchaimuthu, R. and Uma, S. 2018. Assessing nutrient uptake pattern with respect to dry matter accumulation in Ney Poovan (AB) banana at critical growth stages. *Indian Journal of Horticulture*. **75**(3): 405-412.

Manohar Jebakumar, R., Balasubramanian, V. and Selvarajan, R. 2108. Virus titre determines the efficiency of *Pentalonia nigronervosa* (Aphididae: Hemiptera) to transmit banana bunchy top virus. *Virus Disease*. **29**(4): 499-505.

Palanichamy, S., Padmanaban, B., Mayil Vaganan, M. and Uma, S. 2019. Electrophysiological and behavioural responses of banana pseudostem weevil, *Odoiporus longicollis* (Olivier) (Coleoptera: Curculionidae) to aggregation pheromone, 2-methyl-4-heptanol and host plant kairomones, *Current Science*. **116**(10):1753 - 1757.

Praveena, M., Surya Prabha, M., Ravi, I. and Mayil Vaganan, M. 2018. Anti-colorectal cancer properties of Hill Banana (cv. Virupakshi AAB) fruits: An *in-vitro* assay. *Indian Journal of Natural Sciences*. **8**(47): 13226-13233.

Ravi, I., Kamaraju, K., Sawan Kumar, K. and Sri

Sailaja Nori. 2018. Evaluation of sea weed bio formulations on yield and yield parameters of banana cv. Grand Naine (AAA). *Indian Journal of Natural Sciences*. **8**(47): 13482-13488.

Ravichamy, P. and Siva Balan, K. C. 2019. Socio-economic status and impact of mass media exposure on banana farmers: A case study. *Journal of Pharmacognosy and Phytochemistry*. **8**(2): 422-426.

Ravichamy, P., Siva Balan, K. C. and Nanda Kumar, S. 2019. A study on diffusion of farm technologies through electronic media among the banana farmers in Tamil Nadu. *Journal of Pharmacognosy and Phytochemistry*. **8**(2): 853-858.

Tharani, G., Alagesan, A., Backiyarani, S., Anitha sree, T., Sundararaju, R. and Manivannan, S. 2018. Cloning of the defense gene PlchiIII and its potential role in the biocontrol of *Pratylenchus coffeae* nematodes and *Meloidogyne incognita* eggs in *Musa*. *Biocatalysis and Agricultural Biotechnology*. <https://doi.org/10.1016/j.bcab.2018.10.004>.

Thirugnanavel, A., Saraswathi, M.S., Backiyarani, S., Uma, S., Durai, P. and Vignesh Kumar, B. 2018. Evaluation of genetic variability in wild *Musa* spp. suitable for ornamental value, *Current Horticulture*. **6**(2): 12–16.

Venkataraman, S. and Selvarajan, R. 2019. Recent advances in understanding the replication initiator protein of the ssDNA plant viruses of the family Nanoviridae. *Virus Disease*. [10.1007/s13337-019-00514-9](https://doi.org/10.1007/s13337-019-00514-9).

9.2 Popular articles

Kumar, V., Jeyabaskaran, K. J. and Uma, S. 2018. Reviving of banana plants affected by Gaja cyclone – ICAR-NRCB's suggestion (Tamil). *Dinamalar* (Tamil daily) dated 18 November, 2018.

Kumar, V., Jeyabaskaran, K. J. and Uma, S. 2018. How to revive banana plantations affected by Gaja cyclone (Tamil). *Daily Thanthi* (Tamil daily) dated 19 November, 2018.

Kumar, V., Jeyabaskaran, K. J. and Uma, S. 2018. How to revive banana plants uprooted by Gaja cyclone (Tamil). *Dinakaran* (Tamil daily) dated 19 November, 2018.

Kumar, V., Jeyabaskaran, K. J. and Uma, S. 2018. A helping hand to Gaja cyclone affected banana

growers. *The Hindu* (English daily) dated 22 November, 2018.

Kumar, V., Jeyabaskaran, K. J. and Uma, S. 2018. Maintenance of Gaja cyclone affected banana plantation (Tamil). *Valarum Vivasaya Thamizhagam*, December, P. 37-38.

Kumar, V., Jeyabaskaran, K. J. and Uma, S. 2018. Revive the Gaja affected banana (Tamil). *Kalki*, December. P. 62.

Mayil Vaganan, M., Ravi, I., Palanichamy, S. and Uma, S. 2018. Banana flower bract anthocyanins are health-promoting natural food colorants. *Beverage and Food World*. **45**(5): 24-27.

Padmanaban, B. and Uma, S. 2018 Management of banana aphid to prevent the spread of BBTv in banana (Tamil). *Vanoli Uhzavar Sanga Seithikathir*. August. P. 40.

Shiva, K. N. and Suresh Kumar, P. 2018. Recent advances in postharvest care of banana (Tamil). In: *District level seminar on recent advances in banana cultivation*. National Horticulture Mission, DDH, Thanjavur, Tamil Nadu. P. 37- 40.

Shiva, K. N., Suresh Kumar, P. and Uma, S. 2018. Banana fiber for prosperity (Tamil). In: *Naveena Velan Thozhilnutpangal*. ICAR-NRCB, Tiruchirappalli, Tamil Nadu. P. 70.

Shiva, K. N., Suresh Kumar, P. and Uma, S. 2018. Value added by-products from banana (Tamil). In: *Naveena Velan Thozhilnutpangal*. ICAR-NRCB, Tiruchirappalli, Tamil Nadu. P. 72.

Siva balan, K. C., Ravichamy, P. and Nithila, S. 2018. The role of information and communication technology in the climate changes of farming community (Tamil). *Malarum Velanmai*. **17**(12): 56-60.

Uma, S., Saraswathi, M. S., Backiyarani, S. and Durai, P. 2018. Introducing Saba – A high yielding new banana variety, suitable to all banana growing regions. *The Hindu* (Tamil daily) dated 2 August, 2018.

Uma, S., Saraswathi, M. S., Backiyarani, S. and Durai, P. 2018. New banana variety released by ICAR - NRCB. *Dinathanthi* (Tamil daily) dated 19 July, 2018.

Uma, S., Saraswathi, M. S., Backiyarani, S. and Durai, P. 2018. Introducing 'Saba' – A drought tolerant new banana cultivar. *Dinamalar* (Tamil daily) dated 22 July, 2018.

9.3 Books / Book chapters

Ravi, I., Mayil Vaganan, M. and Praveena, M. 2018. Role of microbes in soil moisture deficit stress alleviation in banana. (Eds. P. Jeyakumar *et al.*) In: *Abiotic stress management for sustainable agriculture*. Dept. of Crop Physiology, TNAU, Coimbatore. Thannamikai Publications, Coimbatore. Pp. 163-168.

Selvarajan, R., Anuradha, C., Balasubramanian, V., Elayabalan, S. and Prasanya Selvam, K. 2018. Viruses infecting banana and their transgenic management. *Genes, genetics and transgenics for virus resistance in plants* (Edited by: Basavaprabhu L. Patil). Caister Academic Press, U.K. Pp. 255-276.

Shiva, K. N., Suresh Kumar, P. and Kamaraju, K. 2018. Codex standards in banana. In: *Training manual on Improved production and post-harvest technologies in Nendran banana* (Eds. K. N. Shiva, V. Kumar and S. Uma). ICAR-NRCB, Tiruchirappalli, Tamil Nadu. P. 43-48.

Shiva, K. N., Suresh Kumar, P. and Kamaraju, K. 2018. Value addition in banana. *Ibid.* P. 49-51.

Shiva, K. N., Suresh Kumar, P., Kumar, V. and Kamaraju, K. 2018. Pack house facilities and operations for banana. *Ibid.* Pp. 40-42.

Shiva, K. N., Suresh Kumar, P., Kumar, V., Kamaraju, K. and Uma, S. 2018. Harvest and post-harvest handling, packing, storage and ripening techniques in banana. *Ibid.* Pp. 29-39.

Suresh Kumar, P., Shiva, K. N. and Uma, S. 2018. Problems and prospects of export of Indian bananas. *Ibid.* Pp. 52-57.

Suresh Kumar, P., Shiva, K. N., Mayil Vaganan, M. and Uma, S. 2018. Functional, designer and future food products from banana. *Ibid.* Pp. 58-63.

Thangavelu, R. and Arthee, R. 2019. Fusarium wilt – A destructive disease in banana with special emphasis on tropical race 4 and its possible management. *Wilt Diseases of Crops* (Eds: Ashok Bhattacharyya, B.N. Chakraborty, R.N. Pandey, Dinesh Singh and S C. Dubey). Today and Tomorrow Printers and Publisher, New Delhi. India. Pp. 197-252.

Thangavelu, R., Loganathan, M., Saraswathi, M. S., Backiyarani, S., Selvarajan, R., Padmanaban, B. and Uma, S. 2018. Fusarium wilt – Tropical Race 4: An emerging threat to banana cultivation in India. In: *Souvenir of "Cutting edge approaches for sustainable plant disease management and*

ensuring farmers profit” (Eds. R. Selvarajan, R. Thangavelu, J. Poorani., M. Loganathan., V. Balasubramaniann and S. Sundaram). ICAR-NRCB and Indian Phytopathological Society (South Zone). Pp.143-144.

Thomas, J. E., Selvarajan, R., M-L Iskra-Caruana, L.V., Magnaye and Jones, D. R. 2018. Bract mosaic. *Handbook of diseases of Banana, Abaca and Ensete*. (Eds. D. R. Jones) CAB International. Pp. 376-378.

Uma, S., Raju Karthic, Kumaravel, M., Backiyarani, S. and Saraswathi, M. S. 2019. High-throughput technology for mass production of quality planting material in banana. *Shaping the future of Horticulture* (Eds. K.L.Chadha, S.K.Singh, Jai Prakash and V.B.Patel). Kruger Brentt. Pp. 35-39.

Vignesh Kumar, B., Backiyarani, S., Saranya, S., Saraswathi, M. S., Durai, P., and Uma, S. 2018. Application of information system in conventional breeding: QR code based banana breeding tracker (BBT) for real-time analysis of the breeding information. *Advancements in agriculture research*. (Eds. Geetha, S. and Ramakrishnan, P., Agrobios (India). ISBN: 978-81-937537-7-4. Pp. 3-9.

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

Loganathan, M., Thangavelu, R., Padmanaban, B. and Uma, S. 2019. Status of rhizome and pseudostem wet rot diseases of banana. *International Journal of Current Microbiology and Applied Sciences*. DOI: 10.20546/ 2019.805.089.

Selvarajan, R., Thangavelu, R., Loganathan, M., Poorani, J., Balasubramanian, V., Sundaram, S. and Uma, S. 2018. Souvenir / Book of abstracts. *National symposium on ‘Cutting edge approaches for sustainable plant disease management and ensuring farmers’ profit’*. Organised by Indian Phytopathological Society (South Zone Chapter) and ICAR-NRCB, Tiruchirappalli during 21-23 December 2018. P.215.

Suresh Kumar, P., Shiva, K. N., Mayil Vaganan, M. and Uma, S. 2018. Waste utilization and functional foods from Banana. *Indian Horticulture*. **63**(4): 43-46.

Uma, S. and Suresh Kumar, P. 2018. Improving livelihood security of banana farmers. In:

National conference on ‘Strategies & challenges in doubling farmers income through horticultural technologies in subtropics’ held at ICAR-CISH, Lucknow during 21 - 22 June, 2018. Pp. 74-77.

Uma, S. and Suresh Kumar, P. 2018. New paradigms in banana production and utilization for improved livelihood. (Eds. H. P. Singh, R. C. Srivastava, Dhiraj Sharma and Babita Singh) In: *Intensification and diversification in Agriculture for livelihood and rural development*, ASM Foundation, New Delhi. **10**(344): 141- 156.

Uma, S., Mayil Vaganan, M., Saraswathi, M. S., Suresh Kumar, P. and Giribabu, P. (Eds.) 2018. *Success stories: Flagship technologies of ICAR-NRCB*, ICAR-National Research Centre for Banana, Tiruchirappalli, Tamil Nadu. (ICAR-NRCB technical bulletin No. 36).

9.5 Training manuals

Kumar, V. and Uma, S. 2018. Hi-tech banana cultivation for enhancing the production and productivity of quality bananas. ICAR-NRCB, Tiruchirappalli.

Selvarajan, R., Loganathan, M. and Thangavelu, R. 2018. Careers in Plant Pathology - A special interactive workshop. ICAR-NRCB, Tiruchirappalli and Indian Phytopathological Society (South Zone). P.16.

Shiva, K. N., Kumar, V. and Uma, S. 2018. Technical know-how of ‘Post-harvest handling, packing, storage and ripening in banana for domestic and export markets. ICAR-NRCB, Tiruchirappalli. P. 46.

Shiva, K. N., Kumar, V. and Uma, S. 2018. Improved production and post-harvest technologies in ‘Nendran’ banana. ICAR-NRCB, Tiruchirappalli. P. 63.

Shiva, K. N., Suresh Kumar, P. and Kamaraju, K. 2018. Technical know-how of technical know-how of banana chips, flour and flour based biscuit, soup mix and extraction of fiber. ICAR-NRCB, Tiruchirappalli. P. 36.

Shiva, K. N., Suresh Kumar, P. and Kamaraju, K. 2018. Technical know-how of technical know-how of banana chips. ICAR-NRCB, Tiruchirappalli. P. 33.

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

9.6.1 International

Giribabu, P., Anuradha, C., Anitha Sree, T., Padmanaban, B. and Uma, S. 2018. Isolation

- and molecular identification of native entomopathogenic nematode, *Steinernema siamkayai* Stock, Somsook & Reid, 1998 (Tylenchida: Rhabditidae). In: International symposium on 'Innovations and advancements in agriculture and plant sciences (IAAPS-2018)' held at DSAC, Perambalur, Tamil Nadu on 23 May, 2018.
- Giribabu, P., Anuradha, C., Anitha Sree, T., Padmanaban, B. and Uma, S. 2018. Isolation, identification and evaluation of native isolate of entomopathogenic nematode, *Heterorhabditis indica* Poinar, Karunakar and David, 1992 (Tylenchida: Rhabditidae) against banana stem weevil, *Odoiporus longicollis* (Olivier) (Coleoptera:Curculionidae). In: First international conference on 'Biocontrol (ICBC-2018)' held at Bengaluru during 27 - 29 September, 2018.
- Mayil Vaganan, M., Palanichamy, S., Sowmiya, R., Ravi, I. and Uma, S. 2018. Microencapsulation of anthocyanins from banana flower bracts using freeze and spray drying for nutraceuticals. In: International conference on 'Recent advances in food processing technology (iCRAFPT-18)' held at IIFPT, Thanjavur during 17 - 19 August, 2018.
- Mayil Vaganan, M., Sivagandhi, C., Ganesan, S., Kumaravel, M., Ravi, I., Jeyabaskaran, K. J., Backiyarani, S. and Uma, S. 2019. Iron biofortification in bananas by expression of *Oryza sativa* nicotianamine synthase genes. In: International conference on 'Next generation plant production and bioresources utilisation technologies' held at IIT, Guwahati, Assam during 11-13 February, 2019.
- Padmanaban, B., Suresh Kumar, P., Shiva, K. N., Kannan, M. and Uma, S. 2018. GC - MS profiling of central stem of commercial banana cultivars and its role on renal protection. In: International conference on 'Recent advances in food processing technology (iCRAFPT-18)' held at IIFPT, Thanjavur during 17 - 19 August, 2018.
- Ravi, I., Mayil Vaganan, M. and Kamaraju, K. 2018. Impact of soil moisture deficit stress and its alleviation in banana cv. Grand Naine. In: International conference on 'Climate change, biodiversity and sustainable agriculture (ICBSA-2018)' held at AAU, Jorhat during 13-16, December, 2018.
- Ravi I., Mayil Vaganan, M., and Uma, S. 2018. Climate change and its impact on banana production. *Ibid.*
- Selvarajan, R. 2018. A critical appraisal on the virus indexing method adopted for banana streak viruses. In: International conference on 'Global viral epidemics: A challenging threat (INTERVIROCON 2018)' held at Chandigarh during 10-14 November, 2018.
- Suresh Kumar, P. 2019. Phenolic composition, antioxidant and anticancer properties of banana peel of variety Nendran. In: International conference on 'Recent advances in food processing technology (iCRAFPT-18)' held at IIFPT, Thanjavur during 17 - 19 August, 2018.
- Vignesh Kumar, B., Backiyarani, S., Saranya, S., Saraswathi, M. S., Durai, P., and Uma, S. 2018. Application of information system in conventional breeding: QR code based banana breeding tracker (BBT) for real time analysis of the breeding information. In: International symposium on 'Innovations and advancements in agriculture and plant sciences (IAAPS-2018)' held at DSAC, Perambalur, Tamil Nadu on 23 May, 2018.

9.6.2 National

- Anuradha, C. and Selvarajan, R. 2018. Structural analysis of eukaryotic initiation factor 4E gene interacting with VPg of banana bract mosaic virus in banana. In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.
- Anuradha, C., Upendra Shekhawat and James Dale 2018. Identification of *Fusarium oxysporum* f. sp. *cubense* race 1 resistance gene candidates in cavendish bananas. *Ibid.*
- Backiyarani, S., Thangavelu, R., Saraswathi, M. S., Durai, P., Selvaraj, V. and Uma, S. 2019. Success of banana polyploidy breeding in India. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.
- Elayabalan, S. Subramaniam, S. and Selvarajan, R. 2018. Current updates on plant diseases and management practices in hilly areas of Tamil Nadu. In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.

- Giribabu, P., Thangavelu, R. and Anitha Sree, T. 2018. Evaluation of biocontrol agents against root-lesion (*Pratylenchus coffeae*) and root-knot (*Meloidogyne incognita*) nematodes infecting banana (*Musa* sp.). *Ibid*.
- Jeyabaskaran, K. J. 2019. Developing yield estimates for banana. In: Workshop cum discussion for finalising the work plan of Phase-II of the CHAMAN project held at IARI, New Delhi on 24 January, 2019.
- Jeyabaskaran, K. J., Pitchaimuthu, R. and Uma, S. 2018. Nutrient budgeting in recycling of residues of Ney poovan (AB) banana. In: National conference on 'Strategies and challenges in doubling farmers' income through horticultural technologies in Subtropics' held at ICAR-CISH, Lucknow during 21-22 June, 2018.
- Jeyabaskaran, K. J., Suresh Kumar, P. and Uma, S. 2018. Improved livelihood security of banana farmers. *Ibid*.
- Loganathan, M., Thangavelu, R. and Padmanaban, B. 2018. Survey, isolation and characterization of rhizome rot of banana. In: National Symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit, held at ICAR- NRCB, Tiruchirappalli during December 21 - 23, 2018.
- Manoranjitham, S. K., Muthulakshmi, P., Selvarajan, R., Prakash Patil and Soorianathasundram, K. 2018. PCR assay for screening of germplasm entries for major banana viruses. *Ibid*.
- Mayil Vaganan, M., Amala Claret, E., Palanichamy, S., Padmanaban, B., Ravi, I. and Uma, S. 2019. Red Banana (*Musa* sp., AAA) peel as a functional food. In: National symposium on 'Nutraceuticals and functional foods' held at IIFPT, Thanjavur on 30 January, 2019.
- Mayil Vaganan, M., Sowmiya, R., Palanichamy, S., Backiyarani, S., Suresh Kumar, P., Ravi, I. and Uma, S. 2019. Characterisation of banana flower bracts anthocyanins for utilising as a potential health promoting functional food ingredient. *Ibid*.
- Padmanaban, B., Thangavelu, R., Baskar, N., Backiyarani, Selvaraj, V. and Uma, S. 2018. Association of endophytic entomopathogenic fungi in *Musa* germplasm. In: National Symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit, held at ICAR- NRCB, Tiruchirappalli during December 21 - 23, 2018.
- Padmanaban, B., Poorani, J., Thangavelu, R., Loganathan, M., Baskar, N., Asif, K. K. and Uma, S. 2018. Entomopathogenic fungal association with banana fruit scarring beetle, *Nodostoma subcostatum* (Jac.) (Chrysomelidae: Coleoptera) in the management of the pest. *Ibid*.
- Ravi, I. and Mayil Vaganan, M. 2018. Low light ameliorates soil moisture deficit stress in banana. In: Souvenir and abstract book on National seminar on 'Abiotic stress management: Challenges and opportunities' held at TNAU, Coimbatore during October 25-26, 2018.
- Ravi, I. and Selvarajan, R. 2018. Physiological changes of banana streak virus infected banana cv. Poovan (AAB). In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.
- Ravichamy, P. 2019. Role of print media as communication channel on transfer of technology for banana farmers in Tamil Nadu. In: National conference on 'Farmers orientation towards climate change and upgrading to sustainable agriculture (FOCUS-2019)' held at National College, Tiruchirappalli during 23-24 February, 2019.
- Ravichamy, P. and Shiva balan, K. C. 2019. Socio-economic status and impact of mass media exposure on banana farmers: A case study. *Ibid*.
- Ravichamy, P., Siva balan, K. C., Nandakumar, S. and Uma, S. 2018. A study on dissemination of disease management through electronic media among the banana farmers in Tamil Nadu. In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.
- Renganathan, R., Jain Sarah Jacob, Suresh Kumar, P., Shiva, K. N. and Uma, S. 2018. Formulation and optimization of nutrient enriched pasta by incorporating banana flour and chana powder. In: National seminar On 'Promoting pulses for food, nutrition and health security - The way forward'(NSPPF-2018) held at AC & RI (TNAU), Madurai during 27- 28 September, 2018.

- Saravanan A., Suresh Kumar, P., Shiva, K. N. and Uma, S. 2018. Varietal influence on physico-chemical characterization and total α -amylase activity of banana flour. In: India International Science Festival-2018 held at IGP, Lucknow during 5-8 October, 2018.
- Saravanan, A., Amelia Karan, D., Suresh Kumar, P., Shiva, K. N. and Uma, S. 2019. Resistant starch in green banana as a prebiotic source for pasta. In: National symposium on 'Nutraceuticals and functional foods' held at IIFPT, Thanjavur on 30 January, 2019.
- Selvarajan, R. 2018. Field - usable lateral flow immuno-assay kit for the rapid detection of cucumber mosaic virus (CMV) Infecting banana and plantains. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.
- Selvarajan, R. and Balasubramanian, V. 2018. Virus diagnostics and impact of certification for banana and plantains. In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.
- Selvarajan, R., Balasubramanian, V. and Soorianathasundram, K. 2018. Rapid and sensitive detection of banana bunchy top virus and cucumber mosaic virus in single tube using isothermal reverse transcription-recombinase polymerase amplification. *Ibid.*
- Selvarajan, R., Prasanya Selvam, K. and Balasubramanian, V. 2018. Rapid and sensitive lateral-flow immuno assay (LFIA) test for on-site detection of banana bract mosaic virus. *Ibid.*
- Subesh Kumar, P., Backiyarani, S., Mariadoss, A., Selvaraj, V., Saraswathi, M. S. and Uma, S. 2018. Molecular markers as a tool for the identification of banana hybrids. In: India International Science Festival-2018 held at IGP, Lucknow during 5-8 October, 2018.
- Suresh Kumar, P. 2019. Functional characterization of flour and starch of different banana varieties. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.
- Suresh Kumar, P., Shiva, K. N. and Uma, S. 2018. Prebiotic and functional products from banana and waste utilization. In: National conference on 'Intensification and diversification in agriculture for livelihood and rural development' held at DRPCA, Pusa, Bihar during 28-31 May, 2018.
- Suresh Kumar, P., Shiva, K. N., Mayil Vaganan, M., Ravi, I. and Saravanan, A. 2019. Functional characterization of flour and starch of different banana varieties. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.
- Thangavelu, R., Loganathan, M., Saraswathi, M. S., Backiyarani, S., Selvarajan, R., Padmanaban, B. and Uma, S. 2018. Fusarium wilt - Tropical Race 4: An emerging threat to banana cultivation in India. In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.
- Uma, S. and Suresh Kumar, P. 2018. New paradigms in banana production and utilization for improved livelihood. In: National conference on 'Intensification and diversification in agriculture for livelihood and rural development' held at DRPCA, Pusa, Bihar during 28-31 May, 2018.
- Vignesh Kumar, B., Backiyarani, S., Mariadoss, A., Selvaraj, V., Durai, P., Saraswathi, M. S. and Uma, S. 2019. Characterization and development of dichotomous key using information system for banana hybrids. In: '8th Indian Horticulture congress - Shaping future of Indian Horticulture' held at IGKVV, Raipur, Chattisgarh during 17-21 January, 2019.
- Vignesh Kumar, B., Backiyarani, S., Rekha, A., Saraswathi, M. S., Thangavelu, R. and Uma, S. 2018. Parental polymorphic survey for Fusarium wilt (race 1) resistance in banana. In: National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' held at ICAR-NRCB, Tiruchirappalli during 21 - 23 December, 2018.
- Vignesh Kumar, B., Backiyarani, S., Chandrasekar, A., Durai, P., Saraswathi, M. S. and Uma, S. 2018. A user friendly *Musa* germplasm database for easy identification of banana accessions. In: India International Science Festival-2018 held at IGP, Lucknow during 5-8 October, 2018.

Yogeshwar Singh, Nangare, D. D., Suresh Kumar, P., Mahesh Kumar and Singh, N. P. 2018. Potential of dragon fruit crop for rocky barren lands and water scarce areas of India. In: National conference on 'Intensification and diversification in agriculture for livelihood and rural development' held at DRPCA, Pusa, Bihar during 28-31 May, 2018.

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

Poorani, J. 2018. Image gallery on insect pests of bananas and plantains in India. URL: <http://nrcb.res.in/album/>.



Release of technical bulletin 'Success Stories: Flagship technologies of ICAR-NRCB (Hindi)' during ICAR-NRCB foundation day



Release of ICAR-NRCB Newsletter during QRT visit

10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

Consultancy Services / Contract Research / Commercialization of Technologies

I Consultancy Services / Contract Research				
S. No.	Date	Name of the Technology	Address of the Client	Revenue (Rs. in Lakhs)
1	14 June, 2018	Evaluation of Paraffinic oil for the management of leaf spot diseases of banana cv. Grand Naine.	M/s. Raj Petro Specialities Pvt. Ltd., 2A-D, Doshi Towers, 156, Poonamallee High Road, Kilpauk, Chennai, Tamil Nadu	4.32
2	10 October, 2018	Supply of quality tissue cultured planting material of banana cv. Sabri	Tripura Biotechnology Council, Dept. of Science, Technology and Environment, Govt. of Tripura	30.00
II Commercialisation of Technologies				
1	3 September, 2018	Banana flour, flour based biscuits, chips, soup mix and fibre extraction	Aditi Priya, L-232, Jal Vayu Vihar, Noida Sector 25, Uttar Pradesh - 201 301	0.60
2	7 December, 2018	Post-harvest handling, packing, storage and ripening of banana for domestic and export markets	HT Ragha Universal Exports Medhol T.K., Bagalkot, Karnataka	0.25
3	2 March, 2019	Banana juice [ready to serve (RTS) beverage], Central core stem juice (RTS beverage) and Central core stem pickle	B.S. Harikumar, Santhi Nilayam, Thevalapuram (Po), Puthoor, Kottarakara, Kollam-6918507, Kerala	0.60
4	2 March, 2019	Banana fruit and central core (stem) Juice / RTS beverage and stem pickle	Mr. B.S. Harikumar (Chairman, M/s Biootique), Santhi Nilayam, Thevalapuram, P.O., Puthoor, Kottarakara, Kollam – 691 507, Kerala	0.60
5	29 January, 2019	Banana chips	Mr. P.C. Surendran, Kianarullaparampil, Keezhariyoor Post, Kozhikode - -673 307, Kerala	0.10

III	Other Services		
1.	Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants	Virus indexing of mother plants and mother cultures and tissue culture raised banana plants	34.56
2.	Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants	797 batches of tissue culture plants (Grand Naine, Williams, Robusta, Ney Poovan, Red banana, Quintal Nendran, Sabri etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports issued.	14.10
3.	Supply of Antisera	Production and sale of polyclonal antiserum for banana viruses viz., cucumber mosaic virus (CMV), banana bract mosaic virus (BBrMV) and banana bunchy top virus (BBTV) to various State Agricultural Universities	1.36
4.	Tamil Nadu banana Export to Europe	Technical consultant for export of traditional banana fruits to Europe by TNBGF, Thottiyam, Tamil Nadu.	Honorary
5.	Insect identification service	Insect identification services were given to students and researchers of institutions viz., ICAR-IIVR, Varanasi; ICAR-CPCRI, Kasaragod; ICAR-NBAIR, Bangalore; UAHS, Shivamogga; ADAC & RI (TNAU), Tiruchirappalli; IGKV, Raipur; Annamalai University, Chidambaram	Honorary

Signing of MoUs / MoCs / MoAs

MoU was signed by ICAR-NRCB with Tamil Nadu banana growers federation (TNBGF), Greeners' Agro, Tiruppur and SMV Exports, Theni for banana export and sent banana through DP world, Cochin Port, Kerala



Dr. S. Uma, Director, ICAR-NRCB signing MoU with Tripura Biotechnology Council for supply of quality tissue cultured planting material of banana cv. Sabri



Drs. A. K. Singh, DDG (Horti. Sci.), ICAR, S. Uma, Director, ICAR-NRCB and other dignitaries at flag off ceremony for export of banana to Europe

11. RAC/ IRC / IMC MEETS

IRC meet

22nd Institute research council meet was held during 5, 12 and 23rd October, 2018. Scientists of the centre presented salient research achievements of institute as well as externally funded projects of 2018 and the technical program for 2019. Scientific discussions were held and recommendations were made.



Scientists of ICAR-NRCB at IRC meet

IMC meet

24th Institute management committee meet was held at ICAR-NRCB on 23rd May and 6th October, 2018. Salient research achievements made by the centre during 2018 were presented which were appreciated by the members. Director, ICAR-NRCB briefed about the infrastructural developments taken place during the last year, and various issues pertaining to IMC were deliberated and discussed in the meet.



IMC members at ICAR-NRCB

QRT meet

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



QRT members with Scientists, ICAR-NRCB

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

Human Resource Development

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

Name of the Staff	Name of the program	Venue	Date
I. Ravi, Principal Scientist	Advanced bioinformatics tools and its applications in agriculture	ICAR- NAARM, Hyderabad	25 - 29 September, 2018
C. Anuradha, Scientist	Biosafety training online conducted by QUT office of ethics and integrity	QUT, Brisbane, Australia	20 April, 2018

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

Name of the Staff	Event	Venue	Date
All staff of ICAR-NRCB	ISO 9001: 2015 meeting	ICAR-NRCB, Tiruchirappalli	18 April, 2018
	Brainstorming meet on "Banana fibre: Research needs for commercial exploitation"	" "	10 May, 2018
	ICAR-NRCB foundation day	" "	21 August, 2018
	National workshop on 'Sensitization of tissue culture industries in preventing the spread of newly emerging disease - Fusarium wilt (Tropical Race 4) of banana'	" "	26 November, 2018
	National symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmer's profit' organized by Indian Phytopathological Society (South Zone Chapter) and ICAR-NRCB	" "	21 - 23 December, 2018
	One day workshop on Arabi to Banana: Potential & Fruitful Research Projects	" "	13 March, 2019
	One day workshop on 'ICAR- KRISHI Portal – A Central Research Data Repository'	" "	25 March, 2019
S. Uma B. Padmanaban R. Thangavelu V. Kumar K.J. Jeyabaskaran S. Backiyarani K. N. Shiva P. Suresh Kumar	6 th Group Discussion of ICAR-AICRP (Fruits)	AAU, Jorhat, India	14 – 16 February, 2019

Name of the Staff	Event	Venue	Date
S. Uma R. Thangavelu V. Kumar K. N. Shiva P. Suresh Kumar	Interactive meet with Maersk for exploring possibility of Sea voyage using controlled atmospheric containers for banana	Chennai	27 August, 2018
S. Uma R. Thangavelu V. Kumar K. N. Shiva P. Suresh Kumar	Interactive meet with board members of Port of Trieste, Italy and TNBGF, Thottiyam, Tamil Nadu	ICAR-NRCB, Tiruchirappalli	30 November, 2018
S. Uma R. Thangavelu S. Backiyarani M. S. Saraswathi P. Durai	State variety release committee meet	TNAU, Coimbatore	17 December, 2018
	State variety release committee meet	Secretariat, Chennai	7 January, 2019
S. Uma S. Backiyarani	Annual review meet for DBT-QUT project	NABI, Mohali	4 August, 2018
S. Uma M. S. Saraswathi	XXX International Horticultural Congress: IHC2018	Istanbul, Turkey	12 - 16 August, 2018
S. Uma R. Selvarajan S. Backiyarani M. S. Saraswathi P. Suresh Kumar	8 th Indian Horticulture congress- 2019. Shaping future of Indian Horticulture.	Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chattisgarh, India	17 - 21 January, 2019
S. Uma P. Ravichamy	National conference on 'Farmers orientation towards climate change & upgrading to sustainable agriculture (FOCUS-2019)'	Life Science Society, National College, Tiruchirappalli	23 - 24 February, 2019
S. Uma R. Selvarajan	Brainstorming workshop for ranking of ICAR Institutes	ICAR-NAARM, Hyderabad	20 July, 2018
S. Uma V. Kumar	Krishi Kissan Karyasala organized by Dept. of Agri., Govt. of Puduchery, Villianur	Pudhuchery	2 May, 2018
S. Uma K. N. Shiva	Investors' consultation meet of supply chain management of fruits, vegetables and other perishables in Tamil Nadu, organized by Dept. of Agri. Marketing and Agri Business, Govt. of Tamil Nadu	Chennai	20 September, 2018
S. Uma	IIFPT Board Meeting	Thanjavur	4 May, 2018
	Banana Seminar organized by DDH, Thanjavur	ICAR-NRCB, Tiruchirappalli	8 May, 2018
	Selection committee meet	CREED-KVK, Ariyalur	29 May, 2018
	SICCI Agri Summit	CII, Tiruchirappalli	6 June, 2018
	Meeting with Secretary, Min. of Food Processing	Govt. of Andhra Pradesh, Amara-vathi	23 June, 2018 & 22 November, 2018

Name of the Staff	Event	Venue	Date
S. Uma	ICAR Institutes Directors' Conference	ICAR, New Delhi	16-18 July, 2018
	Meeting on Banana Export to EU – with TN Banana Federaiton	ICAR-NRCB, Tiruchirappalli	24 July, 2018
	Seminar on banana cultivation	Pondichery	26 July, 2018
	Kisan Samridhi Mela	CODISSIA, Coimbatore organized by ICAR-SBI, Coimbatore	24 - 25 August, 2018
	IIFPT board meet	New Delhi	29 August, 2018 & 20 February, 2019
	Consultative meet on Agri marketing and Agri business, Govt. of Tamil Nadu	Chennai	20 September, 2018
	Meeting with CEO-MEARSK	Chennai	8 October, 2018
	IBSC Meeting as Outside Expert Member	Bharathidasan University, Tiruchirappalli	15 October, 2018
	Flag-off ceremony of banana to Europe	TNAU, Coimbatore	31 October, 2018
	Meeting of representatives from the Triesti port Trust, Italy.	ICAR-NRCB, Tiruchirappalli	30 November, 2018
	DBT Sabri banana review meet	ICAR, New Delhi	12 December, 2018
	Dean / Registrar selection committee meet	TNAU, Coimbatore	9 - 10 January, 2019
	Pre-rabi season campaign	SKVK, Karur	22 January, 2019
	CGIAR Review Meeting	ICAR, New Delhi	24 – 25 January, 2019
	ICAR Institute Directors' Conference	New Delhi	31 January to 1 February, 2019
	Annual review meet for DBT-NER projects	DBT, New Delhi	7 February, 2019
	TR-4 Fusarium wilt meet	ICAR, New Delhi	19 February, 2019
	International women day celebration	ICAR-NBAIR, Bengaluru	8 March, 2019

Name of the Staff	Event	Venue	Date
S. Uma	NABARD project review meet	KNCET, Thottiam	14 March, 2019
	International women day celebration	NIT, Tiruchirappalli	20 th March, 2019
	Higher Education Fair	Dinamani (Tamil Daily), Tiruchirappalli	23 March, 2019
B. Padmanaban M. Mayil Vaganan K. N. Shiva P. Suresh Kumar	International conference on 'Recent advances in food processing technology (iCRAFPT'18)'	Thanjavur, Tamil Nadu	17 – 19 August, 2018
B. Padmanaban R. Thangavelu V. Kumar K. N. Shiva	Workshop cum training on banana organized by ATMA, Solapur	Solapur, Maharashtra	7 - 8 February, 2019
R. Thangavelu	11 th International Congress of Plant Pathology (ICPP) 2018	Boston, USA	July 28 to August 3, 2018
R. Thangavelu R. Selvarajan	National symposium on "Recent challenges and opportunities in sustainable plant health management"	Banaras Hindu University, Varanasi	26 – 28 February, 2019
R. Selvarajan	Academia - Vegetable seed industry workshop for developing solutions to the plant virus problems organised by Society for promotion of Horticulture (SPH)	ICAR - IIHR, Bengaluru	15 September, 2018
	National workshop on data management (Kriportal)	NASC, New Delhi	4 December, 2018
	INTERVIROCON 2018: International conference on 'Global viral epidemics: A challenging threat'	Postgraduate Institute of Medical Education and Research, Chandigarh	10 – 14 November, 2018
	CRP on vaccine diagnostics - Project review meet	ICAR-CIBA, Chennai	30 – 31 October, 2018
M. Mayil Vaganan	Board meet at Department of Biochemistry, Holy Cross College, Tiruchirappalli	Holy Cross College, Tiruchirappalli	7 April, 2018
	International conference on 'New vistas in life sciences'	Holy Cross College, Tiruchirappalli	11 September, 2018
	International conference on 'Next generation plant production and bioresources utilisation technologies'	IIT, Guwahati	11 - 13 February, 2019

Name of the Staff	Event	Venue	Date
I. Ravi	8 th National conference on 'Natural Sciences'	Bose Science Society, Pudukkottai, Tamil Nadu	15 September, 2018
	National seminar on 'Abiotic stress management: Challenges and opportunities'	TNAU, Coimbatore	25 - 26 October, 2018
	International conference on 'Climate change, biodiversity and sustainable agriculture'	AAU, Jorhat	13 - 16 December, 2018
V. Kumar K. N. Shiva P. Durai P. Ravichamy T. Anitha Sree N. Marimuthu V. Selvaraj	7 th SICCI Agri Expo and Summit - 2018 Organised by SICCI, TNAU and ICAR-NRCB	Tiruchirapalli	8 - 10 June, 2018
V. Kumar K. N. Shiva P. Suresh Kumar	Seminar on 'Banana cultivation and marketing' organised by Dept. of Agriculture, Govt. of Puducherry	Puducherry	26 July, 2018
V. Kumar P. Ravichamy K. Kamaraju	<i>Kisan Samruddhi Mela</i> - 2018 organised by ICAR-SBI, ICAR-NRCB and TNAU	CODISSIA Trade Centre, Coimbatore	24 - 26 August, 2018
V. Kumar P. Ravichamy P. Durai	National Horticultural Fair - 2019 organised by Society for promotion of Horticulture	ICAR-IIHR, Bengaluru	23 - 25 January, 2019
V. Kumar	Conference of National Horticulture Board -ICAR Horticulture Institutes, SAU/SHU/CAU and Horticulture training Institutes	NASC, IARI, New Delh	28 - 29 January, 2018
	International Agri Expo	Morocco	21 - 30 April, 2018
	International Buyer-Seller meet	Mumbai	15 - 16 May, 2018
	NHB project approval committee meet	NHB, Gurugram	8 August, 2018
K. J. Jeyabaskaran	Zonal work shop meet of JDA	Tiruchirappalli	15 May, 2018
	Selection committee meet for recruiting lab technician, computer programmer, SMS -soil science, crop protection, veterinary science	ICAR-KVK, Theni	17 May, 2018
	National horticultural mission meet	Collectorate, Tiruchirappalli	25 September, 2018

Name of the Staff	Event	Venue	Date
K. N. Shiva P. Suresh Kumar	Interactive meeting on 'Promotion of Banana fiber for value addition'	Vaishali	5 April, 2018
	Interactive meet for the demonstration of cable way conveyor system	ICAR-NRCB, Tiruchirappalli,	29 April, 2018
	One day interactive meet with Danfoss and Maersk official for export of banana to European market	ICAR-NRCB, Tiruchirappalli,	27 July, 2018
K. N. Shiva	First zonal council meet of CII	SRM Hotel, Tiruchirappalli	21 April, 2018
	<i>Kissan Kalyan Karyashala</i>	Palur, Tiruchirappalli	2 May, 2018
	Meet with State agriculture price board, Govt. of Kerala	ICAR-NRCB, Tiruchirappalli	13 June, 2018
	Scientist - farmer interactive meet organised by Dept. of Horticulture, Pudukottai	AC & RI, Kudmuyanmalai, Pudukottai, Tamil Nadu	6 July, 2018
	Scientist - farmer interactive meet organised by BDO, Lions Club	Jeeyapuram, Tiruchirappalli	22 September, 2018
	UVTRSC meet	TNAU, Coimbatore	17 December, 2018
S. Backiyarani	Bishop Heber College Board meet	Bishop Heber College, Tiruchirappalli	8 April, 2018
	Annual meet of the IITA project	NM-AIST, Arusha, Tanzania	23 - 25 April, 2018
	11 th NPTC review meet	ICAR-NRCPB, New Delhi	7 - 8 June, 2018
	BIRAC review meet	ICAR-NRCB, Tiruchirappalli	20 - 21 January, 2019
M. S. Saraswathi	ICAR regional committee	ICAR-SBI, Coimbatore	17 April, 2018
	DUS project review meet	NASC, New Delhi	31 May, 2018
D. Ramajayam	16 th Scientific Advisory Committee meet	ICAR-KVK, Salem	13 December, 2018
	11 th Scientific Advisory Committee meet	ICAR-KVK, Krishnagiri	13 March, 2019
	10 th Scientific Advisory Committee meet	ICAR-KVK, Vamban	14 March, 2019
	Scientific Advisory Committee meet	ICAR-KVK, Thirunelveli	28 March, 2019

Name of the Staff	Event	Venue	Date
P. Suresh Kumar	Processing and value addition of Banana	Tamil Nadu Horticulture Management Institute, Chennai	23 April, 2018
	Kisan Kalyan Karyashala meet	District Collectorate, Ariyalur	2 May, 2018
	National conference on 'Intensification and diversification in agriculture for livelihood and rural development'	DRPCA, Pusa, Bihar	28 - 31 May, 2018
	One day interactive meeting for "Doubling the farmers Income"	TNAU, Coimbatore	14 July, 2018
	Meeting on doubling of farmers income and follow up of action on the proceeding of the 5th group discussion of ICAR- AICRP fruits	ICAR-IIHR, Bengaluru	17 September, 2018
	Post-harvest supply chain infrastructure for horticultural produce in Krishnagiri and Coimbatore districts (Tamil Nadu) on PPP mode: Investors Consultation meet	Chennai	20 September, 2018
	RKVY-RAFTAAR- Agribusiness incubators meet	Krishi Bhavan, New Delhi	22 November, 2018
	National workshop on Horti-produce transport in India - Present status and issues for a reduction in postharvest losses	NASC complex, New Delhi	8 January, 2019
	Setting up Incubation facility on Banana: Opportunities. Govt. of Andhra Pradesh		12 February, 2019
P. Giribabu	International Symposium on "Innovations & Advancements in Agriculture & Plant Sciences (IAAPS-2018)"	Organized and held at Dhanalakshmi Srinivasan Agriculture College, Perambalur	23 May, 2018
	First International conference on 'Biocontrol (ICBC-2018)'	Organized by Society for Biocontrol Advancement (SBA) held at Bengaluru	27 - 29 September, 2018
C. Anuradha	One day seminar on 'Bioclay sustainable crop protection clay nanosheets for non GM delivery of ds RNA'	CTCB, QUT, Brisbane, Australia	23 April, 2018
T. Anitha Sree T. Sekar	Workshop on 'Prevention of sexual harassment of women at workplace'	Bharathidasan University, Tiruchirappalli	26 April, 2018

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

25th ICAR-NRCB foundation day & Kisan Mela

ICAR-NRCB has celebrated its silver jubilee foundation day and kisan mela on 31st August, 2018. Shri. Chhabilendra Roul, IAS, Special Secretary DARE and Secretary, ICAR, New Delhi was the chief guest of the function. He inaugurated three new facilities at ICAR-NRCB, released silver jubilee publications including Success Stories of ICAR-NRCB (Hindi) and distributed awards to various banana stake holders. He also chaired the "Banana stake holders meet" which was attended by more than 40 stakeholders representing banana exports, processors, FPO's, engineers involved in developing instruments for banana value chain, other ICAR institutes, SAU's, State department functionaries, academicians, scientists and leading banana growers from various parts of the country. During technical session, Drs. K. N. Shiva and V. Kumar, Principal Scientists delivered lectures on pre and post-harvest handlings, value addition, shelf life enhancement, package of practices for export bananas. About 600 participants including banana growers, entrepreneur, KVK scientists, state department officials and exporters attended the function.



Secretary, ICAR, Director, ICAR-NRCB along with awardees at ICAR-NRCB Foundation day and Kisan Mela

Brainstorming meet on Banana fibre

ICAR-NRCB has organized a one day brainstorming meet on "Banana fibre: Research needs for commercial exploitation" on 10th May, 2018. Representatives from ICAR-CIRCOT, Mumbai; ICAR-CIAE (RS), Coimbatore; CSTRI, Mysuru; TNAU, Coimbatore; NAU, Gujarat NIT, Tiruchirappalli; SITRA, Coimbatore; MSME of Tamil Nadu Govt.; TNHDCL, Chennai; CII, Tiruchirappalli; KNCET, Thottiyam etc. have participated and presented the technologies for utilizing fibre based products, sheets, composite boards etc. Salient technologies discussed include conversion of banana pseudostem in to liquid manures; spinning yarn from banana fibre for blending with other fabrics in textile industry; fibre based nanofilm wrappers for

extending the shelf life of horticultural commodities. Dr. S. Uma, Director, ICAR-NRCB outlined the contribution of the centre on entrepreneurship development and stressed the need to convert enormous biomass produced in banana cultivation into wealth for doubling the farmer's income. The meeting was culminated with the identification of researchable issues and development of project proposals for utilizing banana fibre. An exhibition was also arranged during the event with the displays of handicrafts and fabrics made from banana fibre.



Dr. S. Uma, Director, ICAR-NRCB with Researchers and Entrepreneurs at 'Brainstorming meet on banana fibre'

National workshop on 'Sensitization of *Fusarium* wilt (Tropical Race 4)'

ICAR-NRCB hosted a one day workshop on "Sensitization of tissue culture industries in preventing the spread of newly emerging disease - *Fusarium* wilt (Tropical Race 4) of banana" on 26th November, 2018. The meeting was attended by delegates representing major tissue culture companies from different parts of India. Dr. N. Kumar, Vice Chancellor, TNAU, was the guest of honour. Dr. B.N.S. Murthy, Horticulture Commissioner, was the Chief Guest. Dr. R.R. Hanchinal, Consultant, Bioversity International, attended the meet as a special invitee. Dr. B. Padmanaban, Principal Scientist, welcomed the gathering. Dr. S. Uma, Director, in her inaugural address gave a brief overview of the Workshop.



Dr. S. Uma, Director, ICAR-NRCB addressing stakeholders at National workshop on 'Sensitization of *Fusarium* wilt - Tropical race 4

National Symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit'

Indian Phytopathological Society (Southern Zone Chapter) and the ICAR-NRCB have jointly organized a three days National Symposium on 'Cutting edge approaches for sustainable plant disease management and ensuring farmers' profit' during 21-23rd December, 2018 at ICAR-NRCB. The symposium was inaugurated by Dr. N. Kumar, Vice-Chancellor, Tamil Nadu Agricultural University, Coimbatore, with Dr. W. S. Dhillon, ADG (Horticultural Science), Indian Council of Agricultural Research, New Delhi as the Guest of Honour. Dr. S. Uma, Director, ICAR-NRCB; Dr Dinesh Singh, Secretary, IPS, New Delhi; Dr M Anandaraj, Former Director, ICAR-IISR and former President, IPS; Dr A.S.Krishnamoorthy, Director, CPPS, TNAU and Dr R.Selvarajan, President of Indian Phytopathology Society - South zone / Organizing Secretary of the National Symposium were the dignitaries in the function. Scientists across the country, farmers, industrial firms, students and research scholars from SAUs of southern India have participated and benefitted. Around 179 students participated in the one day special interactive workshop conducted on 22nd December, 2018.



Release of souvenir by scientific delegates at IPS - National symposium held at ICAR-NRCB

Workshop on Arabi to Banana

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



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

Workshop on 'ICAR-KRISHI Portal'

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



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

Silver Jubilee Lectures

Dr. Ghanshyam B. Patil, Assistant Professor, Plant Tissue Culture Laboratory, AAU, Anand delivered a lecture on "Innovative Approaches for Micropropagation and Crop Improvement Techniques" on 31st May, 2018 to scientific fraternity of ICAR-NRCB.

Professor Michael Pillay, Dept. of Biotechnology, Vaal University of Technology, South Africa had visited ICAR-NRCB on 10th July, 2018 and delivered lecture on banana breeding and interacted with the institute's scientific staff.

Special lecture on ISO: 9001-2015

Dr. A. K. Ghosh of Nebulous Management System Consultants, Ahmedabad visited ICAR-NRCB and delivered a lecture cum training on "Sensitization of ISO: 9001-2015" on 18th April, 2018.

14. DISTINGUISHED VISITORS

Name	Date
Dr. A. K. Ghosh, Nebulous Management System Consultants, Ahmedabad	18 April, 2018
Mr. J. P. Meena, Secretary, Ministry of Food Processing & Industries, GoI, New Delhi	4 May, 2018
Dr. B. K. Behera, Economic adviser, Ministry of Food Processing & Industries, GoI, New Delhi	
Dr. C. Anandharamakrishnan, Director, IIFPT, Thanjavur	
Prof. Michael Pillay, Dept. Of Biotechnology, Vaal University of Technology, South Africa	10 July, 2018
Dr. S. Letchumanane, Retd. Professor, TNAU, Coimbatore	21 July, 2018
Mr. K. Rajamani, I.A.S., District Collector, Tiruchirapalli	31 July, 2018
Prof. Nazeer Ahmed, Vice-Chancellor, Sher-e-Kashmir University of Agril. Science and Technology of Kashmir, Srinagar	1 August, 2018
Dr. Narendra Pratap Singh, Director, ICAR-NIASM, Baramati	16 August, 2018
Mr. Chhabilendra Raul, Additional Secretary (DARE) & Secretary (ICAR), New Delhi	31 August, 2018
Dr. M. Jawaharlal, Director of Extension Education, TNAU, Coimbatore	6 October, 2018
Mr. A. R. Sengupta, Deputy Secretary (DARE)	27 October, 2018
Dr. Puran Singh, Assistant Director (OL) (DARE)	
Dr. Amar Veer Singh, IRS, Principal Commissioner of Income Tax, Tiruchirappalli	
Dr. A. K. Singh, Deputy Director General (Horticultural Science), ICAR, New Delhi	1 November, 2018
Dr. N. Kumar, Vice Chancellor, TNAU, Coimbatore	26 November, 2018 & 21 December, 2018
Dr. B. N. S. Murthy, Horticulture Commissioner, DAC&FW, GoI, New Delhi	26 November, 2018
Dr. R. R. Hanchinal, Consultant, Bioversity International, New Delhi	
Dr. Neelam Chaudhary, Deputy Director, Directorate of Plant Protection, Quarantine & Storage, Faridabad	
Dr. W. S. Dhillon, ADG (Horticultural Science), ICAR, New Delhi	21 December, 2018
Dr. Dinesh Singh, Secretary, IPS, New Delhi	
Dr. M. Anandaraj, Former Director, ICAR-IISR and former President, IPS	
Dr. A. S. Krishnamoorthy, Director, CPPS, TNAU, Coimbatore	
Dr. G. Krishnamohan, Eurofins Agrosience services, Ltd., Coimbatore	
Dr. V. G. Malathi, Adjunct professor, TNAU, Coimbatore	

Name	Date
Dr. K. V. Peter, Former Vice Chancellor, KAU, Kerala	25-26 February, 2019
Dr. Abraham Varghese, Former Director, ICAR-NBAIR, Bangalore	
Shri. N. Ravichandran, Commissioner, Tiruchirappalli City Corporation	7 March, 2019
Dr. V. Padmavathi, Principal, Seethalakshmi Ramasamy College, Tiruchirappalli	
Dr. Sujatha, Principal, Cauvey College for Women, Tiruchirappalli	
Dr. Albert Premkumar, Visiting Guest Scientist, Istanbul University, Istanbul, Turkey	13 March, 2019
Dr. K. Alagusundaram, DDG (Agril. Eng.), ICAR, New Delhi	25 March, 2019
Dr. Prakash Patil, Project Co-ordinator, AICRP on Fruits	
Dr. S.K. Chaudhari, ADG (SWM), ICAR, New Delhi	
Shri. M. Girija Shankar, I.A.S., Secretary to Chief Minister of Andhra Pradesh & Secretary, APFPS	26 March, 2019
Shri. Y.S. Prasad, CEO-APFPS	



Mr. Chhabilendra Raul, Additional Secretary (DARE) & Secretary (ICAR) and Dr. S. Uma, Director, ICAR-NRCB visiting stalls at ICAR-NRCB foundation day



Dr. A. K. Singh, DDG (Horticultural Science), ICAR visiting ICAR-NRCB transgenic nethouse

15. EMPOWERMENT OF WOMEN

More than 1000 women farmers, entrepreneurs, students, SHG members etc. from different parts of country visited ICAR-NRCB and learnt various technologies on improvement, production, protection and post harvest management of banana.



Training on Macropropagation to women farmers'



Women students visit to ICAR-NRCB

16. PERSONNEL

16.1 Staff News

Name	Event	Date
Mr. R. Natarajan, Scientist (Economic Botany)	Premature retirement	14 August, 2018
Mr. R. Krishnamurthy, Assistant Administrative Officer	Superannuation	31 January, 2019
Mr. R. Pitchaimuthu, Technical Officer	Promoted from Senior Technical Assistant to Technical Officer	w. e. f. 1 January, 2018
Mr. N. Marimuthu, Technical Officer	Promoted from Senior Technical Assistant to Technical Officer	
Mrs. S. Durgavathy, Assistant	Promoted from Upper Division Clerk to Assistant	w. e. f. 1 January, 2019

16.2 Staff position

Scientific Staff

Sl. No.	Name	Designation
1	Dr. S. Uma	Director
2	Dr. B. Padmanaban	Principal Scientist (Entomology)
3	Dr. J. Poorani	Principal Scientist (Entomology)
4	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
5	Dr. R. Selvarajan	Principal Scientist (Plant Pathology)
6	Dr. M. Mayil Vaganan	Principal Scientist (Plant Biochemistry)
7	Dr. I. Ravi	Principal Scientist (Crop Physiology)
8	Dr. V. Kumar	Principal Scientist (Horticulture)
9	Dr. K. J. Jeyabaskaran	Principal Scientist (Soil Science)
10	Dr. K. N. Shiva	Principal Scientist (Horticulture)
11	Dr. S. Backiyarani	Principal Scientist (Biotechnology)
12	Dr. M. S. Saraswathi	Principal Scientist (Horticulture)
13	Dr. M. Loganathan	Principal Scientist (Plant Pathology)
14	Dr. D. Ramajayam	Principal Scientist (Horticulture)
15	Dr. P. Suresh Kumar	Senior Scientist (Horticulture)
16	Dr. P. Giribabu	Scientist (Nematology)
17	Dr. C. Anuradha	Scientist (Biotechnology)

Technical Staff

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

Sl. No.	Name	Designation
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	Ms. C. Gomathi	Asst. Finance & Accounts Officer
2	Mr. R. Krishnamurthy	Asst. Administrative Officer
3	Mr. M. Krishnamoorthy	Private Secretary
4	Mr. R. Sridhar	Personal Assistant
5	Mr. P. Murugan	Assistant
6	Ms. S. Durgavathy	Assistant
7	Mr. R. Neela Mega Shyamala Kannan	Steno Gr. III
8	Ms. A.V. Suja	Lower Division Clerk
9	Mr. R. Mohanraj	Lower Division Clerk
10	Mr. V. Pandiyan	Skilled Supporting Staff
11	Mr. V. Thangaraju	Skilled Supporting Staff
12	Mr. P. Kamaraj	Skilled Supporting Staff
13	Mr. V. Ganesan	Skilled Supporting Staff
14	Ms. K. Mariammal	Skilled Supporting Staff



Mr. R. Krishnamurthy, retired from the post of Assistant Administrative Officer on 31 January, 2019

17. OTHER INFORMATION

Visit of Secretary, MoFP&I

Shri. J. P. Meena, Secretary, Ministry of Food Processing & Industries, Govt. of India, New Delhi had visited ICAR-NRCB on 4th May, 2018. He emphasized the need for commercializing ICAR-NRCB technologies for entrepreneurship development in the processing sector. Dr. S. Uma, Director, ICAR- NRCB, briefed the institute's

achievements in developing more than 25 different processed products and 18 technologies that were transferred to more than 60 entrepreneurs. The Secretary along with Dr. B. K. Behera, Economic adviser, MoFP&I and Dr. C. Anandharamakrishnan, Director, IIFPT, Thanjavur also visited the farm, lab and processing facilities of the institute along with the scientists of the Institute.



Visit of Secretary, MoFPI, Govt. of India at ICAR-NRCB

International Yoga Day

ICAR-NRCB celebrated International yoga day on 21st June, 2018. All the staff of the institute had participated and practiced various 'asanas' for a period of four days from 18 - 21 June, 2018. Dr. Sugumar, BNYS from Shri Jayaranga Nature Cure Hospital, Tiruchirappalli and Yoga Masters from two different Yoga Centres viz., Amirtha Yoga Mandiram and Vivekananda Yoga Centre, Tiruchirappalli were participated and conducted yoga lectures and practical sessions.



Staff of ICAR-NRCB practicing Yoga

Parthenium Awareness week

Staff of ICAR-NRCB had observed 'Parthenium Awareness week' during 16 - 22 August, 2018. Dr. B. Padmanaban, Principal Scientist, explained the importance of removal of the obnoxious weed to farm labourers. On the eve, special drive was arranged to

eradicate parthenium at ICAR-NRCB farm in which all the staff were actively participated.

Sadbhavana Diwas

Staff of ICAR-NRCB had observed 'Sadbhavana Diwas' on 20 August, 2018 and took pledge to promote National Integration and Communal Harmony among the people of all religion, language and region.

Sports Meet

ICAR - NRCB participated in ICAR Inter - Institutional sports meet for south zone held at Kakinada, Andhra Pradesh, organized by ICAR-CTRI, Rajamundry on 4 - 9 September, 2018. A sport contingent of eight members was participated in various events.

Swachh bharath

Swachh bharath campaign was organized on 2nd October, 2018 to commemorate the 150th birth anniversary of Mahatma Gandhi. The staff members of ICAR-NRCB in association with nearby villagers and school children have carried out activities viz., drama, street plays, songs, speeches, slogans on *Swachhta* related by school children; Sanitation practices like hand washing, safe handling of sprayers, clean habits, use of toilets etc.; Demonstration on

segregation of solid wastes into biodegradable and non-biodegradable wastes, compost making, waste utilization, etc.; Toilet pit digging activities; Distribution of cotton cloth bags to school children, Farm workers and village peoples; Distribution of T-Shirt containing Swachh Bharat logos/slogans and cleaning of roads and office premises.



Staff of ICAR-NRCB with school children at Swachh Bharath Pakhwara

Hindi Pakhwara

ICAR-NRCB celebrated 'Hindi Pakhwara' on 27th October, 2018. Various competitions viz., singing, quiz, news reading etc. were held and prizes were distributed. Dr. Amar Veer Singh, IRS, Principal Commissioner of Income Tax, Tiruchirappalli was chief guest and Mr. A. R. Sengupta, Deputy Secretary (DARE); Dr. Puran Singh, Assistant Director (OL) (DARE) were guests of honour.



Chief guest address during Hindi fortnight celebrations at ICAR-NRCB

National Unity Day

To commemorate the birth anniversary of Sardar Vallabhbhai Patel, Staff of ICAR-NRCB had observed 'National Unity Day' on 31st October, 2018 and took pledge for National unity.

Inauguration of Pradhan Mantri Kisan Samman Nidhi

ICAR-NRCB had live telecasted the launching of Govt. of India's "Pradhan Mantri Kisan Samman Nidhi" program on 24th February, 2019 to banana farmers. Around 200 farmers had visited the institute and witnessed the launching and got benefitted.

Visit of Secretary, Andhra Pradesh

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

International Women's day

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



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

ANNEXURE – I

I. Institute projects

Name of the Project	Principal Investigator
Crop Improvement	
1. Improvement and management of banana genetic resources in Indian subcontinent	S. Uma
2. Improvement of banana through conventional breeding	S. Backiyarani
3. Development of trait specific markers for <i>Fusarium</i> wilt resistance through association mapping studies in banana (<i>Musa</i> spp.)	M. S. Saraswathi
4. Improvement of cv. Grande Naine (Cavendish – AAA) for <i>Fusarium</i> wilt resistance through non-conventional breeding	M. S. Saraswathi
5. Production of doubled haploids for improvement of bananas (<i>Musa</i> 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 race 1 and tropical race 4 of <i>Fusarium oxysporum</i> f. sp. <i>cubense</i>	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. Studies on active packaging on extending the shelf-life of banana	K. N. Shiva
13. Functions of resistant starch and designer food development from banana flour	P. Suresh Kumar
Physiology & Biochemistry	
14. 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
15. Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower	M. Mayil Vaganan
Crop Protection	
16. Identification of banana stem weevil pheromone for the management of pest	B. Padmanaban
17. Pest mapping in bananas and plantains of India	J. Poorani
18. Investigation on fungal and bacterial diseases of banana and their management	R. Thangavelu
19. Integrated management of Tropical race 4 of <i>Fusarium</i> wilt disease in banana	R. Thangavelu
20. Survey, etiology and management of rhizome rot of banana	M. Loganathan
21. Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan
22. Proteomic analysis of host-BBTV interaction in banana	C. Anuradha
23. Investigations on <i>Musa</i> nematode's diversity, biology, behavior, interactions and its management	P. Giribabu

II. ICAR funded projects

Name of the Project	Principal and Co-Investigator(s)
1. Network project on Transgenic in crops – Banana functional genomics (Sigatoka & Drought component)	S. Uma R. Thangavelu S. Backiyarani M. S. Saraswathi I. Ravi
2. Survey, characterization and management of a most virulent strain of <i>Fusarium oxysporum</i> f. sp. <i>cubense</i> (TR4) infecting banana in India	R. Thangavelu S. Backiyarani
3. Development and utilization of diagnostics to viruses of banana under Consortium research platform on vaccines and diagnostics	R. Selvarajan C. Anuradha
4. Assessment of post-harvest losses in banana	K. N. Shiva
5. Development of banana sucker paring equipment, pseudo-stem injector, bunch harvester and pseudo-stem outer sheath plate making equipment (collaborating institute : ICAR-CIAE, RS, Coimbatore)	B. Padmanaban, V. Kumar, K. N. Shiva, P. Suresh Kumar

III. 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	IITA	S. Uma S. Backiyarani R. Thangavelu M. S. Saraswathi
2. Bio fortification and development of disease resistance in Banana	DBT - QUT	
Component - 1: Biofortification and evaluation of Indian banana with pro Vitamin A (PVA) constructs		S. Backiyarani S. Uma M. Mayil Vaganan
Component - 2: Biofortification and evaluation of Indian banana with Iron constructs		M. Mayil Vaganan I. Ravi K. J. Jeyabaskaran
Component - 3: Development of efficient ECS for Rasthali and providing authentic virus free IMFC to Indian Partners		S. Uma S. Backiyarani
3. Twinning programme on 'Molecular characterization of <i>Fusarium oxysporum</i> f.sp. <i>cubense</i> causing Fusarium wilt on banana and its sustainable management'	DBT	R. Thangavelu S. Backiyarani
4. National certification system for tissue culture raised plants	DBT-ATL	R. Selvarajan M. S. Saraswathi C. Anuradha S. Uma

Name of the Project	Funding Source	Principal and Co-Investigator(s)
5. Development of non-chimeral mutants with durable resistance to <i>Fusarium</i> wilt in Rasthali through induced mutagenesis	DAE	M. S. Saraswathi R. Thangavelu S. Uma S. Backiyarani
6. Framing crop specific DUS guidelines for banana (<i>Musa spp.</i>)	PPV & FRA	S. Uma M. S. Saraswathi S. Backiyarani
7. Consortium for managing Indian banana genetic resources	DBT - NER	S. Uma M. S. Saraswathi S. Backiyarani
8. Genetic resource assessment, <i>in-situ</i> conservation and impact of banana waste as a feed for animals in NE region of India	DBT - NER	S. Uma M. S. Saraswathi
9. Whole genome and transcriptome study to stress tolerant banana cultivars	DBT - NER	S. Backiyarani S. Uma I. Ravi
10. Collection, evaluation, documentation and conservation of banana genetic resources from NE region	DBT - NER	M. S. Saraswathi M. Mayil Vaganan S. Uma
11. <i>In vitro</i> mass propagation of high value hill area banana	DBT - NER	M. S. Saraswathi R. Thangavelu I. Ravi
12. Diversity assessment, germplasm conservation and database development on banana resources in NE India	DBT - NER	M. S. Saraswathi S. Backiyarani
13. Characterization of high value phyto-chemicals of anti diabetic and immune-modulatory properties in NE banana varieties	DBT - NER	M. Mayil Vaganan I. Ravi P. Suresh Kumar
14. Management of low temperature and soil moisture deficit stresses in banana growth in NE India	DBT - NER	I. Ravi M. Mayil Vaganan M. S. Saraswathi
15. Development of pre & post harvest bunch care management methods for fresh banana	DBT - NER	P. Suresh Kumar K. N. Shiva
16. Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	DBT - NER	P. Suresh Kumar V. Kumar K. N. Shiva
17. Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	DBT - NER	P. Suresh Kumar K. N. Shiva
18. Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	DBT - NER	B. Padmanaban S. Backiyarani J. Poorani
19. Molecular dissection of defense against Sigatoka infection in banana - Exploitation of <i>Musa</i> germplasm of NE for development of Sigatoka resistant hybrid	DBT - NER	R. Thangavelu

Name of the Project	Funding Source	Principal and Co-Investigator(s)
20. Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	DBT - NER	R. Thangavelu M. Loganathan
21. Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRISPR – Cas9 system	DBT - NER	R. Selvarajan C. Anuradha
22. Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	DBT - NER	R. Selvarajan C. Anuradha

Contract research projects

Name of the Project	Funding Source	Principal Investigator
1. Evaluating the product viz., Paraffinic oil adjuvant for the management of leaf spot diseases of banana	M/s. Pure Chemicals Co., Chennai	R. Thangavelu
2. Evaluating the effect of foliar spray of Pronos and Dormulin for the suppression of <i>Eumusae</i> leaf spot disease of banana	M/s. Nagarjuna Fertilizers and Chemicals Limited, Hyderabad	R. Thangavelu
3. Evaluating Paraffinic oil for the management of leaf spot diseases of banana cv. Grand Naine	M/s. Raj Petro Specialities Pvt. Ltd., Chennai	R. Thangavelu
4. Evaluation of farmer's banana variety – Kamal Vikas A1	National Innovation Foundation – India, Ahmedabad	M. S. Saraswathi

ANNEXURE – II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
April 2018	37.93	27.26	39.23	-
May 2018	37.51	26.87	46.74	214.2
June 2018	37.33	27.76	40.20	40.0
July 2018	35.35	27.25	43.06	35.6
August 2018	36.12	29.96	39.93	27.3
September 2018	36.73	26.33	40.10	19.5
October 2018	32.80	25.00	60.90	90.5
November 2018	30.56	23.86	67.16	152.6
December 2018	30.61	22.80	59.93	-
January 2019	31.00	20.61	45.74	-
February 2019	34.32	23.60	42.89	-
March 2019	37.67	25.06	33.77	-
Total				941.2





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

Agrisearch with a human touch

Cleanliness
is next to
Godliness



भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

(भारतीय कृषि अनुसंधान परिषद)

थायनूर पोस्ट, तोगमलै रोड,

तिरुचिरापल्लि - ६२० १०२, तमिल नाडु, भारत

**ICAR-National Research Centre for Banana
(Indian Council of Agricultural Research)**

Thayanur Post, Thogamalai Road,

Tiruchirappalli - 620 102, Tamil Nadu, India

Ph : +91-431-2618125

E-mail : director.nrcb@icar.gov.in; www.nrcb.res.in