ICAR-National Research Centre for Banana

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

ANNUAL REPORT 2015 - 16

वार्षिक प्रतिवेदन 2015 - 16

भाकृअनुप
ICAR

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

2015 - 16

ANNUAL REPORT
वार्षिक प्रतिवेदन

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

तायनूर पोस्ट तोगमलै रोड तिरूच्चिरापक्कि ६२० १०२, तमिल नाडु

ICAR-National Research Centre for Banana

Thayanur Post, Thogamalai Road, Tiruchirapalli - 620 102,Tamil Nadu

Citation

ICAR – NRCB, 2016. Annual Report 2015 – 16.

ICAR – National Research Centre for Banana, Tiruchirapalli

Editors

Dr. P. Giribabu

Dr. J. Poorani

Dr. I. Ravi

Dr. K. N. Shiva

Dr. M. S. Saraswathi

Published by

Dr. B. Padmanaban

Acting Director

ICAR – National Research Centre for Banana

Thayanur Post, Thogamalai Road

Tiruchirapalli – 620 102

Tamil Nadu, India

A) Bunch sprayed with *Trichoderma asperellum*

B) Bunch sprayed with carbendazim

Photocredits

Mr. P. Ravichamy

Designed & Printed at

Sri Sakthi Promotional Litho Press

No. 283, Masaniamman Nagar,

Anna Nagar East, Edayarpalayam,

Coimbatore – 641 025

Phone: 0422 – 2403500

E mail: info@sakthipress.com

Web: www.sakthipress.com

S.No.	CONTENTS	Page No.

PREFACE

It gives me great pleasure to inform that ICAR–National Research Centre for Banana has been awarded ISO 9001:2008 certification. Salient research progress has been made during 2015–16 is presented in this report.

During 2015-16, twenty four new banana germplasm lines were added to the field gene bank. Phenotyping of 54 germplasm accessions led to the identification of three wilt resistant accessions viz. Manohar (BB), Borkal Baista (BB) and *Musa acuminata* ssp. *burmannica*. The centre has identified a superior progeny of Bhat Manohar (progeny no. 667) having a yield potential of 19.5 kg bunch. Under breeding for nematode resistance, the Centre has produced progenies of cv. Nendran crossed with cvs. Rose and Pisang Lilin, which performed better in terms of yield. The Centre has identified salicylic acid as defense priming and reduced root-lesion nematode infection in nematode susceptible banana cv. Nendran. Carrageenan, a sea weed derived from *Eucheuma cottonii* as a cost effective substitute for gelling agent in tissue culture medium has been identified and evaluated. SSR markers which can distinguish the leaf spot resistant cultivars from the susceptible ones have been developed. Musa Transcriptome SSR database (MusatransSSRDB) was further updated using advanced bioinformatics tools like MUSABLAST and MUSASAT.

Significant research achievements were made by Scientists of the Production section comprising of Horticulture (Production), soil science, physiology, biochemistry and post-harvest technology. Nutrient dynamics studies in banana cvs. Ney Poovan and Rasthali gave insights into the nutrient composition of crop residue and residue derived vermicompost. Foliar priming of banana cv. Grand Nain with acetyl salicylic acid (0.1mM) and butylated hydroxy toluene (100 ppm) mitigated the drought stress and improved bunch weight to 18.78 kg comparable to irrigated conditions.

Proteomic studies on banana fruit have identified 43 differentially expressed proteins. Transgenics of iron rich banana cvs. Rasthali and Grand Nain were produced using the iron gene construct pBMGFDC- 53 carrying OsNAS1 gene. Post–harvest losses in popular banana cultivars in four districts of Tamil Nadu indicated the loss to the extent of 16.50% in 'Poovan' 10.52% in Grand Nain. Value added products like banana fruit and central core (stem) juice based jellies, Ginger and nannari flavoured banana central core juice and banana flour based biscuits were developed.

Noteworthy achievements have been made by the Protection Scientists of entomology, pathology, virology and nematology. Thirty three accessions were identified as resistance against banana weevils. Natural enemies of banana weevils and skipper were identified from different parts of India. Liquid formulation of endophytes *viz*. *Bacillus flexus* and *Trichoderma asperellum* were identified as promising agents for Fusarium wilt disease management. Zimmu leaf extract has been identified as excellent botanical pesticide for the management of wilt and post–harvest diseases. The occurrence of Banana Mild Mosaic Virus is reported for the first time in India. Loop Mediated Isothermal Amplification (LAMP) based detection of Cucumber Mosaic Virus (CMV) and Banana Streak Mysore Virus has been standardized at this Centre. Two banana cultivars, *viz*. Bangrier and Saba, cooking bananas have been identified as moderately resistant to root-lesion nematode.

Under HRD, seven scientific, five technical, one administrative and two skilled supporting staff were trained and I am sure this will improve their performance. A total of 14 research papers having good impact factor have been published from the Centre and 10 research papers were presented in various forum.

The centre has conducted 12 on–campus training programs which include tissue culture production, improved production and post–harvest techniques and production of value added products from banana. The centre also conducted off–campus training programmes for the farmers in the North eastern states under Tribal Sub Plan.

I congratulate and thank Dr. J. Poorani, Chairperson and Drs. I. Ravi, K.N. Shiva, M.S. Saraswathi and P. Giribabu, members of the Publication Committee for their good work in compiling, editing and bringing out this annual report.

I express my sincere gratitude to Dr. S. Ayyappan, Ex–Secretary, DARE & DG, ICAR and to Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR for their valuable guidance and Dr. N.K. Krishna Kumar, Dy. Director General (Hort. Science), ICAR for his constant inspiration and encouragement, also his keen interest in improving ICAR–NRCB.

(B. Padmanaban)
Acting Director

2. EXECUTIVE SUMMARY

Improvement

Field gene bank of ICAR–NRCB, Tiruchirappalli, was strengthened by the addition of 27 germplasm accessions including 24 cultivated and three wild accessions. Morphotaxonomic characterization was completed for five germplasm accessions using *Musa* descriptor. DNA profiles were developed for 16 plantain types using ISSR markers and this would serve as reference for use in genetic fidelity testing. Out of 54 germplasm accessions, which were screened under pot culture conditions for Fusarium wilt resistance, only three accessions, namely Manohar (BB), Borkal Baista (BB) and *Musa acuminata* ssp. *burmannica* were resistant to Fusarium wilt (VCG 0124). Out of four ICAR–NRCB selections tested, selection–08 (Saba) was found to be moderately resistant to Fusarium wilt with a score of 3.1. A score card has been developed for the evaluation of varieties / hybrids. Among the 22 open pollinated progenies of Bhat Manohar, progeny no. 667 performed better in terms of yield (19.5kg as against 10.5kg). This could be used either directly for commercial cultivation or in the development of superior triploids by crossing with diploids. Breeding for nematode resistance in cv. Nendran has led to the development of two progenies, *viz.,* NCR12/17 (Nendran x cv. Rose) and NPL12/33 (Nendran x Pisang Lilin) which yielded 12.5 and 9.5kg respectively. Gene expression studies during pollen–stigma interactions indicated that Pectin esterase and EXO70A1 which are highly responsible for pollen hydration and germination were upregulated in cv. Saba at 5 and 45 (MAP) at 6-fold and 2-fold, respectively leading to seed set. The lethal dose LD_{50} has been determined for EMS (0.1% for 2 hours) in cv. Rasthali using ECS explants.

Defense priming mediated by salicylic acid reduced root-lesion nematode infection in nematode susceptible banana cv. Nendran. Use of Carrageenan, a sea weed derived from *Eucheuma cottonii* as a substitute for gelling agent in tissue culture medium reduced the medium cost by 42-61%. Macropropagation in cv. Rasthali resulted in the production of 14.5 plants in a short span of 37.42 plants during the tertiary decortication stage as against 10-12 suckers produced in its life span of 12-13 months. *In silico* derived SSRs were able to distinguish the *Mycosphaerella eumusae* resistant cultivars from the susceptible ones. Comparative proteomic analysis was carried out between embryogenic (EC) and non-embryogenic calli (NEC) of cv. Rasthali and results indicated that 5 spots were uniquely expressed in NEC than EC. Their analysis would lead to the understanding of molecular mechanism underlying the process of somatic embryogenesis and help to rectify the problems associated with it so that the EC% could be enhanced in recalcitrant varieties.

About 874 batches of tissue culture plants at various stages of production (Grand Nain, Williams, Robusta, Neypoovan, Red banana, Quintal Nendran, etc.) were tested for their genetic fidelity using SSR and ISSR markers and reports issued. Mother cultures of cvs. Udhayam and Rasthali were supplied to HRC, Nagicherra, Agartala, Tripura and IGKV, Raipur, Chhattisgarh. ECS of cv. Rasthali and cv. Grand Nain, respectively were supplied to Indian partners (NABI and BARC) including ICAR-NRCB after checking their regeneration efficiency. *Musa* Transcriptome SSR database (*Musa*transSSRDB) was further updated using advanced bioinformatics tools like MUSABLAST and MUSASAT. Links are also provided for the online bioinformatics tools like BATCHPRIMER3 and KEGG. Search tools are provided for doing all categorical searches by CUFF ID, Genome ID, SSR type, Protein Name, Forward, Reverse Primer and Pathways.

Production

Nutrient dynamics studies were carried out in cv. Ney Poovan and after harvest the amount of nutrients recycled/added (kg/ha) through reincorporation of residues were worked out as N-307.7, P-45.3, K-447.7, Cu-1.93, Mn-6.6, Zn-1.75 and Fe-4.45. The nutrient contents (g) in vermicompost obtained from residues of a single plant of Neypoovan after harvest of bunch were N-113.24, P-21.74, K-273.99, Cu-0.92, Mn-2.46, Zn-0.82 and Fe-1.65. Similarly in cv. Rasthali, the amount of nutrients recycled/added (kg/ha) through reincorporation of residues were worked out as N-248.8, P-49.3, K-513.1, Cu-1.73, Mn-4.9, Zn-2.15 and Fe-4.65. The nutrient contents (g) in vermicompost obtained from residues of a single plant of Rasthali after harvest of bunch were N-130.38, P-24.42, K-264.78, Cu-0.68, Mn-1.71, Zn-0.81 and Fe-1.76.

An attempt to alleviate the negative effects of drought in banana yield was studied. In cv. Grand Nain, foliar priming with acetyl salicylic acid (0.1mM) combined with butylated hydroxy Toluene (100 ppm) before the imposition of soil moisture stress recorded bunch weight (18.78 kg) comparable to irrigated (19.72). The cvs. Poovan, Karpuravalli and Saba recorded higher membrane stability at 50 mM of NaCl stress level compared to salt stress susceptible cvs. Nendran and Rasthali. The proteomic study resulted in identification of mechanism of action by 1-MCP. The biological identity of 43 highly abundant, differentially expressed proteins (31 up-regulated and 12 down-regulated) were established after mass fingerprinting and the important enzymes/ proteins such as ACC oxidase and synthase, polygalacturonase, pectate lyase, xyloglucan endotransglycosylase / hydrolase were highly down-regulated in the biochemical treated bananas as compared to untreated control implying that ethylene synthesis and cell wall modifying enzymes are suppressed by 1-MCP.

The biochemical mechanism of 'green ripe' in a dessert banana was unravelled. The impairment of Mg dechelatase and pheophorphide a oxygenase activities and partial degradation of chlorophylls were observed in peel of Cavendish (Grand Nain) bananas at elevated temperatures exhibiting green ripe character. Transgenics for iron rich banana fruits in cvs. Rasthali and Grand Nain were produced using the iron gene construct pBMGFDC- 53 carrying OsNAS1 gene.

For leaf purpose, the variety 'Nattu (Monthan) Vazhai' is preferred for cultivation in Melur, Madurai District., while it is 'Nattu (Monthan) Vazhai' and 'Poovan' for Tirunelveli and Tuticorin districts of Tamil Nadu. In Tamil Nadu, four Districts, namely, Theni (more than 70% cultivated area) and Erode (less than 70%) preferred Grand Nain (internationally popular variety); Tiruchirapalli (more than 70%) and Turticorin (less than 70%) preferred Poovan (local commercial variety) were identified. In 'Grand Nain' variety, overall 10.52% and 10.48% post-harvest losses were estimated in Theni and Erode Districts, respectively. In 'Poovan' variety, overall 16.50% and 9.10% post-harvest losses were recorded in Tiruchirapalli and Tuticorin Districts of Tamil Nadu. Superior rehydration and sensory score was observed when the banana slices were dried at 55^{0}C. Banana fruit juice based jelly and central core stem juice based jelly were developed by blending fruit juice with sugar and citric acid having TSS content of 65^{o}Brix and acidity of 0.2%. Flavoured and non-flavoured banana central core (stem) juice based RTS beverages were evaluated for their nutrient contents under storage. Minimum changes were associated with quality parameters under 13.5^{o}C storage as compared to ambient temperature. Initially and in storage, the ginger flavoured pseudostem beverages had highest organoleptic scores. Banana flour based biscuits were prepared with different proportions and compared with 100% maida biscuit as absolute control. Among

the various combinations, 50% banana flour proved better for most of the quality parameters. Banana central core (stem) juice based squash and syrup were developed by blending stem juice with sugar and citric acid. Banana central core (stem) based soup mix and ice cream mix were developed by incorporating banana central core stem powder with 40% and 10%, respectively. Of seven commercial varieties of banana evaluated for central core stem powder, Rasthali had the highest amount of starch, total carbohydrates and energy. However, the highest crude fiber was recorded with Saba and Mortaman. Out of six varieties of banana varieties evaluated for corm juice, Udhayam recorded maximum recovery, followed by Nendran and Saba. Various formulations consisting of 100% durum wheat (control) and mixtures of wheat:banana flour and resistant starch were prepared for pasta processing. Nutritional composition and sensory characteristics were determined. The addition of banana flour increased the indigestible fraction and the content of phenolic compounds in the pasta. Moreover, addition of banana flour increased the antioxidant capacity and mineral content.

Protection

A slow release delivery system for banana stem weevil was developed using materials like alginate gel, polyurethane foam (PUF) and cotton wick and evaluated. Maximum weevil attraction (34.0%) was observed in PUF and a minimum attraction of 7.0% was recorded in other treatments and 8% attraction was registered in leaf sheath bit. Out of 29 accessions of *Musa* germplasm screened *in vitro* against banana corm weevil, *Cosmopolites sordidus*, the accessions belonging to AB (5), ABB (3), AA (2), BB (1), and AAA (1) were identified as resistant as revealed by absence of feeding damage and weevil mortality. Out of 28 accessions screened for resistance against pseudostem borer, *Odoiporus longicollis*, 21 accessions belonging to AAA (8), AA (6), ABB (4), BB (1), AB (1) and AAB (1) were free from weevil damage, whereas seven accessions belonging to genomic group ABB (7) were susceptible. In surveys for natural enemies of banana weevils in six states, earwigs, beetles and entomopathogenic fungi (*Beauveria* sp.) were collected in association with banana weevils. Natural enemies of banana skippers, *Erionota* spp. were recorded from different parts of India. Three egg parasitoids of *Erionota* sp. collected from Mizoram were identified as *Agiommatus* sp. (Pteromalidae), *Ooencyrtus* sp. (Encyrtidae), and *Tetrastichus* sp. (Eulophidae). An unidentified species of *Telenomus* (Platygastridae) was recorded on the eggs of *E. torus* from Karnataka. *Brachymeria* sp. (Chalcididae) was recorded as a pupal parasitoid of *E. torus* from Kerala. Two unidentified tachinid parasitoids were collected on *Erionota* spp. from Tamil Nadu and Mizoram.

In a field trial at a fusarium wilt (*Foc*) hotspot area at Muthulapuram of Theni district, Tamil Nadu, efficacy of microbes and botanicals in suppression of fusarium wilt and plant growth promotion was evaluated. Liquid formulation of endophytic *Bacillus flexus* + endophytic *Trichoderma asperellum* recorded the lowest disease score of 1.7, followed by rice chaffy grain formulation of endophytic *Penicillium pinophilum* + rhizospheric *Trichoderma* sp. (disease score of 1.8) and zimmu (*Allium sativum* x *A. cepa*) leaf extract treated banana plants (disease score of 2.1) as compared to carbendazim (4.4) and control (5.4). Apart from decreasing the disease severity, these treatments also significantly increased the plant growth parameters such as plant height, girth, total number of leaves, leaf area and average bunch weight.

Among 33 botanicals screened against *Foc*, zimmu leaf extract @ 50% concentration was very effective in the inhibition of mycelia and spore germination of *Foc*. The active

principle compound (PC1) and volatiles from zimmu recorded 100% inhibition of mycelial growth and spore germination of *Foc* at 0.1% concentration. Six defense related genes were expressed in the root tissues of both *Foc* alone and *Foc* + *T. asperellum* inoculated Grand Nain in RT-PCR. The expression level of all these genes was consistently higher in *Foc* + *T. asperellum* inoculated plants as compared to *Foc* alone inoculated plants. Vegetative compatibility group analysis of seven *Foc* isolates of Rasthali collected from different banana growing regions of Assam indicated the presence of VCG 0124 and 0125 of race 1. ISSR analysis of the isolates indicated genetic variation within populations of *Foc* was significant, although the genetic identity was high. Zimmu leaf extract @ 50% concentration was very effective in inhibiting the mycelial and spore germination of post-harvest pathogens (*Lasiodiplodia theobromae* and *Colletotrichum musae*). It was also effective in controlling post-harvest diseases *in vivo* besides extending the shelf life of banana. *In vivo* evaluation studies on *T. asperellum* (prr2) for the control of post-harvest diseases and extension of shelf life of banana in packing house condition at 13.5 °C in Cumbum, Tamil Nadu, indicated its efficacy in extending the shelf life of banana hands of 46, 48, 50 and 52 calliper size by 68-75 days compared to standard control (17 days). None of the treatments recorded post-harvest emergence of anthracnose or crown rot disease indicating their efficacy against post-harvest diseases.

Occurrence of Banana Bract Mosaic Virus (BBrMV) along with Banana Streak Mysore Virus (BSMYV) in cv. Poovan in Assam and Banana Streak Gold Finger Virus (BSGFV) in hill banana at Lower Pulney Hills has been recorded for the first time and confirmed by cloning and sequencing of partial genome of the respective viruses. The occurrence of Banana Mild Mosaic Virus (BMMV) in India was reported for the first time. Sequence of the Indian isolate of BMMV shared 74.4–91.7% nucleotides and 87.3–95.7% deduced amino acid similarities with other BMMV isolates. The symptom of this virus infection is very mild on leaf lamina and is very common in cvs. Karpuravalli and Udhayam. Loop Mediated Isothermal Amplification (LAMP) based detection of Cucumber Mosaic Virus (CMV) and BSMYV was standardized in banana. The LAMP based technique developed for CMV was highly specific, 100 times more sensitive than RT-PCR. Candidate Disease Biomarkers have been identified for the detection of BBrMV, which can be used in disease diagnosis after validation.

Banana cultivars Bangrier and Saba were found moderately resistant to root-lesion nematode. Mother cultures of Tissue culture (TC) banana plants received from 47 DBT recognized and unrecognized TC industries were tested for banana viruses under DBT–ATL scheme and under contract service, respectively. Totally 23563 samples were tested for the presence of viruses. Certificate of quality was issued for 52.55 million TC plants.

Transfer of Technology

Around 4500 visitors comprising farmers, students, entrepreneurs, agriculture / horticulture officers visited ICAR–NRCB and they were informed about production, protection and post-harvest technologies of banana developed at this Centre. ICAR–NRCB has participated in eight out-station and two local exhibitions organized by various institutions and conducted Kisan mela at the centre. Three radio talks (All India Radio) and one television talk (Puthiya Thalaimurai) were given and 16 press notes and press releases in various dailies and news magazines were published by the faculty of ICAR–NRCB. Twelve on-campus and four off-campus trainings were organized by the centre. Technology on tissue culture multiplication of banana cvs. Udhayam and Sabri were transferred to two entrepreneurs. Technology

on value added banana products which include banana fig, banana flour, flour based health drink and banana pickle were transferred to 18 entrepreneurs. Technology on production of liquid formulation of entomopathogenic fungus (*Beauveria bassiana*) was transferred to one entrepreneur.

Linkages and Collaborations

ICAR–NRCB has research collaborations with international institutes which include Bioversity International, France and Queensland University of Technology, Australia. The institute has linkages with National institutes, namely, ICAR–NBPGR, New Delhi; BARC, Mumbai; ICAR–IIHR, Bengaluru; ICAR–CIAE, Bhopal, DST and DBT, New Delhi; PAU, Ludhiana; TNAU, Coimbatore. ICAR–NRCB also coordinates with AICRP (Fruits) centers 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. The centre has research collaboration with ICAR–CIAE (RS), Coimbatore, for developing post-harvest mechanization package for banana central core and development of mechanization package for rope making from outer sheath of banana pseudostem.

HRD and Education

Under Human Resource Development, seven scientific, five technical, one administrative and two skilled supporting staff participated in various training programs and refreshed their working knowledge. The centre has published 14 research papers in various journals of International and National repute and ten research papers (5 International and 5 National) were presented in various conferences / symposia / seminars, etc. held across the country. Nine students pursuing B. Tech., M. Tech. & M. Sc. from different Universities were guided by the centre's faculty for their dissertation work on banana.

Revenue Generated

A total of Rs. 24.31 lakh was generated by the centre during the financial year 2015-16.

3. INTRODUCTION

The ICAR–National Research Centre for Banana was established on 21st August 1993 at Tiruchirapalli, Tamil Nadu by the ICAR, New Delhi with an aim to increase the production and productivity of bananas and plantains through mission mode basic and strategic research approaches. This Centre is located at 11.50° N latitude and 74.50° E longitude, 90 m above MSL and receives 800 mm rain annually. The climate is warm and humid and the average minimum and maximum temperature are 25 and 35°C respectively. The Centre has a research farm of 36 ha with laboratory complex in 3 ha.

The major thrust areas of research include *viz.,* Improvement, Production, Post-harvest Management and Protection. ICAR–NRCB has well-equipped research laboratories for tissue culture, biotechnology, soil science, nutrient management, physiology, biochemistry, entomology, nematology, fungal, bacterial, viral pathology and post-harvest technology. The ICAR–NRCB has been identified as the National Repository for banana germplasm. It has a field gene bank consisting of 566 banana germplasm of indigenous collections from North-Eastern region, Western Ghats, Andaman and Nicobar Islands and also exotic banana accessions from International Transit Centre (ITC), Belgium through ICAR–NBPGR, New Delhi. The Centre has completed nine in-house research projects and twenty four are in progress. Sixteen externally funded projects funded by ICAR, DBT, BARC, etc. are in progress. The Perspective Plan and 'Vision 2050' document on the research priorities and also reports by QRT and RAC were published. The Centre has conducted Institute Research Council meet and Research Advisory Council meet to review the on-going research projects and to monitor the progress made on RAC and QRT recommendations. The vision of the Centre is "To be the world leader in production and productivity of bananas and plantains thereby to meet the growing need in India". The Research Advisory Committee, under the Chairmanship of Dr. S. N. Pandey, Retd. ADG (Hort. Sci.), ICAR, New Delhi reviewed the research activities of the Centre and recommended future research activities for the banana development.

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.

Salient Achievements

Improvement

A field gene bank with 590 core accessions (502 indigenous and 88 exotic) have been assembled and maintained in the field gene bank repository at ICAR–NRCB, Tiruchirapalli. Among the collections, 92 accessions are highly resistant and 25 are resistant to Sigatoka leaf spot disease. ICAR–NRCB has released banana variety Udhayam, which belongs to Pisang Awak sub group, is a higher yielder than the local Karpuravalli. Embryogenic cell suspensions (ECS) for five different commercial varieties *viz.,* Rasthali, Nendran, Ney Poovan, Robusta and Grand Nain have been developed and regeneration protocol from ECS for Nendran and Rasthali have been standardized. ICAR–NRCB has developed a DNA Bank for *Musa* germplasm with 310 accessions. A farmers' friendly, low cost mass production method of banana

planting material known as 'Macropropagation' technique was developed at the centre to meet the local need of small and marginal farmers, for multiplication of disease free traditional varieties of banana. The centre has introduced banana cv. Formosona (a high yielding Cavendish banana resistant to Fusarium wilt, race-4) from Taiwan Banana Research Institute (TBRI), Taiwan. ICAR–NRCB banana selection-08 proved its superiority for higher yield and shorter duration in all the AICRP centers tested. Cultivar Saba based progeny (No.183) was found promising in terms of fruit qualities like firm pulp, good cooking quality and suitability to chips making. Namwa khom (Pisang Awak, ABB), a dwarf exotic introduction was found promising and was suitable for high density planting. Screening of *Musa* germplasms against biotic stresses resulted in identification of five diploids resistant to banana weevils and 8 triploids resistant to both root-lesion and root-knot nematodes.

Three banana germplasm accessions namely Manohar (BB), Borkal Baista (BB) and *Musa acuminata* ssp. *burmannica* were resistant to fusarium wilt (VCG 0124). Selection-08 (Saba) was moderately resistant to fusarium wilt. Among the 22 open pollinated progenies of Bhat Manohar, progeny no. 667 performed better in terms of yield. Two progenies namely NCR12/17 and NPL12/33 obtained by crossing with nematode susceptible cv. Nendran with nematode resistant cvs. Rose and Pisang Lilin yielded bunch weighing 12.5 and 9.5 kg respectively. Salicylic acid primed nematode susceptible banana cv. Nendran reduced nematode infection. Use of Carrageenan, a sea weed derived from *Eucheuma cottonii* as a substitute for gelling agent in tissue culture medium reduced the medium cost by42-61%. Macropropagation in cv. Rasthali resulted in the production of 14.5 plants in a short span of 37.42 plants during the tertiary decortication stage as against 10-12 suckers produced in its life span of 12-13 months. *In silico* derived SSRs were able to distinguish the *Mycosphaerella eumusae* resistant cultivars from the susceptible ones. *Musa* Transcriptome SSR database (*Musa*transSSRDB) was further updated using advance bioinformatics tools like MUSABLAST and MUSASAT.

Production

Poovan plants supplied with 20 litres of water/day/plant with 75% N (150 g N/plant) as fertigation increased the yield by 20% and recorded maximum net profit with a benefit ratio of 1.96. A combination of distillery sludge 2.5 kg + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure per plant recorded the maximum growth and yield parameters in Rasthali and Karpuravalli bananas. Application of gypsum 2 kg / plant + FYM 15 kg / plant + 120% recommended K in saline sodic soil increased the yield by 51 % over control in Nendran and Rasthali bananas. Paired row planting system with 4,500 - 5,200 plants/ha, increased the productivity and fruit quality with 75% of recommended fertilizers dose as fertigation in Robusta, Grand Nain and Red Banana. In the second ratoon crop, application of 20kg FYM, 0.9 kg Neem cake, 2.0kg vermicompost and 0.9kg groundnut cake recorded the highest bunch weight of 15.9 kg with more number of hands (12.1) and fingers/bunch (188.5). Application of 20 kg FYM + 0.9 kg Neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake as well as other organic treatments significantly improved the porosity (45.5 %) as well as particle density (44.3%) as against porosity of 40.2% with 100% inorganic that was on par with 125% inorganic fertilization .

Application of 15 kg rice husk ash + 25g VAM + 80% recommended NPK gave an additional profit of Rs. 32,500/ha. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, increased the bunch weight of Ney Poovan by 43.5% over control, resulting in an additional net profit of Rs. 38,000/ha. In cv. Ney Poovan under high pH soil condition indicated

a application of sulphur 20g/plant reduced the soil pH from 8.6 to 7.8 in the rhizosphere soil and increased the plant growth (up to 12.5 %) and yield parameters (up to 14%) significantly over the control. In the first ratoon crop of cv. Udhayam, application of recommended dose of NK fertilizers (RDF) (300:400g N&K plant^{-1}) in ratio of 7:2:1 N and 4:3:3 K_2O at vegetative, flowering and bunch development stages recorded the earliest fruit maturity. Fertilizer adjustment equations for Poovan and Karpuravalli bananas were developed. The fertilizer adjustment equations developed at ICAR - NRCB were validated at different banana growing areas in Tamil Nadu, West Bengal, Kerala and Karnataka through AICRP Centres. Impact of source reduction (leaf pruning) on flowering and fruit yield studies indicated in cvs. Poovan, Ney Poovan and Karpuravalli, reduction in source area increased more photosynthesis as a compensation mechanism. Eight drought tolerant accessions were identified based on leaf water retention capacity. The leaf longevity was more in Robusta than Nendran, Rasthali and Ney Poovan bananas. Saba, Karpuravalli and Ney Poovan have been identified as tolerant cultivars to salt stress. Drought tolerant Saba and Karpuravalli cultivars maintained higher (>200) K/Na ratio in leaf (lamina and midrib) than susceptible Ney Poovan, Nendran and Robusta cultivars (4.52 to 17.56) at shooting and fruit maturity.

Foliar priming of 5 month old banana cv. Grand Nain with 0.1mM acetyl salicylic acid (ASA) prevents bunch malformation and yield reduction due to soil moisture deficit. Foliar priming banana cv. Grand Nain with 20 mM glycine betaine and subsequent imposition of salt stress with 50mM NaCl increased two and five fold dry matter production compared with unprimed salt stressed plants. Similarly, foliar priming of three month old banana cv. Grand Nain with 200µM beta amino butyric acid and subsequent imposition of salt stress (50mM NaCl) recorded significantly less Na+(0.03%) accumulation in leaves than non-primed plants (0.18%) and increased K+ accumulation (3.45%) than non-primed plant leaves (1.82%). Salt tolerant 'Saba' produced higher total dry matter and recorded less susceptibility index under 100 mM NaCl stress compared to other banana cultivars. In cv. Grand Nain, the plants foliar primed with acetyl salicylic acid (0.1mM) combined with butylated hydroxy toluene (100 ppm) before the imposition of soil moisture stress recorded bunch weight (18.78 kg) comparable to irrigated (19.72). The impairment of Mg dechelatase and pheophorphide a oxygenase activities and partial degradation of chlorophylls in peel of Cavendish (Grand Nain) bananas at elevated temperatures exhibiting green ripe character. Transgenics for iron rich banana fruits in cvs. Rasthali and Grand Nain were produced using the iron gene construct pBMGFDC- 53 carrying OsNAS1 gene.

Post-harvest Technology

Pre-packaging in 400 gauge LDPE bags, low temperature storage, use of ethylene absorbents and pre-storage treatments have resulted in extension of shelf life up to 3 months in Robusta, Grand Nain, Rasthali and Ney Poovan bananas. Several value added products like flower *thokku*, peel *thokku*, fruit pickle, fig, biscuits, jam, ready to serve beverages and functional foods like *chapathi*, bread and health drink have been developed. Banana and Jamun juice blend was the best among blends made with other fruit juices rich in antioxidants. A recipe for banana flower based ready to make soup has been standardized. A new product, banana pulp based 'Sip-up' was prepared without pasteurization. The product can be stored up to 15 days at 0°C. An improved post-harvest packing and storage technique, modified atmosphere packaging (MAP) of harvested green banana at 13.5°C, recorded 28, 35 and 68 days of shelf life of 'Saba' (100% maturity), Poovan

(90% maturity) and Nendran (75% maturity) respectively. Prevention of enzymatic browning in central core stem of banana was standardized for commercially grown banana cultivars namely, Poovan, Karpuravalli, Ney Poovan, Pachanadan, Saba and Mortman (Andhra Rasthali). Banana central core stem juice based products (RTS stem juice and Jelly) were developed.

In cv. Grand Nain, overall 10.52% and 10.48% post-harvest losses were estimated in Theni and Erode Districts, respectively. In cv. Poovan, overall 16.50% and 9.10% post-harvest losses were recorded in Tiruchirapalli and Tuticorin Districts of Tamil Nadu. Superior rehydration and sensory score was observed when the banana slices were dried at 55^0C. Out of six varieties of banana varieties evaluated for corm juice, Udhayam recorded maximum recovery, followed by Nendran and Saba.

Protection

Mass production technique for *Paecilomyces lilacinus* (an egg parasite of root-knot nematode) using banana petiole and pseudostem has been developed. Combined application of *Bacillus subtilis* and *B. cereus* in cv. Ney Poovan resulted in 60% increase in plant growth with 90% reduction of root lesion nematode populations than individual treatments. Maximum reduction of 90% nematode population with 50% increase in plant growth and bunch weight was recorded in plants treated with *P. lilacinus* + *Pseudomonas fluorescens* + Neem cake + Marigold as intercrop. Screening of *Musa* germplasms against major nematodes resulted in the identification of 5 diploids and 8 triploids resistant to both root-lesion and root-knot nematodes. Banana cultivars Bangrier and Saba were found to be moderately resistant to root-lesion nematode.

Swabbing 0.06% chlorpyrifos 20 EC on the pseudostem of 1.2 m height during 5 to 8 months completely controlled banana stem weevil incidence. Treating suckers with monocrotophos 36 EC (14 ml/litre) followed by soil application of carbofuran 3G at the rate of 30 g per plant at 4th and 7th month after planting found effective against corm weevil. Pseudostem split trap swabbed with chaffy grain formulation of *Beauveria bassiana* trapped the stem and corm weevils better than traps swabbed with maize flour formulation. Of the 37 semiochemicals tested, maximum olfactory response by corm weevil was recorded to bisabol-ol, and found effective for banana corm weevil monitoring under field conditions. Field evaluation conducted using funnel trap in a weevil (*O.longicollis)* endemic areas of Theni and Dindigul districts of Tamil Nadu showed that the weevil attraction was maximum (80%) in the treatment of Semiochemical No. 1 + host plant volatile extract obtained from cv. Nendran.

Root dipping of soil endophyte, *Beauveria bassiana* on cv. Grand Nain was found promising as it recorded 100% weevil mortality, whereas soil drenching of *M. anisopliae* recorded 75 % mortality. By insect dip method, aqueous and hexane extracts of zimmu showed 100% stem weevil mortality at 100% concentration on 10th day. The solvent extract of zimmu tested against banana corm weevil resulted in 100% mortality at 100% concentration on 6th day. Screening of *Musa* germplasm accessions against banana weevils showed that Adukkan (AB), Dinamalakol (ABB), Norman (AB), KNR mutant (AB) and Jurmony (BB) as resistant. Studies on amylase inhibitor bioassay against 3rd instar stem weevil grub showed 100% mortality with 75mg/20ml concentration at 10th day after treatment. Natural enemies of banana skippers, *Erionota* spp. were recorded from different parts of India. Cross reaction between race 1 and race 2 of *Foc* has been observed in VCG analysis. Diversity of *Foc* isolates has been studied using RAPD, PCR-RFLP analysis of IGS region and the sequence analysis of rDNA-ITS region. Use of Carbendazim (0.1 %) for dipping the suckers before planting followed by soil drenching

in root zone (@ 1-2 lit at 2,4 & 6 month after planting) and stem injection(@2ml at 2,4 &6 MAP) effectively controlled the Fusarium wilt disease in Ney Poovan cultivar under field conditions. The combined application of rhizospheric and endophytic fungal antagonists along with or without fungicide application under field condition significantly increased the bunch weight (up to 74.8%) and suppressed the Fusarium wilt disease. The bio-priming of banana plants with the combined application of *Pseudomonas putida* + Alpinia, *Pseudomonas putida* + *Hibiscus* sp., *Pseudomonas putida* + zimmu, *Bacillus* sp. + zimmu combinations resulted in complete control (100 %) and significantly increased the plant growth parameters. Zimmu planting was found to reduce the soil inoculum load of fusarium wilt from 5.60 x 10^5 to 6.6 x 10^2. Microscopic examination and molecular analysis of 96 isolates of *Mycospharella* spp. isolated from different cultivars of banana grown in different regions of India revealed the presence of *M. eumusae* indicating that the leaf spot in India is caused by *M. eumusae.* Foliar spray of *Bacillus* spp. (1e2 and 12acy) at shooting stage reduced eumusae leaf spot disease by 56.8% and 54.3% respectively. Bio-control agents, *Trichoderma asperellum* and *T. longibrachiatum* were found better in inhibiting mycelial colonies of post harvest pathogens, *Colletotrichum musae* and *Lasiodiplodia theobromae*. *T. asperellum* (prr2) was also found effective in extended shelf life of banana fruits by 28 days at 23°C and 55 days at 13°C from post harvest pathogens.

Among 33 botanicals screened against *Foc*, zimmu leaf extract @ 50% concentration was very effective in the inhibition of mycelia and spore germination of *Foc*. The active principle compound (PC1) and volatiles from zimmu recorded 100% inhibition of mycelial growth and spore germination of *Foc* at 0.1% concentration. Six defense related genes were expressed in the root tissues of both *Foc* alone and *Foc* + *T. asperellum* inoculated Grand Nain in RT-PCR.

Soil application of increased dose of fertilizer (150% of RDF) in cv. Poovan has compensated the yield loss due to BBrMV. Polyclonal antiserum to BBTV was produced and ELISA technique has been standardized for detection. NA probe and PCR based diagnostic techniques have been developed for all the banana viruses. A multiplex PCR technique has been developed for detecting three banana viruses simultaneously. Complete genome of BSV infecting Poovan has been cloned and sequenced. Promoter sequences from BBTV were cloned and sequenced. Duplex PCR for all the four viruses CMV, BBrMV, BBTV and BSV has been standardized. Real Time-PCR technique for simultaneous detection of banana viruses was standardized. Rolling circle amplification (RCA) approach which uses bacteriophage Phi29 DNA polymerase has been standardized to detect episomal virus of BSMysV in Poovan and BBTV in Hill banana. Primers and probe have been designed for rep gene of BBTV and assessed the quantity of its transcripts in latent and severely infected plant susing real time-PCR. Three complete genomes (7.6 Kbp) of Banana Streak Virus (BSV) species infecting cvs. Rasthali and Poovan were amplified by RCA and cloned. A solvent free simple extraction protocol was developed and validated for the detection of banana bunchy top virus (BBTV). Studies showed that streak virus severity and yield loss were significantly higher in TC plants than healthy and Banana Streak Mysore Virus (BSMYV) infected sucker grown plants. Complete genomes of BSMYV and BBTV were obtained in dually infected Poovan sample. Transgenic banana plants resistant to BBTV were generated using BBTV-rep gene construct and the resultant 52 plants tested negative to BBTV inoculation through banana aphid (*Pentalonia nigronervosa*). Multivirus resistant transgenic plants were generated using RNAi construct from 8 embryonic cell suspension (ECS) lines. These plants were inoculated with BBTV through banana aphid, *P. nigronervosa* and symptom expression was absent in three lines.

Occurrence of Banana Bract Mosaic Virus (BBrMV) along with Banana Streak Mysore Virus (BSMYV) in cv. Poovan in Assam and Banana Streak Gold Finger Virus (BSGFV) in hill banana at Lower Pulney Hills has been recorded for the first time and confirmed by cloning and sequencing of partial genome of the respective viruses. The occurrence of Banana Mild Mosaic Virus (BMMV) in India was reported for the first time.

Transfer of Technology

Around 4500 visitors comprising farmers, students, entrepreneurs, agriculture / horticulture officers visited ICAR–NRCB and they were informed about production, protection and post-harvest technologies of banana developed at this centre. ICAR–NRCB has participated in eight out station and two local exhibitions organized by various institutions and conducted Kisan mela at the centre. Three radio talks (All India Radio) and one television talk (Puthiya Thalaimurai) and 16 press notes and press releases in various dailies and news magazines were published by the faculty of ICAR–NRCB. Twelve on-campus and four off-campus trainings were organized by the centre. Technology on tissue culture multiplication of banana cvs. Udhayam and Sabri was transferred to two entrepreneurs. Technology on value added banana products which include banana fig, banana flour, flour based health drink and banana pickle was transferred to 18 entrepreneurs. Technology on production of liquid formulation of entomopathogenic fungus (*Beauveria bassiana*) was transferred to one entrepreneur.

Linkages and Collaborations

ICAR–NRCB has research collaborations with international institutes which include Bioversity International, France and Queensland University of Technology, Australia. The institute has linkages with National institutes namely, ICAR–NBPGR, New Delhi; BARC, Mumbai; ICAR–IIHR, Bangaluru; ICAR–CIAE, Bhopal, DST and DBT, New Delhi; PAU, Ludhiana; TNAU, Coimbatore. ICAR–NRCB also coordinates with AICRP (Fruits) centers 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. The centre has research collaboration with ICAR–CIAE (RS), Coimbatore, for developing post-harvest mechanization package for banana central core and development of mechanization package for rope making from outer sheath of banana pseudostem.

Budget details (Revised Estimate) for the year 2015 - 16 (Rs. in lakhs)

A total of Rs. 24.31 lakh was generated by the Centre during the financial year 2015 - 16.

S. No	Head of Account	Plan	Non-Plan
1	Establishment charges	0.00	448.09
2	Overtime Allowance	0.00	0.05
3	Travelling Allowance	0.69	5.99
4	Contingencies	82.33	139.39
5	HRD	2.16	0.00
6	Equipments	94.63	4.57
7	Works	69.21	0.00
8	Library & Journals	0.46	0.00
9	Pension and Retirement Benefits	0.00	42.10
	Total	**249.48**	**640.19**

4.1 CROP IMPROVEMENT

4.1.1 Improvement and Management of Banana Genetic Resources in Indian Subcontinent

Survey and Collection

A total of 27 banana germplasm accessions have been collected through exploration in Tripura and Nagaland states and from secondary sources like BRS, Kannara, Kerala. Survey was also conducted in Mannarkad area of Palakkad District, Kerala and Chidambaram areas of Cuddalur District, Tamil Nadu for banana diversity (Table 1). Seventy exotic accessions were also introduced through ICAR–NBPGR, New Delhi.

Seeds of *Musa nagensium, M. sikkimensis, M. velutina* hybrid, *M. rosaceae, M. aurantiaca, M. saddlensis* and *M. itinerans* were initiated *in vitro* and plants were regenerated successfully through embryo culture.

Table 1. Details of germplasm collection

Sl. No.	Name of the collection	Probable genome/section	Place of collection
1	Pachottan	AAA	BRS, Kannara, Kerala
2	Paka	AA	BRS Kannara, Kerala
3	Karim Kadali	AA	BRS Kannara, Kerala
4	FHIA -23	AAAA	BRS Kannara, Kerala
5	Kadali	AA	BRS Kannara, Kerala
6	Big Ebanga	AAB	BRS Kannara, Kerala
7	SH- 34 36-9	AAAA	BRS Kannara, Kerala
8	FHIA - 01	AAAB	BRS Kannara, Kerala
9	SH 36 -40	AAAA	BRS Kannara, Kerala
10	5295 - 1	-	BRS Kannara, Kerala
11	Gera	ABB	Tripura
12	Wild Banana	BB	Tripura
13	Wild Kela	BB	Tripura
14	Jahaji/DC	AAA	Tripura
15	Bhimkol	BB	Tripura
16	Jatikol	AAB	Tripura
17	Amrit Sagar	AAA	Tripura
18	Kashkol	ABB	Tripura
19	Red Banana	AAA	Tripura
20	Nendran	AAB	Changanacherry, Kerala
21	Swarnamukhi	AAB	Erode, Tamil Nadu
22	Quintal Nendran	AAB	Erode, Tamil Nadu
23	Grand Nain	AAA	TERI, New Delhi
24	Grand Nain -Dwarf	AAA	Periyakulam, Tamil Nadu
25	Rasthali	AAB	Tiruchirapalli, Tamil Nadu
26	Red banana	AAA	Periyakulam, Tamil Nadu
27	Kothia	ABB	Chidhambaram,Tamil Nadu

Characterization and Classification

Morphotaxonomic characterization was completed for five accessions using IPGRI *Musa* descriptor, and they were classified according to their genomic and subgroups through 15 character score card system (Table 2).

Table 2. Morphotaxonomic characterization of *Musa* germplasm

Sl. No.	Name of the accession	Genome	Sub group
1	Kurangu Vazhai	AAB	Pome
2	Shasra Poovan	AB	Kunnan
3	Safed Velchi	AB	Ney Poovan
4	Dole	ABB	Bontha
5	Pisang Berangan	AA	Unique

DNA profiling of plantain clones using ISSR markers

ISSR markers were used for DNA profiling of Nendran, Quintal Nendran and Swarnamukhi as these are similar and difficult to identify in early stages.

A total of 11 ISSR primers were used to detect DNA polymorphism among 16 clones of plantain. A total of 223 fragments were amplified whose size ranged from 200 bp to 2700 bp in size. 93.79% polymorphism was observed in the present study. UBC 808 produced the highest number of polymorphic bands (28), whereas UBC 818 produced lowest number of polymorphic bands (12 bands). Cluster analysis was performed and a dendrogram was generated that separated the clones into two distinct clusters. The genetic distance for the 16 test accessions ranged from 0.52 to 0.95. The lowest genetic distance was observed between Nedu Nendran and Nijokhome, while the highest genetic distance was detected between Zanzibar and FH (False Horn) plantain. The study was also able to generate clone specific bands for all plantain clones tested except Nijokhome, False Horn plantain and Mysore Eathen. They could be converted into SCAR markers for use in clonal identification. The specific markers would also serve as reference for use in genetic fidelity testing of plantain clones (Fig 1).

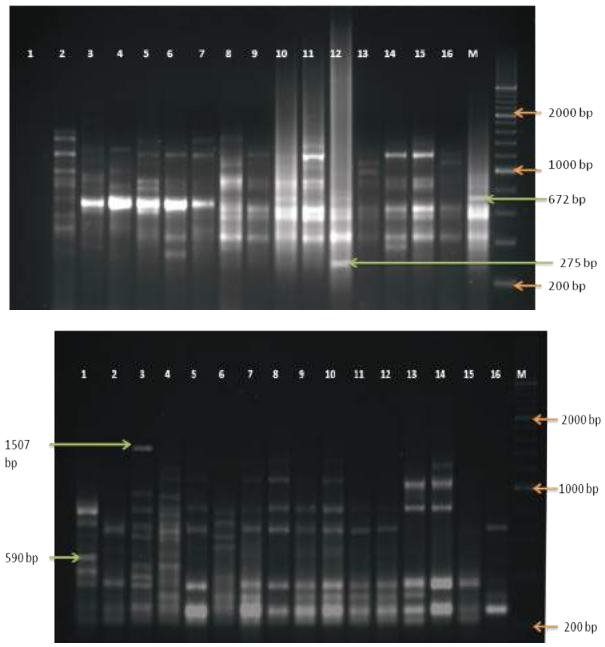


Fig 1. DNA profile of plantain clones generated using ISSR markers UBC 811 and UBC 834

Lanes 1. Attu Nendran, 2. NeduNendran, 3. Big Ebanga, 4. Myndoli, 5. Chengalikodan, 6. ManjeriNendran, 7. Swarnamukhi, 8. Nendran, 9. FHIA 21, 10. Nijokhome, 11. Kaliyethan, 12. Quintal Nendran, 13. Zanzibar, 14. False Horn Plantain, 15. Mysore Eathen, 16. PisangNangka, M. Ladder

Studies on different regeneration systems in banana

Plants derived from three different explants, namely, shoot tip, cormlet and male flower bud of cv. Udhayam and shoot tip and male flower bud derived plants of cv. Rasthali along with their respective sucker controls have been planted in the farmer's field for evaluation. In case of cv. Ney Poovan, plants derived from two different explants, namely, shoot tip, and male flower bud are in the rooting stage.

Macropropagation

Macropropagation of cv. Rasthali included two set of treatments, namely, differently aged suckers and steaming. Results indicated that use of five months old, steam sterilized corms resulted in an average production of 14.5 plants in a short span of 37.42 days during the tertiary decortication stage as against 10-12 suckers in its life span of 12-13 months. BAP treatment did not seem to have a significant effect on the number of shoots produced (Fig 2, Table 3 & 4).

Table 3. Effect of sucker age and steaming treatment on multiple shoot bud formation during different decortication stages in cv. Rasthali

Age of sucker	Stage of decortication							
	Primary		Secondary		Tertiary		Fourth	
	Steam	Non-steam	Steam	Non-steam	Steam	Non-steam	Steam	Non-steam
3 months	1.17	1.83	2.33	3.00	3.50	5.00	1.17	1.33
5 months	3.83	3.00	6.17	4.33	14.50	10.00	3.33	2.33
7 months	2.83	2.17	5.67	4.00	9.33	6.67	3.67	2.83
Sources	SEd	CD (p = 0.05)	SEd	CD (p = 0.05)	SEd	CD (p = 0.05)	SEd	CD (p = 0.05)
S	0.31	0.70	0.29	0.65	0.85	1.89	0.23	0.52
T	0.14	NS	0.24	0.51	0.36	0.76	0.30	NS
S x T	0.36	0.79	0.42	0.90	0.95	2.11	0.43	NS
T x S	0.25	0.53	0.42	0.88	0.62	1.32	0.51	1.09

Table 4. Effect of sucker age and steaming treatment on days taken for multiple shoot bud formation during different decortication stages in cv. Rasthali

Age of sucker	Stage of decortication							
	Primary		Secondary		Tertiary		Fourth	
	Steam	Non-steam	Steam	Non-steam	Steam	Non-steam	Steam	Non-steam
3 months	21.67	29.50	16.50	13.50	28.67	22.17	36.00	42.00
5 months	17.92	26.50	7.00	10.17	12.50	15.00	25.00	29.00
7 months	28.08	29.17	9.00	12.00	10.17	19.00	21.00	31.00
Sources	SEd	CD (p = 0.05)	SEd	CD (p=0.05)	SEd	CD (p=0.05)	SEd	CD (p=0.05)
S	0.92	2.04	0.75	1.68	0.66	1.48	0.53	1.17
T	0.48	1.02	0.29	0.62	0.49	1.05	0.63	1.34
S x T	1.09	2.39	0.83	1.84	0.90	1.96	0.93	2.01
T x S	0.92	2.04	0.75	1.68	0.66	1.48	0.53	1.17

Fig 2. Macropropagation in cv. Rasthali

Use of low cost alternatives in banana tissue culture

Carrageenan is a gelling agent derived from the sea weed *Eucheuma cottonii* and the potential of using it as a low cost alternative for the routinely used gelling agents like agar / phytagel was explored in banana tissue culture. Accordingly, MS media were gelled with two types of carrageenan (CN I with hormone and CN II without hormone) either alone or in combination with sago / agar using agar and phytagel individually as controls I and II respectively. CN I with sago was found optimum for initial establishment of cv. Udhayam as the days taken for greening of shoot tips (11.80 days) were on par with controls (10.40 and 10.80 days). Shoot proliferation was maximum in T_7 (11.20

Table 5. Effect of Carrageenan and their combinations on tissue culture multiplication of cv. Udhayam

S. No.	Treatment	Number of days taken for greening of shoot tips	Number of days taken for primary bud formation	Number of shoots produced per explant during proliferation	Medium cost (per litre) in Rs.	Per cent reduction in medium cost against controls
1	CN I + no reg hormones	17.00 b	23.35b	3.50c	27.45	61.32/57.74
2	CN I + reg. hormones	16.80 b	13.85a	5.60c	28.22	60.23/56.56
3	CN II + reg. hormones	13.00 ab	14.00a	6.00c	31.97	54.95/50.79
4	CN I + Sago + reg. hormones	11.80 a	13.60a	4.00c	33.44	52.88/48.54
5	CN II + Sago + reg. hormones	21.40 c	14.75a	4.00c	37.19	42.73/42.76
6	CN I + Agar + reg. hormones	14.60 ab	12.70a	7.90b	31.00	56.31/52.29
7	CN II + Agar + reg. hormones	14.00 ab	11.25a	11.20a	32.50	54.21/49.98
8	T8 (Agar)	10.80 a	11.25a	7.00b	70.97	
9	T9 (Phytagel)	10.40 a	11.35a	8.45b	64.97	
SEd		2.07	3.43	1.13		
CD(0.05)		4.20	7.03	2.32		
Level of significance		**	*	**		

shoots) and significantly different from controls (7.00 and 8.45 shoots). Rooting was also early in T_2 (5.20 days) which contained CN I supplemented with NAA, IBA and activated charcoal. Use of carrageenan substantially reduced the medium cost by 42-61% when compared to control (agar). This reduction in medium cost would ultimately bring down the production cost thereby making tissue culture bananas accessible to small and marginal farmers (Fig 3 & Table 5).

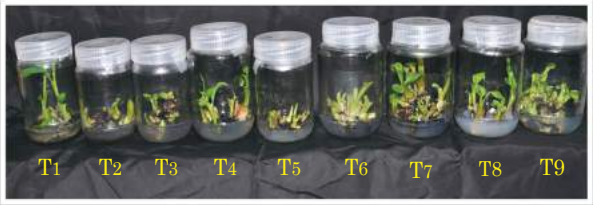


Fig 3. Effect of Carrageenan and their combinations on shoot proliferation in cv. Udhayam

Multiple shoot induction in *Musa aurantiaca*

Multiple shoot induction was observed in 80% matured embryos of *M. aurantiaca* which was initiated in MS medium supplemented with BAP and IAA (Fig 4).

Fig 4. Multiple shoot induction and regeneration in 80% mature embryos of *M. aurantiaca*

Proteomic analysis of somatic embryo development in Banana (*Musa* spp.) Comparative proteome analysis between embryogenic and non-embryogenic calli of cv. Rasthali

In cv. Rasthali, around 11.11% of initiated immature floral hands developed into embryogenic calli (EC), whereas the rest 88.89% developed into non embryogenic calli (NEC). Hence, proteome analysis of EC and NEC was carried out in order to increase the percentage of EC by understanding the molecular mechanism underlying the process of somatic embryogenesis. Totally 28 spots were uniquely expressed in EC than NEC. Similarly 5 spots were uniquely expressed in NEC alone (Fig 5 & 6).

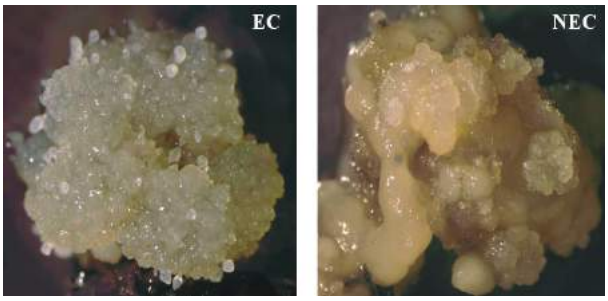


Fig 5. EC-Embryogenic calli and NEC-Non embryogenic calli of cv. Rasthali

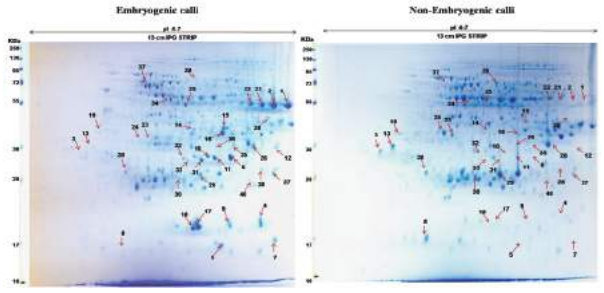


Fig 6. 2D gel image of EC and NEC of cv. Rasthali

Comparative proteome analysis among different development stages of somatic embryo of cv. Grand Nain

In cv. Grand Nain, 25 protein spots were differentially expressed in different developmental stages of somatic embryo. Of these, 9 and 14

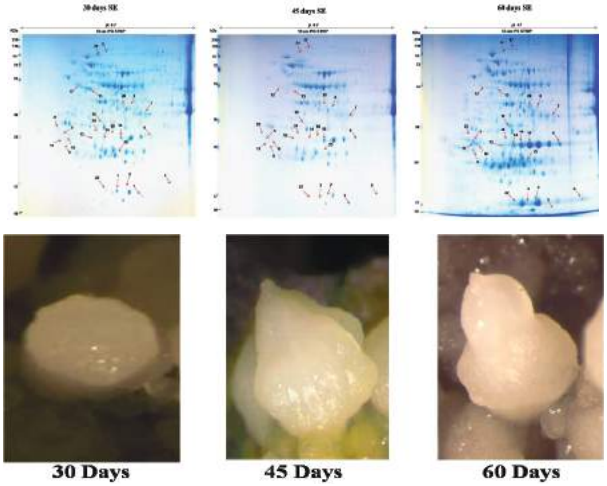


Fig 7. Development stages of somatic embryos of cv. Grand Nain (30, 45 and 60 days somatic embryos)

spots were uniquely expressed in 30 and 60 days old somatic embryo, respectively. All the 25 spots were successfully identified through MS/MS analysis. The classification of proteins based on their physiological role is in progress. Around 16% of differentially expressed spots were found to be involved in developmental process while 19% were involved in metabolic processes (Fig 7).

Comparative proteome analysis among different development stages of somatic embryo of cv. Rasthali

In cv. Rasthali, 19 spots were differentially expressed in developmental stages of somatic embryo. Of these 3 and 9 spots were uniquely expressed in 30 and 60 days old somatic embryos respectively. 6 protein spots were highly abundant in 60 days old somatic embryos. All the spots were successfully identified through MS-MS analysis. Approximately 10% of the proteins were involved in developmental process and 13% in metabolic processes while 4% were involved in immune system processes (Fig 8).

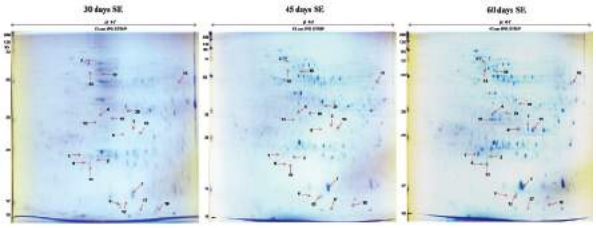


Fig 8. Development stages of somatic embryos of cv. Rasthali (30, 45 and 60 days somatic embryo

Comparison of germinating and non germinating somatic embryos of cv. Grand Nain

In cv. Grand Nain, 25 protein spots were differentially expressed between germinating and non-germinating somatic embryos. Among them, 7 and 2 spots were uniquely expressed in germinating and non germinating somatic embryos, respectively. Sixteen spots were also found to be highly abundant in germinating somatic embryos (Fig 9).

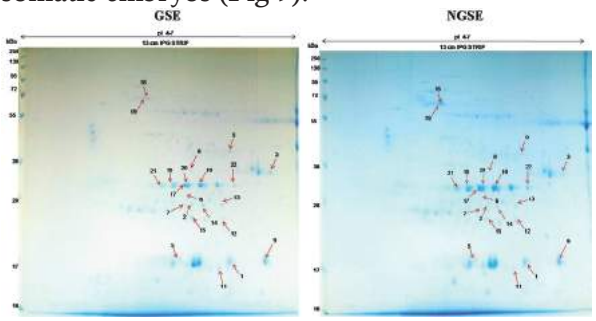


Fig 9. Comparison of germinating and non germinating somatic embryos of cv. Grand Nain

Table 6. Yield data of the ratoon crop of elite clones of cv. Ney Poovan at farmer's field

S.No.	Plant No.	Bunch weight	No.of hands	No.of fingers	Days taken for shooting	Crop Duration(days)
1	1	9.80ab	9.6	161cd	168.0	269.3
2	4	9.50b	9.6	166ab	163.6	270.0
3	8	9.30bc	9.3	160d	16.05	270.0
4	22	10.00a	10.3	168a	168.6	268.6
5	26	8.80cd	9.3	159d	165.3	269.3
6	27	9.30bc	9.6	161cd	171.0	269.3
7	29	10.00a	9.6	164bc	169.0	268.6
8	Control	8.50d	9.0	153e	166.3	270.0
S.Ed		0.28	0.44	1.68	2.18	0.74
Level of significance		**	NS	**	NS	NS

Evaluation of elite clones of cv. Ney Poovan

Seven superior clones of cv. Ney Poovan which were allowed for first ratoon at farmer's field have been harvested and it yielded a maximum of 10 kgs in a time span of 268-270 days while one set of suckers which was brought from the farmers field and planted at ICAR-NRCB, Tiruchirapalli are yet to flower. Suckers from the high yielding clones have also been initiated *in vitro* for mass multiplication (Table 6 & Fig 10).

Fig 10. Ratoon of cv. Ney Poovan during harvest at farmer's field

Evaluation of ICAR-NRCB selections against wilt pathogen, *Fusarium oxysporum* f.sp. *cubense* (*Foc*)

ICAR–NRCB selections (NRCB-04, 08, 09 and 10) were evaluated for reaction to *Foc*.

Table 7. Reaction of ICAR–NRCB selections for *Foc* (VCG–0124)

S. No.	ICAR–NRCB Selections	Average disease score
1	Selection-04	4.9
2	Selection-08	3.9
3	Selection-09	3.1
4	Selection-10	5.5
5	Local Check	3.5

Of the four ICAR–NRCB selections tested, selection-08 (Saba) was found to be moderately susceptible to *Foc* with a score of 3.1 (Table 7).

4.1.2 Improvement of banana through conventional breeding

Hybridization

During 2015-16, a total of 307 bunches were crossed involving different combinations of AA x AA, AAB x AA, ABB x AA and BB x AA, etc., and 17,428 hybrid seeds were obtained from 96 cross combinations. Out of 14,850 good seeds, only 7860 embryos were obtained, of which only 550 embryos germinated under *in vitro* conditions Out of 550 embryos germinated, only 365 were regenerated which are in various primary and secondary hardening stages. Eighty eight plants were field planted at ICAR-NRCB and 40 hybrid progenies from various cross combinations were planted at Agali, Kerala for further field evaluation.

Identification of improved diploids

Progeny No. 429 (Cv. Rose X Pisang Lilin) exhibited field tolerance to *M. eumusae*, pollen fertility, appreciable fruit size, TSS, etc. This could be used in breeding programme as a potential synthetic diploid.

Evaluation of open pollinated tetraploid progenies of Bhat Manohar (ABBB)

Primary tetraploids are important in developing secondary triploids. A total of 22 open pollinated Bhat Manohar (ABBB) (Progeny nos. 619-628, 664-675) progenies were planted at Agali, Kerala, of which only 12 plants were harvested. Of these, progeny No. 667 performed better in terms of yield and other quantitative traits. In terms of bunch weight, it recorded 19.5Kg which is 90% higher than the normal Bhat Manohar (10.5Kg). Fruit length (14.5 cm) was 50% more than the normal Bhat Manohar fruits (9.5cm) (Table 8 & Fig 11). This progeny has potential use in developing superior triploids through crossing. With good yield and fruit qualities, they could be directly utilized for commercial cultivation.

Table 8. Performance evaluation of open pollinated tetraploid progenies of Bhat Manohar

Characteristics	Open pollinated progenies of Bhat Manohar (4X)												Bhat Manohar
	P 619	P 620	P 624	P 627	P 628	P 667	P 668	P 669	P 671	P 672	P 674	P 675	
Height (in cm)	395	380	398	380	378	385	378	389	387	385	383	380	360.5
Girth (in cm)	84	86	82	78	79	86	86	90	92	88	87	92	76
No. of leaves at shooting	16	16	16	16	15	16	17	16	17	16	18	16	15.5
No. of leaves at harvesting	11	12	11	12	11	12	12	12	10	10	12	11	12
Bunch weight (Kgs)	12.5	12.5	9.5	9	11	19.5	11.5	10.5	10	9	8	8	10.5
No. of hands	7	7	8	8	7	14	8	7	7	6	6	5	7.5
No. of fruits / hand	12	10	10	12	11	14	12	12	11	10	12	12	13
Fruit length (in cm)	9	10	10	10	9	14.5	8	9	10	10	10	9	9.5
TSS (in brix)	28.5	28	29	28	27	28	28	27	27.5	27	27	26	27

Fig 11. Bunch of tetraploid progeny of Bhat Manohar

Performance evaluation of progenies of Saba (ABB) x Pisang Lilin (AA)

During this reporting period, 24 hybrid progenies of Saba x Pisang Lilin were planted at Agali, Kerala for evaluation (Progeny no. 581-583, 630- 634, 676-691), of which only 11 plants survived and same were evaluated for their agronomic attributes. Maximum height (372cm) and pseudostem girth (69cm) were observed in progeny no. P 691. Minimum height of 358cm was observed in P 676 and girth of 67 was observed in P 581. All the progenies were phenotypically triploid like parent Saba. Minimum bunch weight was recorded in P581 (12.5kgs) and maximum bunch weight of 22kgs was recorded in progeny no. P 684. Bunch and fruit characteristics, were like Saba (Dark green fruits, blunt tip) except progeny 685 which had green and pointed tip as in Kothia (ABB). This needs further investigation through molecular characterization. With improved yield, this progeny can go for large scale evaluation and screening against biotic and abiotic stresses (Table 9, Fig 12 & 13).

Table 9. Performance evaluation of progenies of Saba (ABB) x Pisang Lilin (AA)

Characteristics	Hybrids of Saba(ABB) x PisangLilin(AA)											Saba
	P 581	P 632	P 634	P 676	P 680	P 681	P 684	P 685	P 686	P 690	P 691	
Height (in cm)	360	365	360	358	360	365	368	359	360	370	372	340
Girth (in cm)	67	72	69	69	72	69	71	72	70	72	69	68
No. of leaves at shooting	13	14	13	15	13	14	14	14	15	15	15	15
No. of leaves at harvest	8	9	8	8	9	9	8	8	9	10	9	9
Bunch weight (Kgs)	12.5	14	15	15	15.5	15.5	22	19.5	19.2	16.5	12.5	20
No. of Hands	6	6	7	7	7	8	10	9	10	8	6	8
No. of Fruits / hand	12	12	13	12	13	12	14	12	13	12	12	12
Fruit length (in cm)	15	12	12	14	13	13	16	15	15	14	12	15.5
TSS (in brix)	19	21	20	20	19	20	18	19	19	19	18	21

Fig 12. Bunch of Progeny No. 684

Fig 13. Bunch of Saba

Evaluation of Kothia (ABB) based progenies

A total of 56 hybrid progenies were developed from different cross combinations of Kothia using Pisang Lilin, Calcutta-4 and cv. Rose as male parents. All the hybrids were characterized through morphotaxonamic traits using Banana Descriptor which indicated that they are phenotypically diploids in nature and are highly polleniferous. Invariably all hybrids obtained through the three different cross combinations (Kothia x Pisang Lilin, Kothia x Calcutta - 4 and Kothia x cv.Rose) are slender in stature, bunch and fruits are not of harvestable quality. Fruit development was very poor with little or no pulp in the fruit. However, all are found to be field tolerant to Sigatoka leaf spot disease.

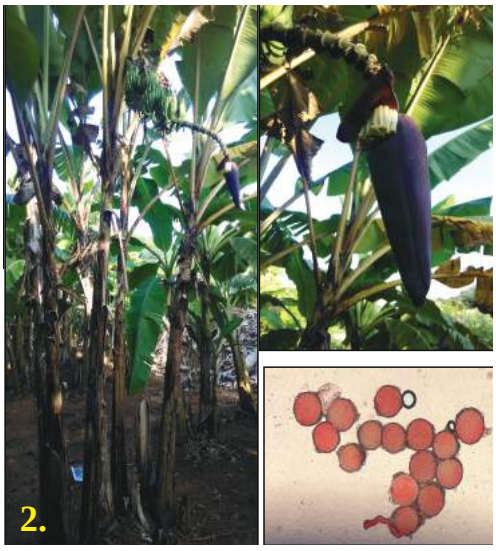
Score card for evaluation of banana variety / hybrid

Preference ranking has been a popular tool with an aim to identify user's assessment of the "best" or "most important" trait from a list of traits. A variety developed is considered as superior based on a set of scores/ranks which needs to be defined based on the objective for improvement. This is both variety and crop specific and we have developed score card for five groups, namely, Red banana, Plantain, Pisang Awak, Cooking and AAB group of bananas.

Development of synthetic tetraploids from triploid x diploid cross combination

Totally 38 hybrid seeds were obtained from Marabale (AAB) which was crossed with Pisang Jajee (AA). Fifteen hybrid embryos were germinated and regenerated through embryo culture, of which only 10 plantlets survived.

Fig 14. 1. Progeny 443- 4x
Marabale (AAB)X Pisang Jajee (AA)



14. 2. Progeny 447- 2x
Marabale (AAB) X Pisang Jajee (AA)

These hybrid plantlets were planted in Satellite Breeding Block, Agali, Kerala. All the hybrid plantlets were assessed for their ploidy level through flow cytometry method in ICAR-IIFGR, Jhansi. Results indicated that 9 were tetraploid (4x) and 1 diploid (2x). Among the 9 tetraploid progenies, progeny no. 443 was identified as parthenocarpic type, yielding 8 to 10 kg as against 8 Kg in parent. Another progeny no. 447 (Marabale (AAB) X Pisang Jajee (AA) was identified to have fertile pollen grains against Pome members which are generally male sterile, and cannot be used as male parent in breeding programmes (Fig 14).

Studies on factors affecting seed set in banana

Gene expression studies during pollen-stigma interactions

Totally seven genes which were highly involved in pollen-stigma interactions were selected for this experiment. Two different parthenocarpic cultivars, Saba (ABB) and Grand Nain (AAA) were crossed with Calcutta-4 (AA). The pollinated samples were collected at different time intervals (5 mins to 60 mins). Out of seven genes, pectin esterase, EXO70A1 was found to be up-regulated in cv. Saba at 5 and 45 minutes after pollination (MAP) by 6 and 2-fold, respectively. These genes were highly responsible for pollen hydration and germination process during the pollination. Pollen germination was observed in only cv. Saba, so these genes seemed to play a vital role in the pollen hydration and pollen germination and Indole-3-acetic acid-amido synthetase GH3.1 was unregulated in cv. Grand Nain compared with cv. Saba (Fig 15).

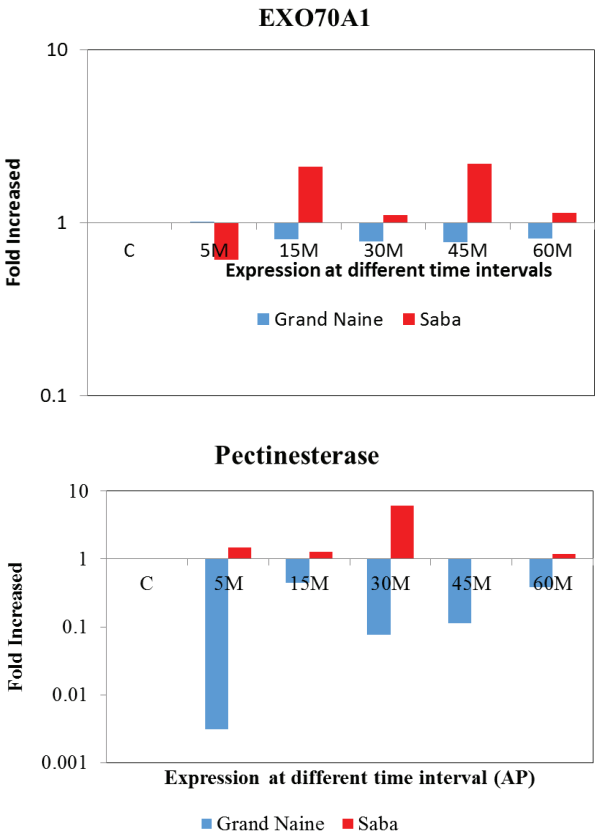


Fig 15. Gene expression pattern of banana cv. Grand Nain and Saba

Role of enzymes and their activities during pollen-stigma interactions

After pollination, Esterase (EST) and Superoxide dismutase enzymes (SOD) were analyzed in cvs. Saba (ABB) and Grand Nain (AAA) which were crossed with Calcutta-4 (AA). Pollinated pistils were collected at different time intervals such as 5 min. to 24 hours. Two different types of isoforms (Fig 16A) were noticed in cv. Saba for both enzymes but in cv. Grand Nain samples, EST2 isoform (Fig 16B) was missing. Similar results were recorded for the enzyme SOD ie. SOD2 isoform was missing in cv.Grand Nain. So these results clearly showed that enzymes play a vital role at the time of pollen-stigma interactions.

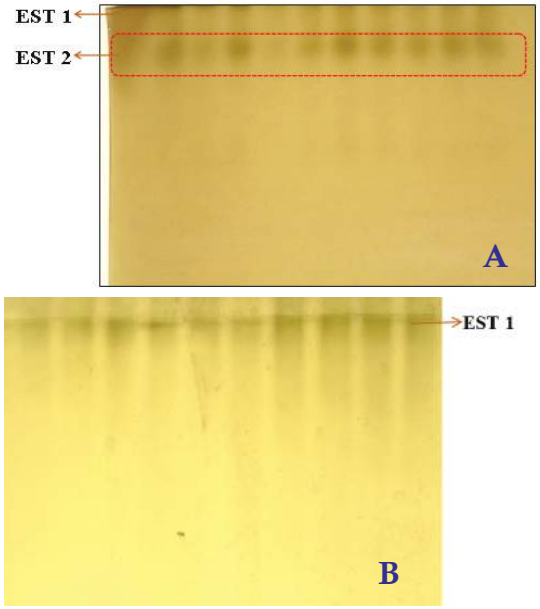


Fig 16. Esterase activity in banana cv. Saba and Grand Nain

4.1.3 Improvement of Rasthali through induced mutagenesis

During the reporting period, around 120 plants of mutated Rasthali were screened for Fusarium wilt resistance under pot culture conditions and this led to the identification of 30 putative mutants, namely, RM 5, 8, 20, 41, 45, 50, 59, 63, 64, 71, 81, 87, 92, 93, 96, 100, 102, 103, 118, 130, 141, 143, 153, 154, 172, 180, 188, 189, 197, and 211 all of which are in various stages of multiplication (Table 10, Fig 17).

Table 10. Details of the pot screening of mutated Rasthali against Fusarium wilt (sand maize meal)

Treatment	No. of plants screened	Score					
		1	2	3	4	5	6
EMS – 2%	5	1	-	-	-	4	-
EMS – 0.6%	88	28		2	2	54	2
SA – 0.02%	10	1	-	3	-	4	2
SA – 0.01%	12	-	1	-	4	5	2
Control	6	-	-	-	-	-	6

Total	121	30	1	5	6	67	12

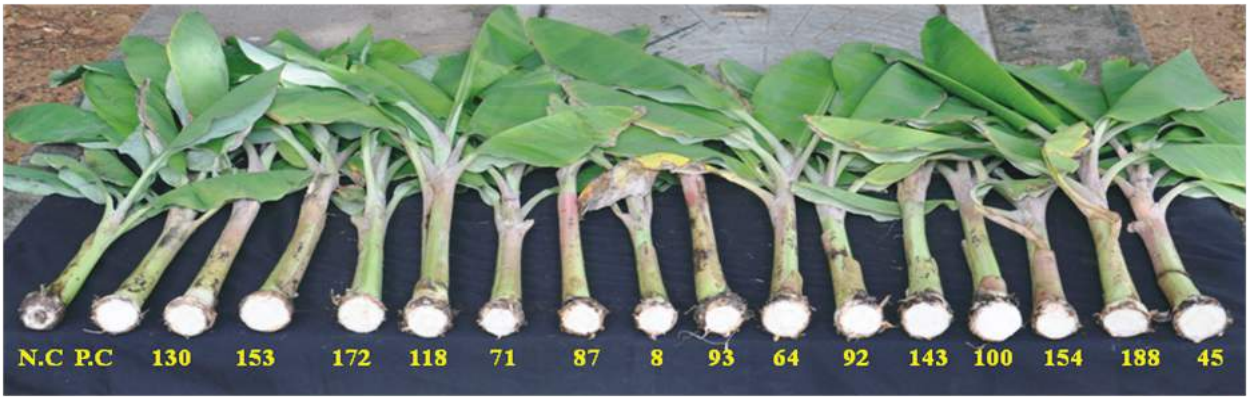


Fig 17. Identification of Fusarium wilt resistant mutants of cv. Rasthali under pot culture conditions

Around 250 mutated plants of cv. Rasthali derived from three different mutagens and two different explants are being screened *in vitro* for Fusarium wilt resistance

Out of the 12 putative mutants with Fusarium wilt resistance which were mass multiplied, plants of eight putative mutants, namely, 60, 74, 133, 176, 207, 217, 219 and 230 have been multiplied and 50% of them have been planted in pots to confirm their resistance and the remaining 50% have been field planted for multiplication purpose.

Table 11. Status of mutated cultures of cv. Rasthali

S. No.	Treatment	No. of cultures under *in vitro* screening
1	ST - EMS – 2%	52
2	PB - EMS - 0.6%	40
3	ST - DES - 10mM	26
4	PB- DES – 4mM	37
5	ST - NaN_3 - 0.02%	72
6	PB - NaN_3 - 0.01%	23
	Total	250

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

About 54 accessions of the banana mini core were planted in pots (five replications each) and screened for Fusarium wilt resistance. Only three accessions, namely, Manohar (BB), Borkal Baista (BB) and *M. acuminata* ssp. *burmannica* were resistant to Fusarium wilt (VCG 0124).

4.1.5 Identification of nematode resistance gene(s) in banana

Defense priming mediated by salicylic acid attenuate nematode infection in banana plants

Sucker derived plants of root-lesion nematode (*Pratylenchus coffeae*) susceptible cv. Nendran grown in pots were treated with physiological concentration of chemical 1, an inhibitor of octadecanoid signaling and chemical 2, a major phytohormone involved in systemic acquired resistance. Nematodes were inoculated on the next day after treatment. Roots of nematode susceptible plants treated with chemical 2

Table 14. Morphological observations after three months of chemical treatment

Treatment	No. of leaves	Girth (cm)	Root length (cm)	Plant height (cm)	Root wt.(g)	Corm wt.(g)	Shoot wt. (g)	No. of roots	Leaf Length (cm)	Petiole length (cm)	Leaf Width (cm)
Control	7	20	52	87	64	586	668	71	67	26	30
Chemical 1	5	12	40	80	28	384	332	42	62	20	24
Chemical 2	7	19	54	90	60	648	718	61	65	25	30

Control | Chemical 1+Nematode | Chemical 2+Nematode

Fig 18. Root morphology of chemically treated susceptible cultivar Nendran- three months after nematode inoculation

remained healthy as un-inoculated control plant even after three months of nematode inoculation (Fig 18). Whereas roots of nematode susceptible plant that were treated with chemical 1 were found to be totally infested with *P. coffeae.* Though the nematode population was on par in both the chemical treated plants, the root and shoot characters of chemical 2 treated plants were on par with the control plants (Table 14). Thus it is suggested chemical 2 treatment primes the banana plants for an effective defense response against *P. coffeae.*

4.1.6 Improvement of banana for root lesion nematode resistance and marker development

Detection of parental polymorphic markers

To detect the parental polymorphic primers a total of 42 *in silico* polymorphic SSR primers were selected from the MusatransSSR database (http://nrcb.res.in/nrcbbio) and tested against nematode resistant contrasting parents (three female and seven male parents). Except three primers all others showed polymorphism among any one of the female and male combinations (Fig 19). This parental polymorphic information will be useful for molecular characterization of the progenies obtained from the respective parents and to develop nematode resistant markers.

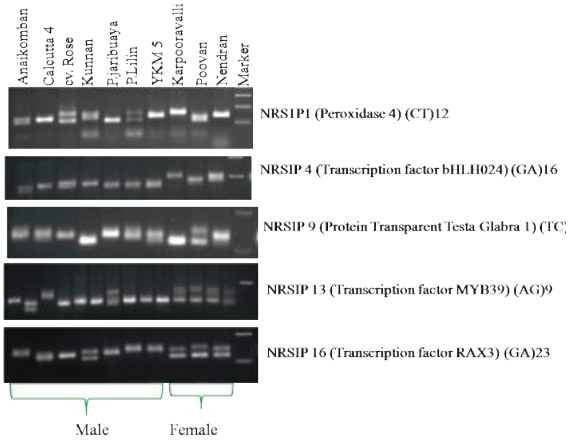


Fig 19. Detection of parental polymorphic primers

Evaluation of Nendran based progenies

A total of 520 Nendran female buds were crossed with three male parents namely cv. Rose, Calcutta 4 and Pisang Lilin. Out of 520 crossed, only 37 Nendran based progenies, which include 20 Nendran x cv. Rose (NCR), 12 Nendran x P. Lilin (NPL) and 5 open pollinated Nendran (OPN), were obtained and planted in the field. Variations in morphological and molecular characters were observed between the cross combinations; within the same

combinations and within the OPN (Fig 20 and 21). This result suggested that either male or female or both the parents are heterozygous in nature. Out of 37 Nendran based progenies, only 21 plants yielded, of which one progeny from each hybrid combination namely NCR12/17 (Nendran x cv. Rose) and NPL12/33 (Nendran x Pisang Lilin) were harvested and the yield parameters were recorded. NCR12/17 recorded 12.5kg of bunch weight whereas NPL12/33 recorded 9.5kg. Though both the progenies recorded the same number of hands (6) and number of fruits per bunch (60) variation was observed in the single fruit weight (Fig 22A, B & 23).

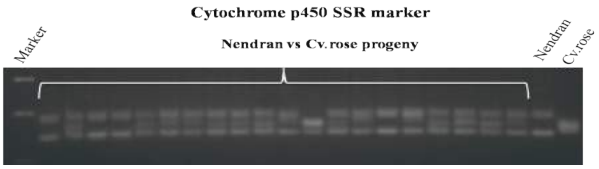


Fig 20. Molecular variation among the progenies of cv. Nendran x cv. Rose

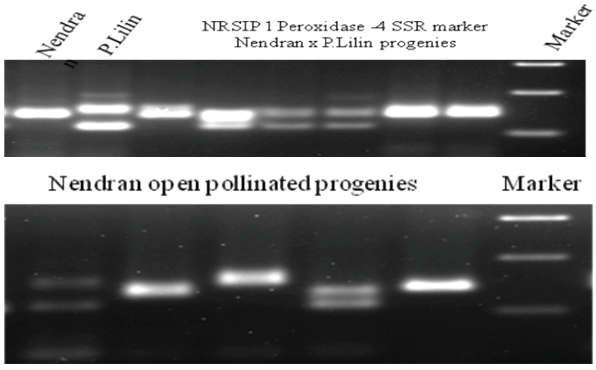


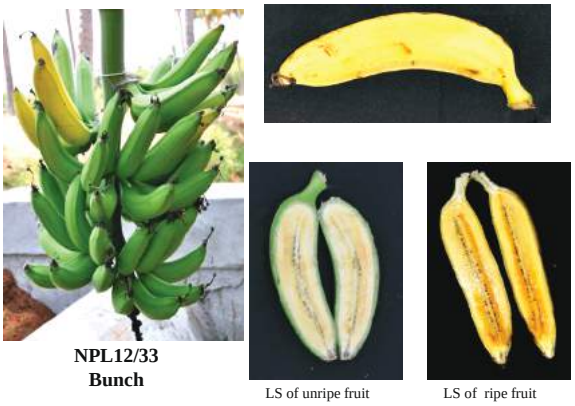
Fig 21. Morphological (Bunch) variation among the progenies (within the cross combinations)

Horizontal Towards erect

Fig 22A. Variation in bunch position in cv. Nendran x cv. P. Lilin progenies.

Absence Persistent

Fig 22B. Variation in nature of male flowers and bracts in cv. Nendran x cv. Rose progenies



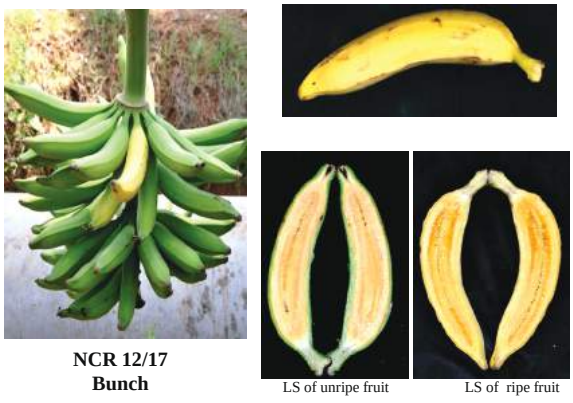


Fig 23. Bunch/fruit characters of cv. Nendran based progenies

4.2 CROP PRODUCTION AND POST-HARVEST TECHNOLOGY

4.2.1 Crop Production

Studies on nutrient dynamics in banana

Ney Poovan

At harvest in Ney Poovan, total dry matter production (TDM) was increasing with increasing levels of recommended dose of fertilizer (RDF) of NPK from control to 150%. The highest TDM of 13673g was recorded at 150%RDF while control recorded 11522g (Fig 24). The TDM in a plant was partitioned in different segments of the plant in the order of bunch (3983g) > pseudostem (3322.3g) > Leaf (1722.2g) > corm (1670.7g) > Peduncle (830.6g) > petiole (389.3g) > root (278.3g) > male bud (110.7g). The per cent fractions of TDM in a plant were male bud-1%, bunch-32%, peduncle-7%, leaf-14%, petiole-3%, pseudostem-27%, corm-14% and root-3% (Fig 25).

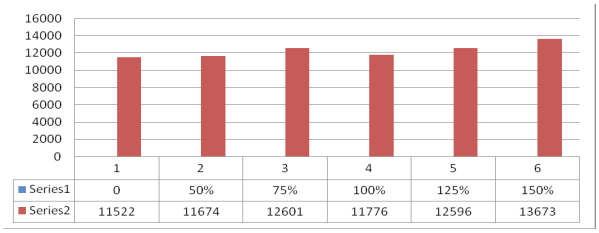


Fig 24 Effect of graded levels of NPK on TDM (g) of Ney Poovan at harvest

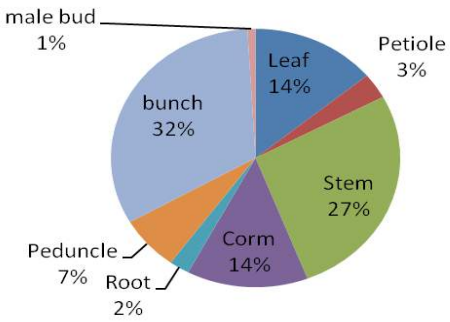


Fig 25. Dry matter accumulation in Ney Poovan at harvest

The nitrogen concentrations in different segments of a plant were leaf-2.38%, petiole-1.61%, pseudostem-1.92%, corm-0.54%, root- 0.63%, peduncle-2.31%, bunch-0.88% and male bud-0.70%, while the phosphorus concentrations were leaf-0.25%, petiole-0.30%, pseudostem-0.27%, corm-0.12%, root-0.52%, peduncle-0.21%, bunch-0.19% and male bud-0.17% and the potassium concentrations were leaf- 2.15%, petiole-2.00%, pseudostem-3.09%, corm-1.48%, root-1.39%, peduncle-9.40%, bunch-2.85% and male bud-1.49% (Fig 26).

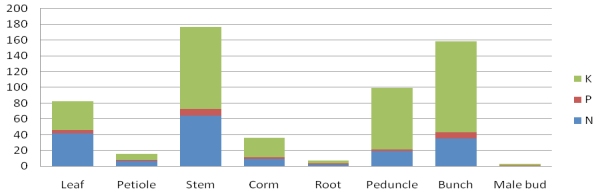


Fig 26. Accumulation (g/plant) of macronutrients in different segments of Ney Poovan at harvest

The copper concentrations (ppm) in different segments of a plant were leaf-82.3, petiole-94.5, pseudostem-115.2, corm-99.7, root-103.9, peduncle-46.9, bunch-35.2 and male bud-12.1 while the manganese concentrations (ppm) were leaf-149.8, petiole-242.0, pseudostem-153.1, corm-235.7, root-220.9, peduncle-64.4, bunch-23.0 and male bud-53.7, the zinc concentrations (ppm) were leaf-114.6, petiole-20.1, pseudostem-119.3, corm-61.3, root-27.0, peduncle-77.8, bunch-142.5 and male bud-12.1 and the iron concentrations (ppm) were leaf-245.8, petiole-30.3, pseudostem-311.1, corm-163.9, root-75.1, peduncle-232.8, bunch-94.7 and male bud-104.6 (Fig 27).

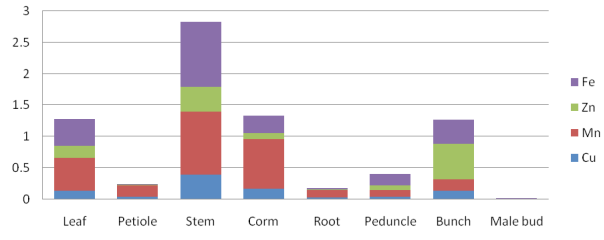


Fig 27. Accumulation (g/plant) of micronutrients in different segments of Ney Poovan at harvest

Table 12. Nutrient balance sheet of banana cv. Ney Poovan

Nutrients (Kg/ha)	A	B	C	D	E	F	G	H	I
	Initial Soil content	Added through fertiliser	Total A+B	Uptake by plant	Balance in the soil (Calculated) C-D	Actual in Post-harvest soil (Estimated)	Loss of nutrient E-F	Nutrient added through recycling	Dose required for next season B-F-H+G
N	230	500	730	444.3	285.7	121.5	164.2	307.7	235
P	8.5	75	83.5	68.8	14.7	9.2	5.5	45.3	26
K	150	1000	1150	932.5	217.5	110.6	106.9	447.7	548.6
Cu	6	0.54	6.54	2.35	4.19	1.2	2.99	1.93	0.4
Mn	19.3	1.01	20.31	7.33	12.98	3.5	9.48	6.6	0.39
Zn	12.3	1.18	13.48	3.35	10.13	4.2	5.93	1.75	1.16
Fe	15.3	1.07	16.37	5.93	10.44	3.1	7.34	4.45	0.86

At harvesting stage, the total nutrient uptake (kg/ha) by Ney Poovan were worked out as N-444.3, P-68.8, K-932.5, Cu-2.35, Mn-7.33, Zn-3.35 and Fe-5.93 and about 137kg N, 23.6kg P, 484.8kg K, 0.45kg Cu, 0.73kg Mn, 1.6kg Zn and 1.43kg Fe were removed through bunch harvest, in one hectare soil. The amount of nutrients recycled/added (kg/ha) through reincorporation of crop residues after bunch harvest were worked out as N-307.7, P-45.3, K-447.7, Cu-1.93, Mn-6.6, Zn-1.75 and Fe-4.45. After harvest, the residues were vermicomposted and the average nutrient concentrations in this vermicompost were N-1.05%, P-0.20%, K-2.54%, Cu-84.66ppm, Mn-229.37ppm, Zn-77.31ppm and Fe-151.57ppm. The nutrient contents (g) in vermicompost obtained from residues of a single plant of Ney Poovan after harvest of bunch were N-113.24, P-21.74, K-273.99, Cu-0.92, Mn-2.46, Zn-0.82 and Fe-1.65 (Table 12).

Rasthali

At harvest stage in cv. Rasthali, a gradual increase in total dry matter production (TDM) was observed in increasing levels of RDF of NPK from control to 150% (Fig 28).

The highest TDM of 16839g was recorded at 150% RDF while control recorded 12050g. The

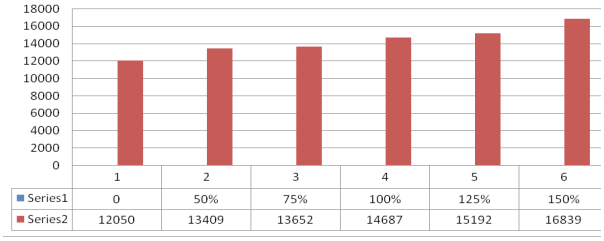


Fig 28. Effect of graded levels of NPK on TDM of cv. Rasthali at harvest

total TDM in a plant was distributed in different segments of the plant in the order of bunch (4059g) > pseudostem (3451g) > corm (2678g) > leaf (2090g) > peduncle (971g) > petiole (538g) > root (400g) > male bud (119g). The per cent fractions of TDM in a plant were male bud-1%, bunch-28%, peduncle-7%, leaf-14%, petiole-4%, pseudostem-24%, corm-19% and root-3% (Fig 29).

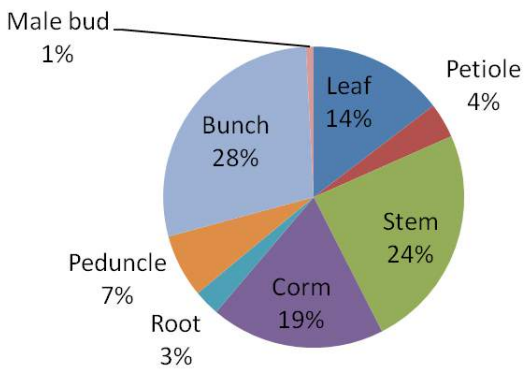


Fig 29. Dry matter accumulation in cv. Rasthali at harvest

The nitrogen concentrations in different segments of a plant were leaf-2.30%, petiole-0.58%, pseudostem-0.88%, corm-0.51%, root-0.51%, peduncle-1.10%, bunch-1.15% and male bud-0.68% while the phosphorus concentrations were leaf-0.26%, petiole-0.21%, pseudostem-0.24%, corm-0.14%, root-0.13%, peduncle-0.12%, bunch-0.17% and male bud-0.17% and the potassium concentrations were leaf-2.10%, petiole-2.02%, pseudostem-3.15%, corm-1.24%, root-1.24%, peduncle-9.13%, bunch-2.95% and male bud-0.80% (Fig 30).

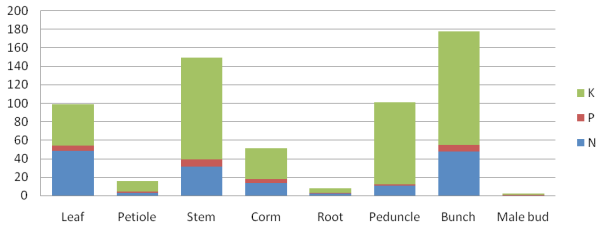


Fig 30. Accumulation (g/plant) of macronutrients in different segments of Rasthali at harvest

The copper concentrations (ppm) in different segments of a plant were leaf- 58.1, petiole-65.6, pseudostem-91.4, corm-108.7, root-110.4, peduncle-38.4, bunch-41.8 and male bud-9.4 while the manganese concentrations (ppm) were leaf-205.4, petiole-206.4, pseudostem-205.7, corm-206.9, root-206.1, peduncle-78.2, bunch-24.6 and male bud-72.8, the zinc concentrations (ppm) were leaf-121.6, petiole-25.3, pseudostem-22.1, corm-24.2, root-31.4, peduncle-19.8, bunch-80.6 and male bud-14.6 and the iron concentrations (ppm) were leaf-276.9, petiole-243.6, pseudostem-224.2, corm-192.2, root-223.3, peduncle-213.8, bunch-157.1 and male bud-83.6 (Fig 31).

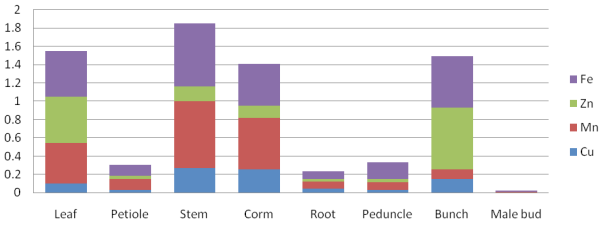


Fig 31. Accumulation (g/plant) of micronutrients in different segments of Rasthali at harvest

At harvesting stage, the total nutrient uptake (kg/ha) by Rasthali were worked out as N-395.5, P-69.4, K-1044.6, Cu-2.2, Mn-5.3, Zn-3.95 and Fe-6.48 and about 146.7kg N, 20.1kg P, 531.4kg K, 0.45kg Cu, 0.45kg Mn, 1.8kg Zn and 1.85kg Fe were removed through bunch harvest, in one hectare soil. The amount of nutrients recycled/added (kg/ha) through reincorporation of Rasthali residues after bunch harvest were worked out as N-248.8, P-49.3, K-513.1, Cu-1.73, Mn-4.9, Zn-2.15 and Fe-4.65. After harvest, the residues were vermicomposted and the average nutrient concentrations in this vemicompost were N-1.07%, P-0.20%, K-2.19%, Cu-54.55ppm, Mn-139.38ppm, Zn-66.58ppm

Table 13. Nutrient balance sheet of banana cv. Rasthali

Nutrients (Kg/ha)	A	B	C	D	E	F	G	H	I
	Initial Soil content	Added through fertiliser	Total A+B	Uptake by plant	Balance in the soil (Calculated) C-D	Actual in Post-harvest soil (Estimated)	Loss of nutrient E-F	Nutrient added through recycling	Dose required for next season B-F-H+G
N	230	500	730	395.5	334.5	159.4	175.1	248.8	266.9
P	8.5	75	83.5	69.4	14.1	8.3	5.8	49.3	23.2
K	150	1000	1150	1044.6	105.4	94.8	10.6	513.1	402.7
Cu	6	0.54	6.54	2.2	4.34	0.98	3.36	1.73	1.19
Mn	15.4	1.01	16.41	5.3	11.11	2.98	8.13	4.9	1.26
Zn	10.2	1.18	11.38	3.95	7.43	2.86	4.57	2.15	0.74
Fe	12.5	1.07	13.57	6.48	7.09	1.24	5.85	4.65	1.03

and Fe-139.21ppm. The nutrient contents (g) in vermicompost obtained from residues of a single plant of Rasthali after harvest of bunch were N-130.38, P-24.42, K-264.78, Cu-0.68, Mn-1.71, Zn-0.81 and Fe-1.76.(Table 13)

Under nutrient dynamics studies the Root Length Densities (RLD in $mm.cm^{-3}$) were determined at different distances from the base of the plant and at different depths, in Ney Poovan and Rasthali at harvesting stage (Table 14).

Table 14. Root Length Density ($mm.cm^{-3}$) in Rasthali at shooting and harvest

Depth	Distance from base of the plant (Ney Poovan)					
	Ney Poovan			Rasthali		
	0 – 30 cm	30 – 60 cm	60 – 90 cm	0 – 30 cm	30 – 60 cm	60 – 90 cm
0 – 15 cm	0.209	0.038	0.021	0.131	0.043	0.028
15 – 30 cm	1.327	0.266	0.112	1.331	0.430	0.300
30 – 45 cm	0.974	0.170	0.105	0.853	0.269	0.195

In Ney Poovan, the specific root length (cm/g) increased rapidly with increasing distance from base of the plant but in Rasthali, it increased gradually. These observations inferred more rapid tapering roots in Ney Poovan than in Rasthali. (Table 15).

Table 15. Specific root length ($cm.g^{-1}$) of Ney Poovan and Rasthali at harvesting stage

Variety	Distance from base of the plant		
	0 – 30 cm	30 – 60 cm	60 – 90 cm
Ney Poovan	6.28	6.16	9.09
Rasthali	5.07	5.26	5.18

4.2.2 Post-harvest Technology

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

Survey of pre- and post-harvest practices on leaf production of banana

For leaf purpose, the variety 'Nattu (Monthan) Vazhai' is preferred for cultivation in Melur, Madurai District., while it is 'Nattu (Monthan) Vazhai' and 'Poovan' for Tirunelveli and Tuticorin districts of Tamil Nadu. First/ main crop is grown for bunches and the first ratoon (second crop) is allowed for leaf purpose. Leaf harvesting is done 4th month onwards. Twenty five to 40 leaves are harvested per hill.

Physico-chemical changes in Poovan leaves as influenced by different levels of N & K

The treatments registered significant influence on moisture, chlorophyll and lignin content. Among the various treatments imposed, the highest moisture content was recorded with N 200g and K 400 g per plant. However, the lowest chlorophyll content was recorded with N 150g and K 400 g per plant. The highest lignin content was registered with K 200 g per plant (Table 16).

Assessment of post-harvest losses in banana

In Tamil Nadu, four districts, namely Theni, Erode, Tiruchirapalli and Tuticorin were identified based on primary and secondary data provided by the State Department of Horticulture for assessment of post-harvest losses in banana. In cv. Grand Nain, overall 10.52% and 10.48% post-harvest losses were estimated in Theni and Erode Districts, respectively. In cv. Poovan, overall 16.50% and 9.10% post-harvest losses were recorded in Trichy and Tuticorin Districts (Table 17).

Development and refinement of value added products in banana and plantain

Development of fruit and central core (stem) juice based jelly

Banana fruit juice based jelly was developed by blending fruit juice with sugar and citric acid having TSS content of 65°Brix and acidity of 0.2% was highly accepted (Hedonic scale: 8.5). Banana central core stem juice based jelly was developed by blending stem juice with sugar and

Table 16. Physico-chemical changes in Poovan leaves as influenced by different levels of N & K

Moisture (%)						
Treatments	K (Nil)	K (100g)	K (200g)	K (300g)	K (400g)	Mean
N (Nil)	75.62	68.02	68.37	69.2	70.12	70.266
N (100g)	75.99	68.98	68.16	70.87	66.69	70.138
N (150g)	61.38	67.36	68.43	71.93	72.99	68.418
N (200g)	65.28	69.3	72.7	69.99	74.34	70.322
N (250g)	71.1	69.95	70.56	72.14	73.43	71.436
Mean	69.87	68.72	69.64	70.83	71.51	
CD at 5%	Nitrogen = 0.775	Potash = 0.775	Interaction = 1.733			
Chlorophyll (µg / g)						
N (Nil)	21.38	20.14	22.78	22.93	43.24	21.38
N (100g)	21.56	20.15	24.62	20.94	59.46	21.56
N (150g)	23.04	20.99	25.61	23.45	34.3	23.04
N (200g)	23.27	22.59	26.01	25.16	42.7	23.27
N (250g)	22.86	22.73	26.16	22.65	38.5	22.86
Mean	22.42	21.32	25.04	23.03	43.64	
CD at 5%	Nitrogen = 1.023	Potash = 1.023	Interaction = 2.288			
Lignin (mg / g)						
N (Nil)	17.93	8.93	18.27	9.43	18.9	17.93
N (100g)	17.23	6.77	26.53	7.13	17.47	17.23
N (150g)	15.6	6.63	23.33	10	17.87	15.6
N (200g)	16.13	4.63	24.7	8.53	8	16.13
N (250g)	17.07	4.6	15.73	15.8	7.6	17.07
Mean	16.79	6.31	21.71	10.18	13.97	

citric acid having TSS content of 65°Brix and acidity of 0.2% was highly accepted (Hedonic scale: 8.3).

Comparative evaluation of flavoured and non-flavoured banana central core (stem) juice based RTS beverages

Chemical analysis of flavoured and non-flavoured (control) ready to drink (RTD) banana pseudostem beverages indicated that initially the TSS and titratable acidity of flavoured (ginger and nannari) and control RTD banana pseudostem beverages were adjusted to 12° brix and 0.2 per cent and kept as a constant. The chemical analysis of control pseudostem beverages showed higher amount of total sugar (11.07 g / 100 ml), total CHO (16.08 g / 100 ml), Vitamin C (0.736 mg / 100 ml) and sodium (1.015%) compared to ginger and nannari flavoured pseudostem beverages. Among the flavoured pseudostem beverages, the ginger flavoured pseudostem beverages had significant amount of total sugar (10.83 g / 100 ml), total CHO (14.12 g / 100 ml), sodium (0.935 %), potassium (8.30 %), zinc (1.117 ppm / 100 ml), copper (0.9190 ppm / 100 ml) and manganese (1.0144 ppm / 100 ml) followed by nannari flavoured pseudostem beverages. At the same time vitamin C content (0.673 mg / 100 ml) was found slightly lower amount in ginger flavoured pseudostem beverages than nannari flavoured pseudostem beverages (Table 18).

Table 17. Post-harvest losses (%) in banana

	Cultivar	Grand Nain		Poovan	
	District	Theni	Erode	Tiruchirapalli	Tuticorin
S. No	Stage/ Level				
1.	Field	0.254	0.83	0.002	0.363
2.	Dehanding, Sorting, Grading, Cleaning and Washing	0.246	0.277	-	-
3.	Transport	0.410	0.646	3.70	4.05
4.	Assembly market	6.246	5.382	4.93	3.34
5.	Storage and Ripening	3.364	3.34	7.87	1.351
Total		10.52	10.48	16.50	9.10

Table 18. Proximate composition of flavoured and non-flavoured banana central core (stem) juice based RTS beverages

Proximate composition	Treatments		
	Control (Non-flavoured)	Ginger flavoured	Nannari flavoured
TSS (o Brix)	12.0±0.304	12.0±0.158	12.0±0.257
Titratable acidity (%)	0.2±0.004	0.2±0.004	0.2±0.005
Total sugar (g / 100 ml)	10.83±0.195	10.62±0.096	11.07±0.190
Total CHO (g / 100 ml)	16.08±0.198	14.12±0.136	13.92±0.124
Vitamin "C" (mg / 100 ml)	0.673±0.001	0.707±0.011	0.736±0.006

Quality changes in flavoured and non-flavoured banana central core (stem) juice based RTS beverages during storage

The experimental results showed that the TSS content of flavoured and control RTD pseudostem beverages increased with the increased storage period while a gradual decrease in titratable acidity was found in all the treatments. The changes in TSS (12°Brix to 13.8°Brix) and titratable acidity (0.2 % to 0.152 %) was found to be highest in control pseudostem beverages followed by nannari and ginger

Table 19. Changes in the TSS of flavoured and non-flavoured (control) ready to drink (RTD) banana pseudostem beverages during storage

Treatments	Storage temperatures	Storage period (months)							Mean
		Initial	1	2	3	4	5	6	
Control (Non-flavoured)	RT	12.0	12.0	12.0	12.4	12.8	13.2	13.8	12.60
	13.5°C	12.0	12.0	12.0	12.2	12.6	12.8	13.0	12.37
Ginger flavoured	RT	12.0	12.0	12.0	12.4	12.6	12.8	13.0	12.40
	13.5°C	12.0	12.0	12.0	12.0	12.2	12.2	12.4	12.11
Nannari flavoured	RT	12.0	12.0	12.0	12.4	12.6	13.0	13.4	12.49
	13.5°C	12.0	12.0	12.0	12.0	12.4	12.4	12.6	12.20
CD at 5%	Treatments (T) : 0.054 ; Storage temperatures (S) : 0.044 ; Storage periods (M) : 0.082 ; TS : NS ; SM : 0.116 ; TM : 0.142 ; TSM : NS								

flavoured pseudostem beverages. But the changes in TSS (12°Brix to 13.0°Brix) and titratable acidity (0.2 % to 0.168 %) were minimum in ginger flavoured pseudostem beverages during storage at ambient temperature and 13.5°C. This may be due to the active compounds of ginger (gingerols), which act as a preservative and minimize the oxidation reactions. All the treatments stored in 13.5°C condition showed minimum changes in TSS and titratable acidity compared to ambient condition. The decrease in the titratable acidity might be due to utilization of acids for hydrolysis of polysaccharides into simple sugar during storage (Tables 19 & 20).

Organoleptic evaluation of flavoured and non-flavoured banana central core (stem) juice based RTS beverages during storage

The sensory quality of flavoured and control pseudostem beverages was analyzed once in 30 days for colour, appearance, flavour, consistency, taste and overall acceptability. Initially and finally the ginger flavoured pseudostem beverages had highest organoleptic scores, *viz.*, colour and appearance (9.0 and 9.0), flavour (8.5 and 8.0), consistency (7.5 and 7.5), taste (8.5 and 8.3) and overall acceptability (8.38 and 8.20), followed by nannari flavoured and control pseudostem

Table 20. Changes in the titratable acidity (%) of flavoured and non-flavoured (control) ready to drink (RTD) banana pseudostem beverages during storage

Treatments	Storage temperatures	Storage period (Months)							Mean
		Initial	1	2	3	4	5	6	
Control (Non-flavoured)	RT	0.2	0.2	0.192	0.184	0.165	0.158	0.152	0.179
	13.5°C	0.2	0.2	0.2	0.198	0.184	0.182	0.178	0.192
Ginger flavoured	RT	0.2	0.2	0.196	0.190	0.188	0.172	0.168	0.188
	13.5°C	0.2	0.2	0.2	0.198	0.192	0.190	0.184	0.195
Nannari flavoured	RT	0.2	0.2	0.196	0.188	0.182	0.166	0.162	0.185
	13.5°C	0.2	0.2	0.2	0.198	0.192	0.188	0.180	0.194
CD at 5%	Treatments (T) : 0.001 ; Storage temperatures (S) : 0.0009 ; Storage periods (M) : 0.002 ; TS : 0.002 ; SM : 0.002 ; TM : 0.003 ; TSM : NS								

Table 21. Changes in the organoleptic evaluation of flavoured and non-flavoured (control) ready to drink (RTD) banana pseudostem beverages during storage

Treatments	Storage temperature	Organoleptic evaluation									
		Colour and appearance		Taste		Consistency		Flavour		Overall acceptability	
		I	F	I	F	I	F	I	F	I	F
Control	RT	8.0	7.4	7.5	6.8	7.0	6.8	7.0	6.4	7.38	6.85
	13.5°C	8.0	7.8	7.5	7.0	7.0	7.0	7.0	6.8	7.38	1.15
Ginger flavoured	RT	9.0	9.0	8.5	8.3	7.5	7.5	8.5	8.0	8.38	8.20
	13.5°C	9.0	9.0	8.5	8.4	7.5	7.5	8.5	8.3	8.38	8.30
Nannari flavoured	RT	8.5	8.2	8.5	8.0	7.5	7.5	8.0	7.3	8.13	7.75
	13.5°C	8.5	8.5	8.5	8.3	7.5	7.5	8.0	7.8	8.13	8.03

RT – Ambient temperature; **I -** Initial; **F -** Final

beverages. Ginger flavour was extensively accepted by majority of the consumers and it enhances the juice colour and aroma. The control pseudostem beverages had considerable loss of sensory quality at the end of 180 days storage at ambient temperature and 13.5°C. Statistically significant loss of sensory qualities was observed in all the treatments especially colour and appearance, flavour and taste. Nevertheless the maximum retention of sensory qualities was recorded when all the samples were stored at 13.5°C than ambient condition (Table 21).

Refinement and evaluation of banana flour based biscuits

Banana flour based biscuits were prepared with different proportions and compared against 100% maida biscuit as absolute control and NRCB as control. Significant differences were observed among the treatments for the various quality parameters. Among the various combinations, 50% banana flour proved to be better for most of the quality parameters, particularly for carbohydrates, protein, fat and carotene with high calorific value with acceptable level (Tables 22 & 23).

Development of banana central core stem based products

Banana central core (stem) juice based squash was developed with TSS content of 45°Brix and acidity of 1.0%. Similarly, banana central core (stem) juice based Syrup was developed by blending stem juice with sugar and citric acid having TSS content of 65°Brix and acidity of 1.0%. Banana central core (stem) based soup mix and ice cream mix were developed by incorporating banana central core stem powder with 40% and 10%, respectively, which was highly accepted (Hedonic scale: 8.0 & 7.83, respectively).

Comparative evaluation of banana central core stem powder and corm juice

Evaluation of central core stem powder of seven commercial varieties of banana indicated

Table 22. Quality parameters of banana flour based biscuits (per 100g)

Treatments	Weight per Biscuit	Moisture (%)	Total CHO (%)	Protein (%)	Fat (%)	Carotene (µg / 100 mg)	Energy (Kcals)
Absolute control (100% Maida)	7.93	0.48	25.33	0.57	1.13	962.32	113.76
Control (NRC Banana)	8.41	0.30	31.67	1.26	1.14	3923.86	142.96
25% Banana Flour	6.03	0.34	32.83	0.75	1.32	2472.98	146.29
30% Banana Flour	8.67	0.73	32.50	0.89	1.26	3026.46	147.63
35% Banana Flour	7.38	0.11	33.50	0.94	1.10	3819.72	147.75
40% Banana Flour	8.73	0.16	34.50	0.98	1.17	4462.55	152.52
45% Banana Flour	5.73	0.73	36.50	0.99	1.07	4765.33	159.66
50% Banana Flour	7.3	0.07	39.00	1.02	1.25	5144.60	171.34
Mean	7.52	0.36	33.31	0.92	1.19	3572.22	147.74
C.D at (0.05%)	1.10	0.34	1.038	0.037	0.014	365.82	4.13

Table 23. Sensory evaluation of banana flour based biscuits

Treatments	Colour & Appearance	Flavour	Texture	Taste	OAA
Absolute control (100% Maida)	8.00	7.00	8.00	8.00	7.75
Control (NRC Banana)	6.00	6.00	7.00	7.00	6.50
25% Banana Flour	6.00	7.00	7.00	7.00	6.75
30% Banana Flour	7.00	7.00	7.00	8.00	7.50
35% Banana Flour	7.00	7.00	7.00	7.00	7.00
40% Banana Flour	7.00	7.00	6.00	7.00	6.75
45% Banana Flour	7.00	7.00	6.00	7.00	6.75
50% Banana Flour	7.00	7.00	6.00	7.00	6.75

that cv. Rasthali had the highest amount of starch (10.66%), total carbohydrates (13%) and energy (52 kcal). However, the highest crude fiber was recorded with Saba and Mortaman. Out of six varieties of banana varieties evaluated for corm juice, Udhayam recorded maximum recovery (94.8%) followed by Nendran (91%) and Saba (88.55%).

Functions of resistant starch and designer food development from banana flour

Drying kinetics and mathematical modeling on thin layer drying of banana

Thin layer drying characteristics of banana cv. Monthan were studied in a convective dryer at different temperatures *viz.,* 45, 55 and 65^{0}C and the experimental data was fitted to drying models to identify the best fit model. Drying rate curves of slices demonstrated a smooth diffusion controlled drying. Drying at the beginning of the process was lower at 45^{0}C with a marked difference between other temperatures. The difference between moisture ratios increased gradually at the commencement of drying. Time required for reaching equilibrium moisture content decreased with increasing temperature. The average value of coefficient of determination (r^2) and RMSE values varied between 0.94-0.99 and 0.014-0.073, respectively. Page and logarithmic models obtained highest r^2 and least RMSE at all temperatures and better reflected drying mechanism of banana slices. Superior rehydration and sensory score was observed when the slices were dried at 55^{0}C (Fig 32 A & B).

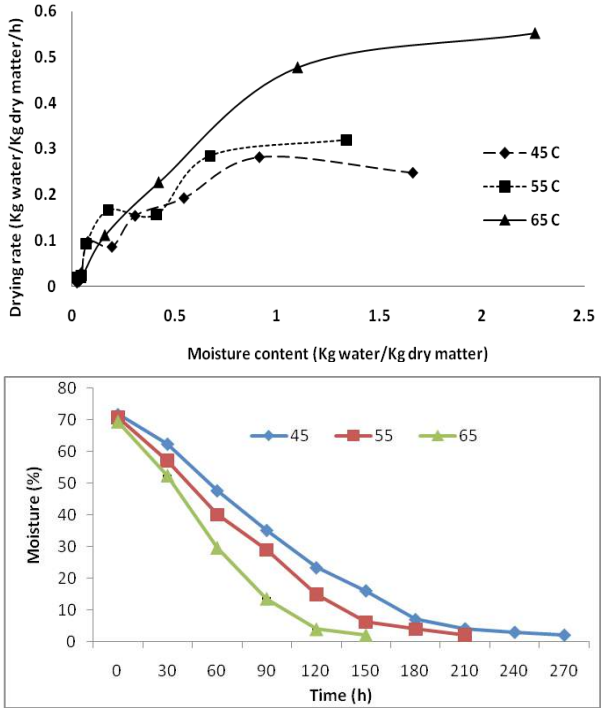


Fig 32 A & B. Drying kinetics on thin layer drying of banana

4.3 PHYSIOLOGY AND BIOCHEMISTRY

4.3.1 Physiology

Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance

In a field grown ratoon crop of banana cv. Grand Nain soil moisture deficit stress was imposed in the field at 3rd and 5th months of their growth. The soil moisture was allowed to deplete to the level of -0.7 to-0.8 MPa. Foliar priming of Grand Nain banana plants with 0.1mM acetyl salicylic acid with butylated hydroxyl toluene (100 ppm), before imposition of soil moisture stress, at 3rd and 5th month stages sustained the 8-9 fold higher photosynthesis and stomatal conductance than unprimed plants. In cv. Grand Nain, the plants foliar primed with acetyl salicylic acid (0.1mM) combined with butylated hydroxy toluene (100 ppm) before the imposition of soil moisture stress recorded bunch weight (18.78 kg) comparable to irrigated control (19.72 Kg) (Fig 33) and higher than all other treatments, i.e., glycine betaine (20mM), beta aminobutyric acid alone and 2% urea and number of hands (12) and number fingers (15.25) per hand were on par with irrigated control.

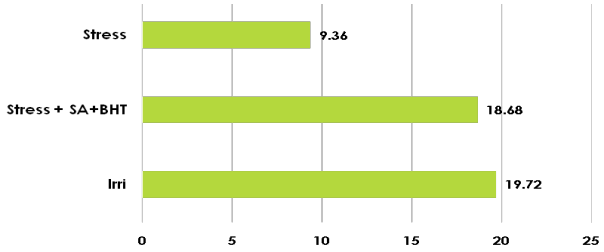


Fig 33. Effect of soil moisture stress alleviation chemicals on bunch weight (Kg)

The specific leaf weight (SLW) is associated with photosynthetic efficiency of leaf. In 36 diploid banana genotypes, SLW was taken and it ranged from 3.02 to 5.60. Most of the wild diploid genotypes recorded higher SLW (>4.0) and it did not distinguish AA and BB diploids (Table 24).

Table 24. Specific Leaf Weight (SLW) of diploid *Musa* accessions

Acc.No.	Name of the Genotype	SLW (mg/cm²) leaf wt./ area	Ranking
1717	*M. flaviflora* (Arunachal collection)	5.60	1
208	Anaikomban (AA)	4.97	2
64	Kanai Bansi (AA)	4.90	3
1147	TMB x 9128-3 (AA)	4.71	4
1914	BeejiKela (BB)	4.70	5
631	*Musa acuminata* spp. *burmannica* (AA)	4.61	6
555	Elavazhai (BB)	4.61	7
638	Cultivar Rose (AA)	4.37	8
1030	*Musa ochracea* Chengdawt (AA)	4.30	9
682	Pisang Jajee (AA)	4.29	10
446	Bacharia Malbhog (BB)	4.24	11
195	Pisang Lilin(AA)	4.21	12
21	Hatidat (AA)	4.11	13
645	Pisang Jari Buya (AA)	4.09	14
380	Tongat (AA)	4.09	15

49	Sasra Bale (BB)	3.99	16
153	Agniswar (AB)	3.93	17
185	Namarai (AA)	3.92	18
2063	Jurmony (BB)	3.87	19
1712	*M. flaviflora*-I (Assam)	3.83	20
174	K.K.Kunnan (AB)	3.79	21
1168	Khungsong Wild (BB)	3.74	22
642	*Musa accuminata* spp. *bumannica* (AA)	3.72	23
656	Pisang Berlin(AA)	3.71	24
482	Padalimoongil (AB)	3.70	25
147	Adukkan (AB)	3.70	26
1731	*M. flaviflora* (AP)	3.66	27
1912	Jungle Kela -I (BB)	3.55	28
717	Rasakadali (AB)	3.53	29
2064	Srisailam Collection (BB)	3.53	30
1184	Pahalapad Wild II (BB)	3.37	31
47	Manohar (BB)	3.34	32
67	Manguthaman (BB)	3.33	33
635	Khungsong Wild (BB)	3.27	34
1715	*M. flaviflora*-II(Assam)	3.20	35
1836	Siguzani (AA)	3.02	36

Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance

In a controlled pot experiment, salt stress (NaCl) at 50 and 100 mM was imposed in cvs. Saba, Nendran, Grand Nain, Karpuravalli, Rasthali and Poovan plants under controlled condition. The membrane stability of all the cultivars were damaged beyond 100mM of NaCl stress. Poovan, Karpuravalli and Saba recorded higher membrane stability at 50 mM of NaCl. Nendran and Rasthali shown less membrane stability. The pigments (total chlorophyll content) reduced in all salt treated plants. Cvs. Saba and Karpuravalli recorded higher chlorophyll content. The Na^+ and K^+ content in the third leaf from top showed that, the tolerant cultivar (Saba) recorded low sodium content at 50 mM and 100 mM NaCl by accumulating more potassium content in the leaves (Fig 34).

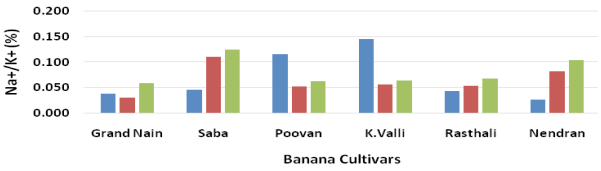


Fig 34. Ratio of sodium and potassium on salt stressed banana

The glycine betaine (20mM) primed Grand Nain plants recorded salt alleviation through reduction in decrease of chlorophyll contents and the leaf senescence did not show significant difference between primed and non-primed plants under salt stress. The gas exchange was always less than control but 2-3 fold higher than non-primed salt stressed plants. Glycine betaine level could not be detected through spectrometric method in salt stressed plants.

4.3.2 Biochemistry

Biochemical and molecular basis of ripening of banana fruit and its manipulation with biochemicals

Treatment of full (100%) mature preclimacteric Grand Nain and Poovan fruits with 1-Methylcyclopropene (1-MCP) at one µl/L concentration by fumigation for 12 hrs and storage at ambient temperatures (25-27°C) enhanced green life by 10 days over the untreated control. Gibberellic acid (GA_3; 500 mg/L concentration) treatment of full (100%) mature preclimacteric Grand Nain and Poovan by dipping method and storage at ambient temperature enhanced the green life of six days more at over the untreated controls. GA_3 at 75, 100 and 250 mg/L concentrations were not found effective in enhancement of green life at ambient temperature. However, GA_3 treatment of Grand Nain at 250 mg/L concentrations had 13, 9 and 3 days more green life period respectively, at 13.5, 21 and 29°C (Table 25). Full three quarter (90%) mature preclimacteric Grand Nain bananas treated with gibberellic acid at 250 mg/L concentration and stored at 13.5, 21 and 29 °C showed enhanced green life by 15, 9 and 3 days respectively.

The physiological parameters such as CO_2 and ethylene evolution, biochemical characteristics in terms of ripening enzymes activities and quality parameters of 1-MCP and GA_3 treated and untreated control bananas followed similar trend during green life and ripening periods; however ethylene and CO_2 evolutions and enzyme activities of treated bananas showed subdued behaviour due to the effect of the chemicals at end of preclimacteric and colour breaking stages. The mean ethylene evolution was 0.35ppm in preclimacteric stage, 1.4 ppm at colour breaking stage and 2.6 ppm at stage-6 of ripening for control bananas whereas the mean ethylene evolutions were 0.26 and 0.9 ppm at end of preclimacteric and colour breaking stages of treated bananas (Fig 35). The mean polygalacturonase (main ripening-related enzyme) activity was 0.0045 Unit/g fresh wt. in preclimacteric stages, 0.043 U/g at breaking stage and 0.27U/g at stage-6 of ripening for control bananas whereas the mean activities were 0.0038 and 0.035 U/g at end of preclimacteric and colour breaking stages of treated bananas (Fig 36). The quality parameters (TSS and acidity) of ripe bananas of treated and untreated controls were in the acceptable levels. The TSS were in the range of 21.8-22.2 and 22.6-

Table 25. Green life enhancement (in days) of full mature Grand Nain and Poovan fruits by biochemicals

Genotype / Biochemical / Temp.	Control	Treatment
Grand Nain / 1-MCP (1 mg/L) / Ambient	4	14
Poovan / 1-MCP (1 mg/L) / Ambient	5	15
Grand Nain / GA3 (500 mg/L) / Ambient	4	10
Poovan / GA3 (500 mg/L) / Ambient	5	11
Grand Nain / GA3 (250 mg/L) / 13.5 °C	4	17
Grand Nain / GA3 (250 mg/L) / 21 °C	4	13
Grand Nain / GA3 (250 mg/L) / 29 °C	4	7

24.8 °B and acidity were 0.2-0.26 and 0.30-0.36% of the ripe (stage-6 of ripening) of Grand Nain and Poovan fruits respectively.

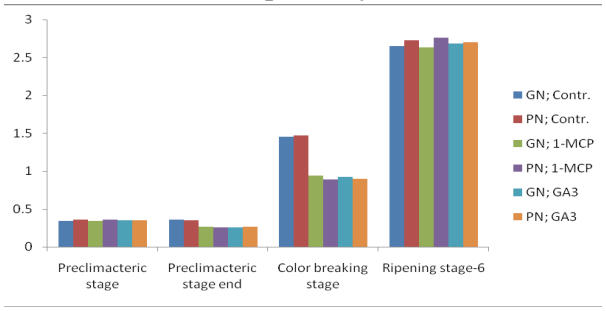


Fig 35. Ethylene evolution (ppm) in GA_3 treated Grand Nain banana during green life and ripening.

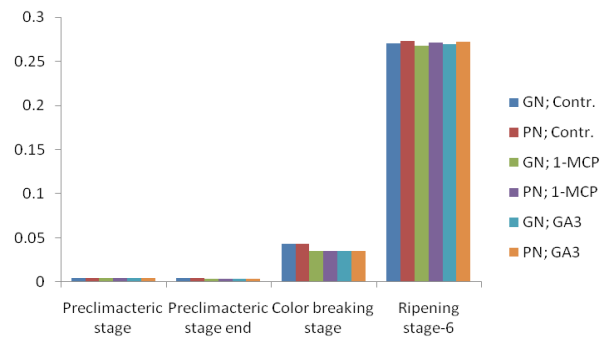


Fig 36. Polygalacturonase activity (U/g fr. wt.) in 1-MCP treated Poovan banana during green life and ripening.

The induced ripening behaviour of 1-MCP and GA_3 treated pre-climacteric Grand Nain and Poovan bananas following ethrel (2-chloroethylphosphonic acid; 500 ppm) treatment was normal as that of untreated control bananas in terms of physiological parameters (CO_2 and ethylene evolutions), biochemical characters (enzymes activities, particularly polygalacturonase) and quality parameters (TSS and acidity) during ripening and the values were in the acceptable as given above.

Mechanism of banana green life enhancement by biochemicals

Total proteome maps of pulp tissues of 1-MCP treated and untreated control Grand Nain bananas were prepared and on comparison, 73 highly abundant differentially expressed proteins (DEPs) out of 150 DEPs were detected between the proteome maps. The biological identity of 43 highly abundant DEPs (31 up-regulated and 12 down-regulated) was established after mass fingerprinting and the important enzymes/ proteins such as ACC oxidase and synthase, polygalacturonase, pectate lyase, xyloglucan endotransglycosylase /hydrolase were highly down-regulated in the biochemical treated bananas as compared to untreated control bananas implying that ethylene synthesis and cell wall modifying enzymes are suppressed by 1-MCP.

Green ripening of Cavendish (Grand Nain) banana

To find out the threshold temperature of green ripening of Cavendish bananas, full mature Grand Nain fruits were stored at 22, 23 and 24°C and at 31°C in ripening chambers/ BOD incubators and the bananas showed yellow ripening in 22- 24°C and green ripening at 31°C. Observation of physiological indicators of CO_2 and ethylene evolutions and biochemical assay of enzymes activities were similar between the banana fingers stored at 22-24°C and 31°C except very low mg dechelatase and pheophorphide a oxygenase activities and accumulation of chlorophyll catabolites (chlorophyllides and pheophorphides) in the peels of green ripe (31°C stored) bananas compared to yellow ripe (21°C stored) bananas.

The chlorophyll catabolites *viz.*, chlorophyllide a and pheophorphide a, the substrates of mg dechelatase and pheophorphide a oxygenase, in peel tissues of yellow and green ripe Grand Nain bananas were profiled and quantified as peak area on relative scale by reverse-phase HPLC during ripening for six days (Fig 37 & 38). The chlorophyllide and pheophorbide a accumulation followed similar trend during ripening and the levels of these chlorophyll catabolites were higher in peels of green ripe bananas than in that of yellow ripe throughout the ripening period corroborating the impairment of mg dechelatase

and pheophorphide a oxygenase activities and partial degradation of chlorophyll in peel of Cavendish (Grand Nain) bananas at elevated temperatures exhibiting green ripe character.

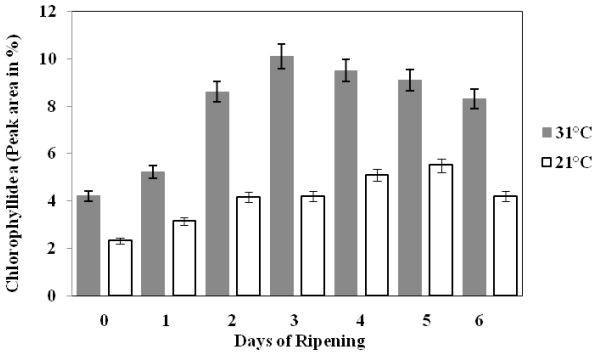


Fig 37. Chlorophyllide a changes (based on relative peak area) in peel of Cavendish banana (*Musa acuminata,* AAA, Grand Nain) stored at 21 and 31°C for 6 days. Data are mean ± SE (n=3).

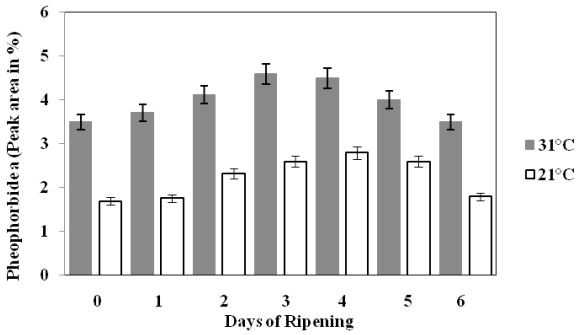


Fig 38. Pheophorbide a changes (based on relative peak area) in peel of Cavendish banana (*Musa acuminata,* AAA, Grand Nain) stored at 31 and 21°C for 6 days. Data are mean ± SE (n=3).

Proteomic analysis in bananas in response to soil moisture deficit stress

Soil moisture deficit (drought) stress was imposed on two months old Grand Nain tissue culture plants for 21 days and control plants were grown with moisture of full field capacity. Proteome maps were prepared from total proteins extracted from leaf tissues of drought imposed and control plants by employing phenol-ammonium acetate procedure. Analysis of proteome maps revealed more than 800 proteins out of which 58 highly abundant differentially expressed proteins (DEPs) (34 up-regulated and 24 down-regulated) with more than 2.0 fold differences in abundance were detected (Fig 39).

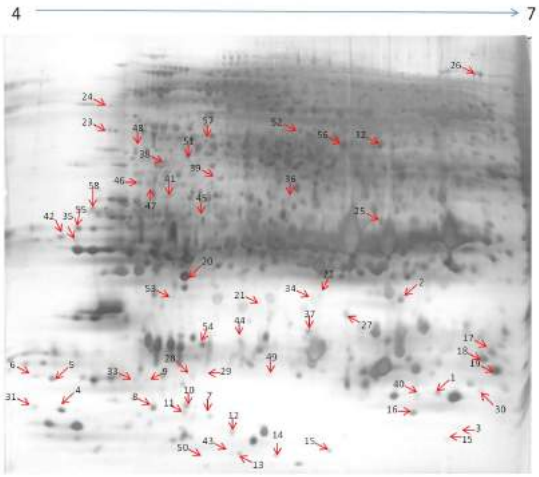


Fig 39. Proteome map (reference gel) of soil moisture deficit stress imposed Grand Nain leaf tissue.

4.4 CROP PROTECTION

4.4.1 Entomology

Management of Banana weevils

Development of slow release delivery system for semio-chemicals

A slow release delivery system for banana stem weevil was developed using materials like alginate gel, polyurethane foam (PUF) and cotton wick. Appropriate quantities of the host plant extract solution containing essential ingredients were loaded inside the matrices for evaluation.

Evaluation of slow release delivery system under *in vitro* by wind tunnel bioassay

The five matrices *viz.*, alginate bead, polyurethane foam, cotton wick, leaf sheath and PUF with solvent were evaluated against banana stem weevil adults in a wind tunnel. The results indicated that maximum weevil attraction of 58 % was recorded in PUF followed by cotton wick (42%) and alginate bead (16 %).

The four treatments, *viz.*, alginate bead, polyurethane foam , cotton wick and leaf sheath bits, were tested under field conditions in an enclosure (to prevent the escape of weevils) and the top was kept open to have the effect of other ecological conditions. The weevils were released and the weevil attraction was recorded after 1 hour. Maximum weevil attraction of 34.0% was in the PUF and a minimum attraction of 7.0% was recorded in other treatments and 8% attraction was registered in leaf sheath bit.

In vitro screening of plant extract of *Tithonia diversifolia* against stem weevil, *Odoiporus longicollis*

Plant extracts of wild sunflower *Tithonia diversifolia* (fresh and dried leaf stem and flower) were prepared and tested *in vitro* at six concentrations (5, 10,25,50,75 and 100) against stem weevil, *Odoiporus longicollis* by leaf sheath technique. The weevils starved for 8 hours were used for the experiment. Among the different treatments, maximum mortality of 58% and 50% was recorded in the fresh flower and dried leaf at 6th day in 100% concentration. At 100% concentration, extracts of fresh leaf, fresh stem, dry stem, and fresh flower indicated a stem weevil mortality of 66.67%, 58.33%, 50.00% and 58.04% respectively. The whole plant extract comprising of leaf, stem and flower caused the maximum mortality of 83.0 % at 100% concentration (Fig 40).

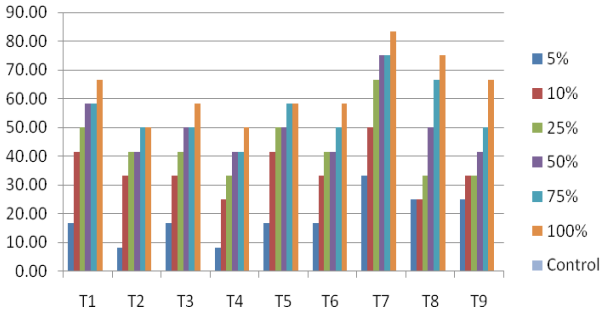


Fig 40. Stem weevil mortality due to plant extract of *Tithonia diversifolia*

T_1- Fresh leaf extract ,T_2 - Dry leaf extract, T_3 - Fresh stem extract, T_4 - Dry stem extract, T_5 - Fresh flower extract, T_7 - Fresh whole plant extract, T_8 - Dry whole plant extract, T_9 - Azadirachtin.

In vitro screening of zimmu leaf extract against banana weevils

Zimmu leaf solvent extract (ZLE) was tested *in vitro* against stem and corm weevils. The extract was prepared using shade dried leaf powder (100g/250ml) in hexane by cold extraction method. The extract was tested at six concentrations (5, 10, 25, 50, 75 and 100 %) by leaf sheath feeding method. At 50% concentration, zimmu registered 100% mortality on 9th day and 75% concentration registered 83.33% mortality on 6th day for stem weevil, *O. longicollis*. Solvent extract of zimmu was not effective against corm weevil, *Cosmopolites sordidus* (Fig41).

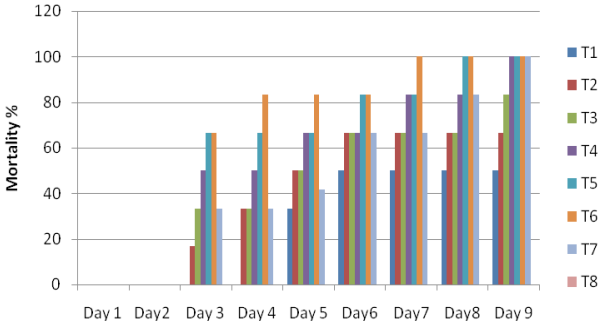


Fig 41. Screening of Zimmu leaf solvent extract against stem weevil, *Odoiporus longicollis*

T_1- Zimmu Leaf Extract (ZLE) 5 %, T_2- ZLE 10 %, T_3- ZLE 25%, T_4- ZLE 50 %, T_5- ZLE 75 %, T_6- ZLE 100 %, T_7-Azadiractin, T_8-Control.

Screening of *Musa* germplasm against banana stem weevil, *Odoiporus longicollis*

Twenty eight *Musa* germplasm accessions belonging to genomic groups [AAA (8), AA (6), ABB (11), AAB (1), AB (1) and BB (1)] were screened for susceptibility to banana stem weevil under field condition. The plants were raised in a plastic drum (80cm × 50cm), filled with soil and covered with self-ventilated polypropylene cloth. Five pairs of stem weevil were released inside the plant at 5th month after establishment. Observations on feeding damage and fecundity were recorded on the 45th day by destructive sampling. Observations indicated that 21 accessions belonging to AAA (8), AA (6), ABB (4), BB (1), AB (1) and AAB (1) were free from weevil damage, whereas seven accessions belonging to genomic group ABB (7) were susceptible to stem weevil (Table 26 and Fig 42).

Fig 42. Weevil susceptible (ABB) plant stem showing feeding damage

Pest mapping in bananas and plantains of India

Insect pests of banana and their natural enemies

A representative collection of insect pests and natural enemies associated with bananas and plantains in different parts of India was established. The following insects were documented on bananas during 2015-16 besides the two weevil borers.

Insect pests

- *Icerya seychellarum* (Westwood) (Hemiptera: Monophlebidae)
- *Acherontia styx* (Westwood) (Lepidoptera: Sphingidae)
- *Erionota torus* (Evans) (Lepidoptera: Hesperiidae)
- *Stephanitis typicus* (Distant) (Hemiptera: Tingidae)
- *Aspidiotus destructor* (Signoret) (Hemiptera: Diaspididae)
- *Nisia nervosa* (Lethierry) (Hemiptera: Meenoplidae)
- *Olene mendosa* (Hubner) (Lepidoptera: Lymantriidae)
- *Pericallia ricini* (F.) (Lepidoptera: Arctiidae)

Table 26. List of resistant and susceptible *Musa* accessions to stem weevil, *O. longicollis*

Resistant accessions	Susceptible accessions
0608 (AAA), 0618 (AAA), 0081 (AAA), 0370 (AAA), 0009 (AAA), 0165 (AAA), 1149 (AAA), 0039 (AAA), 1710 (AA), 1019 (AA), 1836 (AA), 0208 (AA), 0185 (AA), 0638 (AA), 0065 (ABB), 0059 (ABB), 0103 (ABB), 0453 (ABB), 2064 (BB), 0699 (AB), 0554 (AAB)	0732 (ABB), 0799 (ABB), 0803 (ABB), 0804 (ABB), 0163 (ABB), 0130 (ABB), 0736 (ABB)

- *Spilosoma obliqua* (Walker) (Lepidoptera: Arctiidae)

Predators

- *Serangium parcesetosum* Sicard (Coleoptera: Coccinellidae)
- *Stethorus* sp. (Coleoptera: Coccinellidae)
- *Jauravia* sp. (Coleoptera: Coccinellidae)
- *Stethoconus praefectus* (Distant) (Hemiptera: Miridae)

Pollinators

- *Tetragonula iridipennis* (Smith) (Hymenoptera: Apidae)
- *Apis dorsata* F. (Hymenoptera: Apidae)
- *Apis cerana* F. (Hymenoptera: Apidae)

Moderately severe infestation of *Olene mendosa* (Lepidoptera: Lymantriidae) was noticed in ICAR-NRCB farm in February-March 2015, but most of the larvae were killed by an NPV like disease.

Natural enemies of banana pests

Three egg parasitoids of *Erionota* sp. collected from Mizoram were identified as *Agiommatus* sp. (Pteromalidae), *Ooencyrtus* sp. (Encyrtidae), and *Tetrastichus* sp. (Eulophidae). An unidentified species of *Telenomus* (Platygastridae) was recorded on the eggs of *E. torus* from Karnataka. *Brachymeria* sp. (Chalcididae) was recorded as a pupal parasitoid of *E. torus* from Kerala. Two unidentified tachinid parasitoids were collected on *Erionota* spp. from Tamil Nadu and Mizoram.

Stethoconus praefectus (Distant) (Miridae), a common predator of the banana lacewing bug (*Stephanitis typicus* Distant), has not been reported from banana and nearly all the published records of this predator are on coconut in India. It was observed to feed on *S. typica* on banana at ICAR - NRCB farm.

4.4.2 Pathology

Investigation on fungal and bacterial diseases of banana and their management

Field evaluation of effective microbes and botanicals for Fusaium wilt (*Foc*) suppression and plant growth promotion

A field trial was conducted from 2015 with effective microbes and botanicals in a *Foc* hot spot area at Muthulapuram of Theni district, Tamil Nadu, India. In this trial, three effective treatments along with a chemical carbendazim and control were evaluated for Fusarium wilt suppression and plant growth promotion, namely 1) Liquid formulation (endophytic *Bacillus flexus* (Tvpr1) + Endophytic *Trichoderma asperellum* (Prr2)), 2) Rice chaffy grain formulation (endophytic *Penicillium pinophilum* (Bc2) + rhizospheric *Trichoderma* sp. (NRCB3), 3) zimmu (*Allium sativum* x *A. cepa*) leaf extract (50% conc), 4) carbendazim 0.2% (chemical) and 5) Control (untreated). The tissue culture plants cv. Grand Nain were bio-primed and the treatments were given three times at monthly interval through soil application (at the time of planting, 2nd month after planting, 4th month after planting). The results indicated that the liquid formulation of endophytic *B. flexus* + endophytic *T. asperellum* recorded a lowest disease score of 1.7 which was followed by rice chaffy grain formulation of endophytic *P. pinophilum* + rhizospheric *Trichoderma* sp. (disease score of 1.8) and the zimmu leaf extract treated banana plants (disease score of 2.1) as compared to chemical treatment (Carbendazim) (4.4) and the control treatment which recorded a highest disease score of 5.4 on a disease scale of 1-6 where 1 is healthy and 6 is dead (Fig 43). Apart from decreasing the disease severity these treatments also increased the plant growth parameters such as plant height, girth, total number of leaves and leaf area significantly. The average bunch weight was also significantly higher in liquid formulation of endophytic

B. flexus (Tvpr1) + endophytic *T. asperellum* (Prr2) (44 kg) followed by rice chaffy grain formulation of endophytic *Penicillium pinophilum* + rhizospheric *Trichoderma* sp. (38.6 kg) and zimmu leaf extract (36.4 kg) as compared to chemical (23.3 kg) and control (16.2 kg) (Fig 44).

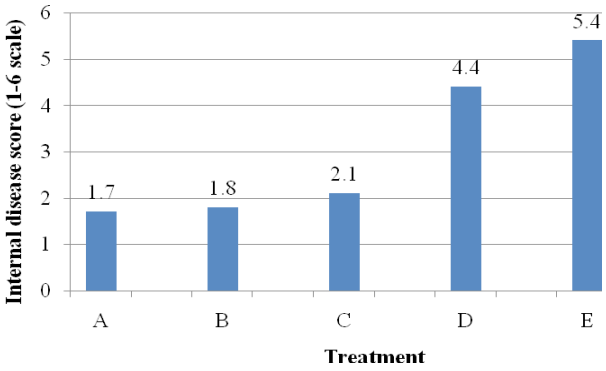


Fig 43. Effect of soil application of biocontrol agents on the internal wilt symptom in corm tissue in cv. Grand Nain (AAA) under field condition.

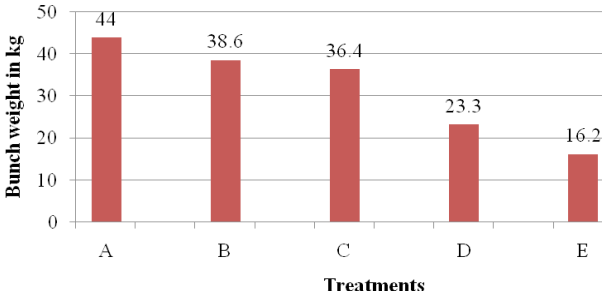


Fig 44. Effect of soil application of biocontrol agents on the bunch weight of cv. Grand Nain (AAA) under field condition. A) Liquid formulation of endophytic *Bacillus flexus* (Tvpr1) + endophytic *Trichoderma asperellum* (Prr2), B) Rice chaffy grain formulation of endophytic *Penicillium pinophilum* (Bc2) + rhizospheric *Trichoderma* sp. (NRCB3), C) zimmu leaf extract (50% conc), 4) Chemical (carbendazim 0.2%) and 5) Control (untreated).

Isolation and characterization of volatiles from zimmu leaf extract

Screening of 33 botanicals against *Foc* indicated that zimmu leaf extract @ 50% concentration was very effective in the inhibition of the mycelia and spore germination of *Foc*. *In vivo* experiment conducted with zimmu leaf extract @ 50% concentration also indicated its efficacy in controlling Fusarium wilt, besides promoting plant growth. Hence, the active principle compound, particularly volatiles present in zimmu were extracted and subjected to GC-MS analysis. The results indicated the presence of a principle compound (PC1) which recorded 100% inhibition of mycelial growth and spore germination of *Foc* at 0.1% concentration (Fig 45).

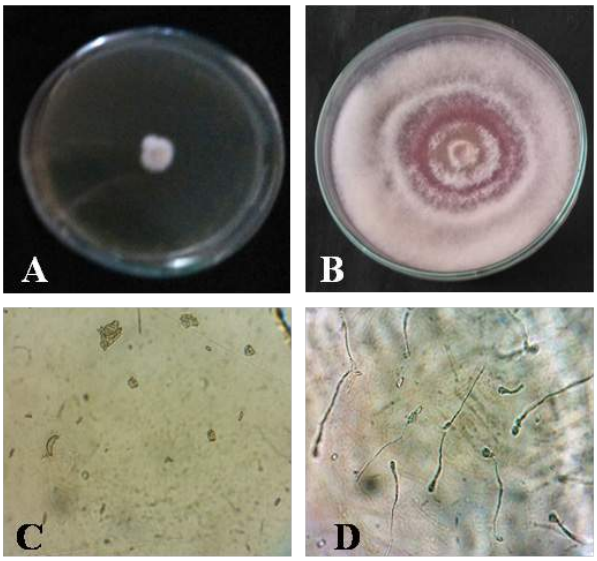


Fig 45. Mycelial inhibition of *Foc* A) PC1 (100% inhibition) B) Control C) Effect of PC1 (100% inhibition) on *Foc* spore germination and D) Control (100% spore germination)

4.4.3 VIROLOGY

Studies on viral diseases of banana and their management

Survey for viral diseases

Occurrence of Banana Bract Mosaic Virus (BBrMV) along with Banana Streak Mysore Virus (BSMYV) in cv. Poovan in Assam and Banana Streak Gold Finger Virus (BSGFV) in hill banana at Lower Pulney Hills was recorded for the first time. This was confirmed by cloning and sequencing of partial genome of the

respective viruses. Natural expression of BSV in Hill banana cv. Virupakshi has been recorded in lower Pulney Hills during 2015.

Molecular Characterization of banana viruses

The *CP* genes of the Indian Banana Mild Mosaic Virus (BMMV) isolates were cloned, sequenced and compared with the CP of the published isolates (Fig.1A &1B). Sequence of the Indian isolate shared 74.4 to 91.7% nucleotides and 87.3 to 95.7% deduced amino acid similarities with other BMMV isolates. The symptom of this virus infection is very mild mosaic on leaf lamina and this disease is very common in cvs. Karpuravalli and Udhayam (Fig 46). This is the first molecular evidence for the occurrence of BMMV in banana in India.

Fig 46. BMMV infection on banana

Virus symptoms resembling banana bract mosaic virus infection in *Alpinia galanga* were characterized. Cloning and sequence analysis of the virus revealed 87-94% and 91-94% identity at the nucleotide and amino acid level, respectively, with Bean yellow mosaic virus (BYMV) isolates from various crops. This is the first report of the natural occurrence of BYMV in *A. galanga* in India. Reverse Transcription for isolates of BBrMV and Rolling Circle Amplification for Banana Streak Virus (BSV) isolates were used to enrich NGS based sequencing.

Diagnostic techniques for banana viruses

Loop mediated isothermal Amplification (LAMP) based detection of Cucumber Mosaic Virus (CMV) and BSMYV was standardized (Fig.47 A & B). The LAMP based technique developed for CMV was highly specific, 100 times more sensitive than RT-PCR. With the use of SYBR green stain, the positive could be visualized by naked eye within 30 min of reaction. Multiplexing to detect two circular DNA viruses infecting banana using rolling circle replication coupled with restriction digestion with single cutting enzyme has been standardized.

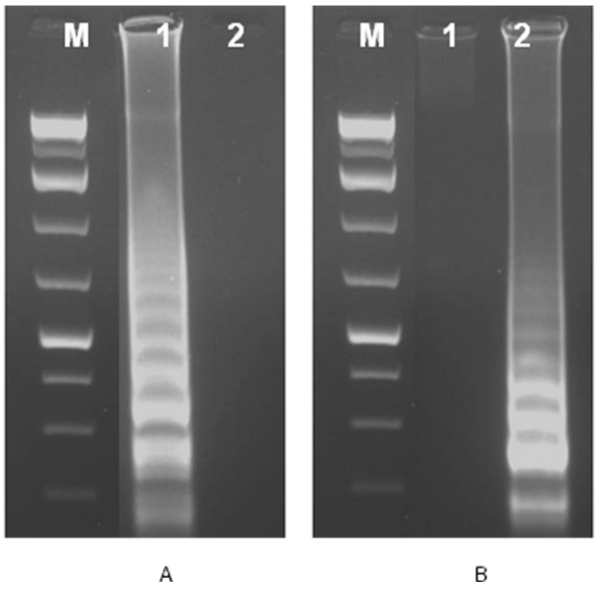


Fig 47. Loop-mediated isothermal amplification (LAMP) and Reverse Transcriptase (RT-LAMP) or rapid and sensitive detection of BSMYV and CMV. Lane M: 1 kb DNA ladder plus; A. Lane 1: Healthy; 2-Infected; B. Lane1: Healthy; Lane 2: Infected

Evaluation of Banana Bunchy Top Virus (BBTV) free Hill banana plants derived from ECS technology

Field experiments were initiated during July, 2015 and Januaray, 2016 for the evaluation of virus free Virupakshi plants developed through ECS at research farm of the centre and at Thadiyankudisai, Lower Pulney hills. Along with virus indexed and genetic fidelity tested Virupakshi plants of ECS (Fig 48), tissue cultured (through shoot tip culture) and sucker derived plants were also planted for comparison of plant growth traits and yield. The result showed no significant changes in plant growth parameters. The time taken for flowering was delayed and this might be due to the age difference of suckers and TC plants as that of ECS derived plants.

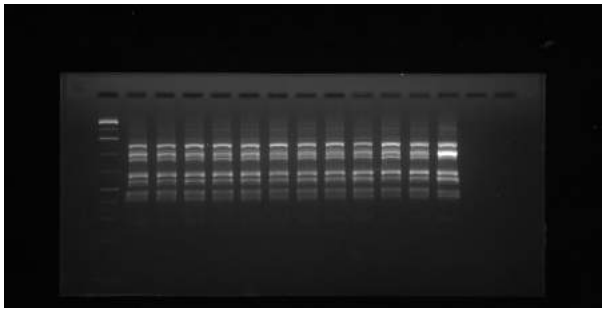


Fig 48. Inter Simple Sequence Repeats profiles for 10 ECS derived hill banana lines using primer UBC-811. M-1kb DNA ladder; Lanes 1-10: ECS derived plants; Lane 11: Control Plant (Hill banana); Lane 12: Grand Nain; B. Field view of evaluation of virus free Virupakshi plants developed through ECS at Thadiyankudisai, Lower Pulney hills.

Screening of commercial cultivars against banana viruses

Screening of commercial cultivars for resistance against BBTV was done using sucker grown plants and twice we transmitted the virus into the plants using viruliferous aphids. The result showed that Hill banana and Grand Nain were more susceptible than other varieties.

Host-virus interaction in banana

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

Tenth ratoon of non-symptomatic Poovan plants planted during the year 2005-06 was continued in 2015-16. This year the expression of BSV symptom was observed newly in 20 plants. So far 176 plants have expressed the symptoms of streak disease for the past 10 years. Analysis of disease severity index, yield, girth and plant height over the years revealed that higher variation between the years and the weather factors prevailed in the corresponding year might have influenced the wide variation. Further, plants that exhibited symptoms previously have turned out to be healthy subsequently.

Plants identified to be free of viruses for the past 10 years were sent for mass propagation at a NCS-TCP recognized lab located at Hosur, Tamil Nadu.

Development of infectious partial dimer construct of Banana Streak Mysore Virus (BSMYV) genome

Using RCA, concatemers of BBTV genome have been prepared and bombardment has been done using Helios gene gun for testing the infectivity of the virus. Infectious clone preparation for BSMYV has partially been completed.

Transcriptomic analysis of banana infected with Banana Bunchy Top Virus (BBTV)

Transcriptome sequencing has also been performed for a healthy and BBTV symptomatic plants of cv. Poovan. Nearly 23-25 million reads with 100% high quality reads were obtained. Among 49722, 7713 were up-regulated, 7633 were down-regulated and 34376 were neutrally expressed. Totally 56066 annotated transcripts and 6917 un-annotated were recorded. Gene ontology (GO) terms were assigned to query sequences, producing a broad overview of groups of genes catalogued in the transcriptome for each of three ontology vocabularies, biological processes, molecular functions and cellular components. The majority of the GO terms were assigned to molecular function (42.32 %) followed by cellular components (42.29 %) and the least were categorized under the biological process (15.39).

Transgenics development

Using BBTV hairpin rep construct and ECS of Virupaskhi (Hill banana) 18 PCR positive transgenic lines were developed and hardened in the glass house. Using MVR-RNAi construct, 74 putative lines were developed, however only one plant was PCR positive. The sense rep construct of BBTV gave seven PCR positive plants. All

the transgenic lines are being maintained in the transgenic glass house. The plants which were non-transgenic were destroyed.

Proteomic analysis of host-Banana Bunchy Top Virus (BBTV) interaction in banana

Time course study-Infectious cycle of BBTV in hill banana

Two hundred hill banana TC plants were planted in pot mixture for studying BBTV infectious cycle. BBTV-free banana aphid colony was reared on tissue culture-derived banana plantlet. The aphids were transferred once in every 15 days to fresh banana plantlets to maintain the culture continuously.

4.4.4 NEMATOLOGY

Screening banana cultivars for resistance to root-lesion nematode, *Pratylenchus coffeae*

Promising banana cultivars *viz.,* Bangrier, Saba, Kothia, Monthan and Namwakhom were inoculated with root-lesion nematode (*Pratylenchus coffeae*) @ 2000 nematodes / plant. Cvs. Bangrier and Saba were moderately resistant and the rest were either susceptible / highly susceptible (Fig 49).

Saba Namwakhom Kothia

Fig 49. Reaction of banana cultivars to root-lesion nematode infection

Investigations on *Musa* nematode diversity, biology, behaviour and their interactions

Soil and root samples were collected from banana fields located in Tiruchirapalli and Theni districts of Tamil Nadu. Nematode isolates obtained include root-lesion nematode, *Pratylenchus coffeae*; burrowing nematode, *Radopholus similis*; root-knot nematode, *Meloidogyne incognita* and spiral nematode, *Helicotylenchus* sp. During winter months, abundant population of stunt nematode, *Tylenchorhynchus* sp. (from Thottiam taluk) and spiral nematode, *Rotylenchus* sp. (from ICAR-NRCB farm) was noticed. They were isolated and inoculated for further multiplication.

4.5 Externally funded projects

4.5.1 Network project on Transgenic in crops-Banana functional genomics (Sigatoka & Drought component) (S. Uma)

Database developed from transcriptome

Musa Transcriptome SSR database (MusatransSSRDB) was developed for transcriptome data for biotic and abiotic stresses like *Mycosphaeralla eumusae*, nematode and drought. This database was developed using HTML, Java and PHP, datasets are stored in MySQL database and accessible in public domain. (http://nrcb.res.in/nrcbbio/). The database was further updated using advanced bioinformatics tools like MUSABLAST and MUSASAT. Links are also provided for the online bioinformatics tools like BATCHPRIMER3 and KEGG. Search tools are provided for doing all categorical searches by CUFF ID, Genome ID, SSR type, Protein Name, Forward, Reverse Primer and Pathways. These advanced search tools will provide the Banana SSR profiles for the scientific community, those who are working in the field of marker development in the same crop or related crops (Fig 50).

Validation of *insilico* derived SSRs

EST-SSRs derived from *M. eumusae* stressed *Musa* transcriptome data were used for the development of marker against eumusae leaf spot disease. Initially, 112 EST-SSRs were tested against 10 each of resistant and susceptible *Musa* cultivars. Dendrogram was plotted, which resulted in three clusters. One of the clusters consisted of all the resistant cultivars along with one susceptible cultivar, another with 8 susceptible cultivars and cv. Rasthali, a susceptible cultivar was present in a separate cluster (Fig 51 & 52).

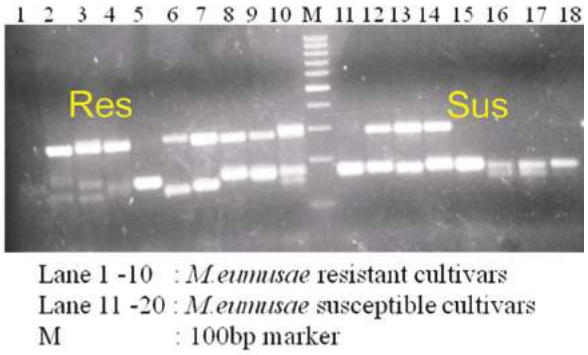


Fig 51. Validation of SSR derived from *M. eumusae* transcriptome

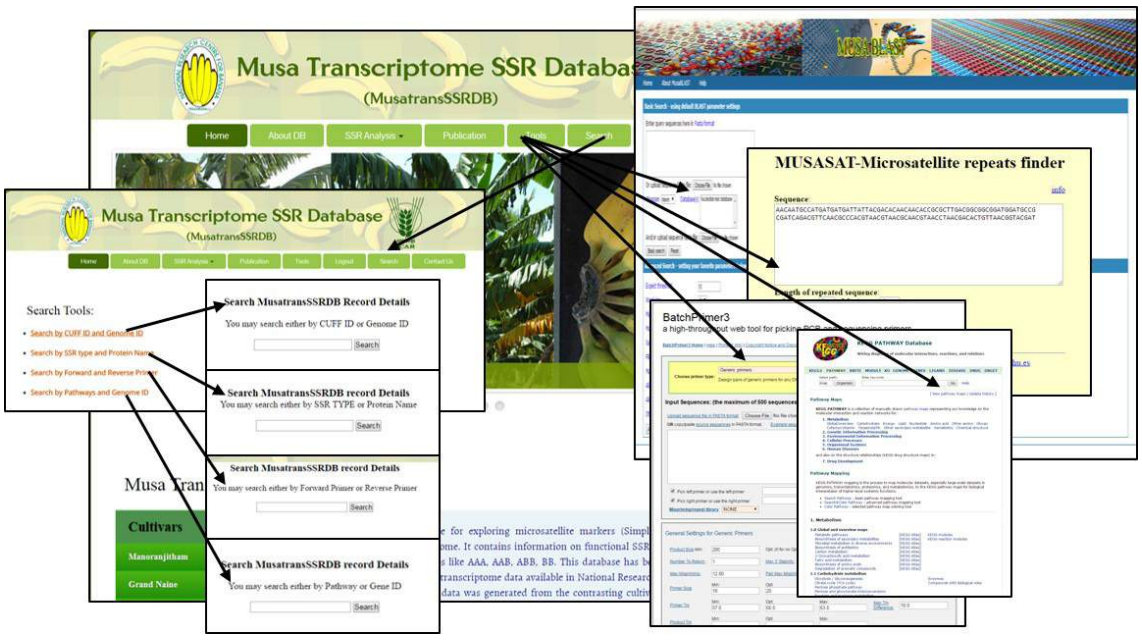


Fig 50. MusatransSSR Database web interface showing advanced tools

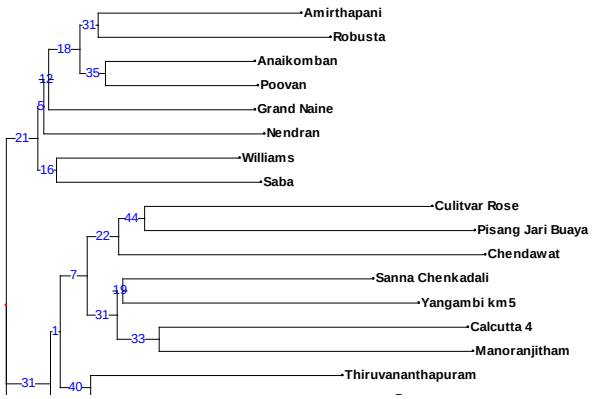


Fig 52. Dendrogram showing the phylogenetic relationship between *M. eumusae* resistant and susceptible *Musa* cultivars

Characterization of unknown proteins

Uncharacterized proteins were found to be abundant in *M. eumusae* stressed *Musa* transcriptome data and efforts were taken to characterize these proteins using *in silico* analysis. Initially 92 transcripts which resulted from DGE ($p = >0.05$; with >2 fold) were considered for analysis, out of which, 62 were aligned with characterized proteins from *Viridi plantae* database using TBLASTX tool. Among these, six characterized proteins were selected (Orange carotenoid-binding protein, Proprotein convertase subtilisin/kexin type 9, MarR Like Protein, UBIQUITIN-PROTEIN LIGASE, Peroxisomal bifunctional enzyme, Guanine nucleotide-binding protein) and 3D protein structures were predicted using SWISS-MODEL tool. These proteins were validated using PROSA, PROCHECK tool. (Fig 53).

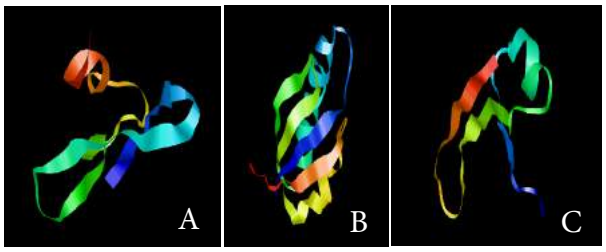


Fig 53. Characterization of proteins expressed in *Musa* transcriptome upon *M. eumusae* infection
A. Ubiquitin-protein ligase
B. Peroxisomal bifunctional enzyme
C. Guanine nucleotide-binding protein

Genome wide analysis of MYB transcription factor

One of the unique genes expressed in challenged resistant cultivar of *M. eumusae* stressed *Musa* transcriptomics was MYB transcription factor. Further analysis of this unique transcript was performed using comparative genomics studies by genome wide analysis. Gene expression studies were performed for four uniquely expressed MYB isoform transcripts. Among which, except MYBLHY all others namely MYB1, MYB4, MYBZM38 were found to be up-regulated in resistant cultivar (Fig 54).

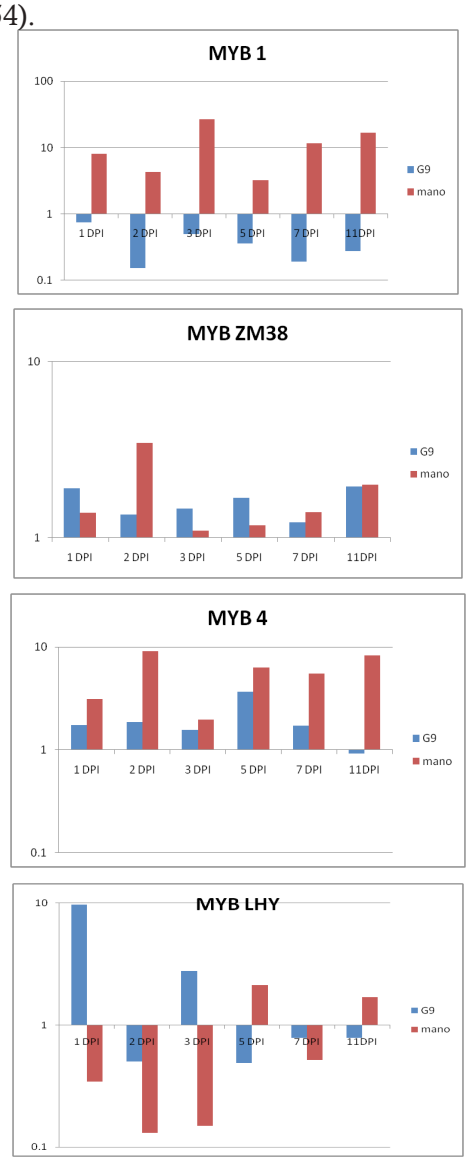


Fig 54. Gene expression studies for the MYB isoforms resulted from DGE of *M. eumusae* stressed *Musa* transcriptome

MYB transcription factor coding sequences were retrieved from *Musa* Genome Hub and subjected to comparative genomics analysis using GreenPhyl. It was observed that about 33 plant genera shared orthologous homology with *Musa* MYB sequences. Plant Gene Duplication Database was used to analyse MYB genes and it was observed that for MYB APL gene, about 739 genes were involved in the construction of Gene tree, among which 554 are speciation nodes, 166 duplication nodes, 16 ambiguous nodes and 2 gene split event. Alignment of *Musa* MYB sequences with *Oryza sativa japonica* was performed and found that MYB sequences aligned with 42 regions in *Oryza* across various chromosomes, with a maximum of 6 in chromosome 4. (Fig 55).

Splice sites were predicted for *Musa* MYB sequences using Alternative Splice Site Predictor tool, which includes alternative isoform donor, acceptor, constitutive donor, and constitutive acceptor sites. Untranslated region (UTR) were also predicted using UTRscan tool and it was observed that about 683 UTR sequences matched with that of *Musa* MYB sequences. (Fig 56 & 57).

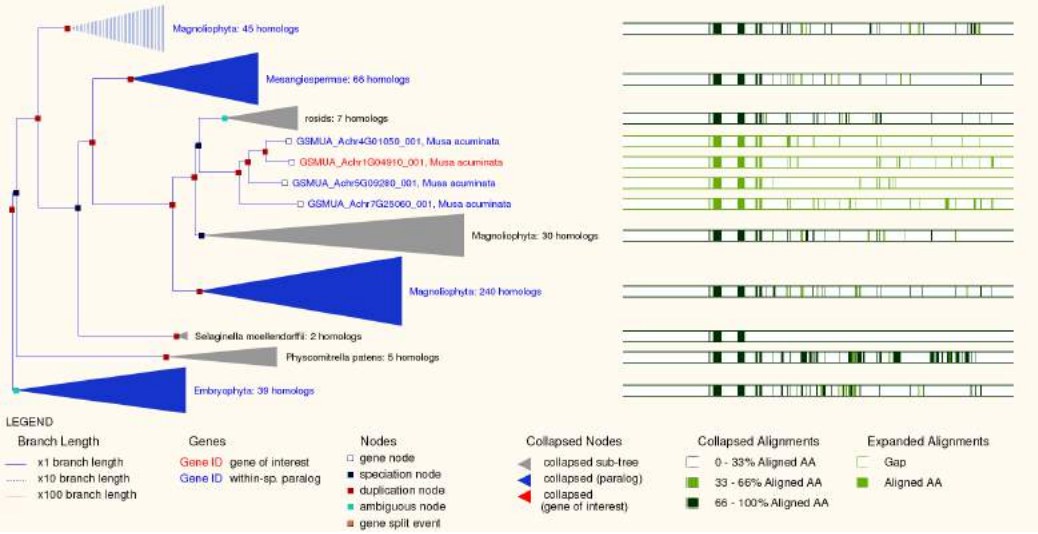


Fig 55. Analysis of MYB gene in plant gene duplication database and paralogous assembly of MYB with other genes in *Musa* and other species

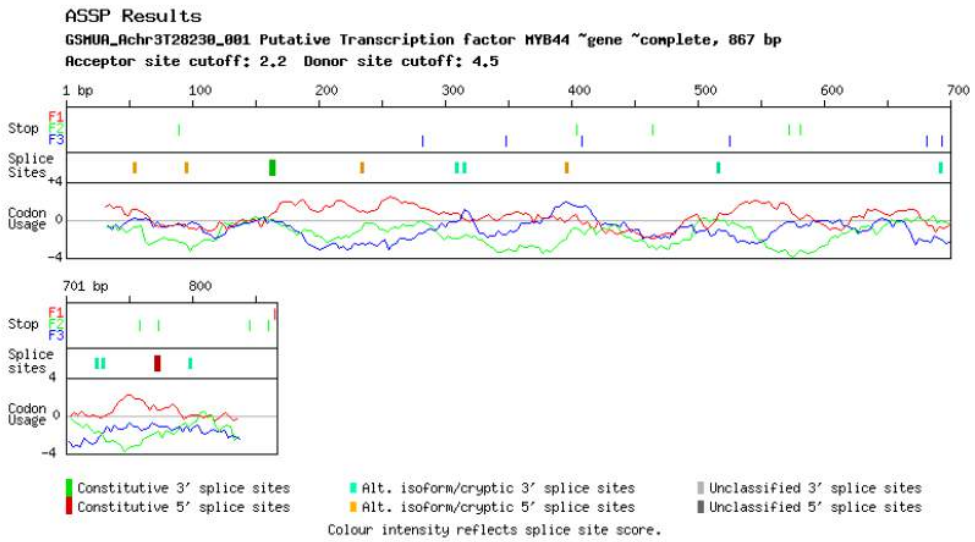


Fig 56. Analysis of MYB gene for splice site prediction and colored vertical bars indicates the presence of splice site, classified based on the color code indicated above

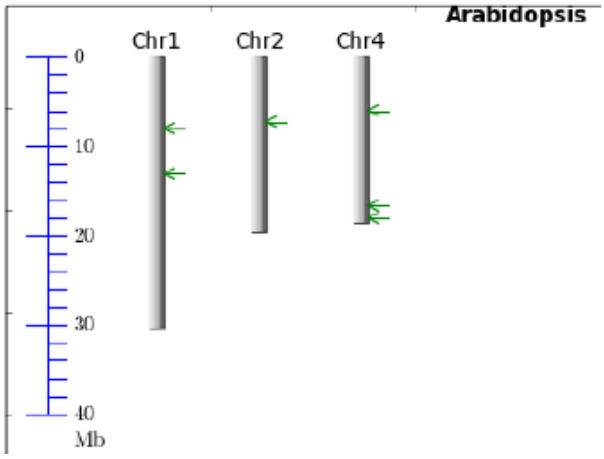


Fig 57. Analysis of MYB gene sequences using Map view tool in Plant Gene Duplication Database for mapping the MYB gene across the chromosome of plant genus.

4.5.2 Income generation through conservation and cultivation of near extinct banana landraces of Kolli Hills, Tamil Nadu (S. Uma)

Rehabilitation of near extinct cultivar Manoranjitham was achieved through micro propagation technique. Shoot buds of Manoranjitham were sub-cultured in the MS medium for large scale multiplication of plants. Totally 300 cultures are in S_{11} stage. Secondary hardened Manoranjitham plants (100 plants) are being maintained for distribution to interested farmers.

4.5.3 Lab Accreditation Facility for Virus indexing and Genetic fidelity testing of tissue culture plants – Genetic fidelity component (M. S. Saraswathi)

Totally 874 batches of tissue culture plants at various stages of production (Grand Nain, Williams, Robusta, Ney Poovan, Red banana, Quintal Nendran etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports issued. This generated an income of 15 lakh to the Centre.

4.5.4 Biofortification and development of disease resistance in banana

Component I: Biofortification and evaluation of Indian banana with pro Vitamin A (PVA) constructs (S. Backiyarani)

The construct pBMGF-DC49 which contains two genes, namely, Mt2a and APsy2a driven by Mt2a promoter was received from NABI, Mohali and presence of gene of interest was confirmed through PCR analysis (Fig 58). This was then mobilized into *Agrobacterium* strain Agl 2. Transformation of Rasthali and cv. Grand Nain using these constructs have been completed.

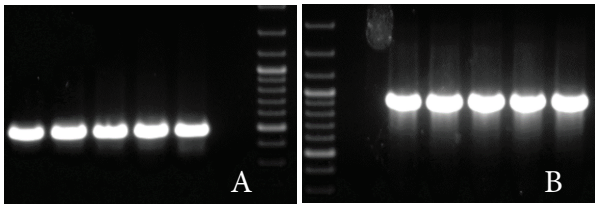


Fig 58. Confirmation of genomic DNA of *Agrobacterium* containing gene of interest
A) Confirmation of Apsy2a gene driven by Mt2a promoter
B) Confirmation of DXS gene driven by Mt2a promoter

Validation of transformed plants

DC-34 transformed Grand Nain plants have been PCR confirmed with DC-34 primer, and the transformants are maintained *in vitro* for multiplication. Among DC34 transformed Grand Nain plants, 45 were validated using primers targeting the Maize Ubiquitin promoter and Asupina PSY2a gene of the construct of which 39 plants were found to be transformed properly as they showed an expected amplification at 737 bp (Fig.59).

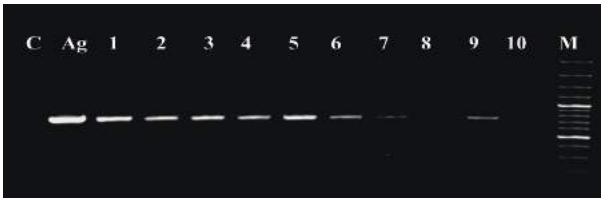


Fig 59. Confirmation of transformants through PCR

One set of 55 plants of Grand Nain transformed with DC-32 are in hardening phase and monitored regularly for any morphological changes or variations.

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

The Rasthali and Grand Nain transgenic plants numbering around 200 in each genotype produced using the iron gene construct *p*BMGF-DC-53 carrying *Os*NAS1 gene are maintained in growth media in bottles and sub-cultured regularly. The presence of selectable marker gene *nptII* and gene of interest *Os*NAS1 using the gene specific primers from genomic DNA of 20 each of Grand Nain and Rasthali transformed plants with construct *p*BMGF-DC-53 and the same set of plants were subjected to PCR analysis with VirA primer to rule out the *Agrobacterium* contamination in transgenics. Another set of 10 plants each of Grand Nain and Rasthali were analysed by multiplex PCR with primers of gene and VirA for confirming the presence of OsNAS1 gene in the transgenics simultaneously ruling out *Agrobacterium* contamination (Fig 60). Twenty untransformed control Rasthali and Grand Nain plants were mobilized to greenhouse under 28°C for primary hardening.

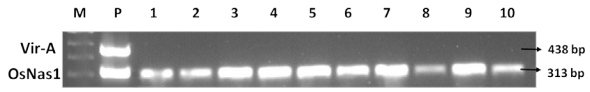


Fig 60. Confirmation of presence of *Os*NAS1 gene and absence of *Agrobacterium* contamination in transgenics by multiplex PCR; M: Marker, P: *Agrobacterium* culture,1-5:*p*BMGF-DC-53 (Rasthali transgenics) and 6-10:*p*BMGF-DC-53 (Grand Nain transgenics).

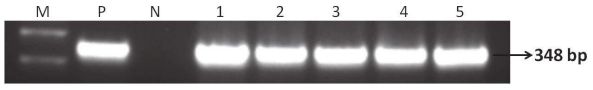


Fig 61. PCR confirmation of *Agrobacterium* carrying Gen-III iron construct *p*BMGF-DC-68for the presence of *Os*NAS2 gene;M: Marker, P: Plasmid DNA of *p*BMGF-DC-68, N: Negative control,1-5: pBMGF-DC-68 *Agrobacterium* culture.

A new Gen-III construct *p*BMGF-DC-68 with gene *Os*NAS2 was received from the National Agri-Food Biotechnology Institute, Mohali, Chandigarh, the national coordinating centre of the Network Project of Biofortification and development of disease resistance in bananas and presence of target gene in the construct was confirmed by PCR using gene-specific primers in *Agrobacterium* (Fig 61). Rasthali and Grand Nain ECS were cocultivated with construct *p*BMGF-DC-68 for five times each and the cocultivated ECS were transferred to their respective stage of growth medium (Fig 62).

Fig 62. Co-cultivated Rasthali and Grand Nain ECS with *Agrobacterium* containing iron gene construct *p*BMGF-DC-68.

Component III: Development of an efficient ECS of cv. Rasthali and providing to Indian partners (S. Uma)

Collection of male flower buds and supply to Indian partners

The male flower buds of cv. Rasthali (60 nos.) and cv. Grand Nain (85 nos.) were collected from Lalgudi and Theni areas of Tamil Nadu and supplied to Indian partners. At ICAR-NRCB, 72 buds of cv. Rasthali and 70 buds of cv. Grand Nain were initiated for callus induction.

Supply of ECS to Indian partners

ECS of cvs. Rasthali and Grand Nain 78ml and 110ml, respectively, were supplied to Indian partners including ICAR-NRCB after checking their regeneration efficiency.

Hardening of ECS derived plants

One hundred and twenty plants of cv. Grand Nain (lines NGFB0274 and NGFB0189) and 60 plants of cv. Rasthali were secondary hardened.

Genetic fidelity test

Genetic fidelity test was carried out for ECS derived cv. Grand Nain plants using ISSR marker-UBC 834 and they were found to be genetically uniform (Fig 63).

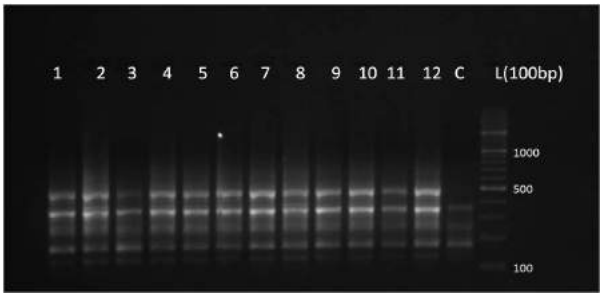


Fig 63. Genetic fidelity test for ECS derived cv. Grand Nain plants using ISSR marker-UBC 834

Maintenance of virus free mother plant nursery

Due to water scarcity and drastic climatic change, most of the mother plants were lost. Only twenty Rasthali accessions were available. Yield performance of ECS derived plants of cvs. Rasthali and Grand Nain is being studied by growing in a conducive environment at Gudalore in a farmers field.

4.5.5 Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis (M. S. Saraswathi)

Survey and collection of virus free male flower buds of cv. Rasthali

Survey was carried out in the surrounding villages of Tiruchirappalli namely Kuzhumani, Koppu, Neithalur colony and Lalgudi for the collection of male flower bud (150 numbers) explants from disease free (especially virus free) mother plants and they were initiated in MA1 medium for callus induction. The embryogenic calli derived from two petriplates were transferred to MA2 medium for the establishment of ECS (embryogenic cell suspension). The calli derived from those two plates are being maintained as two different cell lines and it was proliferated up to 50 ml SCV (settled cell volume). This is currently being used for both chemical and physical mutation studies.

Chemical mutagenesis

Using the suspension, the lethal dose LD_{50} for the chemical mutagen, EMS (0.1% for 2 hours) based on fresh weight gain (FWG), SCV and regeneration efficiency was determined. LD_{50} was determined for DES based on FWG and SCV and the one based on regeneration efficiency is in progress. Then, they were regenerated in MA3 medium and germination was done in MA 4 medium. (Fig 64).

In vitro screening

In vitro screening was done in germination medium using fusaric acid and culture filtrate at different concentrations and the optimal dose was found to be 0.1 mM and 6%, respectively. The germinated plants were taken for primary hardening (Table 27).

Table 27. Details of plants in primary hardening stage

Treatments (%)	No. of plantlets under *in vitro* screening	No. of plantlets under primary hardening
EMS 0.1	1764	348
EMS 0.2	1677	214
EMS 0.3	1173	179
EMS 0.4	515	81
Total	5129	822

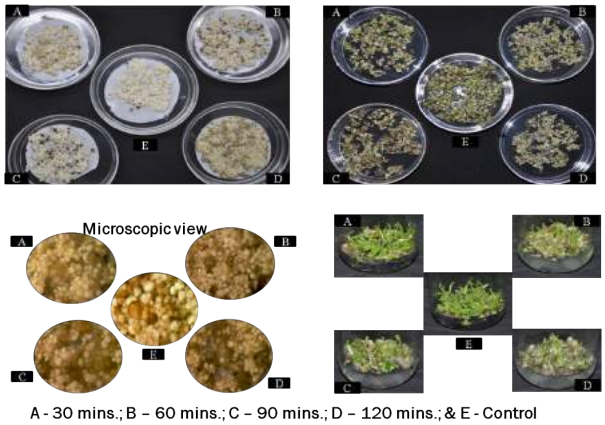


Fig 64. Effect of EMS (0.1%) on regeneration and germination of ECS

Contract research project

4.5.6. Evaluation of HYT®™ A and HYT®™ B against growth and yield of banana cvs. Grand Nain and Ney Poovan (V. Kumar)

Soil application of HYT®™ A @ 800 ml and foliar application of HYT®™ B @ 400 ml/acre in cv. Grand Nain recorded vigorous plant growth with thick pseudostem (88.1cm), retained more number of leaves at flowering (16.8) with greater leaf length (2.54m), leaf breadth (100.8cm and total chlorophyll (2.32 mg/g) and more number of side suckers per plant. In addition, the treatment recorded the highest bunch weight of 32.7 kg plant^{-1} with more number of hands (9.98) and fingers (190.48) per bunch. In addition, it also improved the fruit quality in terms of more TSS (24.5°B) and total sugars (25.13%) with the least acidity of 0.23%. Similar trend was also recorded in cv. Ney Poovan and soil application of HYT®™ A @ 800 ml and foliar application of HYT®™ B @ 400 ml/acre recorded vigorous plants and produced highest bunch weight (16.9 kg) and better fruit quality as compared to the plants grown under the untreated control. The treatment also enhanced the soil microbial status in terms of soil bacterial, fungal and actinomycetes population as compared to other treatments in both the varieties and locations.

4.5.7 CRP on borers (B. Padmanaban)

Survey for natural enemies of banana weevils

During 2015-16, surveys were undertaken in six banana growing states, *viz.,* Tamil Nadu (Vellore, Coimbatore, Thanjavur, and Tiruchirapalli Districts); Kerala (Palghat, Thrissur, Ernakulam and Idukki districts) ; Andhra Pradesh (Chittoor and Kadapa districts); Bihar (Bhagalpur district); Odisha (Cuttack district) and Mizoram (Kolasib district). The survey resulted in the collection of predators (Dermapterans 5 types, Coleopterans 3 types), entomopathogenic fungi (*Beauveria* sp.) and a small banana weevil, *Polytes mellerborghi* from the banana growing areas.

Screening of *Musa* accessions against banana corm weevil, *Cosmopolites sordidus* (Germar)

Twenty-nine accessions of *Musa* germplasm were screened *in vitro* against banana corm weevil, *Cosmopolites sordidus*. The accessions belonging to AB (5), ABB (3), AA (2), BB (1), AAA (1) were identified as resistant to banana corm weevil as revealed by no feeding damage and weevil mortality (Table 28 & Fig 65).

Table 28. List of resistant and susceptible *Musa* accessions to corm weevil, *C. sordidus*

Resistant accessions	Susceptible accessions
0147 (AB), 0113 (AB), 0486 (AB), 0623 (AB), 0178 (AB), 0065 (ABB), 0059 (ABB), 0584 (ABB), 0389 (AA), 0638 (AA), 2065 (BB), 1621(AAA)	0687 (AA), 0957 (AA), 0201 (AA), 1019 (AA), 0195 (AA), 0107 (AB), 0153 (AB), 0388 (AB), 0369 (AB), 0553 (ABB), 0171 (ABB), 0246 (ABB), 1066 (AAB), 0355 (AAB), 0608 (AAA), 0166 (AAA), 0047 (BB)

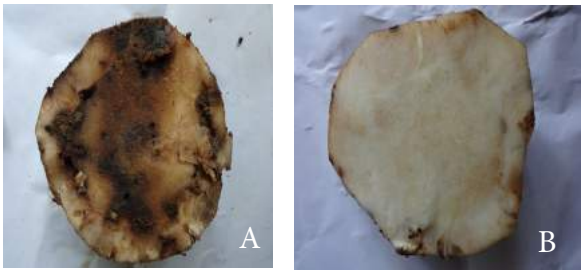


Fig 65. Cross section of banana corm indicating the feeding damage

A) Susceptible AA genome corm showing feeding damage

B) Healthy AB genome plant

4.5.8. Outreach project on *Phytophthora, Fusarium* and *Ralstonia* diseases of horticultural and field crops (R. Thangavelu)

Differential expression of genes in Fusarium wilt and biocontrol agent interaction in banana by SSH approach

To identify the differentially expressed genes due to the interaction of *Foc* pathogen and effective biocontrol agent in banana, Suppressive Subtractive Hybridization (SSH) was carried out in cv. Grand Nain. Out of 300 clones sequenced 258 readable sequences were obtained. All the readable sequences were assembled through CAP3 analysis which resulted in the construction of a unigene set of 109 ESTs. Among them 87 were singletons and the remaining sequences were grouped into 22 contiguous sequences (contigs). Gene ontology analysis was carried out for all the unigenes using the Blast2go software. The sequences were classified into three categories: biological process, molecular function and cellular component. The similarity search for all these ESTs with the existing sequences in Gen Bank using BLASTX resulted in 88 hits and among these only 24 sequences that had significant matches (E value $<10^{-3}$) were categorized into five groups namely, defense/ resistance, signal transduction, transcription, protein synthesis and metabolism. Out of these 24 genes, six defense related genes, namely, banana lectin-methyl-alpha-mannose complex (mannose binding lectin), calmodulin binding protein, pleotropic drug resistance protein, endochitinase, isoflavone reductase and polyubiquitin were selected for further studies by RT-PCR (Fig 66).

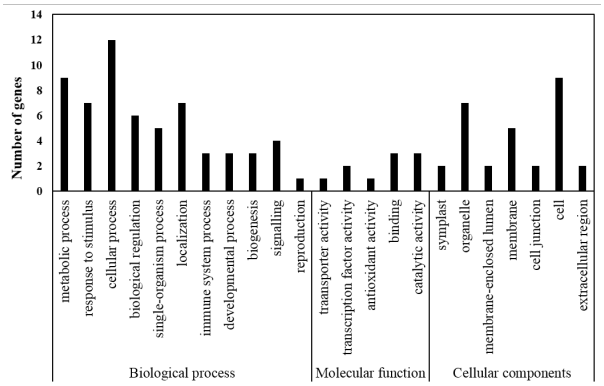


Fig 66. Gene ontology (GO) annotations of unigenes obtained from suppression subtractive hybridization in cv. Grand Nain inoculated with *Foc* and challenged with *T. asperellum* (tester) as against *Foc* alone inoculated driver genes.

Real-Time PCR analysis of differentially expressed genes

The validation for six defense related genes performed by RT-PCR in cv. Grand Nain indicated that all these genes were expressed in the root tissues of both *Foc* alone and *Foc* + *T. asperellum* inoculated banana plants. However, the expression level of all these genes was consistently higher in *Foc* + *T. asperellum* inoculated plants as compared to *Foc* alone inoculated plants (Fig). With regard to time of expression of these defense related genes, the transcript level of endochitinase, mannose binding lectin and polyubiquitin genes reached the maximum at 5 DPI, whereas the isoflavonereductase and pleotropic drug resistance gene reached maximum level (10 fold) at 7DPI and calmodulin binding protein at 3DPI in *Foc* + *T. asperellum* inoculated plants compared to *Foc* alone inoculated plants. Altogether this expression study showed that defense related gene mechanism peaked between 3DPI and

7DPI in *Foc* + *T. asperellum* inoculated banana plants.(Fig 67).

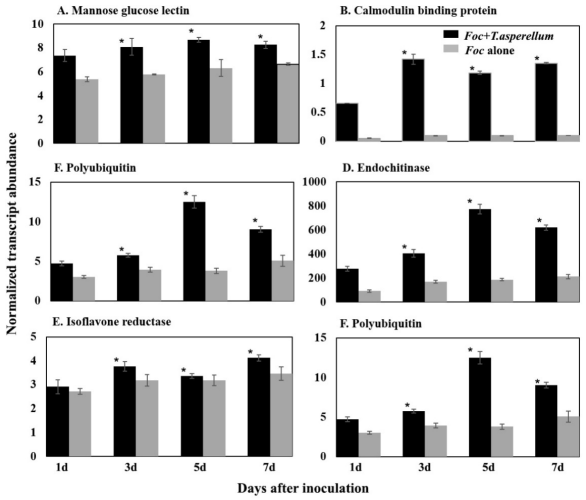


Fig 67. Relative quantification of defence-related genes in roots of cv. Grand Nain inoculated with *Foc* and challenged with *T. asperellum* (prr2). Gene expression quantified by RT-PCR after 1, 3, 5 and 7 DPI. Gene expression is shown as PCR/25S rRNA product. Data was normalized with endogenous control. All experiments performed with 3 biological replicates (n=3). Designation of treatments is as follows: Black bars, *Foc* + *T. asperellum* inoculated plants; Gray bars, *Foc* alone inoculated plants. Means ± SE, n =3. * Tukey's test was used for proof of significance ($P < 0.05$) compared with corresponding *Foc* + *T. asperellum* or *Foc* alone inoculated treatments.

Comparative proteomics study of pathogenic (*Foc* VCG 0124) and non-pathogenic *Fusarium oxysporum* (NP-*Fo*)

Proteomics study of pathogenic *Fusarium oxysporum* f.sp.*cubense* (P-*Foc*-VCG0124) and non-pathogenic *F. oxysporum* (NP-*Fo*) strain mycelia proteins was carried out. A total of 600 reproducible protein spots were detected by silver staining method. Of these, 20 spots were found to be differentially expressed with ≥ 1.5 fold changes. Among these 20 differentially expressed proteins, 5 significantly up-regulated (P1 to P5) and 1 unique spot (P6) were excised and subjected to MALDI-TOF/mass spectrometry analysis. Further, MASCOT search and functional annotation indicated that the significantly up-regulated proteins are P1-Vesicle transport v-SNARE protein,P2-developmentally regulated GTP-binding protein, P3-ankyrin repeat containing protein, P4-Isocitrate dehydrogenase, P5-Homogentisate 1, 2-dioxygenase and P6-hypothetical protein (unique), respectively (Fig 68). According to literature consensus, up-regulation of homogentisate 1, 2-dioxygenase might lead to pyomelanin production which implies that the protein might play a key role in eliciting pathogenicity in pathogenic *Foc* and disease persistence.

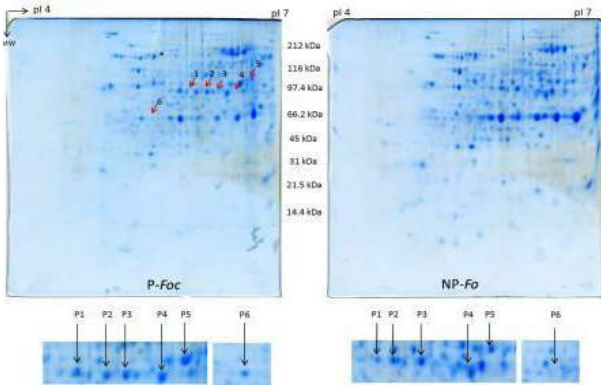


Fig 68. Proteome map of pathogenic *Fusarium oxysporum* f.sp. *cubense* (P-*Foc*) and non-Pathogenic *F. oxysporum* (NP-*Fo*). P1-Vesicle transport v-SNARE protein,P2-developmentally regulated GTP-binding protein, P3-ankyrin repeat containing protein, P4-Isocitrate dehydrogenase, P5-Homogentisate 1, 2-dioxygenase and P6-Hypothetical protein

Comparative proteomics of Tamil Nadu *Foc* (TN-*Foc*) and virulent Bihar *Foc* (Bi-*Foc*)

Proteomics study of mycelial proteins from a pathogenic *Foc* Tamil Nadu isolate (TN-*Foc*, VCG 0124) and a virulent *Foc* Bihar isolate (Bi-*Foc*) was carried out. A total of 800 reproducible protein spots over a pH range of 4-7 with a molecular weight ranging from ~45kDa to ~220kDa were detected. Among the 800 protein spots detected, 82 spots were found to be differentially expressed with ≥ 2-fold changes. Forty six out of 82 differentially expressed proteins (Bi-*Foc*-21 spots and TN-*Foc*-25 spots)

were subjected to MS/MS analysis. Functional classification of proteins based on Gene ontology indicated that most of the identified proteins correspond to enzymes that are involved in various processes which include carbohydrate metabolism, pathogenicity related process (Hydrolase, Cellobiohydrolase, Exoglucanase A, MAPKKinase, pH response regulator protein, Myb-like DNA-binding domain-containing protein and Arylsulfotransferases), protein synthesis, transport and regulation and signal transduction (Fig 69).

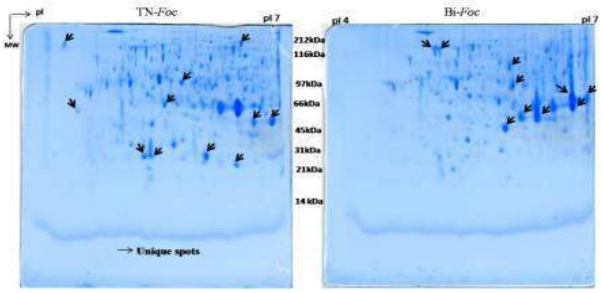


Fig 69. Contrasting proteome map of pathogenic *Fusarium oxysporum* f.sp. *cubense* Tamil Nadu isolate (TN-*Foc*) and virulent Bihar isolate (Bi-*Foc*).

4.5.9. Twinning project on Fusarium wilt (R. Thangavelu)

Diversity analysis of *Foc* isolates of Assam by VCG and ISSR analysis

Vegetative compatibility group analysis

VCG analysis carried out for seven numbers of *Foc* isolates of Rasthali collected from different banana growing regions of Assam indicated the presence of VCG 0124 and 0125 of race 1.

ISSR analysis

A total of 10 ISSR primers were used to discriminate the polymorphism among the isolates of *Foc* (Fig 70). Totally four primers (890, 842, (GAC)5 and CCA(TG)7T) showed good polymorphism. The amplicon sizes of the products ranged from 200bp to 6.5kb. The number of DNA fragments amplified and scored per isolate for individual primer ranged from 5 to 9 bands. The phylogenetic analysis showed the presence of two clusters A and B. The main cluster A contained only one isolate and the cluster B contained the remaining 11 isolates of Rasthali indicating genetic variation within populations of *Foc* was significant, although the genetic identity was high.

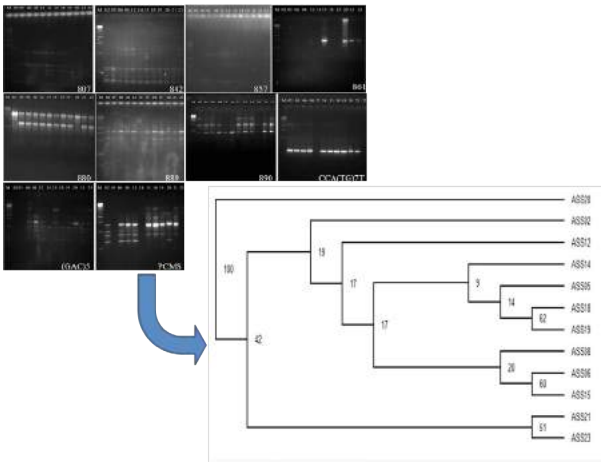


Fig 70. List of ISSR primers used for molecular divergenicity analysis for *Foc* from different areas of Assam using NTSYSpc 2.0.

4.5.10. Management of Postharvest diseases of banana (R. Thangavelu)

Isolation and characterization of volatile metabolites from zimmu leaf extract

Among 33 botanicals screened against different banana pathogens, zimmu leaf extract @ 50% concentration was very effective in inhibiting the mycelia and spore germination of postharvest pathogens (*Lasiodiplodia theobromae* and *Colletotrichum musae*). Zimmu leaf extract @ 50% concentration was effective in controlling postharvest diseases *in vivo* besides extending the shelf life of banana. Hence, the principle compound, particularly volatiles present in the zimmu was extracted and subjected to gas chromatography/mass spectrometry (GC/MS) analysis.

GC-MS analysis of zimmu leaf volatiles resulted in the identification of principle compound (PC1) which is phenolic in nature. *In vitro* bioassay conducted against postharvest pathogen showed that there was 100% mycelial inhibition of postharvest pathogens at 0.1%

concentration (Fig 71 & 72).

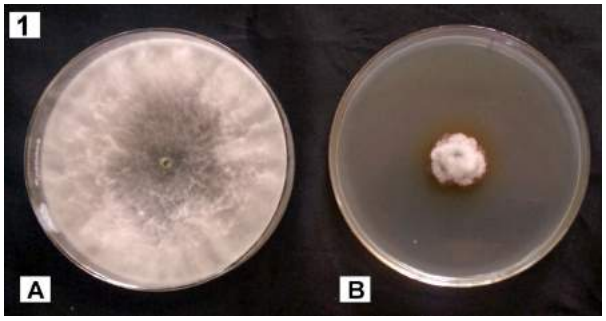


Fig 71. Effect of PC 1 (0.1% concentration) on the mycelial inhibition of *L. theobromae* pathogen under *in vitro* condition. A) Control (*L. theobromae*), B) Effect of PC1 on *L. theobromae* mycelial growth (90% inhibition)

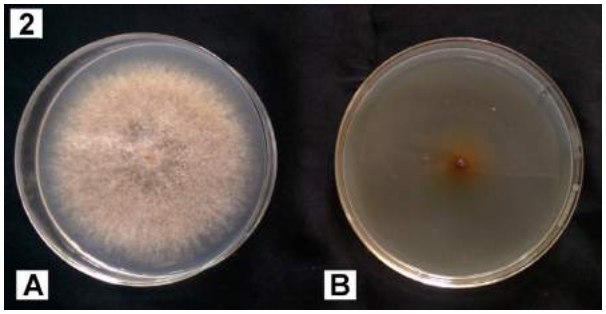


Fig 72. Effect of PC 1 (0.1% concentration) on the mycelial inhibition of *C. musae* pathogen under *in vitro* condition. A) Control (*C. musae*), B) Effect of PC1 on *C. musae* mycelial growth (100% inhibition)

Field evaluation (pre-harvest spray) of microbes and botanical for the suppression of preharvest and postharvest diseases of banana at Cumbum, Theni district in cv. Grand Nain

Bio agents and botanicals identified as effective based on *in vivo* experiments were tested for their efficacy under field conditions for the management of post-harvest diseases such as crown rot and anthracnose and extension of shelf life (green and yellow life) of banana fruits.

Field evaluation (pre-harvest spray) of native microbes (of fungal and bacterial origin) and botanical (zimmu) individually and in combination was conducted in cv. Grand Nain at Cumbum, Theni district of Tamil Nadu. Three pre-harvest sprays were given at monthly interval immediately after the formation of last hand. The microbes were applied as talcum powder formulation (1 X 10^8 cells/ gram) at 50g/ litre of water and zimmu as aqueous leaf extract at 50% concentration (v/v). The results from the pre-harvest spray indicated that bunches sprayed with talcum powder formulation of *T. asperellum* (prr2) recorded 32.8% increase in weight as compared to water sprayed control. Bunches sprayed with aqueous zimmu leaf extract (50% concentration) recorded 25.1% increase in weight as compared to water sprayed control. None of the biocontrol agent treated banana bunches recorded incidence of pre-harvest disease. However, chemical (Carbendazim at 1.5 ppm) and water sprayed bunches recorded 20% and 30% incidence of cigar end rot disease (Fig 73).

Fig 73. Banana bunches after pre-harvest treatment. A) Bunch sprayed with *T. asperellum* (prr2), B) Bunch sprayed with chemical (carbendazim 1.5ppm) with cigar end rot symptoms (Insert: cigar end rot on banana hand)

In vivo evaluation of *Trichoderma asperellum* (prr2) for the control of postharvest diseases and extension of shelf life of banana in packing house condition at 13.5 °C in Cumbum, Tamil Nadu

To evaluate the effect of *T. asperellum* (prr2) for the control of postharvest diseases and extension of shelf life of banana, an experiment

was conducted in packing house condition (13.5 °C) at Cumbum, Theni district of Tamil Nadu. The banana bunches of 80% maturity of cv. Grand Nain were harvested and different sizes of banana hands of 46, 48, 50 and 52 calliper size were used for *in vivo* evaluation. The banana hands were sprayed separately with *T. asperellum* (prr2) spores (10^8 cells/ml), chemical (1.5 ppm carbendazim) and air dried under room temperature. Banana hands sprayed with carbendazim and packed with ethylene absorbent were treated as standard control.

The result indicated that banana hands of 46, 48, 50 calliper size treated with *T. asperellem* and packed without ethylene absorbent extended the shelf life of banana up to 75 days as compared to standard control (50 days) (Figure 74). Banana hands of 52 calliper size treated with *T. asperellem* extended the shelf life of banana up to 68 days as compared to standard control (17 days). None of the treatments recorded postharvest emergence of anthracnose or crown rot disease indicating their efficacy against postharvest diseases.

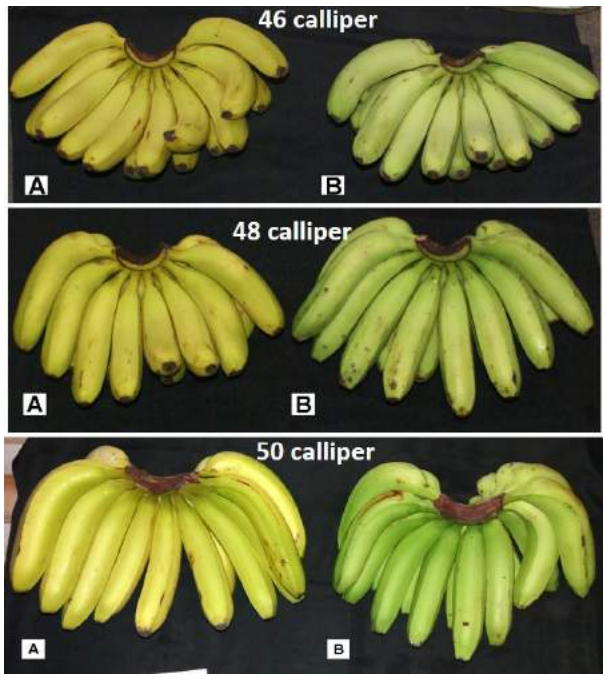


Fig 74. Banana hands at different calliper size treated with A) Chemical (carbendazim 0.1%) and B) *T. asperellum* (prr2) (spore suspension 1 X 10^8 spores/ml). The banana hands of standard control ripened in 50 days whereas *T. asperellum* (prr2)treated banana hands ripened only after 75 days.

4.5.11. Development of Diagnostics for viruses of banana under CRP-on vaccines and diagnostics (R. Selvarajan)

Primers were designed to express coat protein of two RNA viruses in a single vector for expression of fused viral proteins to produce antiserum suitable for certification programme. Expressed BBrMV coat protein using bacterial expression system and obtained 4 mg of viral coat protein for developing dipstick based on-site detection kits for diagnostics. LAMP based detection methods have been fine tuned to reduce the cost and time for BBTV after standardizing under centre's project. Real time LAMP has proved to be more efficient and time saving in the detection of BBTV as there is a SYBR Green dye provided in the master mix itself.

4.5.12. National certification system for tissue culture raised plants DBT-ATL scheme for virus indexing / virus indexing -contract services (R. Selvarajan)

Mother cultures of tissue culture (TC) banana plants received from 47 DBT recognized and unrecognized TC industries were tested for banana viruses under DBT-ATL scheme as well as contract service respectively. Totally 23563 samples were tested for the presence of viruses. Certificate of quality was issued for 52.55 million TC plants.

4.5.13. Proteomic studies of host-pathogen interactions in Banana-Banana Bract Mosaic Virus (BBrMV) system (C. Anuradha)

Candidate disease biomarkers were identified for the detection of BBrMV which can be used in disease diagnosis after validation.

SHOOT	BRACT	PSEUDOSTEM
Phosphoglycerate mutase-like protein	Putative receptor kinase	Translation Initiation Factor EIF2
Rice tungro bacilliform virus P46 protein	Electron transfer flavoprotein subunit beta, mitochondrial	Small Heat Shock Protein 23.6
Pre-sequence translocase-associated protein import motor (PAM)	8s globulin alpha isoform precursor	Rho GDP-dissociation Inhibitor 1-like
Peptidyl-prolyl cis-transisomerase	Putative disease resistance protein RGA1-like	Glutathione -S-transferase
Ring finger domain	Granule-bound starch synthase	Tubulin-tyrosine ligase-like protein

Validation of the candidate biomarkers from shoot, pseudostem and bract by RT-PCR/Semi quantitative PCR

Semi-quantitative PCR analysis was carried out for all the biomarkers identified from different tissues by 2DE analysis. Rho GDP-dissociation Inhibitor 1-like, Putative receptor kinase, Peptidyl-prolyl cis-transisomerase, Translation Initiation Factor EIF2, Small Heat Shock Protein 23.6, 8S globulin alpha isoform precursor, Tubulin-tyrosine ligase-like protein, Granule-bound starch synthase, Ring finger domain, Phosphoglycerate mutase-like protein Electron transfer flavoprotein subunit beta, mitochondrial, Glutathione-S-transferase genes gave single band and corroborated the protein results (Fig 75).

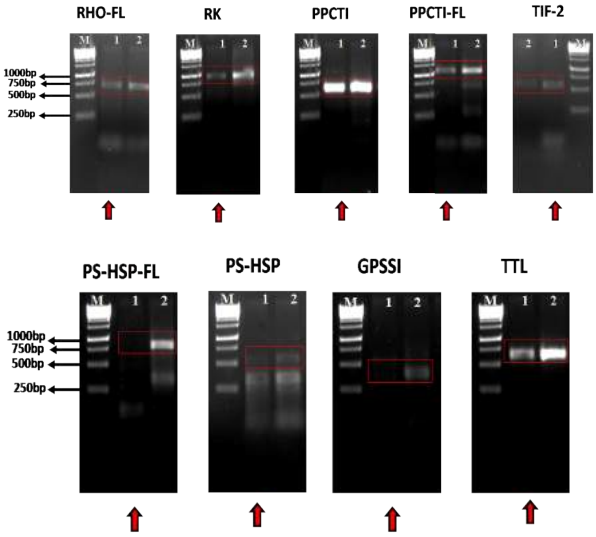


Fig 75. Semi-quantitative PCR analysis for candidate biomarkers.

Protein-protein interactions of host and virus in a banana-BBrMV interaction system

Based on the previous studies on other potyviruses, six viral genes from BBrMV (VPg, CP, HC-Pro, NIa, NIb, CI) and nine plant genes from Nendran banana were taken for interaction studies. Primers were designed for all the six viral genes and nine plant genes (eIF4E, eIF4E (iso), Poly Adenylate Binding Protein (PABP), Chlorophyll A/B binding preprotein, Photosystem I N-subunit, RGS-CAM (calmodulin related protein), Ring finger protein (HIP1and HIP2), DNA J like (Nt CPIPs) Nt CPIP2a and Photosystem I PSI-K subunit). Complementary DNA was subjected to PCR amplification using virus and plant gene specific primers and was subsequently cloned in pTZ57R/T and sequenced. The sequences were then blasted in NCBI and found to be the same gene.

Both the viral genes (HC-Pro and VPg) and plant genes (calmodulin and eIF4E (Iso)) which were cloned in pZT cloning vector were restriction confirmed (Fig 76) then subcloned in yeast vectors pJG4-5 and pEG202, respectively (Fig 77). pEG202 calmodulin fusion was then co-transformed along with SH18-34 into EGY48. Then screening for positive interactions was done by transforming a pJG4-5 HC-Pro fusion (with) into EGY48 yeast containing a pEG202 calmodulin fusion and pSH18-34, and assayed for simultaneous activation of *Leu2* and *lacZ* reporters in a galactose-dependent manner. Similar procedure was carried out for VPg and eIF4E (Iso) to study the interaction between these viral and plant genes. In both the cases the results were not clear and the experiment has to be repeated. Along with this we need to study the interactions between all the BBrMV proteins with its host proteins from Nendran banana (cDNA libraries) using the yeast two hybrid system.

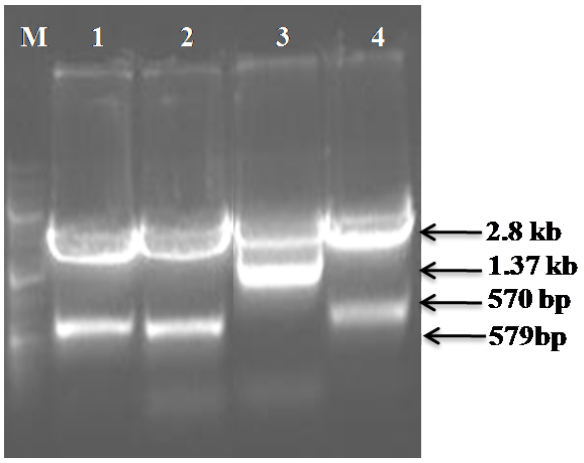


Fig 76. Cloning of CAM19, eIF4E(Iso) HC-Pro, VPg genes from the Nendran and BBrMV. Restriction confirmation of recombinant clones pTZ57R/T::*CAM19,* pTZ57R/T::*eIF4E(Iso),* pTZ57R/T::*HC-Pro,* pTZ57R/T::*VPg*. Lane M = GeneRuler™ 1 kb DNA Ladder; Lane 1 = Restriction of plasmid pTZ57R/T::*CAM19 with Hind* III and *Xba* I enzymes to release the insert of 591 bps fragment; Lane 2 = Restriction of plasmid pTZ57R/T::*eIF4E(Iso) with Hind* III and *Xba* I enzymes to release the insert of 579 bps fragment; Lane 3 = Restriction of plasmid pTZ57R/T::*HC-Pro with Hind* III and *Xba* I enzymes to release the insert of 1.37 kb fragment; Lane 4 = Restriction of plasmid pTZ57R/T::*VPg with Hind* III and *Xba* I enzymes to release the insert of 570 bps fragment.

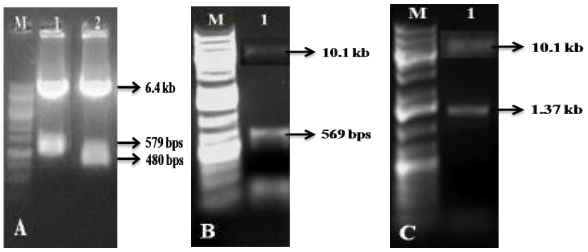


Fig 77. Cloning of CAM19, eIF4E (Iso) genes from the Nendran and VPg and HC-Pro from BBrMV into yeast vectors.

Restriction confirmation of recombinant clones pJG4-5::*eIF4E(Iso),* pJG4-5::*CAM19.* Lane M = GeneRuler™ 1 kb DNA Ladder; Lane 1 = Restriction of plasmid pJG4-5::*eIF4E(Iso) with ECoR* I and *Not* I enzymes to release the insert of 579 bps fragment; Lane 2 = Restriction of plasmid pJG4-5::*CAM19* with *ECoR* I and *Not* I enzymes to release the insert of 480 bps fragment. **B)** Restriction confirmation of recombinant clones pEG202::*VPg.* Lane M = DNA Ladder; Lane 1 = Restriction of plasmid pEG202::*VPg with ECoR* I and *Not* I enzymes to release the insert of 569bps fragment; **C)** Restriction confirmation of recombinant clones pEG202::*HC-Pro.* Lane M = DNA Ladder; Lane 1 = Restriction of plasmid pEG202::*HC-Pro* with *ECoR* I and *Not* I enzymes to release the insert of 1370bps fragment.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Training

Around 4500 visitors comprising of banana farmers, entrepreneurs, horticultural/ agricultural officers and school/college students visited ICAR-NRCB and they were briefed about improved production and protection technologies, post-harvest management and value addition of banana.

5.2 Radio talks through All India Radio, Tiruchirappalli

Name of the Scientist	Topic	Date of broadcast
B. Padmanaban	Integrated pest management in Banana	7 July, 2015
R. Selvarajan	Virus disease management in banana (Vazhaiyil virus noi melanmai)	7 September, 2015
M. Mayil Vaganan	Health benefits of banana fruit	1 March, 2016

5.3 Television talks

Name of the Scientist	Topic	Date of telecast & TV channel
K. N. Shiva	Production of handicrafts from banana fiber (*Vazhai naarilirunthu khaivinaiporutkal undakkuthal*)	12–14 January, 2016 Puthia Thalaimurai, Chennai

5.4 Exhibitions conducted / participated

Name of the Event	Organizer & Venue	Date(s)
Island Kisan Mela, 2015	ICAR–CIARI, Port Blair, Andaman & Nicobar Islands	9–10 April, 2015
Agriculture Exhibition, 2015	ICAR, Pipra Kothi, Motihari, Bihar	20–21 August, 2015
Seminar & Kisan Mela	ICAR–CIAE (Regional station), Coimbatore, Tamil Nadu	27 August, 2015
Kisan Mela, 2015	ICAR–NRCB, Tiruchirapalli, Tamil Nadu	28 August, 2015
Agri Expo–2015 (5th Mega Agriculture Fair)	Dinamalar–Tamil Daily Newspaper, Tiruchirappalli, Tamil Nadu	19–21 September, 2015
Tuber crops food festival (Tuber food fest–2015)	ICAR–CTCRI, Thiruvananthapuram, Kerala	24–25 November, 2015
South zone Agri Expo–2015	ANGRAU, Lam farm, Guntur, Andhra Pradesh	19–21 December, 2015
Indian Science Congress	Govt. of India, Mysuru, Karnataka	3–7 January, 2016
Agri Expo–2016	Pasumai Vikatan, Tiruchirappalli, Tamil Nadu	12–15 February, 2016
Farmers' interface meeting	KVK, ICAR–IIVR, Kushinagar, Uttar Pradesh	18–20 February, 2016
Krishi Unnati Mela–2016	Ministry of Agriculture & Farmers' Welfare and CII, ICAR–IARI, New Delhi	19–21 March, 2016

Dr. S. Ayyappan, Secretary–DARE & Director General–ICAR, New Delhi visited the exhibition of ICAR–NRCB during Kisan Mela conducted on the eve of 22nd foundation day celebrations.

Exhibition of ICAR–NRCB at ICAR–IARI, New Delhi during Krishi Unnati Mela

5.5. Publicity

Different press notes / releases on ICAR –NRCB activities / events / technological information / articles were published in different national and local dailies including Tamil magazines / journals, AIR–farm division, etc. for the benefit of farmers.

Subject	Date
Nematode management in banana (Tamil)	18 April, 2015
Rust thrips and leaf eating caterpillar management in Banana (Tamil)	28 May, 2015
Kisan Mela at ICAR–NRCB	26 August, 2015
22nd Foundation day & Kisan Mela (press release)	28 August, 2015
About ICAR–NRCB's 22nd foundation day celebrations (press note)	7 September, 2015
New report of leaf eating caterpillars on banana (press note)	17 October, 2015
World soil day celebrations at ICAR–NRCB (press note)	5 December, 2015
Nutrient management in banana cultivation during rainy season (press note)	16 December, 2015
Leaf spot disease management in banana during winter season (press release)	23 December, 2015
Leaf spot disease management in banana during winter season (press note)	25 December, 2015
Farmers–Scientists Interaction (*Jai Kisan Jai Vigyan*) (press note)	29 December, 2015
Post harvest management in banana and plantain (Tamil)	20 January, 2016
National science day celebration (press release)	29 February, 2016
Stem weevil management in banana (Tamil)	1 March, 2016
Banana Shakti–General recommendation for banana cultivation (press note)	22 March, 2016
Control of stem weevil in banana cultivation (Tamil)	31 March, 2016

6. EDUCATION AND TRAINING

6.1 Students guided

Student Name	Degree	Project title	Chairperson
A. K. Sreenija	M.Tech. (Biotechnology)	Cloning, sequencing and bioinformatic analysis of C1 and VPg gene of Banana bract mosaic virus (BBrMV) isolate infecting plantain	R. Selvarajan
P. Pragathy	M.Tech. (Biotechnology)	Cloning, sequencing and bioinformatic analysis of Banana streak virus (BSV) isolate infecting cv. Poovan	R. Selvarajan
S. Abirami	M.Sc. (Microbiology)	Cloning, sequencing and bioinformatic analysis of P1 gene of Banana bract mosaic virus (BBrMV) isolates	R. Selvarajan
M. Vijayalakshmi	M.Sc. (Microbiology)	Cloning, sequencing and bioinformatic analysis of Banana streak virus (BSV) isolates	R. Selvarajan
M. Mohammed Ziad	B.Tech. (Biotechnology)	*Agrobacterium tumefaciens* based tobacco transformation and micropropagation of banana	R. Selvarajan
M. Sujitha	B.Tech. (Biotechnology)	Studies on Carrageenan, a low cost gelling agent in mass multiplication of banana (*Musa* spp.) cv. Udhayam (Pisang Awak, ABB)	M. S. Saraswathi
G. Jithu	B.Tech. (Biotechnology)	DNA profiling of plantain clones (*Musa* spp.) using ISSR markers	M. S. Saraswathi
G. Sasikala	B.Tech. (Biotechnology)	DNA fingerprinting of *Musa* wild species from Arunachal Pradesh using SSR markers	M. S. Saraswathi
J. Dhivya	M.Sc. (Food Processing)	Functions of resistant starch and designer food development from banana flour var. Monthan	P. Suresh Kumar

6.2.1. On–Campus Training

Title of the training	Date(s)	No. of Trainees	Course Co–ordinator(s)
'Improved production and post–harvest management technologies in banana' to officers of Malappuram District, Kerala (sponsored by State Horticulture Mission, Kerala).	8–9 April, 2015	25	V. Kumar, K. J. Jeyabaskaran & K. N. Shiva
Training on 'banana fig' to entrepreneurs from Malappuram & Kannur, Kerala under licensing of technical know–how.	25–26 June,2015 & 14–15 July, 2015	6	K. N. Shiva

'Production of value added products from banana' to farmers. (Sponsored by *Uzhavar Magan* Farmer producer company limited, Erode, Tamil Nadu).	6–10 July, 2015	10	K. N. Shiva
'Production of banana flour based health drink and soup mix' to Mr. K. Dinesh, Nellore, Andhra Pradesh.	8–9 July, 2015	1	K. N. Shiva
Hands on training on 'Banana Tissue Culture'.	14–16 September,2015	2	M. S. Saraswathi
Training on 'banana Fig'.	6–7 October, 2015	3	K. N. Shiva
Hands on training on banana tissue culture to persons from M/s. Madappally service co-operative bank ltd., Kottayam, Kerala.	14–19 December, 2015	7	M. S. Saraswathi
Training on 'banana fig' and 'banana flour' to trainees from Kerala.	15–16 December, 2015	4	K. N. Shiva
Training on 'banana flour based baby food' and 'banana peel pickle' to Ms. Divya, Tamil Nadu.	15–16 December, 2015	1	K. N. Shiva
Training on 'post-harvest handling, packing, storage and ripening in banana for domestic and export markets' to Mr. Vinod Mocharla, M/s Coastal lines–trading & distribution, Nellore, Andhra Pradesh.	23–25 February, 2016	1	K. N. Shiva
Training on 'banana flour' and 'banana flour based baby food'.	2–3 March, 2016	3	K. N. Shiva
Technical training on 'Tissue culture of banana cv. Sabri' to M/s. Saveer Biotech, New Delhi.	28 January– 3 February, 2016	2	S. Uma & M. S. Saraswathi
'Viral diseases of banana and their management' to trainees from M/s. Saveer Biotech, New Delhi.	26 January, 2016	2	R. Selvarajan
'Nematode diseases of banana and their management' to trainees from M/s. Saveer Biotech, New Delhi.	26 January, 2016	2	P. Giribabu

Participants of the training on 'Improved production and post–harvest management technologies in banana'

Participants of the 'Hands on training on banana tissue culture'

6.2.2. Off-Campus Training

Title	Location	Period	No. of trainees	Course Co-ordinator(s)
Improved scientific cultivation and value addition in banana.	ICAR, RC NEHR, Basar, Arunachal Pradesh	14 October, 2015	100	V. Kumar & P. Suresh Kumar
	SASRD, Nagaland University, Medzhiphema, Nagaland	16 October, 2015	100	
	College of Agriculture, Agartala, Tripura	19 October, 2015	150	
Training on 'Technical inputs to alleviate salt injuries in banana and guidelines and demonstration on method of application of fertilizers and other cultural operations in banana'.	Kushinagar, Uttar Pradesh	27 February– 2 March, 2016	15	I. Ravi & K. J. Jeyabaskaran

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name of Scientist	Name of the award	Awarded by / Organizer/ Place/ Date
R. Selvarajan	DST–Lockheed Martin–India Innovation growth program award	DST, Govt. of India & Lockheed Martin Corporation, New Delhi. 13 May, 2015.
K. N. Shiva	Best poster presentation award (Second prize)	50th Annual convention of 'Indian Society of Agricultural Engineers', OUAT, Bhubaneswar, Odhisha. 19–21 January, 2016.

7.2 Recognitions

Name of the Scientist	Particulars
B. Padmanaban	Fellow of AAPMHE, ICAR–IIHR, Bengaluru.
S. Uma	Executive councilor (southern zone), Horticulture Society of India.
	Member, Editorial committee of the journal 'Current Horticulture'.
	Expert member in 'Dossier meeting for GM crops' organized by Ministry of Environment and Forests.
	External examiner for M. Sc. theses of HC & RI, TNAU, Periyakulam, Tamil Nadu and YSRHU, Venkatamannagudem, Andhra Pradesh.
	External examiner for final *Viva Voce* for Ph.D., Division of Horticulture, TNAU, Coimbatore, Tamil Nadu.
R. Selvarajan	Fellow of Phytopathological Society of India (FPSI), Indian Phytopathological Society, New Delhi.
	Fellow of Indian Virological Society (FIVS), Indian Virological Society (VIROCON 2015), Shillong, Meghalaya.
	Member, Organizing committee of symposium on "Challenges in plant virology and our preparedness". Division of Plant pathology, ICAR - IARI, New Delhi.
	Co–chairman in a technical session on "Advances in use of tools and techniques in plant pathology" at the International conference on "Plant, pathogens and people'' organized by Indian Phytopathological Society, NASC, New Delhi. 23–26 February, 2016.
	Judge for selection of Young Scientist award at XXIV Annual conference of the Indian Virological Society (IVS)–VIROCON 2015, Shillong, Meghalaya. 8–10 October, 2015.
	External examiner for M.Sc (Agri) thesis, TNAU, Coimbatore and Central Agricultural University, Umiam, Meghalaya.
	Editor of 'Virus Disease' (formerly Indian Journal of Virology) for the year 2015–16.

R. Selvarajan	External expert by DBT, GOI for IBSC committee in ICAR–IIHR, Bengaluru, Karnataka.
	Selection committee chairman and member for selection of research fellows / technical assistant for various projects at ICAR–NRCB, Tiruchirappalli, Tamil Nadu.
M. Mayil Vaganan, V. Kumar, I. Ravi, K. J. Jeyabaskaran, M. S. Saraswathi, P. Giribabu	ISO Internal Auditor Certificate
V. Kumar	External examiner for qualifying *Viva Voce* for Ph.D. HC&RI, TNAU, Coimbatore, Tamil Nadu.
	External examiner for evaluation of M. Sc. Theses. HC&RI, TNAU, Periyakulam and Coimbatore, Tamil Nadu.
	Chaired technical session on 'Horticultural crops', Mega Agricultural Fair–Agri Expo 2015, Tiruchirappalli, Tamil Nadu.
K. N. Shiva	Panel member in the Farmer–Scientists interactive meeting. 5th Mega Agrl. Fair, Agri Expo–2015, Tiruchirappalli, Tamil Nadu.
	Panel member in the 'Banana producer company: Project introduction–farmers group interaction meeting'. Keela Kattalai, Tirunelveli, Tamil Nadu.
	External examiner, Ph.D. thesis. JNTU, Hyderabad, Telengana.
	Member, Executive council, Indian Society for Spices, ICAR–IISR, Calicut, Kerala.
	Panel Chairman for export survey on 'Ney Poovan' at Varuna village in Mysuru District' for APEDA, New Delhi on 18–19 November, 2015 along with APEDA officials.
	Panel Chairman for export survey of 'Nendran' at Lingapuram village in Sirumugai area of Mettupalayam Tk. for APEDA, New Delhi on 6 December, 2015 along with APEDA officials.
	Chief Guest in the Valedictory function of the Training programme on "Banana Fiber Handicrafts" on 20–30 January, 2016, organized by SSKJ Trading Pvt. Ltd., Tiruchirapalli, Tamil Nadu.
	Reviewer for the 'DPR on Establishment of Integrated Pack–house in Tiruchirapalli', submitted by Dept. of Agrl. Marketing & Agri–Business, Chennai to APEDA, Bengaluru.
	Chairman and member for selection of Senior Research Fellows/Technical Assistant for various projects at ICAR–NRCB, Tiruchirapalli, Tamil Nadu.
S. Backiyarani	External examiner for M.Sc. by AC&RI, Madurai & AC&RI, Killikulam, TNAU, Tamil Nadu.
	External examiner for *Viva Voce* examination of five Ph.D. students.

S. Backiyarani	Reviewer for 'Plant Gene, Scientific Reports and Advances in Applied Research'.
M. S. Saraswathi	Reviewer for 'International Journal of Fruit Science' and 'Journal of Crop Improvement'.
	External examiner for M. Sc. theses from UAS, Bagalkot, Karnataka.
	Chairperson in various review committees for recruitment of Technical Assistants and Junior Research Fellows, ICAR–NRCB, Tiruchirappalli, Tamil Nadu.
P. Suresh Kumar	Editor in 'African Journal of Agricultural Research', 'Journal of Horticulture & Forestry' and 'Journal of Stored Products & Postharvest Research'.
	Reviewer for 'Scientia Horticulturae', 'Fruits', 'Indian Journal of Agricultural Sciences' and 'PNAS'.
A. Thirugnanavel	Reviewer for 'Indian Journal of Agricultural Sciences' and 'Indian Journal of Hill Farming'.

8. LINKAGES AND COLLABORATIONS

Project Title	Collaborating Institute	Scientist involved
Research trial for extreme temperature stress on banana cultivars, Grand Naine, Rasthali, Udhayam and Saba	Department of Horticulture, Punjab Agriculture University, Ludhiana, Punjab	I. Ravi
Development of mechanization package for rope making from outer sheath of banana pseudostem	ICAR–CIAE (RS), Coimbatore, Tamil Nadu	K. N. Shiva
Developing postharvest mechanization package for banana central core	ICAR–CIAE, Coimbatore, Tamil Nadu	K. N. Shiva
Assessment of post-harvest losses in banana	ICAR–AICRP on Fruits, ICAR –IIHR, Bengaluru and other coordinating centres	K. N. Shiva
Development of non–chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	Bhabha Atomic Research Centre, Mumbai	M. S. Saraswathi

9.PUBLICATIONS

9.1 Research Papers

Alagesan, A., Tharani, G., Padmanaban, B., Siva Vijayakumar, T. and Manivannan, S. 2016. Screening and characterization of developing resistant cultivars against *Odoiporus longicollis* (Olivier) (Coleoptera: Curculionidae) using reference genotypes in India. *Inter. J. Phar. & Pharm. Sci.* **8** (7): 1–3.

Anuradha, C., Balasubramanian, V. and Selvarajan, R. 2015. Sequence motif comparison and homology modeling of helper component proteinase (HC–Pro) of banana bract mosaic virus. *Plant Path. J.* **14** (3): 123–129.

Backiyarani, S., Raja, K., Uma, S., Chandrasekar, A., Saraswathi, M. S., Sundararaju, P. and Mayil Vaganan, M. 2016. Genome and transcriptome–wide analysis of WRKY transcription factors for *Pratylenchus coffeae* resistance in banana. *Acta Hort*. **1114**, 119–124 DOI:10.17660/ActaHortic.2016.1114.17.

Backiyarani, S., Uma, S., Nithya, S., Chandrasekar, A., Saraswathi, M. S., Thangavelu, R., Mayil Vaganan, M., Sundararaju, P. and Singh, N. K. 2015. Genome-wide analysis and differential expression of chitinases in banana against root lesion nematode (*Pratylenchus coffeae*) and eumusae leaf spot (*Mycosphaerella eumusae*) pathogens. *App. Biochem. & Biotech.* DOI 10.10007/s/2010–015–1528–Z.

Backiyarani, S., Uma, S., Saraswathi, M. S., Saravanakumar, A. S. and Chandrasekar, A. 2015. Transcriptome analysis of banana (*Musa balbisiana*) based on next generation sequencing technology. *Turkish j. Agrl. For.* DOI: 10.3906/tar–1406–171.

Biswas, C., Dey, P., Selvarajan, R., Bera, A., Mitra, S. and Satpathy, S. 2016. First report of Corchorus golden mosaic virus (CoGMV) infecting ramie (*Boehmeria nivea*) in India. *Plant Disease.***100** (2): 541.

Krishna Surendar, K., Durga Devi, D., Jeyakumar, P., Velayudham, K. and Ravi, I. 2015. Changes in Proline and Polyphenol oxidase enzyme activity in some banana cultivars and hybrids under water stress. *Genomics and App. Biol.* **6** (4): 1–6.

Muthusamy, M., Uma, S., Backiyarani, S. and Saraswathi, M. S. 2015. Genome–wide screening for novel, drought stress–responsive long non–coding RNAs in drought–stressed leaf transcriptome of drought tolerant and susceptible banana (*Musa* spp.) cultivars using Illumina high throughput sequencing. *Plant Biotech. Rep*. **9** (5): 279–286.

Nikita, S. A., Sridharan, S. and Padmanaban, B. 2016. Analysis of technologies gap and relative importance of banana pseudostem borer, *Odoiporus longicollis* (Olivier) in Tamil Nadu. *Indian J. Ecol.* **43** (1): 506–511.

Saraswathi, M. S., Uma, S., Kannan, G., Selvasumathi, M., Mustaffa, M. M. and Backiyarani, S. 2016. Cost effective tissue culture media for large scale propagation of three commercial banana (*Musa* spp.) varieties. *J. Hort. Sci. Biotech*. **91** (1): 23–29.

Selvarajan, R., Balasubramanian, V. and Mandal, B. 2015. First report of bean yellow mosaic virus in *Alpinia galanga* in India. *J. Plant Path*. **97** (3): 545.

Selvarajan, R. and Balasubramanian, V. 2016. First Report of banana mild mosaic virus infecting banana in India. *Plant Disease.* **100** (6): 1254.

Selvarajan. R., Balasubramanian, V. and Gayathrie, T. 2016. Highly efficient immunodiagnosis of episomal Banana Streak Mysore Virus (BSMYV) using polyclonal antibodies raised against recombinant viral associated protein. *J. Phytopath.* DOI: 10.1111/jph.12475.

Thangavelu, R. and Gopi, M. 2015. Combined application of native *Trichoderma* isolates possessing multiple functions for the control of *Fusarium* wilt disease in banana cv. Grand Naine. *Biocon. Sci. & Tech.* **25 (**10): 1147–1164.

Thangavelu, R. and Gopi, M. 2015. Field suppression of *Fusarium* wilt in banana using combined application of native endophytic and rhizospheric bacterial isolates possessing multiple functions. *Phytopath. Mediter.* **54** (2): 241–252.

Uma, S., Backiyarani, S., Saravanakumar, A. S., Chandrasekar, A., Thangavelu, R. and Saraswathi, M. S. 2016. Identification of *Mycosphaerella eumusae* responsive unique genes / transcripts from a resistant banana cultivar. *Acta Hort*. **1114**, 111–118

9.2 Popular articles

Anuradha, C., Lakshmi, K. and Sasikumar, K. 2015. Protein engineering of *Bacillus thuringiensis* toxins. *Research News For U* (RNFU). **20** : 223–226.

Giribabu, P., Padmanaban, B. and Mustaffa, M. M. 2015. Nematode damage in banana and their integrated management (Tamil). *Vanoli uzhavar sanga seithikkathir*. **15** : 175, 38–41.

Giribabu, P., Padmanaban, B. and Mustaffa, M. M. 2015. Vazhayil Noor puzhukkalin thakkam, June, 2015. *Malarum Velanmai.* pp. 28–30.

Jeyabaskaran, K. J. 2015. "Vaazai saagupadiyil mazhai kaala ura nirvaagam" (Tamil)– Fertilizer management during rainy season in banana cultivation. Dinamalar. 17 December, 2015.

Jeyabaskaran, K. J. 2015. Thengi nirkkum mazahi neeraal vaazai saagupadiyil erpadum magasool izhappai thaduppathu epppadi? (Tamil)–How to prevent yield loss in banana plantation inundated with rain water? Dinakaran. 8 December, 2015.

Lakshmi, K., Anuradha, C., Boomiraj, K. and Kalaivani, A. 2015. Applications of biotechnological tools to overcome climate change and its effects on agriculture. *Research News For U* (RNFU). **20** : 218–222.

Minhas, P.S., Singh, Y., Nangare, D. D. and Suresh Kumar, P. 2015. Establishing orchards in shallow soils. *Ind. Hort.* Nov–Dec: 5–8.

Padmanaban, B. 2015. Vazhaiyai Thakkum Asuviniyai Evvaru Kattupaduthalam? (Tamil). Vanoli Uzhavar Seithikathir, April, 2015. Pp. 40 – 41.

Padmanaban, B. 2016. Vazhayil Ilaipulli Noi (Tamil). *Dinamalar*, Tiruchi Edition. 10.1.2016.

Padmanaban, B. and Mustaffa, M. M. 2015. Vazhai ilaithinnum puzhu (Tamil). June 2015. *Vanoli Uzhavar Sanga seithikathir*, pp. 29–30.

Padmanaban, B. and Mustaffa, M. M. 2015. Vazhaiai thakkum kaipaen (Tamil). June, 2015–*Vanoli Uzhavar Sanga seithikathir*, pp. 31–33.

Padmanaban, B. 2016. Vazhaiai padappaduthi upaporutkal thayarikkum murai, Dinamalar Tamil. 31.1.2016.

Padmanaban, B. 2016. Vazhayil thandu thulaippanai kattupaduthum muraikal (Tamil). March, 2016. *Vanoli Uzhavar Sanga seithikathir*, pp. 42–45.

Shiva, K. N. 2016. Vazhaiyilurunthu upaporukkal thayarithal (Value addition in banana) (Tamil), Suyathozhil Awareness Seminar, Published by Puthiya Thalaimurai Foundation, Chennai, Tamil Nadu. pp. 24 –28.

Shiva, K. N. and Padmanaban, B. 2016. Vazhayil aruvadai pinsar nirvakam matrum mathiputtudhal(Tamil). February, 2016. *Vanoli Uzhavar Sanga seithikathir*, pp. 29–30.

Shiva, K. N. and Padmanaban, B. 2016. Vazhaiyai padapaduthi upaporukkal thayarikkum murai (Preservation and procedure for production of value added products from banana) (Tamil), Dhinamalar Tamil Daily, pp. 2.

Shiva, K. N. and Padmanaban, B. 2016. Vazhayil aruvadai pinsar nirvagam and madhippukoottal (Post-harvest management and value addition in banana) (Tamil), *Vanoli uzhavar sanga aeithikathir.* **16** (184): 29 –36.

Suresh Kumar, P., Sangeetha, A., and Choudhary, V.K. 2015. Wounded fruits and processing wastes are future source of bio–factories and nutraceuticals. *Bever.&Food World*, **42** (8): 25–29.

9.3 Books / Book chapters

Padmanaban, B., Mustaffa, M. M. 2016. Mealybugs and their management in Agricultural and Horticultural crops. In: Fruit Crops: Banana. (Eds. M. Mani and C.Shivaraju). DOI 10.1007/978-81-322–2677-2-45, pp.423-427, Springer India.

Ravi, I. and Mayil Vaganan, M. 2016. Abiotic stress tolerance in banana, In: Abiotic stress physiology of horticultural crops. Rao, N. K. S., Shivasankara, K. S. and Laxman, R. H. (Eds.), Springer–VerlagGmBH Heidelberg, Germany, P. 207–222.

Selvarajan, R., Balasubramanian, V. and Padmanaban, B. 2016. Mealybugs as Vectors. In: Mealybugs and their management in Agricultural and Horticultural Crops. (Eds: M. Mani, C. Shivaraju) 123–130. Springer.

9.4 Technical bulletins

Kumar, V. and Padmanaban, B. 2016. Technical Bulletin in "Baale beleya nutan utpaadanaa tanntrikategalu"–Advances in Banana Cultivation (Kannada).

Mustaffa, M. M., Mayil Vaganan, M., Padmanaban, B. and Ravichamy, P. 2013. NRCB–20 years achievement: 1993–2013, ICAR–National Research Centre for Banana, Thogamalai Road, Thayanur Post, Tiruchirapalli, Tamil Nadu.

Padmanaban, B. 2016. Integrated Pest Management of Banana and Plantains–In Assamese. Technical Bulletin No.28, ICAR–NRCB, Tiruchirapalli–620102. Tamil Nadu, India. 16 p.

Padmanaban, B. 2016. Integrated Pest Management of Banana and Plantains–In Malayalam. Technical Bulletin No.29, ICAR-NRCB, Tiruchirapalli–620102. Tamil Nadu, India. 13 p.

Padmanaban, B. 2016. Integrated Pest Management of Banana and Plantains–In Kannada. Technical Bulletin No.30, ICAR-NRCB, Tiruchirapalli–620102. Tamil Nadu, India. 7 p.

Padmanaban, B. 2016. Integrated Pest Management of Banana and Plantains–In Marathi. Technical Bulletin No.31, ICAR–NRCB, Tiruchirapalli–620102. Tamil Nadu, India. 13 p.

Padmanaban, B. 2016. Integrated Pest Management of Banana and Plantains–In Telugu. Technical Bulletin No.32, ICAR–NRCB, Tiruchirapalli–620102. Tamil Nadu, India. 11 p.

Uma, S., Mayil Vaganan, M., Thangavelu, R., Giribabu, P., Ravichamy, P. and Kannan, R. N. M. S. 2015. Banana production techniques (Tamil). ICAR–National Research Centre for Banana, Thogamalai Road, Thayanur Post, Tiruchirapalli, Tamil Nadu.

9.5 Extension/ Technical folders / Reports/ Scientific reviews

Ravindra Naik, Ambrose, D. C. P., Annamalai, S. J. K. and Shiva, K. N. 2015. Mechanization package for minimal processing of banana central core. Published by ICAR–CIAE and ICAR- NRCB, Tiruchirappalli, Tamil Nadu.

Selvarajan. R. 2015. Viral diseases of banana. CAB Reviews 10 (50).

Uma, S., Saraswathi, M. S., Backiyarani, S. and Durai, P. 2015. Banana breeding–A brief review. *Inter. J. Inn. Hort*. **4** (1): 11–19.

9.6 Training manual

Shiva, K. N. and Marimuthu, N. 2015. Training manual on production of value–added products from banana. Published by Director, ICAR–NRCB, Tiruchirapalli, Tamil Nadu.

Shiva, K. N. and Marimuthu, N. 2015. Training manual on technical know–how of banana fig, banana flour based health drink, soup mix, baby food and banana peel pickle. ICAR–NRCB, Tiruchirapalli, Tamil Nadu.

Shiva, K. N. and Marimuthu, N. 2016. Training manual on technical know–how of 'Post–harvest handling, packing, storage and ripening in banana for domestic and export markets. ICAR–NRCB, Tiruchirapalli, Tamil Nadu.

Shiva, K. N. and Marimuthu, N. 2016. Training manual on technical know–how of 'Banana flour based baby food'. ICAR–NRCB, Tiruchirapalli, Tamil Nadu.

9.7 Research papers / Abstracts / Presentations in Conferences / Symposia / Seminars / Workshop and other fora

9.7.1 International

Mayil Vaganan, M., Sivagandhi, C., Uma, S., Ganesan, S., Backiyarani, S. and Ravi, I. 2006. An efficient protocol for *Agrobacterium* mediated gene transformation using embryogenic cell suspensions of *Musa acuminata* cvs. Grand Naine (AAA) and Rasthali (AAB). International conference on biodiversity and biotechnology. Bharathidasan University, Tiruchirapalli, Tamil Nadu. 25–27, February, 2016.

Ravi, I. and Mayil Vaganan, M. 2015. Soil moisture deficit stress effect on flowering and fruit development in banana cv. Grand Nain. Third International Plant Physiology Congress on Challenges and Strategies in Plant Biology Research, Jawaharlal Nehru University, New Delhi. 11–14 December, 2015.

Selvarajan, R. 2016. CRISPR/Cas9 based genome editing: a new tool in the molecular biology for improving the traits in crop plants. International Conference on Frontiers in Life Sciences (ICFLS–'16). Department of Botany, St. Joseph's College, Tiruchirappalli, Tamil Nadu. 7–8 January, 2016.

Selvarajan, R. 2016. Integrated management strategies for viral disease of banana and Plantain. International Conference on "Plant, Pathogens and People" organized by Indian Phytopathological Society. NASC, New Delhi. 23–26 February, 2016.

Suresh Kumar, P. 2015. Oral presentation on 'Bamboo shoots, food of future–Nutritional, antioxidants, medicinal and economic importance under changing climatic conditions'. Third International Symposium on Under-utilized Plant Species –Exploration and Conservation for Future Generation. KVK, AC & RI, Madurai, Tamil Nadu. 5–8 August, 2015.

9.7.2 National

Ravi, I. 2016. Recent advances in soil moisture deficit stress tolerance in banana. National seminar on "Recent trends in botany" Organised by PG & Research, Department of Botany, Jamal Mohamed College (Autonomous), Tiruchirapalli, Tamil Nadu. 24 February, 2016.

Ravindra Naik, Dawn, C. P., Ambrose, S. J. K., Annamalai, V., Krithika, E., Mohanraj and Shiva, K. N. 2016. Package of equipment for juice extraction for banana central core (Poster presentation). In: 50th Annual convention of Indian Society of Agricultural Engineers and symposium on "Agricultural Engineering in National Building: Contributions and Challenges". Agricultural Engineering and Technology, OUAT, Bhubaneswar, Odhisha. 19–21 January, 2016.

Selvarajan, R. 2015. Innovative virus detection technology developed at ICAR–NRCB. India Innovation Growth Programme–2015, DST–Lockheed Martin India Innovation Growth Program–2015, FICCI. DRDO Bhavan, New Delhi. 12–13 May, 2015.

Selvarajan, R. 2015. Multiplexing technology for the detection of plant viruses: present status and future perspectives. XXIV Annual conference on "Trans–boundary viral diseases under one health: Perspectives & Challenges," Indian Virological Society –VIROCON 2015, North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences, Shillong, Meghalaya. 8–10 October, 2015.

Vijayalakshmi, P., Shiva, K. N. and Marimuthu, N. 2015. Standardization and evaluation of banana flour based biscuits (Poster presentation). In: 47th Annual national conference of Nutrition Society of India, National Institute of Nutrition, ICMR, Hyderabad, Telengana. 9–10 October, 2015.

9.8 Guest lecture / Invited talks

Name	Topic and Place	Date
R. Selvarajan	Virus detection and management for conservation of banana. St. Joseph college, Tiruchirapalli, Tamil Nadu.	7 July, 2015
	Molecular diagnostics. St. Joseph college, Tiruchirapalli, Tamil Nadu.	2 September, 2015
	Detection of plant viruses using nano-technological tools. Department of Nanotechnology, TNAU, Coimbatore, Tamil Nadu.	19 November, 2015
M. Mayil Vaganan	Nutrition and health benefits of banana flower. 22nd Foundation day of ICAR–NRCB, Tiruchirapalli, Tamil Nadu.	28 August, 2015
I. Ravi	Recent advances in soil moisture deficit stress tolerance in banana. National Seminar on Recent Trends on Banana (RTB–2016) at Jamal Mohamed College, Tiruchirapalli, Tamil Nadu.	24 February, 2016
V. Kumar	District seminar on horticulture crops. Organized by State Dept. of Horticulture, Vellore, Tamil Nadu.	10 July, 2015
	Improved technologies in banana cultivation, Pre kharif awareness program, KVK, Sirugamani, Tiruchirappalli, Tamil Nadu.	13 August, 2015
	Improved cultivation practices in banana, Seminar & Kisan Mela, ICAR–CIAE (RS), Coimbatore, Tamil Nadu.	27 August, 2015
	Horticulture workshop on 'Strategic action planning to achieve double digit growth in horticulture sector' under 'Rythu Kosam Project'. ICRISAT, Hyderabad, Telengana.	13–14 November, 2015
	Organic cultivation of banana, Agri. Expo. 2016, Pasumai Vikatan, Tiruchirappalli, Tamil Nadu.	14 February, 2016
	Improved production technologies for enhancing productivity of banana in Uttar Pradesh, KVK, ICAR–IIVR, Kushinagar, Uttar Pradesh.	20 February, 2016
K. J. Jeyabaskaran	Soil suitability for banana cultivation. 22nd Foundation day of ICAR– NRCB, Tiruchirapalli, Tamil Nadu.	28 August, 2015
	Importance of soil testing for healthy banana cultivation. World soil day celebration at ICAR–NRCB, Tiruchirapalli, Tamil Nadu.	5 December, 2015
	How to manage nutrients and soil efficiently for healthy banana production? Jai Kisan–Jai Vigyan celebrations. Nachalur, Tiruchirapalli, Tamil Nadu.	28 December, 2015
	Agronomic aspects of growing banana with special emphasis on organic nutrition. Farmers' meet at Chinnapanayur Village, Tiruchirapalli, Tamil Nadu.	8 January, 2016

K. N. Shiva	Lectures on 'Post-harvest handling and value addition in banana' and 'Varieties, selection of planting materials, HDP techniques, mat and bunch management practices'. Presented at training program on 'Improved production and post-harvest management technologies in banana'.	8 April, 2015
	Lecture on 'Post–harvest management and value addition in banana'. Farmer–Scientists interactive meeting. 5th Mega Agrl. Fair, Agri Expo– 2015. Tiruchirappalli, Tamil Nadu.	20 September, 2015
	Post–harvest technology of banana. Official meeting with APEDA officials, traders and logistics manager on PoP of banana and protocol for export of banana by seaport from Kochi port to Dubai.	31 October, 2015
	Lecture on 'Post–harvest handling and value addition in banana'. Farmers' Sangosti, '*Jai Kisan Jai Vigyan*' week, Nachalur village, Karur Dist., Tamil Nadu.	28 December, 2015
	Lectures on 'Banana as nutritious food and food processing of banana' and 'Value added products in banana and plantain'. Delivered at Department of food processing and chemical engineering technology, Annamalai University, Annamalainagar, Chidambaram, Tamil Nadu.	11 & 12 January, 2016
	Lecture on 'Production, post–harvest management and value addition in banana: scope and opportunities'. Delivered at 'Banana producer company: project introduction–farmers interested group interaction meeting' held at Keela Kattalai, Tirunelveli Dist., Tamil Nadu.	18 January, 2016
	Lecture on 'Quality banana fiber extraction and its applications for domestic and export markets'. Delivered at training program on 'Banana fiber handicrafts', (Organized by SSKJ Trading Pvt. Ltd., Tiruchirapalli and FDDC–KVIC, Trivandrum). Tiruchirapalli, Tamil Nadu.	21 January, 2016
	Lecture on 'Value addition and byproducts of banana'. Delivered at training program on 'Post–harvest technology', (Organized by Agrl. Engineering Training Centre, Agrl. Eng. Dept., Tiruchirapalli). Tiruchirapalli, Tamil Nadu.	27 January, 2016
	Value addition in banana. In: Suyathozhil awareness seminar. Organized by Puthiya Thalaimurai Foundation. Srimad Andavan Arts & Science College, Thiruvanaikovil, Tiruchirappalli, Tamil Nadu.	20 March, 2016.
S. Backiyarani	'Varietal diversity and status of DUS testing, filling in banana' at 10th DUS review meeting, MPKV, Rahuri, Maharastra.	26–27 February, 2016
	"Application of biotechnological tools in crop improvement" in the National seminar on frontiers in biosciences, Jamal Mohamed College, Tiruchirapalli, Tamil Nadu.	5 March, 2016

S. Backiyarani	"Role of Plant Biotechnology in bioenergy production" in the State level seminar on "Bioresource technology for bioenergy and bioproducts" , J. J. College of Arts and Science, Pudukkottai, Tamil Nadu.	9 March, 2016
	"Socio–economic impact of biotechnological application in banana" at National Horticulture Board–2016 workshop, AC & RI, Madurai, TNAU, Tamil Nadu.	22 March, 2016
M. S. Saraswathi	Lecture on 'Micropropagation in banana'. Delivered to B.Sc. (Agriculture) students from different colleges.	22 April, 7 May, 8 June,10 June, 28 December, 2015 1 & 4 March, 2016
	Lecture on '*In vivo* and *in vitro* techniques in bio–resource conservation'. Delivererd to students of St. Joseph's College, Tiruchirapalli, Tamil Nadu.	14 July, 2015
	Lecture on 'Biotechnological research in banana'. Delivered to students of Biotechnology, PGP College of Arts and Science, Namakkal, Tamil Nadu.	25 January, 2016
	Lecture on 'Propagation methods in banana'. Delivered to students of Don Bosco College of Agriculture, Vellore, Tamil Nadu.	7 March, 2016

10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

CONSULTANCY SERVICES

- A total of 5100 plants (1100 tissue culture and 4000 suckers) of banana cv. Udhayam were supplied to banana growers of various districts of Tamil Nadu.
- Under 'Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants', 874 batches of tissue culture plants at various stages of production (Grand Nain, Williams, Robusta, Ney Poovan, Red banana, Quintal Nendran etc.) were tested for their genetic fidelity using SSR and ISSR markers and reports were issued and an amount of Rs.15 Lakh was generated.
- Mother cultures of banana cvs. Udhayam and Rasthali were supplied to HRC, Nagicherra, Agartala, Tripura and IGKV, Raipur, Chhattisgarh.
- A total of 23,563 samples were tested for the presence of virus and a gross amount of Rs 1.77 Lakh has been generated under virus testing contract service.
- Polyclonal antiserum produced for Cauliflower mosaic virus (CMV), Banana bract mosaic virus (BBrMV) and Banana bunchy top virus (BBTV) has been sold to the State agricultural universities *viz.,* KAU, APHU and TNAU. Approximately an amount of Rs. 36,000/- has been generated from the sale of antisera.

Name of the client	Title of the Contract Research projects/ consultancy services	Principal Investigator(s)	Amount (Rs. in Lakh)	Year
CII–Jubilant Bhartia Food and Agriculture Centre of Excellence, New Delhi	Off–campus training / consultancy programme "Transforming Eastern India's Economies through Innovative Rural Business Hubs (RBH)"	V. Kumar	1.39	January 2014 to December 2015
Mr.Sathyanarayan, Idapadi, Salem	Contract Research Project entitled "*In vitro* evaluation of bio–nematicide (Biolipidomix) to banana root-knot nematode, *Meloidogyne incognita*	B. Padmanaban	1.03	October 2014 to September 2015
M/s. South Asia AGRINOS India (P) Ltd., New Delhi	Contract Research Proposal on "Evaluation of High Yielding Technology®™ System formulations for higher productivity of banana"	B. Padmanaban & V. Kumar	6.97	November 2014 to October 2015
M/s. Sea6 Energy Pvt. Ltd., Bengaluru	Evaluation of bio–efficacy of silica gel on growth and yield attributes in banana	I. Ravi	4.99	November 2015 to April 2017
M/s. Pure Chemicals Co., Chennai	Evaluation of paraffinic oil adjuvant for the management of leaf spot diseases of banana	R. Thangavelu	2.18	January 2016 to June 2017

State Bio–control Laboratory, Mannuthy, Thrissur, Kerala	Transfer of technology entitled "Mass Production of Liquid formulation of Entomopathogenic fungus isolate–*Beauveria bassiana*"	B. Padmanaban	1.14	February 2016 to January 2021
M/s. Madapally Service Co–operative Bank Ltd., Kottayam, Kerala	Consultancy on "Technical advisory for setting up of a tissue culture unit and training to initiate the production of tissue cultured banana"	M. S. Saraswathi	2.00	November 2015 to April 2017

COMMERCIALIZATION OF TECHNOLOGIES

Product Name	Client Name and Address	Date	Income generated (Rs.)
Tissue culture multiplication of cv. Udhayam	M/s. Shaanthi AgroTech, Bengaluru, Karnataka.	4 January, 2016	57,250/-
Tissue culture multiplication of cv. Sabri	M/s. Saveer Biotech. Ltd., New Delhi.	2 February, 2016	3,39,500/-
Production of banana fig	Mr. Anoop, P. J., Puthiyakunnel (H), Edakkara P.O., Nilambur, Malappuram Dt., Kerala.	26 June, 2015	10,000/-
	Mr. Jobi K. John, Kandanatte, Ally, P.O., Mukkom, Kozhikode Dt., Kerala.	26 June, 2015	10,000/-
	Mr. Sunil, C. N., Manayathatthu Mana, Punnathura West, P.O., Ettumanoor, Kottayam Dt., Kerala.	26 June, 2015	10,000/-
	Mr. Vinod Joseph, Peedikackal, Thopramkudy, P.O., Thopramkudy, Idukki Dt., Kerala.	26 June, 2015	10,000/-
	Mr. Sreenivasan, P. C., 'Kinarulla Parampil' House, Keezhariyoor, P.O., Koyilandy, Kozhikode Dt., Kerala.	26 June, 2015	10,000/-

Production of banana fig	Mr. K. Karunakaran, Kala–Temple gate, P.O., Thalasseri, Kannur Dt., Kerala.	15 July, 2015	10,000/-
	Mrs. Roopa Sukhdev, Pandarathil (H), Bhoodhanam Colony P.O., Pulpally–673579, Wayand Dt., Kerala.	7 October, 2015	10,000/-
	Mr. Jose George, Vattathara Mundadan, Nayarambalam, Kochi–682509, Kerala.	7 October, 2015	10,000/-
	Mrs. Neenamma Kurien, Vattathara Mundadan, Nayarambalam, Kochi–682509, Kerala.	7 October, 2015	10,000/-
Production of banana flour based health drink and soup mix	Mr. K. Dinesh, Nellore, Andhra Pradesh.	9 July, 2015	20,000/-
Production of banana fig & banana flour	Mr. K. Gopakumar, Vinod Bhavan, Kadampattukonam, Parippally, P.O., Thiruvananthapuram, Kerala–691 574.	16 December, 2015	20,000/-
	Mr. K.A. Joseph, Kanjiraparambil House, Kuttur, P.O., Thrissur–680013, Kerala.	16 December, 2015	20,000/-
Production of banana fig & banana flour based health drink	Mr. Nikhul Rohit, Villyedathu, Panachepally, P.O., Kanjirappally, Kottayam–686 518, Kerala.	16 December, 2015	20,000/-
Production of banana flour based baby food & banana pickle	Mrs. Divya, R. Alphonsa, I., M/s De Alben, #6/49 A, K. Pungampalayam, Marudhur P.O., Karamadai–641104, Tamil Nadu.	16 December, 2015	20,000/-

Post-harvest handling, packing, storage and ripening in banana for domestic and export markets	Mr. Vinod Mocharla, M/s Coastal Lines–691574 Trading & Distribution, # 24/2/1163, IInd Floor, Opp. Sabari Mandir, Ram Nagar, Nellore, Andhra Pradesh–524002.	25 February, 2016	25,000/-
Production of banana flour based baby food	Mr. Rakesh, J., No. 59, 20th 'A' Main, 1st 'R' Block, Rajajinagar, Bengaluru–560010, Karnataka.	3 March, 2016	10,000/-
	Mr. R.G. Balaaji, M/s. Gem Healthcare, 121A, New Weavers Colony, Saibaba Colony, Coimbatore–641011, Tamil Nadu.	3 March, 2016	10,000/-
Production of banana flour	Mr. Pappu Elango, 180/1,8th Cross– East, Bharathi Nagar, Vayalur Road, Puthur, Tiruchirapalli–620017, Tamil Nadu.	3 March, 2016	10,000/-
Liquid formulation of entomopathogenic fungus (Beauveria bassiana)	M/s. State Bio–Control Laboratory, Mannuthy, Thrissur, Kerala.	27 February, 2016	1,14,500/-

11. RAC/ IRC / IMC MEETINGS

New RAC for ICAR - NRCB

ICAR has constituted the 17th Research Advisory Committee (RAC) for ICAR–NRCB for a period of three years (2015 to 2018) with the following members.

Chairman	Dr. S. N. Pandey, Retd. ADG (Hort. Sci.), ICAR, New Delhi
Member	Dr. P. Anand Kumar, Prinicipal Scientist, ICAR–IIRR, Hyderabad
Member	Dr. N. Kumar, Retd. Professor (Hort.), TNAU, Coimbatore
Member	Dr. T. V. K. Singh, Dean, College of Agriculture, ANGRAU, Hyderabad
Member	Dr. A. K. Mishra, Principal Scientist & Head, ICAR–CISH, Lucknow
Ex–Officio member	Dr. N. K. Krishna Kumar, DDG (Hort.Sci.), ICAR, New Delhi
Ex–Officio member	Director, ICAR–NRCB, Tiruchirapalli
Member Secretary	Dr. B. Padmanaban, Principal Scientist, ICAR–NRCB, Tiruchirapalli

IRC Meeting

The 19th Institute Research Council (IRC) meeting was held on 30 May, 2015 under the chairmanship of Dr. M. M. Mustaffa, Director, ICAR–NRCB. Dr. R. Selvarajan, Member Secretary, IRC welcomed the chairman and other members of the IRC. After introductory remarks by the Chairman, research projects, comments of the last IRC, action taken report, salient achievements for the year 2014–15 and technical programme for the year 2015–16 presented by the scientists were reviewed.

Dr. M. M. Mustaffa, Director, ICAR–NRCB, chairing the 19th IRC meeting

RAC Meeting

The 17th Research Advisory Committee (RAC) meeting was held on 27–28 October, 2015 under the chairmanship of Dr. S. N. Pandey. The RAC members visited the research farm where scientists explained their experimental trials. Dr. B. Padmanaban, Acting Director, presented the salient research achievements of ICAR–NRCB during the last year and the action taken report on the recommendations of the last RAC. The scientists presented their research achievements and fruitful discussions were held for improvement of research at ICAR–NRCB, Tiruchirapalli.

IMC Meeting

The 21st Institute Management Committee (IMC) of ICAR–NRCB was held under the chairmanship of Dr. B. Padmanaban, Acting Director on 29 March, 2016. Members of the IMC are as follows.

Scientists of ICAR–NRCB with RAC members

Chairman	Dr. B. Padmanaban, Acting Director, ICAR–NRCB, Tiruchirapalli
Members	Dr. Vikramaditya Pandey, Principal Scientist, ICAR, New Delhi
	Dr. S. Devasahayam, Head (Crop Protection), ICAR–IISR, Calicut
	Dr. N. Bakthavatsalam, Principal Scientist, ICAR–NBAIR, Bengaluru
	Dr. S. Sriram, Principal Scientist, ICAR–IIHR, Bengaluru
	Dr. (Mrs.) Anuradha Agrawal, Principal Scientist, ICAR–NBPGR, New Delhi
	The Commissioner of Horticulture & Plantation Crops, Govt. of Tamil Nadu, Chennai
	The Additional Director of Horticulture (Fruits), Dept. of Horticulture, Government of Karnataka, Bengaluru
	Dean (Horticulture), Tamil Nadu Agriculture University, Coimbatore
	Finance & Accounts Officer, ICAR–CIBA, Chennai
Member Secretary	Mr. B. Sathish, SAO, ICAR–NRCB, Tiruchirapalli

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

Human Resource Development

During 2015–16, under Human Resource Development, seven scientific, five technical, one administrative and two skilled supporting staff participated in various training programmes and refreshed their working knowledge. An expenditure of Rs. 2.16 lakhs out of the allotted fund of Rs. 2.17 lakhs has been incurred by the Centre for this purpose. Dr. K. J. Jeyabaskaran, Co–Nodal officer (HRD) attended the training cum workshop on 'Competency development for HRD nodal officers of ICAR' held at ICAR –NAARM, Hyderabad during 10–12 February, 2016 and accordingly annual training programme has been proposed with a budget estimate of Rs. 5.12 lakhs for 2016–17.

12.1. Trainings provided to staff under HRD

Name of the Staff	Name of the programme /Venue	Period
R. Selvarajan	User's training workshop on ICAR Krishi Geo-portal, ICAR–NBSS&LUP, Nagpur.	28–30 March, 2016
I. Ravi	Consultancy project management, ICAR - NAARM, Hyderabad, Telangana.	3–7 July, 2015
V. Kumar	Training on "Management Development Programme on Leadership Development (A pre-RMP programme), ICAR – NAARM, Hyderabad	30 Novermber–11 December, 2015
K. J. Jeyabaskaran	Training cum workshop on 'Competency development for HRD nodal officers', ICAR – NAARM, Hyderabad, Telangana.	10–12 February, 2016
K. N. Shiva	ICAR sponsored short-course on "Business planning for developing new agro-technology enterprises" at ICAR - CTCRI, Trivandrum, Kerala.	2–11 September, 2015
M. S. Saraswathi	'Managing Technology Value Chains' at Administrative Staff College of India, Hyderabad	22–26 February, 2016
P. Giribabu	Molecular characterization of nematodes. ICAR – NBAIR, Bengaluru, Karnataka.	1–5 September, 2015
P. Durai	Competent Enhancement training programme for 'Technical Staff' at ICAR–NAARM, Hyderabad.	14–23 December, 2015
N. Marimuthu	Technology for processing fruits and vegetables into value added products, CFTRI, Mysuru.	31 August–11 September, 2015
D. Rama chandramurthy P. Mohan	'Training on farm implements and maintenance' at Saraswathi KVK, Pulutheri.	8–9 February, 2016

D. Rama chandramurthy K. Kamaraju	National workshop on 'Maintenance and operation of basic laboratory equipments' at Lady Doak College, Madurai.	15–19 February, 2016
P. Murugan	Various modules using Oracle ERP, ICAR – IASRI, New Delhi	11–16 May, 2015
A. V. Suja	Training program at ISTM	6–24 November, 2015
V. Pandiyan P. Kamaraj	Training programme on 'Farm maintenance' at Farmers' producers company, Saraswathi KVK, Nachalur, Karur (Dt)	8–9 February, 2016

12.2 Trainings/Seminar/Conference/Symposia/Workshop/Meetings, etc.

Name of the Scientist	Name of the programme / Venue	Period
All staff of ICAR–NRCB	22nd Foundation day of ICAR–NRCB and Kisan Mela, Tiruchirappalli, Tamil Nadu.	28 August, 2015
All staff of ICAR–NRCB	World soil day 2015, ICAR–NRCB, Tiruchirappalli, Tamil Nadu.	5 December, 2015
All Scientific and technical staff of ICAR - NRCB	Quality Management Systems in accordance with ISO 9001-2008	28 - 30 March, 2016
B. Padmanaban S. Uma R. Selvarajan K. J. Jeyabaskaran V. Kumar P. Suresh Kumar	Group discussion meeting of AICRP–Fruits. PAU, Ludhiana, Punjab.	3–6 March, 2016
B. Padmanaban	ICAR Institute Director's conference, ICAR, New Delhi.	23–24 January, 2016
	Round table discussion on semiochemicals, ICAR–NBAIR, Bengaluru, Karnataka.	6 August, 2015
B. Padmanaban S. Uma	Review meeting of the nodal officers of the AICRP–Fruits, ICAR–NRC for Grapes, Pune, Maharastra.	21 November, 2015
S. Uma	Review meeting of the project on Functional Genomics–Sigatoka component of NPTC, ICAR–IIHR, Bengaluru, Karnataka	29 October, 2015
	Pre group discussion workshop of AICRP–Fruits for preparation of AICRP Vision 2015, ICAR–IIHR, Bengaluru, Karnataka.	8–9 February, 2016

S. Uma	Review meeting on 'Mitigation of effects of hailstorm in agriculture'. ICAR–NRC for Grapes, Pune, Maharashtra and ICAR–CRIDA, Hyderabad.	21 November, 2015
	Annual review meeting on Agro–biodiversity–CRP. ICAR–IISR, Calicut, Kerala.	26 January, 2016
S. Uma M. Mayil Vaganan S. Backiyarani	DBT–BIRAC review meeting. BIRAC complex, New Delhi.	23–24 November, 2015
M. Mayil Vaganan S. Backiyarani	Third stewardship training programme on 'Analysis of PVA and iron in banana fruit' at Centre for Tropical crops and bio commodities, Queensland University of Technology, Brisbane, Australia.	12 - 17 October, 2015
M. Mayil Vaganan	International conference on Biodiversity and Biotechnology. Department of Biotechnology, Bharathidasan University, Tiruchirappalli, Tamil Nadu.	25–27 February, 2016
M. Mayil Vaganan S. Backiyarani	DBT–BIRAC review meeting. BIRAC complex, New Delhi.	5 May, 2015 & 11 June, 2015
I. Ravi	Third International Plant Physiology Congress on 'Challenges and strategies in Plant Biology Research' at Jawaharlal Nehru University, New Delhi.	11–14 December, 2015
I. Ravi M. S. Saraswathi	'HortIP 2016' First annual review meeting. South Horticulture ZTMC, ICAR–IIHR, Bengaluru, Karnataka.	8 February, 2016
K. J. Jeyabaskaran	Sensitization workshop on Mera Gaon – Mera Gaurav. Directorate of Extension, University of Agricultural Sciences, Bengaluru, Karnataka.	3 October, 2015
R. Selvarajan	International conference on 'Plant, pathogens and people'. Indian Phytopathological Society, NASC, New Delhi.	23–26 February, 2016
	International conference on 'Frontiers in Life Sciences (ICFLS–16)'. Department of Botany, St. Joseph's College (Autonomous), Tiruchirappalli, Tamil Nadu.	7–8 January, 2016
	XXIV Annual conference of Indian Virological Society (IVS)–VIROCON 2015. North Eastern Indira Gandhi Regional Institute of Health and Medical Sciences, Shillong, Meghalaya.	8–10 October, 2015
	Workshop on 'Nodal Officers of ICAR Research Data Repository for Knowledge Management'. NASC, New Delhi.	4–5 August, 2015

R. Selvarajan	DST–Lockheed Martin India innovation growth programme–technology commercialization and entrepreneurship workshop, Goa.	12–17 April, 2015
	Technology Expo and Investor Innovator meet, New Delhi.	11 December, 2015
	Users training workshop on ICAR–Krishi Geoportal. ICAR–NBSSLUP, Nagpur, Maharastra.	28–30 March, 2016
	DBT–ATL meeting. NCS–TCP, New Delhi.	4 June, 2015
	IBSC meeting at ICAR–IIHR, Bengaluru, Karnataka.	9 June, 2015
	IBSC meeting at ICAR–NRCB, Tiruchirapalli, Tamil Nadu.	7 January, 2016
V. Kumar	Consultation meeting for the world bank sponsored Tamil Nadu Rural Transformation project, Collectorate, Tiruchirappalli, Tamil Nadu.	4 February, 2015
	Island Kisan Mela–2015, ICAR–CIARI, Port Blair, Andaman & Nicobar Islands.	9–10 April, 2015
	APEDA meeting on 'Study on identification of export oriented integrated infrastructure for Agri products from India', PWC (Price Water House Cooper), Dept. of Agri Marketing & Agri Business, Guindy, Chennai, Tamil Nadu.	8 May, 2015
	Technologies review meeting of ICAR institutions and KVKs in the Southern region, ICAR–CIBA, Chennai, Tamil Nadu.	9 May, 2015
	'District seminar on horticulture crops' organized by State Dept. of Horticulture, Vellore, Tamil Nadu.	10 July, 2015
	'Improved technologies in banana cultivation', Pre kharif awareness program, KVK, Sirugamani, Tiruchirappalli, Tamil Nadu.	13 August, 2015
	'Improved cultivation practices in banana', Seminar cum Kisan Mela, ICAR–CIAE (RS), Coimbatore, Tamil Nadu.	27 August, 2015
	Chaired technical session on 'Horticultural crops', Mega Agricultural Fair–Agri Expo 2015, Tiruchirappalli, Tamil Nadu.	20 September, 2015

V. Kumar	Horticulture workshop on 'Strategic action planning to achieve double digit growth in horticulture sector' under 'Rythu Kosam Project', ICRISAT, Hyderabad, Telangana.	13–14 November, 2015
	103rd Indian Science Congress, Mysore University, Mysuru, Karnataka.	3–6 January, 2016
	'Organic cultivation of banana', Agri Expo 2016, Pasumai Vikatan, Tiruchirappalli, Tamil Nadu.	14 February, 2016
	'Improved production technologies for enhancing productivity of banana in Uttar Pradesh', ICAR–IIVR KVK, Kushinagar, Uttar Pradesh.	20 February, 2016
K. N. Shiva	Farmer–Scientists interactive meeting. 5th Mega Agrl. Fair, Agri Expo–2015, Tiruchirappalli, Tamil Nadu.	20 September, 2015
	TOLIC (Hindi) meeting organized by TOLIC at Railway Kalyana Mandapam, Tiruchirappalli, Tamil Nadu.	25 September, 2015
	Official meeting with APEDA officials, traders and logistics manager on PoP of banana and protocol for export of banana by seaport from Kochi port to Dubai, organized by NRC Banana at Podhavur, Tiruchirappalli, Tamil Nadu	31October, 2015
S. Backiyarani	Network project on Transgenic in crops review meeting at IIHR, Bengaluru, Karnataka.	29 October, 2015
	10th DUS review meeting held at Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharastra.	28 February, 2016
M. S. Saraswathi	ICAR extramural fund project meeting, NASC, New Delhi.	10 October, 2015
P. Suresh Kumar	Third international symposium on under–utilized plant species–Exploration and conservation for future generation. KVK, AC & RI, Madurai, Tamil Nadu.	5–8 August, 2015
P. Giribabu	Interactive workshop on 'Harmonizing plant protection recommendations in horticultural crops for South India'. ICAR–IIHR, Bengaluru, Karnataka.	4–5 February, 2016

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

Kisan Mela

ICAR–NRCB celebrated its 22nd foundation day as Kisan Mela with the theme on "Healthy soils for healthy life" on 28 August, 2015. The mela was presided over by Dr. S. Ayyappan, Director General (ICAR), Dr. Sreenath Dixit, Zonal Project Director, Zonal Project Directorate, Zone VIII (ICAR), Dr. B. Padmanaban, Acting Director, ICAR–NRCB and Dr. M. Jawaharlal, Dean, Horticultural College and Research Institute for Women (TNAU), Tiruchirappalli. Dr. S. Ayyappan delivered the chief guest lecture. In his speech, he praised banana farmers of Theni for their professionalism and emphasized the need for bringing rural youths to agriculture. He inaugurated the stalls and distributed prizes to leading banana growers and entrepreneurs. During the mela, Scientists of ICAR–NRCB delivered lectures on banana production, protection and post–harvest technologies and interacted with banana farmers.

Dr. S. Ayyappan, Secretary–DARE & Director General–ICAR, New Delhi addressing audience during Kisan Mela

Farmers' interface meeting

ICAR–NRCB, in collaboration with ICAR–IIVR, Varanasi organized one day banana farmers' interface meeting at KVK, ICAR–IIVR, Kushinagar, Uttar Pradesh on 19 February, 2016. Around 150 banana farmers from Kushinagar District participated in the meet. Dr. B. Padmanaban, Acting Director, ICAR–NRCB, Tiruchirapalli presided over the function and Dr. B. Singh, Director, ICAR–IIVR, Varanasi was the chief guest. Er. Rajesh Yadav, DGM, NABARD was the guest of honour. Principal Scientists Dr. R. Thangavelu and Dr. V. Kumar, ICAR–NRCB presented the improved plant protection technologies. Ten Progressive banana growers of Kushinagar were honoured with recognition certificate.

Dignitaries at Banana farmers' interface meeting held at KVK, ICAR–IIVR, Kushinagar

AICRP–Fruits meet

Annual group discussion meeting on AICRP–Fruits was held at PAU, Ludhiana from 3 to 6, March, 2016. ICAR–NRCB scientists *viz.,* Drs. B. Padmanaban, S. Uma, R. Selvarajan, V. Kumar, K. J. Jeyabaskaran and P. Suresh Kumar attended the meeting. During the meeting, a technical bulletin on 'Integrated Pest Management in Banana' was released by ICAR–NRCB, Tiruchirapalli in five languages (Telugu, Kannada, Malayalam, Assamese and Marathi).

World Soil Day

The ICAR–NRCB, Tiruchirappalli celebrated 'World Soil Day' on 5 December, 2015. Dr. B. Padmanaban, Acting Director presided over the function and Dr. P. Pandiyarajan, Dean, Anbil Dharmalingam Agricultural College and Research Institute (TNAU) graced the function as chief guest. Dr. Pandiyarajan emphasized the soil health management in agriculture through fortification of soil fertility by improving soil microbial population and distributed the soil health cards to the farmers. Dr. K. J. Jeyabaskaran, Principal Scientist delivered a technical lecture on 'Fertile soil for

Staff of ICAR–NRCB with Dr. P. Pandiyarajan, Dean, ADAC & RI, Tiruchiapalli during World Soil Day celebrations

healthy banana', emphasizing soil–test based nutrient management to avoid indiscriminate application of synthetic fertilizers.

Importance of soil testing and soil health cards was discussed in detail and awareness was created in this regard among the farming community. About 50 farmers from Tiruchirappalli, Karur, Tanjore, Dindugul and Perambalur districts participated in this function and 100 soil health cards were distributed. Dr. M. Mayil Vaganan, Principal Scientist welcomed the gathering and Dr. I. Ravi, Principal Scientist gave a vote of thanks.

Jai Kisan Jai Vigyan Week

A farmers' Sangosti was organized by ICAR–NRCB as part of Jai Kisan Jai Vigyan Week celebrations at Nachalur village, Karur District, Tamil Nadu, on 28 December, 2015. Dr. B. Padmanaban, Acting Director and team of scientists comprising Drs. R. Thangavelu, K. J. Jeyabaskaran, K. N. Shiva and P. Suresh Kumar interacted with the farmers.

14. DISTINGUISHED VISITORS

Name and Address	Date
Dr. K. S. Palanisamy, IAS, District Collector, Tiruchirapalli	2 July, 2015
Dr. S. Ayyappan, Director General (ICAR), New Delhi	28 August, 2015
Dr. Sreenath Dixit, Zonal Project Director, Zonal Project Directorate, Zone VIII (ICAR), Bengaluru	28 August, 2015
Dr. M. Jawaharlal, Dean, Horticultural College and Research Institute for Women (TNAU), Tiruchirappalli	28 August, 2015
Dr. T. Prabhu Shankar, IAS, Assistant Secretary, DARE, New Delhi	9 November, 2015
Dr. S. N. Pandey, Retd. ADG (Hort. Sci.), ICAR, New Delhi	27–28 October, 2015
Dr. P. Anand Kumar, Prinicipal Scientist, ICAR–IIRR, Hyderabad	27–28 October, 2015
Dr. N. Kumar, Retd. Professor (Hort.), TNAU, Coimbatore	27–28 October, 2015
Dr. T.V.K. Singh, Dean, College of Agriculture, ANGRAU, Hyderabad	27–28 October, 2015
Dr. A. K. Mishra, Principal Scientist & Head, ICAR–CISH, Lucknow	27–28 October, 2015
Dr. P. Pandiyarajan, Dean, Anbil Dharmalingam Agricultural College & Research Institute (TNAU), Tiruchirapalli	5 December, 2015

15. EMPOWERMENT OF WOMEN

Training Programme	Location	No. of participants
Farmers' training programme on Macropropagation	Semmedu, Kolli Hills, Tamil Nadu	38
Farmers' training programme on Macropropagation	Vellarikattupatti, Kolli Hills, Tamil Nadu	24

16. PERSONNEL

16.1 Staff News

Name	Event	Date
Dr. J. Poorani, Principal Scientist	Joined ICAR–NRCB by transfer from ICAR–NBAIR, Bengaluru, Karnataka	13 May, 2015
Dr. P. Suresh Kumar, Senior Scientist	Joined ICAR–NRCB by transfer from ICAR–NIASM, Baramati, Maharastra	27 May, 2015
Mr. Kishore Kumar Mahanti, Scientist	Transferred to ICAR–IIHR, Bengaluru, Karnataka	20 June, 2015
Dr. A. Thirugnanavel, Scientist	Joined ICAR–NRCB by transfer from ICAR research complex for NEH region, Nagaland Centre, Jharanapani, Nagaland	16 July, 2015
Dr. M. M. Mustaffa, Director	Superannuation	31 July, 2015
Dr. B. Padmanaban, Principal Scientist	Director (Acting)	1 August, 2015
Mr. B. Sathish, Senior Administrative Officer	Joined ICAR–NRCB by transfer from ICAR–CPCRI, Kasaragod, Kerala	27 August, 2015
Mr. Kasinathan	Joined ICAR–NRCB by transfer from ICAR–CIARI, Port Blair, Andaman and Nicobar Islands	14 September, 2015
Mr. Kasinathan	Transferred to ICAR–CIARI, Port Blair, Andaman and Nicobar Islands	2 January, 2016
Mr. D. Ramachandramurthi, Senior Technical Assistant (Civil Overseer)	Promoted as Technical Officer	W. e. f. 11 August, 2013

Dr. M. M. Mustaffa, Director, superannuated from service on 31July, 2015

16.2 Staff position

Scientific Staff

Sl. No.	Name	Designation
1	Dr. B. Padmanaban	Acting Director
2	Dr. S. Uma	Principal Scientist (Horticulture)
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 (Plant 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. P. Suresh Kumar	Senior Scientist (Horticulture)
14	Mr. R. Natarajan	Scientist (Economic Botany)
15	Dr. C. Anuradha	Scientist (Biotechnology)
16	Dr. P. Giribabu	Scientist (Nematology)
17	Dr. A. Thirugnanavel	Scientist (Horticulture)

Technical Staff

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

Administrative, Audits & Accounts and Supporting Staff

Sl. No.	Name	Designation
1	Mr. B. Sathish	Senior Administrative Officer
2	Ms. C. Gomathi	Asst. Finance & Accounts Officer
3	Mr. R. Krishnamurthy	Asst. Administrative Officer
4	Mr. M. Krishnamoorthy	Private Secretary
5	Mr. P. Murugan	Assistant
6	Mr. R. Sridhar	Personal Assistant
7	Mr.R.Neela Mega Shyamala Kannan	Steno Gr. III
8	Ms. S. Durgavathy	Upper Division Clerk
9	Ms. A.V. Suja	Lower Division Clerk
10	Mr. R. Mohanraj	Mali SSG–IV
11	Mr. V. Pandiyan	Mali SSG–III
12	Mr. V. Thangaraju	Messenger SSG–II
13	Mr. P. Kamaraj	Mali SSG–II
14	Mr. V. Ganesan	Mali SSG–I
16	Ms. K. Mariammal	Safaiwala SSG–I

Obituary

We condole the untimely demise of our colleague, Mr. M. Devarajan, Lower Division Clerk, who passed away on 24 March, 2016. He was survived by his wife and two daughters.

17. OTHER INFORMATION

Mera Gaon Mera Gaurav

Under '*Mera Gaon Mera Gaurav*' scheme, five groups of scientists of ICAR–NRCB has adopted 21 villages of Tiruchirapalli, Tanjavur and Karur Districts of Tamil Nadu and collected relevant baseline information, organised interactive meeting with village people, gave suggestions for the betterment of their livelihood, created awareness about the importance of soil testing in agriculture / horticulture and provided timely recommendations for agricultural activities.

National Science Day

ICAR–NRCB celebrated "National Science Day" on 29th February, 2016 with an objective to expose the school children to the research activities in banana and to create awareness and motivation towards scientific research. Around 350 students from different schools of Tiruchirappalli and Karur districts visited the

Students at ICAR–NRCB during National Science Day celebrations

institute and interacted with scientists. Dr. B. Padmanaban, Acting Director, ICAR–NRCB outlined the lucrative career opportunities available in agriculture and allied sectors and invited all students to visit ICAR–NRCB any time. Dr. V. Kumar, Principal Scientist, welcomed the gathering and proposed the vote of thanks.

Swachh Bharat Mission at ICAR–NRCB

During the Swachh Bharat fortnight celebration during 2–17 October, 2015, poster and slogan competitions were conducted. All our staff members including RA and SRF were actively involved in the cleaning of office premises on Wednesday of every week. Similarly, staff who are residing at ICAR–NRCB quarters are regularly involved in cleaning activities after office hours on every Friday. During the period under report, on three different occasions cleaning work has been carried out at ICAR–NRCB farm. Under this cleanliness drive, on March 19, 2016, ICAR–NRCB adopted Keerikalmedu village and five sets of cement blocks were placed in different parts of the village and a lecture on nondecomposable wast and its effect on global warming was given to the village people.

Mr.Malika Sakthivel, Panchayat President enumerated the cleanliness activities going on in Keerikalmedu village.

ISO certification

As a part of our effort to follow quality management systems (QMS) and procedures, ISO certification body auditors from Star Certification International, Bengaluru visited our Centre on 31 March, 2016. After a series of checking of various records, documents and systems maintenance, the auditors recommended an award of ISO 9001:2008 certification (No. 0151160004) to ICAR–NRCB for its research and development on banana towards attaining livelihood and nutritional security. The certificate was issued to Director, ICAR–NRCB by the Honorable DDG (Hort. Sci.).


CERTIFICATE

Quality Management System

ICAR-National Research Centre for Banana

ISO 9001 : 2008

ISO certificate

Right to Information Act

ICAR–NRCB has provided timely information to RTI applicants in fifteen cases during 2015–16 and uploaded the same accordingly in the website of central information commission.

Hindi Fortnight Celebrations

ICAR–NRCB celebrated 'Hindi fortnight 2015' from 16–30 September, 2015. The inaugural function was held on 16 September, 2015 under the chairmanship of Dr. B. Padmanaban, Acting Director, ICAR–NRCB, Tiruchirappalli.

As part of Hindi week celebrations, various competitions in Hindi *viz.*, "poem recitation", "see and tell", "hindi song", "hindi writing", and "hindi newspaper reading" were conducted in which scientific, technical administrative and supporting staff of the centre actively participated and exhibited their talents. On 30 September, the valedictory function of the Hindi fortnight 2015 celebrations was held in which Mr. Vikram Kumar, Zonal Official Language

Officer, State Bank of India, Tiruchirappalli graced the occasion as Chief guest.

In his address he highlighted the importance of use of Hindi language in day–to–day routine in office and emphasized that knowledge of the Hindi language should be imparted to every

Mr. Vikram Kumar addressing staff of ICAR–NRCB during Hindi fortnight celebrations

citizen right from childhood in addition to his mother tongue. Dr. B. Padmanaban, in his chairman's address, emphasized the importance of promoting Hindi as official language and the necessity of learning Hindi as 'Rajbhasha' by every staff. Dr. K. N. Shiva, Principal Scientist and Member–Secretary, Official language implementation committee of the centre welcomed the gathering and also read out the report on Hindi fortnight 2015 at the Centre. The programme came to an end with the vote of thanks by Dr. K. J. Jeyabaskaran, Principal scientist and member, Official language implementation committee of the centre. Mr. B. Sathish, Senior Administrative Officer coordinated the entire programme.

Independence Day Celebration

Independence Day was celebrated at our institute on 15 August, 2015. Dr. B. Padmanaban, Acting Director hoisted the national flag and delivered a speech. He urged for inculcating team work among the staff.

Sadhbhavna Divas

Sadhbhavna divas was observed at our Institute on 20 August, 2015. In order to promote National integration and communal harmony, a pledge was taken by the staff. On this occasion, Swamy Shri Ashok Govind Das, ISKON, Tiruchirappalli delivered a special lecture on importance of integrity and communal harmony through quotes from Bhagavat Gita.

Sports Meet

ICAR–NRCB participated in ICAR Inter–Institutional Sports meet for south zone held at Kochi, Kerala from 25–29 May, 2015.

Medical Camp

Mahatma Gandhi Eye Institute, Tiruchirapalli conducted "Eye check–up and consultancy campaign" at ICAR–NRCB on 21 April, 2015. Staff of our institute were benefitted from this free eye campaign.

Yoga Day Celebration

International Yoga Day was celebrated on 22 June, 2015. Dr. S. Thiyagarajan, Naturopathy, Yoga and Acupuncture consultant from Shri Jeyaranga Yoga centre, Tiruchirapalli taught yoga to staff members.

Digital India Week

ICAR–NRCB celebrated "Digital India Week" from 1–7 July, 2015. This event was organized to popularize Digital Locker–A Government of India's initiative for paper free storage of personal documents.

Vigilance Awareness Week

The Vigilance awareness week was observed at NRCB from 26 to 31 October, 2015. On this occasion, the staff of the institute took a pledge on 26 October, 2015. 'Pick and speak' and 'Essay writing' competitions were conducted. Students from Sivananda Balalaya School, Adavathur, Tiruchirapalli visited ICAR–NRCB and participated in essay writing competitions.

Rashtriya Ekta Divas

The staff of ICAR–NRCB observed the

Rashtriya Ekta Divas on 31 October, 2015 to commemorate the birth anniversary of Sardar Vallabhbhai Patel by taking a pledge for national unity.

Communal Harmony Campaign

ICAR–NRCB celebrated 'Communal harmony campaign' from 19 to 25 November, 2015 by conducting various competitions *viz.,* singing competitions (Bhajans / patriotic songs), essay and painting competitions for children of nearby schools and a powerpoint presentation on the activities of foundation of communal harmony was delivered by M. S. Saraswathi, Principal Scientist.

Constitution Day

ICAR–NRCB celebrated 'Constitution Day' on 26 November, 2015 to commemorate 125th birth anniversary of Dr. B. R. Ambedkar. On this occasion, the preamble of the constitution was recited.

ANNEXURE–I

I. Institute projects

Crop Improvement		
Sl. No.	**Name of the Project**	**Principal Investigator**
1	Improvement of banana through conventional breeding	S. Uma
2	Improvement and management of banana genetic resources in Indian subcontinent	S. Uma
3	Identification and characterization of nematode resistance genes in banana	S. Backiyarani
4	Improvement of banana for nematode resistance and marker development	S. Backiyarani
5	Improvement of Rasthali through induced mutagenesis	M. S. Saraswathi
6	Development of trait specific markers for fusarium wilt resistance through association mapping studies in banana (*Musa* spp.)	M. S. Saraswathi
7	Identification and evaluation of superior clones of cv. Ney Poovan (AB) and Grand Nain (AAA)	R. Natarajan
Crop production & Postharvest Technology		
8	Development of clump management technology for enhanced productivity in banana	V. Kumar
9	Studies on nutrient dynamics in banana	K. J. Jeyabaskaran
10	Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance	I. Ravi
11	Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance	I. Ravi
12	Biochemical and molecular basis of ripening of banana fruit and its manipulation with biochemicals	M. Mayil Vaganan
13	Development of pre and post–harvest techniques for leaf production in banana	K. N. Shiva
14	Development of modified atmosphere packaging techniques in banana and plantain for domestic and export markets	K. N. Shiva
15	Development and refinement of value added products in banana and plantain	K. N. Shiva
16	Functions of resistant starch and designer food development from banana flour	P. Suresh Kumar

Crop Protection		
17	Management of banana weevils	B. Padmanaban
18	Pest mapping in bananas and plantains of India	J. Poorani
19	Investigation on fungal and bacterial diseases of banana and their management	R. Thangavelu
20	Studies on viral diseases of banana and their management	R. Selvarajan
21	Host–virus interactions in banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's	R. Selvarajan
22	Proteomic analysis of host–BBTV interaction in banana	C. Anuradha
23	Investigations on *Musa* nematode's diversity, biology, behaviour and their interactions	P. Giribabu

II. ICAR funded projects

Sl.No.	Name of the Project	Principal Investigator
1	CRP on borers in network mode.	B. Padmanaban
2	Identification of molecular strategies for the control of *Cosmopolites sordidus* (Coleoptera: Curculionidae), a major pest of bananas.	B. Padmanaban
3	On–site diagnostics for insect pests of selected horticulture crops to enable timely pest management decision making.	J. Poorani
4	Network project on Transgenic in crops–Banana functional genomics (Sigatoka & Drought component)	S. Uma
5	CRP on Agrobiodiversity	S. Uma
6	A new vision for quality planting material (QPM) production system in India	S. Uma
7	Outreach project on *Phytophthora*, *Fusarium* and *Ralstonia* diseases of horticultural and field crops	R. Thangavelu
8	Survey, characterization and management of a most virulent strain of *Fusarium oxysporum* f.sp. *cubense* infecting banana.	R. Thangavelu
9	CRP on Vaccines and Diagnostics	R. Selvarajan
10	Studies on active packaging on extending shelf–life of banana.	K. N. Shiva
11	Assessment of post–harvest losses in banana	K. N. Shiva
12	Harnessing the potential of *Musa* species in ornamental and leaf industries and screening for better edible flower and pseudostem	A. Thirugnanavel

III. Projects funded by other agencies

Name of the Project	Funding Source	Principal Investigator
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
Component–2: Biofortification and evaluation of Indian banana with Iron constructs		M. Mayil Vaganan
Component–3: Development of efficient ECS for Rasthali and providing authentic virus free IMFC to Indian Partners		S. Uma
Framing crop specific DUS Guidelines for Banana (*Musa* spp.)		S. Uma
Twinning programme on 'Molecular characterization of *Fusarium oxysporum* f.sp. *cubense* causing Fusairum wilt on banana and its sustainable management'.	DBT	R. Thangavelu
Development of bio–pesticide formulation for reducing post harvest losses and for achieving export quality and increased shelf life of banana fruits.	DBT	R. Thangavelu
National Certification System for Tissue Culture Plants	DBT	R. Selvarajan & M. S. Saraswathi
Development of non–chimeral mutants with durable resistance to Fusarium wilt in Rasthali through induced mutagenesis	BARC	M. S. Saraswathi

IV. Contract research project

- Evaluation of high yielding technology system formulations for higher productivity of banana. M/S South Asia AGRINOS India Pvt. Ltd., New Delhi (V. Kumar & B. Padmanaban).
- Evaluation of Biospor and Ferticop (Organic copper) for the management of leaf spot diseases of banana (R. Thangavelu).
- Evaluation of paraffinic oil adjuvant for the management of leaf spot diseases of banana (R. Thangavelu).

ANNEXURE–II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Rainfall (mm)
April 2015	37.63	26.66	177.2
May 2015	36.16	26.35	240
June 2015	36.43	26.0	25.8
July 2015	38.45	27.12	42.0
August 2015	37.06	26.35	100.3
September 2015	36.93	26.4	104.6
October 2015	33.22	24.35	160.7
November 2015	29.96	23.6	308.9
December 2015	29.51	23.16	38.6
January, 2016	31.19	21.35	–
February 2016	33.14	22.31	–
March 2016	38.78	24.70	–
Total			1198.1

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

(भारतीय कृषि उनुसंधान परिषद)

तायनूर पोस्ठ तोगमलै रोड तिरूच्चिरापक्कि ६२० १०२, तमिल नाडु

ICAR-National Research Centre for Banana

(Indian Council of Agricultural Research)

Thayanur Post, Thogamalai Road, Tiruchirapalli - 620 102, Tamil Nadu

Ph : 0431- 2618125, E-mail : director.nrcb@icar.gov.in, Web : www.nrcb.res.in