Silver Jubilee Year

वर्षिक प्रतिवेदन

ANNUAL REPORT 2017 - 18

25 Years of Excellence

भाकृअनुप
ICAR

ICAR–NRCB

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

(ISO - 9001:2015 Certified Institute)

NATIONAL RESEARCH CENTRE FOR BANANA
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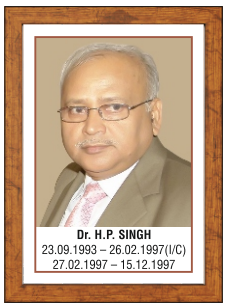
Directors...



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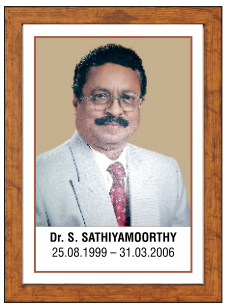

Dr. S. SATHIYAMOORTHY
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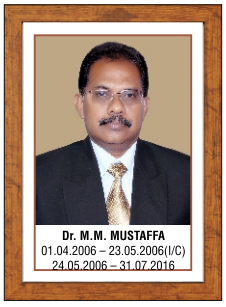

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19.07.2016 – till date

वार्षिक प्रतिवेदन

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भाकृअनुप
ICAR

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

(भारतीय कृषि उनुसंधान पारिषद)

तायनूर पोस्ठ तोगमलै रोड तिरूच्चिरापक्कि ६२० १०२ए तमिल नाडु भारत

ICAR-NATIONAL RESEARCH CENTRE FOR BANANA

(Indian Council of Agricultural Research)

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

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PREFACE

The ICAR-National Research Centre for Banana, Tiruchirappalli, established in 1993, has grown into a nationally and internationally recognized centre of excellence on banana research and is celebrating the Silver Jubilee of its establishment this year. I take immense pleasure in presenting the Annual Report of ICAR-NRCB for the year 2017-18, which encapsulates the salient achievements of the centre in research, education and training pertaining to its mandate.

The Centre works on four major thrust areas, *viz.*, Crop Improvement, Crop Production, Post Harvest Management and Crop Protection. Research during this silver jubilee year has emanated in some fruitful results which needs mention here. It was found that banana juice extract from fruit and peel exhibited anti cancerous properties against colon cancer and breast cancer, respectively. Similarly, banana varieties with low glycemic indices have been identified and they are highly suitable for diabetic patients. The Centre could successfully extract biomolecules like anthocyanin from banana bracts which could be encapsulated for use in the near future. It is disheartening to report that *Fusarium* wilt TR-4 has been confirmed in U.P. in addition to Bihar, while *Fusarium* wilt, race 1 been reported in many states. ICAR-NRCB is working with SAUs and state departments in sensitizing and also training on containment of the spread. The centre has also developed an immunoassay based dipstick technology for banana bract mosaic virus which will have a great value for commercial tissue culture industries.

The Centre is actively engaged in services like virus indexing, fidelity testing, soil nutrient analysis, nutrient profiling of fruits and products, supply of planting materials etc. We have signed MoU's with states like Andhra Pradesh and premier institutions like NIT, Trichy; KNCET, Trichy. We are also actively engaged in providing off and on-campus training programme and successfully demonstrated sea-protocol for export of banana which is economically viable and cheaper than air freight. We have linkages with international institutes like Bioversity International, France, QUT, Australia, IITA-Nigeria, NARO-Uganda and more than 30 National institutions. This year, our Scientists bagged 16 more new projects from Department of Biotechnology worth of Rs.4.5 crores.

An exclusive App has been developed by the Centre for guiding the farmers on improved production techniques. The Centre has been accredited with ISO 9001:2015 certification for its quality standard services. The Centre mainly focus on farmers' empowerment through Kisan Mela, exhibitions, on-campus and off-campus training programmes during this year. Government of India's Farmers welfare programmes and other initiatives like Mera Gaon Mera Gaurav (MGMG); Swachch Bharat, Hindi Pakwada, Agricultural Education Day, International Yoga day, Vigilance awareness Week, Communal Harmony campaign, National Science Day have been successfully organized during the year in a befitting manner.

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

(S.Uma)

2. INTRODUCTION

ICAR-National Research Centre for Banana is celebrating its silver jubilee year after it was established on 21st August 1993 at Tiruchirappalli, Tamil Nadu by ICAR, New Delhi with an aim to increase the production and productivity of banana and plantains through mission mode basic and strategic research approaches. ICAR-NRCB has contributed immensely for the present production estimate of 30.2 MT from an area of 8.47 lakh hectares keeping India in the first place in terms of production since last three decades. The crop has transformed from its status as backyard crop to high value crop in the last 25 years. The Centre has research farm of 36.5 ha and laboratory complex in 3.23 ha. ICAR-NRCB also has an area of 0.80 ha under residential complex in the main city. This Centre is located at 11.50°N latitude and 74.50°E longitude, 90 m above MSL and receives 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 works on four major thrust areas of research *viz.,* Crop Improvement, Crop Production, Postharvest Management and Crop Protection. The Institute has state of the art research laboratories for tissue-culture, bio-technology, soil science, water and nutrient management, physiology, biochemistry, entomology, nematology, fungal, bacterial, viral pathology and postharvest technology research.The institute is home to one of Asia's largest field genebanks with 410 accessions that are conserved using advanced techniques for future generations and used in banana improvement by researchers across the globe. The Institute has released popular varieties like Udhayam, NRCB selections Saba and Bangrier, and two more selections are in pipeline for the benefit of banana farmers. Hybrids with high carotenoid contents is the highlight of the year which are being tested on large scale. The centre has developed advanced technologies such as low cost, farmer friendly mass multiplication of planting material, high density planting, Banana Sakthi (a micronutrient mixture), formulations for eco-friendly production management. ICAR-NRCB was the first to report the occurrence of *Fusarium* wilt Tropical Race 4 (*Foc* TR 4) in India. As a management tool, ICAR-NRCB is screening its germplasm in the sick field of Bihar. Centre has identified, two resistant mutants of Rasthali and one mutant of Grand Naine for *Foc* Race 1. The centre has also developed bioagents for the control of weevils. It has also developed ecofriendly dip-stick for virus detection which has been well appreciated by the global farming community. Besides all, more than 40 technologies on value addition utilizing various plant parts of banana have been developed. The Institute provides services for providing disease-free, quality planting material to banana growers and offers customized training programmes on advanced production, protection, and post-harvest value added products to farmers, entrepreneurs, self-help groups and students.

The Centre has 20 in-house research projects and 27 externally funded projects funded by various agencies like ICAR, DBT, PPV& FRA, BARC, DST and Bioversity International etc. Four contract research projects have been completed and consultancy has provided to APEDA in PPP mode to ship indigenous banana varieties like Nendran and Ney Poovan and to establish tissue culture laboratories for mass multiplication of banana. The Perspective Plan and Vision 2030 and 2050 documents on the research priorities and also inputs from the 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 also monitor the progress made on the RAC and QRT recommendations. 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 sustained production and productivity of bananas in India.

Vision

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

Mandate

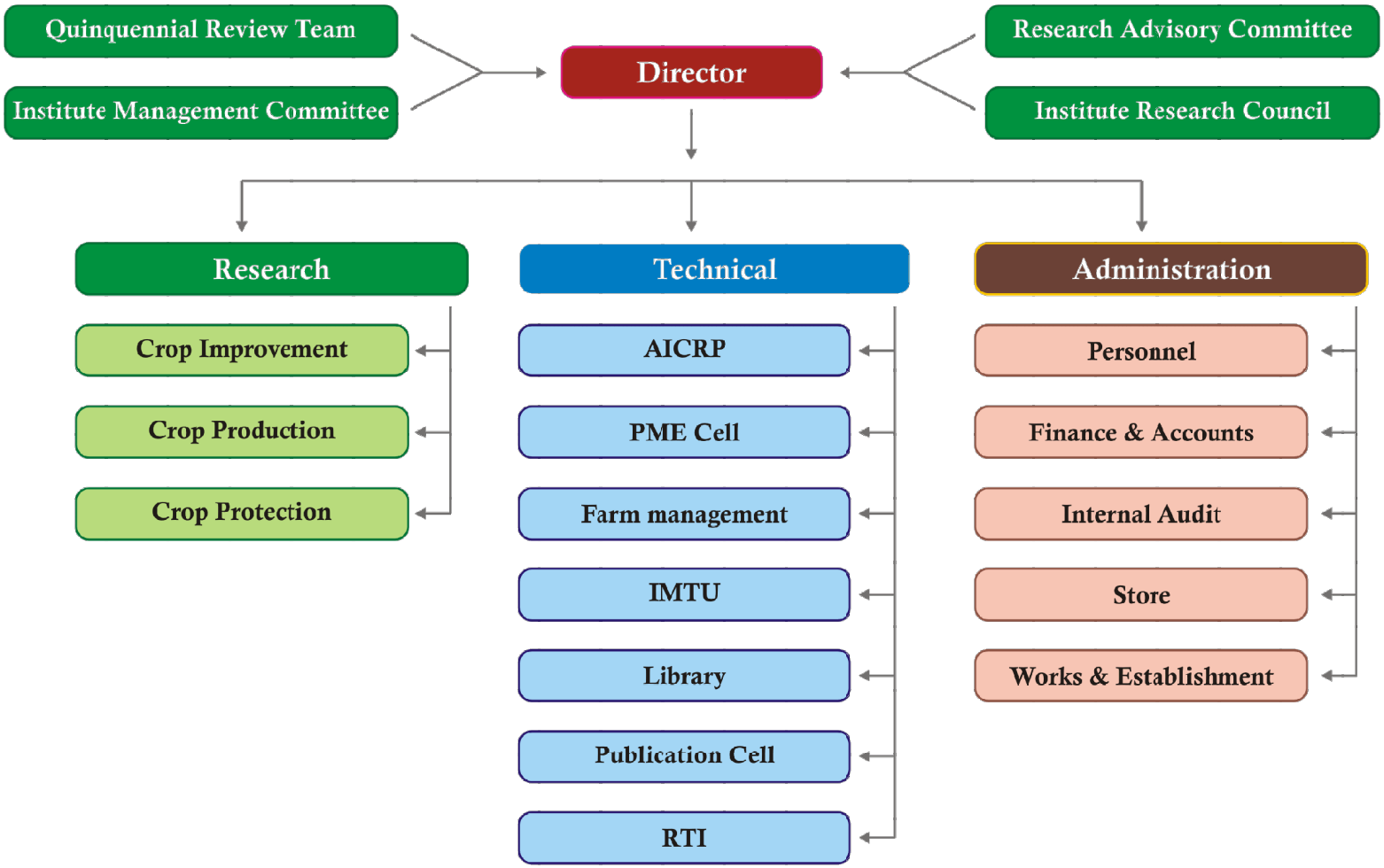
- Basic, strategic and applied research on genetic resource management, crop improvement and production technologies for sustainable and enhanced production and utilization of banana.
- National banana gene bank management, coordination and validation of research for enhancing and sustaining the productivity of banana.
- Transfer of technology and capacity building of stakeholders for enhanced and sustained production of banana.
- Referral laboratory for monitoring the quality of micro-propagated banana plants.

Budget details for the year 2017 - 18 (Rs. in lakhs)

Head of account	Expenditure (Rs. in lakhs)
Equipment	0.00
Establishment	571.77
Overtime Allowance	0.00
Travelling Allowance	15.99
Research Expenses	56.99
Operational Expenses	66.00
Infrastructure	144.97
Communication	23.28
Repair of equipment, Vehicle *etc.*,	22.03
Office building	62.97
Residential building	19.92
Other Admin.	22.77
Miscellaneous	1.98
HRD	0.00
Publicity & Exhibition	0.99
Pension & Retirement Benefits	29.92
Total	1039.58

A sum of Rs. 81.85 Lakhs was generated by the centre during the financial year 2017 - 18.

Organizational Setup of ICAR-NRC on Banana



3. EXECUTIVE SUMMARY

Crop Improvement

Survey in the North Eastern region of India covering Assam, Arunachal Pradesh, Nagaland and Manipur led to the collection of 15 *Musa* accessions including *M. nagensium* which have been collected by ICAR-NRCB for the first time from Changlang of Arunachal Pradesh. A total of 29 accessions have been collected from secondary sources added to the genebank. Also introduced nearly 73 exotic accessions from ITC, Belgium through ICAR-NBPGR, New Delhi. The elite clones of cvs. Nendran including high yielding Nendran, Quintal Nendran, Attu Nendran, Swarnamukhi and Neypoovan have been collected and established. Morpho-taxonomic characterization has been completed for four hybrid progenies, 11 indigenous accessions, and four ITC accessions leading to the identification of their genomic and sub-groups. IC numbers have been obtained for 81 unique germplasm accessions (0623553 to 0623633). Results of the field evaluation of cv. Udhayam derived from three different explants namely shoot tip, cormlet and male flower bud along with suckers as control indicated that the flower bud derived plants yielded better. Results of the *Fusarium* wilt sick plot screening indicated that three AA diploids, two *M. balbisiana* types, two Cavendish clones, seven Mysore types, five Pome types, and one each of Unique and hybrid accessions were found to be resistant to Theni *Foc* (VCG 0124). The performance of NRCB selection 11 (Manoranjitham variant) was found to be better at higher elevations. Front line demonstration established at Nagercoil of Kanyakumari district for popularization of NRCB selection 8 (Bangrier) and NRCB selection 9 (Saba) indicated that they could sustain cyclonic winds due to robust stem girth and yielded normally. Among the eight dwarf mutants of BARC, TBM 9 performed better in the farmers' field. Production of large scale plantlets from embryogenic cell suspension culture using bioreactor has been standardized for different cultivars of banana cvs. Grand Naine, Rasthali and Sabri. GCMS analysis indicated that four volatile compounds namely Oxacyclohexadecan-2-one (1.13%), 2-Dodecylcyclobutanone (0.65%), Chrysantenyl 2-methylbutanoate (0.95%) and Hexanoic acid heptadecyl ester (0.49%) are appearing to be responsible for their fragrance in cv. Manoranjitham. The phase I Nendran based progenies were evaluated and all progenies except NCR 19, NCR 21, NPL 28, NPL 30 and NPL 36 recorded higher yield (>15 kg) than their parents. Progeny No 685 (Saba x Pisang Lilin) and Progeny No 690 (Saba x Pisang Lilin) which were identified for their high yield and good cooking quality, were evaluated further during the reporting period and they were proven to yielding 81 and 64% higher over the female parent. Sick plot screening of 35 putative mutants of cv.Rasthali at Muthalapuram, Theni, Tamil Nadu indicated that NRCB RM 217 and NRCB RM 100 which were found to be resistant under pot culture yielded a normal bunch of 10 kg and 12 kg despite internal disease score of 5 and 6 respectively. We have identified the highly vacuolated uninucleate stage in 10 banana cultivars which were usually located with bract with No. 16 (Popoulu) to No. 32 (Grande Naine). This stage varied according to the clones/lines as follows NPL (18), NCR (27), NOP (23), Rasthali (23), Jurmony (19), Poovan (26), Karpuravalli (17) and Nendran (22). Usually the uninucleate stage was observed in older bracts when flower bud was collected from a peduncle having less number of bract scars.

Disease free healthy suckers of 44 accessions in duplicate have been supplied to ICAR-NBPGR for *in vitro* conservation purpose. Disease free healthy suckers of germplasm have been distributed to UAS,

Arabhavi; Department of Horticulture, Basti (Uttar Pradesh); TNAU, Coimbatore, ICAR-RCER, Regional station – Ranchi; KVK, Ariyalur and FRS, Vengurla for evaluation purpose. Around 5949 tissue cultured cv. Udhayam banana plants have been distributed to interested farmers. Around 250 shoot tip explants of cv. Udhayam have been supplied to a private tissue culture production centre for mass multiplication purpose. Mother cultures of cvs. Udhayam and Grand Naine have been supplied to an another production centre for mass multiplication.

Crop Production and Post Harvest Technology

In Ney Poovan (ratoon-2), a gradual increase in dry matter production (DMP) was observed in increasing levels of RDF of NPK from the initial to 150% at harvesting stage. The highest DMP of 12.62 Kg was recorded at 150% RDF while control recorded 10.66 Kg. The amount of nutrients recycled/added (Kg/ha) through reincorporation of residues Ney Poovan after bunch harvest were worked. The average nutrient contents in vermicompost generated from a single plant of Ney Poovan plant after harvest of bunch were Nitrogen-101.13 g, Phosphorus-14.20g, Potassium-176.62 g, Copper-0.63 g, Manganese-2.22 g, Zinc-0.53 g and Iron-1.25 g.

In Rasthali (ratoon-1), a gradual increase in dry matter production (DMP) was observed in increasing levels of RDF of NPK from control to 150% at harvesting stage. The highest DMP of 18.56 Kg was recorded at 150% RDF while control recorded 13.91 Kg.The amount of nutrients recycled/added (Kg/ha) through reincorporation of residues Rasthali after bunch harvest were worked out. The average nutrient contents in vermicompost generated from a single plant of Rasthali plant after harvest of bunch were Nitrongen-89.15 g, Phosphorus-17.89 g, Potassium-174.09 g, Copper-0.69 g, Manganese-1.63 g, Zinc-0.67 g and Iron-1.23 g.

Under organic banana farming, highest leaf nutrient concentrations (%) were recorded with application of poultry manure + groundnut cake + rural compost + wood ash + VAM + PSB + KSB at 20 leaf stage and shooting stage. The highest nutrient uptakes (g/plant) were recorded with same treatment combination at 20 leaf stage and shooting stage which were on par with that of 100% application of inorganic fertilisers. Clump management for the ratoon crop of cvs. Nendran and Poovan has been worked out.

For the leaf industry, cv. Poovan, three suckers per hill produced maximum number of harvestable leaves, followed by four and five suckers per hill. Similarly, total leaf area also varied from three to five suckers per hill.

Improved post-harvest handling treatments, followed by packing in polybag and kept at cold storage at 13.5^{0}C extended the shelf-life of banana cv. Grand Naine for 108, 94 and 60 days with respect to 75, 85 and 95% maturity without deteriorating in quality parameters. Nendran harvested at 80-85% maturity with improved postharvest treatments and stored at 13.5^{0}C extended the shelf-life up to 32 days. Among the various methods employed for ripening of banana cv. Grand Naine, fruits treated with ethylene gas (100 ppm for 24 hours) gave uniform color development with shelf-life of six days at room temperature and 12 days at 22^{0}C storage temperature.

The removal of water from the banana slices was faster with vacuum drier (300 min.) compared to solar drier with superior sensory attributes. With the increase in temperature the swelling got increased in plantain varieties tested. The percentage of amylose displayed significant difference in selected banana cultivars that ranged between 19.87 to 22.32 per cent. The highest WAC was observed in Monthan compared with Nendran, Grand Naine and Saba. Phosphorylated starch produced the modified starch with higher

retention of resistant starch (25.7%) than other methods. The starch and modified starches of the banana recorded lesser amount of glucose adsorption than the banana flour. The pasta prepared with 65:25:10 ratio of maida: Banana flour and modified starch also recorded the lesser glucose adsorption.

The highest pseudostem fibre recovery and properties like breaking strength, breaking extension, tex and tenacity were found to be good in fibres of Red Banana. Laccase treatment for degumming of banana fibres recorded with good physiomechanical properties as well as chemical composition.

Ferulic acid is found to be produced by the organisms. The results after 24 hrs incubation shows the presence of ferulic acid in PN1, CDF2 and co-culture inoculated samples. Nendran peel is more potent in reducing ferric and involves in 55.10 (IC_{50}) free radical inhibition. The flavonoids content was high with Nendran peel extract that attributes to its antioxidant activity. Moreover, they showed highest tumor inhibition of the breast cell line. Banana flour based extruded products enriched with carrot juice at 70 % (antioxidant) and beet root juices at 90 % were standardized and developed.

In banana cv. Grand Naine, the photosystem healthiness function was analysed under drought stress with and without drought alleviation chemicals. The plants primed with [Acetyl Salicylic Acid (ASA) + ButylatedHydroxy Toluene (BHT)] recorded 65% more photosynthesis than non-primed drought plants. The Quantum Yield (YII) and Fv/Fm ratio of soil moisture stressed banana under natural light recorded lesser than low light (50% of natural light) condition.

PPFM (Pink Pigmented Facultative Methylotrops) primed and drought imposed plants recorded 9.75 kg and 12.32 Kg in ASA treated one.

Application of potassium sulphate (1.5%), a growth regulator, as bunch spray in soil moisture stressed banana plants increased the fruit weight 17.35% more than drought stressed plants in cv. Grand Naine.

1-MCP treated Grand Naine bananas at 1µl/L (500 ppm) for 12 hr with ethylene spray ripened within three days, but the 1-MCP treated bananas on self-ripening took seven days for ripening.

The total soluble solids (TSS) and acidity of the 1-MCP treated pre-harvest Poovan bananas were analysed after self-ripening and induced ripening treatment with ethylene had acceptable levels of TSS and acidity similar to untreated control fruits.

Glycemic index (GI) was analysed for 6 commercial cultivars at ripening stages of 5 and 6 indicated that stage 5 (green at the tips) has relatively low GI compared to state 6 (full yellow). Among the cultivars, Ney Poovan exhibited highest GI followed by Karpuravalli and Grand Naine. Starchy cv. Monthan had the least GI.

Anthocyanin pigment contents in six bracts of male flower bud varied between 57.8 mg in Ney Poovan and 22.2 mg in Grand Naine per 100 g of pigment yielding bracts. Other higher yielding cultivars were Hill banana (57 mg), Poovan (55 mg), Rasthali (54.7 mg), Pachanadan (53 mg) and Nendran (52.5 mg).

The Poovan bract anthocyanins composed of five compounds with a retention time of 2.5, 2.7, 5.9, 10.0 and 10.4 min in 3, 7, 26, 28 and 36%. Anthocyanin pigments at the rate of 52 mg/100 g fresh weight was extracted from flower bracts of Nendran, spray dried and encapsulated at 400 mg per capsule.

Crop Protection

Synthetic analogues of volatiles released from male and female banana weevils and host plant volatiles from susceptible cultivars

(Karpuravalli, Nendran and Poovan) showed <40% attraction of male and female weevils. *In vitro* test of kairomone compounds (Heptane, 2-methyl-4-pentanal, Heptadecane, Octadecane, 4-ethyl-acetophenone and Tetradecane at 0.5 to 2% concentrations) showed 20-40 % of male and female weevil attraction in which female weevils were more. Aphid induced volatiles belonging to six functional groups were identified by GC-MS. Record on banana weevil infestation in *Musa* germplasm lines grown in *Fusarium* wilt sick field indicated that the basal splitting of the pseudostem due to fusarium wilt disease invites banana stem weevil infestation. GC-MS analysis of volatiles from the wilt infected banana (cv. Ney Poovan) leaf sheath revealed that the presence of functional groups *viz*., Aldehyde(1), Dicarbomide (1) and fatty acid ester (FAE: 9).

Under pest mapping in banana and plantains in India, first time in the world, CO1 gene was sequenced from *Kophene cuprea, Aleurolobus musae* and *Basilepta subcostata.* Natural enemies (parasitoids/predators) of banana mites, fruit mealy bugs, root mealy bugs, lacewing bug, whitefly and scales were documented. The rugose spiralling whitefly, *Aleurodicus rugioperculatus*, a recently reported invasive pest, was monitored for further spread in Tamil Nadu.

Preliminary survey conducted for *Fusarium* wilt infection in banana cultivar Grand Naine in Uttar Pradesh (Faizabad), Madhya Pradesh (Burhanpur), Gujarat (Surat), West Bengal (Nadia) and Karnataka (Chikkeballapura and Bengaluru) revealed except in Karnataka all other states the incidence was recorded (10-50%). Characterization of the *Fusarium* wilt indicated the presence of Tropical race 4 in UP while it was race 1 in the other states.

A total of 17 nematode isolates were sequenced and submitted to NCBI. Among the bio-control and botanical agents tested, *Bacillus* sp. was found effective against root-lesion nematode, *Pratylenchus coffeae* on banana cv. Nendran under pot conditions. Banana cvs. Kanai Bansi and Nutepong were found moderately resistant to root-knot nematode, *Meloidogyne incognita.* Four entomopathogenic nematode (EPN) isolates *viz., Rhabditis rainai*, *Steinernema siamkayai* (Two isolates) and *Heterorhabditis indica* were isolated and tested against banana stem weevil under *in vitro* conditions.

Rapid and cheaper method of isolation of crude DNA from the *Eumusae* leaf spot infected tissues was developed as the method took only 2 hours as against 18 hrs in the normal method of isolating DNA for PCR analysis. The method was applicable for isolating DNA from the fungal mycelium as well. Diagnosis of *Eumusae* leaf spot pathogen by LAMP method was validated. Characterization of toxin compounds from *M. eumusae* pathogen by TLC has been carried out and Toxin1 (T1) was found better. GC-MS analysis of the toxin T1 resulted in identification of three different compounds *viz.*, Trimethoxy flavone, Quinizarin and *p*-Benzoquinone dioxime. Two bioactive compounds (0.01- 0.5 g ml^{-1}) from *Penicillium pinophilum* (12DF) out of 18, purified and identified by GC/MS showed 100% mycelial inhibition of *M. eumusae* and an another compound isolated from *E. nidulans* (9DF) showed 100% inhibition only at 0.25 and 0.5 g ml^{-1} concentrations. However, all these three compounds showed 100% *in vitro* inhibition of spore germination of *M. eumusae*.

Characterization of pathogen causing tip and pedicle rot disease in banana (cv. Nendran) by ITS–rDNA sequence analysis revealed that the causal agents were belonging to *Fusarium chlamydosporum* and *Lasiodiploidia theobromae*. Among six different fungicides tested against *F. chlamydosporum in vitro,* three fungicides *viz*., Tebuconazole + Trifloxystrobin (Nativo), Carbendazim and Propiconazole (Tilt) recorded 100% inhibition of the mycelial

growth of the pathogen. Carbendazim and Thiophanate methyl (Roko) recorded 100% inhibition of the mycelial growth of *L. theobromae.*

A survey conducted for rhizome rot of banana in Tamil Nadu, Andhra Pradesh and, West Bengal revealed 8-10% of the disease incidence in different cultivars and the incidence was high in tissue cultured banana seedlings. The incidence was noticed during early stage of planting (2-5 months after planting) and 36 different isolates of rhizome rot pathogen were isolated. Pathogenicity of rhizome rot pathogen was proved in Ney Poovan banana seedlings.

Comparison of complete genome of banana bract mosaic virus (BBrMV) North Eastern Hill with three other isolates showed distinguishable variation in phylogenic tree. One isolate (TN11) out of 49 BBrMV isolates recorded evidence of recombination. Seed transmission of BBrMV was confirmed besides lace wing bug (*Stephanitis typica)* as additional vector. Occurrence of CMV in *Musa ornata* was recorded for the first time. Using MVR-RNAi and hairpin-rep (BBTV) constructs, 22 putative transgenic lines of Hill banana were developed. ECS derived banana bunchy top virus (BBTV) free Hill banana plants showed significant differences in the growth and yield parameters compared to sucker grown plants in second ratoon crop however, it was on par with tissue culture raised plants.

Under proteomic analysis of host–banana bunchy top virus (BBTV) interaction study, through *in–silico* analysis six eIF4E were identified in cv. Nendran. After designing gene specific primers and standardizing PCR conditions, all six eIF4E genes from cv. Nendran were amplified, cloned, sequenced and submitted in NCBI genbank. Further these six genes were sub-cloned in bait and prey vectors for studying the direct interaction of these gene with VPg of BBrMV in yeast system. To study the BBTV infectious cycle in Hill banana, the proteins from infected leaf tissues collected at different intervals were isolated and proteomic studies are in progress.

Transfer of Technology

More than 4500 farmers, scientists from both India and abroad, state agricultural and horticultural officers, various entrepreneurs, students and other stakeholders visited ICAR-NRCB, interacted with scientist and technical staff of ICAR-NRCB and shared their knowledge on banana cultivation and got trained and exposed to various technologies developed at this centre. Eight radio talks, four television talks and twenty five press notes in various dailies and magazines were published by ICAR-NRCB. The institute has participated/ organized 13 exhibitions at state / National levels and a total of nine on-campus and five off-campus trainings were conducted to farmers and entrepreneurs. Ten seminars / conferences / symposia / workshops / meetings were conducted at the Centre during the year. Totally 48 seminars / conferences / symposia / workshops / meetings were attended by the scientists of ICAR–NRCB at regional / National / International levels. Technologies on post harvest handling, packing and storage etc. were transferred to 49 entrepreneurs. A total of 5950 banana cv. Udhayam were distributed to banana growers of various districts of Tamil Nadu and other states.

Linkages and Collaborations

ICAR–NRCB has research collaborations with International institutes which include IITA, Nigeria; Bioversity International, France; KUL, Belgium and University of Queensland, Australia. The institute has linkages with National institutes, namely, BARC, Mumbai; DST and DBT, New Delhi; APEDA ; TNAU, Coimbatore; NIT, Tiruchirapalli and KNCET, Thottiyam, Tamil Nadu. The centre has research collaborations with other ICAR institutes namely, ICAR–NBPGR, New Delhi;

ICAR–IIHR, Bengaluru and ICAR–CIAE (RS), Coimbatore. Under DBT-NER, more than 50 institutes located in different parts of the country are being associated with ICAR-NRCB. ICAR–NRCB also coordinates with ICAR-AICRP (Fruits) centers (11 Nos.) working on banana. Tissue culture industries involved in banana mass propagation, farmers, exporters, State Horticulture and Agriculture departments and self-help groups are linked with the centre for various research and developmental activities.

HRD and Education

Under Human Resource Development, four scientific, eight technical, two administrative and three supporting staff of ICAR–NRCB had undergone various training programs and updated their working knowledge. The centre has published 12 research papers in various journals of International and National repute and 25 research papers were presented in various conferences / symposia / seminars, etc. held across the country. Twenty students pursuing B. Tech., M. Tech., M. Sc., & Ph. D. degrees from different Universities were guided by the centre's scientists for their dissertation work on banana of which 3 students have completed and awarded doctorate from Bharathidasan University, Trichy.

Revenue Generated

A sum of Rs. 81,85,962/- was generated by the centre during the financial year 2017 - 18.

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

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

Collection

Primary sources

The North Eastern regions of India covering Assam, Arunachal Pradesh, Nagaland and Manipur was surveyed and collected 15 *Musa* accessions including *Musa nagensium, M. sikkimensis, M. itinerans, M. cheesmanii and* ornamental *Musa* species like *M. aurantiaca, M. velutina* and *M. velutina* variants (Table 1 & Fig.1).

Secondary sources

A total of 29 accessions have been collected from Banana Research Station, Kannara, Kerala (7); Salem (1), Kanyakumari (1) and Anaimalai hills (2) of Tamil Nadu, Assam Agriculture University, Jorhat, Assam (10) and University of Horticulture Sciences, Bagalkot, Karnataka (8) and added to the genebank (Table 2).

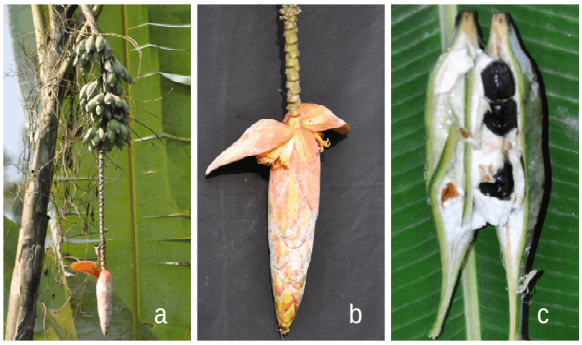


Fig. 1. *Musa nagensium* – collected for the first time from Changlang district of Arunachal Pradesh. a) Habit; b) Male flower bud; c) LS of fruit

Introduction

Seventy three exotic accessions have been introduced from ITC, Belgium through ICAR-NBPGR, New Delhi in two batches. Of which, 19 accessions have been regenerated and planted in the field and the rest are in various stages of regeneration (Table 3).

Table 1. List of collections from primary sources

S.No.	Accession name	Section	State
1	*Musa sikkimensis Type I*	Eumusa	Arunachal Pradesh
2	*Musa nagensium Type I*	Eumusa	-do-
3	*Musa itinerans Type I*	Eumusa	-do-
4	*Musa nagensium Type I*	Eumusa	-do-
5	*Musa itinerans Type II*	Eumusa	-do-
6	*Musa itinerans Type III*	Eumusa	Nagaland
7	*Khunsang Wild type*	Eumusa	-do-
8	*Musa itinerans Type IV*	Eumusa	-do-
9	*Musa rosaceae*	Rhodochlamys	-do-
10	*Musa velutina variant I*	Rhodochlamys	-do-
11	*Musa aurantiaca*	Rhodochlamys	-do-
12	*Musa velutina variant II*	Rhodochlamys	-do-
13	*Musa sikkimensis Type II*	Eumusa	-do-
14	*Musa cheesmanii*	Eumusa	Manipur
15	*Musa ochracea*	Eumusa	-do-

Table 2. List of collections from secondary sources

Centre	Collections
BRS, Kannara, Kerala	Pisang Madu, Paka, Suganthi, PA 03 -22, PV 03-44, Pisang Mulick, TMB -15108-6
AAU, Jorhat , Assam	Bhimkol, Athiakol, Honda, Jatikol, Manohar, Digjowa, Assamese Malbhog, Manjahji, Lesari Manohar, Fesa Manohar
Marthandam, Kanyakumari, Tamil Nadu	*Musa siamea*
Shervaroy Hills, Salem, Tamil Nadu	Ladan
Anaimalai Hills, Pollachi, Tamil Nadu	*M. acuminata* ssp. *burmannica, Ensete superbum*
UHS, Bagalkot, Karnataka	Rajapuri, Sakkarabale, Karibale, Budumitika, Bargibale, Budubale Shanbale, Mitli

Table 3. List of accessions introduced from ITC, Belgium during 2017-18

Sl.No.	ITC No.	Accession Name	Genome	Ploidy
1	ITC 0005	Guineo	AAA	3x
2	ITC 0063	Pisang Tongat	AA	2x
3	ITC 0090	Tjau Lagada	AA	2x
4	ITC 0094	Balbisiana(10852)	BB	2x
5	ITC 0180	Grand Naine	AAA	3x
6	ITC 0200	Kelong Mekintu	AAB	3x
7	ITC 0217	Akpakpak	AAB	3x
8	ITC 0258	Pisang Madu	AA	2x
9	ITC 0280	Rajapuri India	AAB	3x
10	ITC 0319	Biu Ketip	AAA	3x
11	ITC 0433	Pisang Mulick	AA	2x
12	ITC 0446	Pu-te La-Bun	AA	2x
13	ITC 0448	Pisang Keling	AAB	3x
14	ITC 0471	Bebek	AA	2x
15	ITC 0530	A 3617	AA	2x
16	ITC 0727	Phang	AA	2x
17	ITC 1067	THA018	AA	2x
18	ITC 1287	Pisang Berangan	AAA	3x
19	ITC 1520	*Musa acuminata* (11/9-02)	AA	2x

Morphotaxonomic characterization

Morpho-taxonomic characterization has been completed for three Saba based hybrid progenies, one progeny each of the cross Pisang Jajee x Matti (Pisang jajee x Lairawk), 11 indigenous accessions, and four ITC accessions leading to the identification of their genomic and sub-groups (Table 4).

Table 4. List of accessions morphotaxonomically characterized during 2017-18

S. No.	Accession No.	Accession name	Genome assigned	Sub-group assigned
1.	2428	Kadali	AA	Unique
2.	2457	Uthiran	AAB	Pome
3.	2458	Durga	AAA	Manoranjitham
4.	2459	Mathuranga	ABB	Monthan
5.	2447	Ambiamor	AAA	Cavendish
6.	2449	Mutheli	ABB	Pagar Banana
7.	2472	G-9 dwarf	AAA	Cavendish
8.	2450	Hanuman	AAA	Amrit Sagar
9.	2434	Champa Gante	AAB	Unique
10.	2443	Jahaji Mutant	AAA	Cavendish
11.	2446	Pachakadali	AAB	Unique
12.	ITC 0005	Guineo	AAA	Unique
13.	ITC 0279	Byiong	AA	Plantain
14.	ITC 1129	Big Ebanga	AAB	FHP
15.	ITC 0504	FHIA 01	AAAB	Pome
16.	Progeny No.97	Pisang Jajee x Matti	AA	Unique
17.	Progeny No.148	Pisang Jajee x Lairawk	AA	Unique
18.	Progeny No.690	Saba x Pisang Lilin	ABB	Bluggoe
19.	Progeny No.685	Saba x Pisang Lilin	ABB	Bluggoe

Registration

Passport data of 81 unique germplasm accessions have been submitted to ICAR-NBPGR, New Delhi and IC nos. from 0623553 to 0623633 have been obtained.

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

Field evaluation of cv. Udhayam derived from three different explants namely shoot tip, cormlet and male flower bud along with suckers as control was conducted at farmers field, Malliyampathu and the results indicated that the flower bud derived plants yielded on an average 26 kgs in 373 days as against sucker control of 20.3 kgs in 391 days. All yield related parameters were found to be significant among the treatments except for acidity (Table 5 & Fig. 2).

Table 5. Yield data of tissue culture plants derived from different explants of cv. Udhayam

S.No.	Explant	Bunch weight	Total No. of hands	No. of fruits per hand	Total No. of fruits	Crop duration	TSS	Acidity
1	Sucker	20.30	14.00	19.10	287.00	391.00	30.00	0.60
2	Shoot tip	19.00	13.20	18.10	208.40	433.00	29.10	0.58
3	Cormlet	18.00	13.00	18.00	184.10	406.00	26.10	0.60
4	Male bud	26.00	15.40	19.10	300.10	373.00	29.40	0.60

Explants - Sucker | Explants - Shoot tip | Explants - Male flower bud | Explants - Cormlet

Fig. 2. Bunches of tissue culture plants derived from different explants of cv. Udhayam

Supply of planting material

Fifty tissue cultured plants each of cvs. Rasthali and Sabri have been supplied to Tripura University for field evaluation. Hundred tissue cultured plants of cv. Rasthali have been supplied to Assam Agricultural University, Jorhat for evaluation against *Fusarium* wilt. Disease free healthy suckers of 44 accessions in duplicate have been supplied to ICAR-NBPGR for *in vitro* conservation. Disease free healthy suckers of germplasm have been distributed to UAS, Arabhavi; Department of Horticulture, Basti (Uttar Pradesh); TNAU, Coimbatore, ICAR-RCER, Regional station – Ranchi; KVK, Ariyalur and FRS, Vengurla for evaluation purpose. Around 5949 plants of tissue cultured cv. Udhayam have been distributed to farmers through M/s. Shaanti Agrotech, Bengaluru. Around 250 shoot tip explants of cv. Udhayam have been supplied to M/s. Shaanti Agrotech, Bengaluru for mass multiplication purpose. Mother cultures of cvs. Udhayam and Grand Naine have been supplied to M/s. Aranya Agri Biotech, Gujarat.

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

The core collection comprising of 311 accessions have been planted in two phases in sick plot at Muthalapuram, Theni District of Tamil Nadu for screening against *Fusarium* wilt race 1 (Theni *Foc* VCG 0124). Internal scoring on the disease scale (0-5) has been completed for the first batch of 231 accessions. Preliminary results indicated that three AA diploids, two *M. balbisiana* types, two Cavendish clones, seven Mysore types, five Pome types, and one each of Unique and hybrid accessions were found to be resistant to *Fusarium* wilt.

Evaluation of NRCB selections 6 and 7 along with local check at ICAR-NRCB

Performance evaluation of ICAR-NRCB selections 6 and 7 was carried out at ICAR-NRCB farm, Tiruchirappalli with local cvs. Monthan & Adukku Monthan respectively as local checks. Results indicated that Selection 6 was on par with the local check in terms of crop duration, bunch weight, number of hands, number of fruits per hand etc. Selection 7 was superior to its local check in terms of crop duration and bunch weight (Table 6).

Evaluation of NRCB selection 11 at plains and hills of Tamil Nadu

ICAR-NRCB selection 11 (Manoranjitham variant) was evaluated in plains and hills. Results showed that the performance was better at higher elevations in terms of higher bunch weight (18.5 to 22.5 kgs) and plant height (4.3-4.5 m). However, crop duration was longer (410-415 days) as against bunch weight of 8 kgs, 3.5 m height and crop

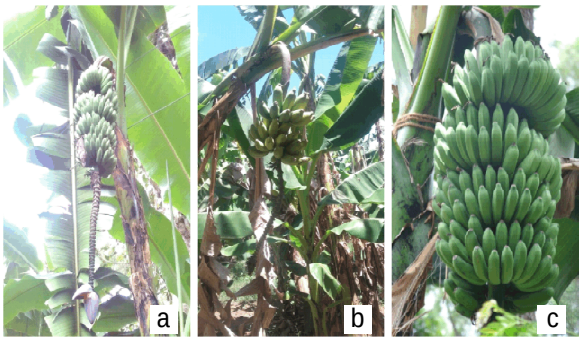


Fig. 3. NRCB selection 11 at maturity. a) Pulney Hills, b) ICAR-NRCB, Tiruchirappalli, c) Kolli Hills

Table 6. Evaluation of NRCB selections 6 and 7 along with their respective local check at ICAR-NRCB, Tiruchirappalli

Characteristics	NRCB Selection 6	Local Check (Monthan)	NRCB Selection 7	Local Check (Adukku Monthan)
Height (cm)	366.8	367.0	356.8	360.5
Girth (cm)	80.4	82.2	85.1	82.5
Days taken for flowering	315.0	318.0	295.0	302.0
Days taken for fruit maturity	116.0	113.6	115.0	120.5
Duration in days	431.2	431.6	410.0	422.5
Bunch weight (kg)	21.7	21.4	20.8	19.0
No. of hands	6.8	6.2	8.6	9.0
No. of fruits per hand	13.0	12.2	12.5	12.0
Total no. of fruits	93.0	79.2	111.5	118.0

Table 7. Comparative data on growth and yield parameters of NRCB selection 11

Characteristics	ICAR-NRCB, Tiruchirappalli (Plains)	Kolli Hills (1350 m above MSL)	Pulney Hills 1500 m above MSL)
Height (m)	3.5	4.5	4.3
Girth (cm)	75.0	98.0	86.0
Days taken for flowering	240.5	295.0	299.0
Days taken for fruit maturity	105.0	120.5	119
Duration in days	355	415	410
Bunch weight (kg)	8.0	22.5	18.5
No. of hands	8	9.0	9.0
No. of fruits per hand	15	18	16.0
Total no. of fruits	120	162	144

duration of 355 days in plains (Table 7). The fruits were highly fragrant and it was retained even after cold storage at 13^{0}C (Fig. 3).

Evaluation of dwarf mutants of Giant Cavendish (in collaboration with BARC, Mumbai)

Eight mutant lines of Giant Cavendish inclusive of control and one mutant line TBM-9 were received from BARC, Mumbai. Suckers were planted at ICAR-NRCB, Tiruchirappalli, Tamil Nadu and tissue cultured plants were planted in the farmers field at Malliyampathu, Tiruchirappalli, Tamil Nadu. The mutant line TBM 9 performed better in the farmers field yielding an average of 26.8 kg in a crop duration of 302.4 days and the average plant height was 1.69 m which is lesser than the control (Fig. 4a, 4b & 4c.)

Fig. 4a. Dwarf mutant lines from BARC, Mumbai planted at ICAR-NRCB farm, Tiruchirappalli

Fig. 4b. Field view of TBM-9 planted at farmer's field at Malliyampathu, Tiruchirappalli

Fig. 4c. TBM-9 with bunch weight of 29 kg

Front line demonstration of NRCB selections 8 and 9

Front line demonstration was done through KVK, Nagercoil in a farmers field. Performance of NRCB selections 8 and 9 were assessed with local Monthan and Naadu as checks respectively. Results indicated that selection 8 was found on par with local check in terms of crop duration and yield, however the number of hands and total no. of fruits were higher in the selection. In case of selection 9, though the duration was higher than the local check, the yield parameters namely number of hands, number of fruits per hand and total number of fruits were higher in selection 8 (Table 8 & Fig 5).

Fig. 5. Front line demonstration of NRCB selections 8 and 9

Table 8. Growth and vegetative parameters of NRCB selections 8 and 9 as against their local checks in the FLD at Nagercoil of Kanyakumari district, Tamil Nadu

Characteristics	NRCB Selection - 8	Local Check (Monthan)	NRCB Selection - 9	Local Check (Naadu)
Height (cm)	378.4	367.0	371.5	320.0
Girth (cm)	78.0	82.2	85.1	68.0
Days taken for flowering	314.6	318.0	294.0	280.0
Days taken for fruit maturity	113.2	113.6	107.8	110.0
Duration in days	427	431.6	401.8	390.0
Bunch weight (kg)	22.9	21.4	23.5	15.5
No. of hands	9.0	6.2	8.5	7.5
No. of fruits per hand	13.4	12.2	12.8	12.0
Total no. of fruits	123.2	79.2	113	92.0

Pot screening of ICAR-NRCB selections against *Fusarium* wilt disease race-1 (*Foc*)

ICAR-NRCB selections of various genomic groups have been evaluated against *Foc* under pot culture conditions. All cooking banana types recorded disease score ranging from 3-4, while Manoranjitham variant (AAA) was recorded as resistant and Popoulou (AAB) as tolerant (Table 9).

Establishment of somatic embryogenesis in commercial banana cultivars

Embryogenic calli have been successfully developed in five different banana cvs. Ney Poovan (AA), Red Banana (AAA), Sabri (AAB), Monthan (ABB) and Karpooravalli (ABB) (Fig. 6).

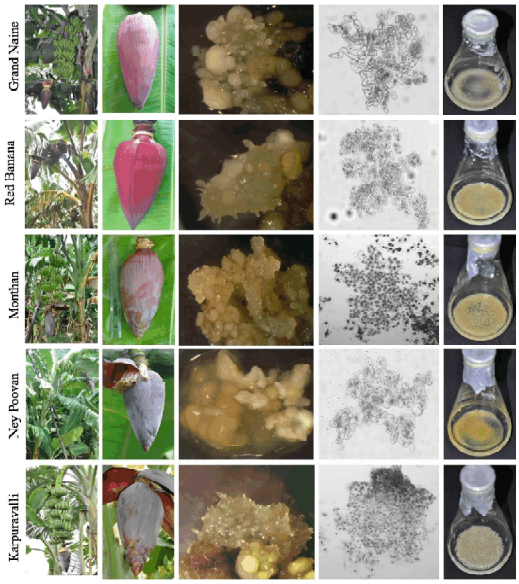


Fig. 6. ECS established from different commercial cultivars

Table 9. Disease scores of ICAR-NRCB selections against *Foc*

S. No.	Cultivar	Genome	Average disease score
1	NRCB selection 11	AAA	0.0
2	Pacha Bontha Batheesa	ABB	3.3
3	Ashy Batheesa	ABB	4.0
4	NRCB selection 7	ABB	3.0
5	NRCB selection 6	ABB	4.3
6	Bainsa	ABB	3.0
7	Nutepong	ABB	3.0
8	Popoulou	AAB	2.0

Regeneration and germination efficiency of Embryogenic Cell Suspension (ECS) obtained from different cultivars

Somatic embryogenesis protocol has been standardized for three cultivars namely Ney Poovan, Red Banana and Sabri. ECS of cv. Ney Poovan (Cell line- NNFB T5) produced 4000 somatic embryos from 1mL settled cell volume (SCV). While ECS of cvs. Red Banana (Cell line- NRBFB T13) and Sabri (Cell line- NSFB T2) produced 5600 and 5950 somatic embryos from 1mL SCV respectively (Fig.7A & B).

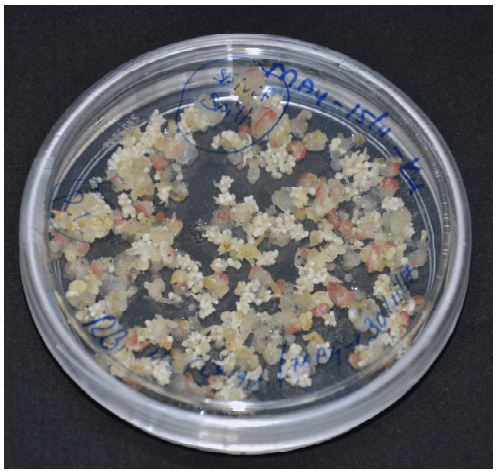


Fig. 7A. Red Banana ECS

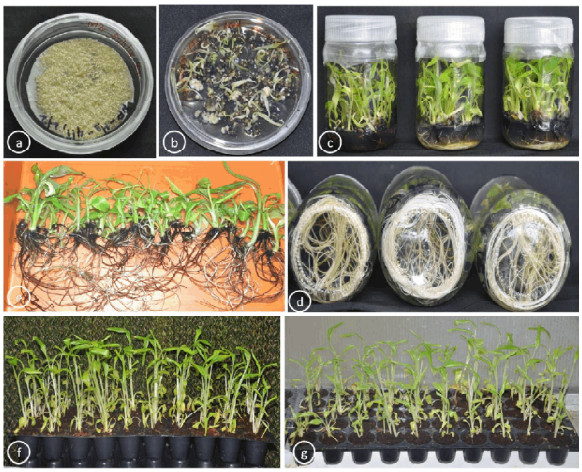


Fig. 7B. Ney Poovan(NNFBT5) ECS a) Somatic embryo regenerated from ECS, b) Germinated plants from somatic embryos, c) Shooted plants, d) Rooted plants, e) Plants subjected to hardening, f & g) Plants at primary hardening stage

In cv. Ney Poovan, around 80% germination of somatic embryos was observed in modified germination medium. The average root and shoot lengths of the ECS derived plants of Red banana were 14 cm and 8 cm respectively.

Scaling up the production of banana plantlets

Production of large scale plantlets from embryogenic cell suspension culture using bioreactor has been standardized for different cultivars of banana cvs. Grand Naine, Rasthali and Sabri. One ml embryogenic cell suspension of cv. Grand Naine produced *ca* 45,000 plantlets while Rasthali produced 12,000 plantlets (Fig. 8).

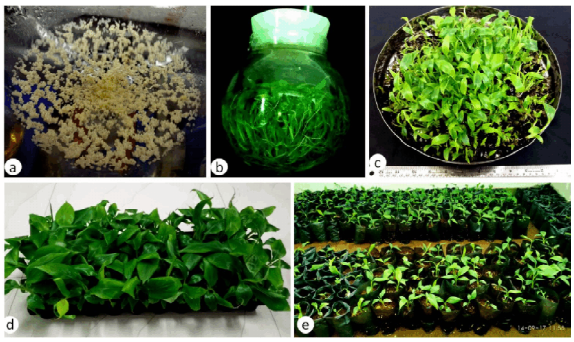


Fig. 8. High-throughput large scale production of banana plantlets. (a) Matured somatic embryos (b) Germinated plantlets (c) Development of plantlets (d) Primary hardened plants (e) Plants in secondary hardening

Maintenance of ornamental banana germplasm

The ornamental banana species like *Musa laterita, M. ornata, M. siamensis, M. rubra, M. velutina, M. velutina* intersectional hybrids, *M. beccari, M. aurantiaca, M. coccinea* and *Ensete glaucum* are being maintained at ICAR-NRCB farm.

Development of ornamental banana hybrids

Various cross combinations involving ornamental species like *M. laterita,* M. *ornata*, *M. rubra, M. velutina* and *M. siamensis* have been attempted. A total of 575 hybrid seeds have been extracted from the ripe bunches. Only

34% of the seeds had embryos and they are in various stages of regeneration. One hundred and twelve hybrid progenies are in secondary hardening which includes 95 open pollinated progenies of *M. velutina.*

Identification of fruit volatiles from cv. Manoranjitham

Totally 21 volatile compounds have been identified from fruits of cv. Manoranjitham. Out of 21 compounds, four volatile compounds namely Oxacyclohexadecan-2-one (1.13%), 2-Dodecylcyclobutanone (0.65%), Chrysantenyl 2-methylbutanoate (0.95%) and Hexanoic acid heptadecyl ester (0.49%) contribute apparently for their fragrance (Fig. 9). While in other bananas the volatile components responsible for aroma detected through GCMS analysis include *E*-2-hexenal, limonene and eugenol.

4.1.2 Improvement of banana through conventional breeding

Development of Sigatoka leaf spot (*Mycosphaerella eumusae*) resistant hybrids

The sigatoka leaf spot susceptible cv. Poovan was crossed with Calcutta 4, Pisang Lilin, cv. Rose, SH-3436-9 and *Musa microcarpa*. Totally 314 hands of Poovan were crossed and resulted in 478 hybrid seeds (Poovan x Calcutta 4 - 354 seeds; Poovan x Pisang Lilin – 110 seeds; and Poovan x cv. Rose – 4 seeds). Though per cent seed set and viable embryos were maximum in Poovan crossed with *M. microcarpa* and Calcutta 4, none of them germinated. The maximum seed set per hand was recorded by Pisang Lilin (2.3 seeds per hand), followed by Calcutta 4 (1.5 seeds per hand) and cv. Rose (0.12 seeds per hand). Out of 478 seeds, 119 embryos (24.1%) have been recovered and cultured *in vitro*.

Studies on increasing the seed set in banana

To increase the seed set, different pollination techniques were used *viz.,* control (single pollination), pioneer pollen technique (double pollination) and pollination with sucrose 5 % + boric acid 100 ppm. The results indicated that the seed set in cv. Poovan was increased from 0.44 seeds per hand to 3.43 seeds per hand by the application of pioneer pollen and chemicals, using Pisang Lilin as male parent. Similarly, the seed set was increased from 0.1 seed per hand to 0.14 and 0.25 seeds per hand using pioneer pollination and chemicals respectively, using cv. Rose as male parent. In case of Calcutta 4, there was not much significant difference among the pollination methods attempted.

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

Evaluation of phase I Nendran based progenies revealed that progenies NCR 17, NCR 18, NCR 2 and NOP 43 recorded higher yield (>15kg) than their parents. Four progenies namely NCR 17 (40%) (Fig. 10a), NCR 2 (30.6%), NCR 18 (30.6%) and NOP 43 (21.3%) recorded 20% higher yield than the female parent Nendran. All progenies involving

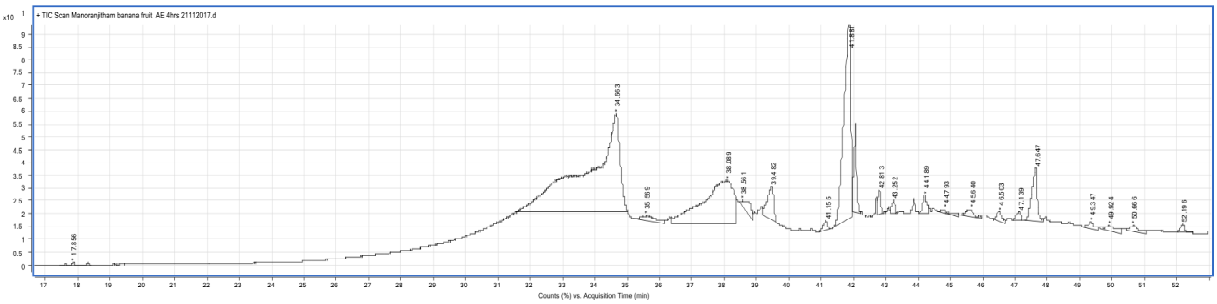


Fig. 9. Manoranjitham banana fruit HSS-GCMS chromatogram

either cv. Rose or Pisang Lilin as male parents (except NCR 19) produced more number of fingers per bunch than the female parent Nendran. The progeny NPL 33 recorded more number of fingers (102) than their parents (Fig. 10b). Four progenies namely NCR 28, NCR 30, NPL 36 and NOP 45 recorded significantly low pulp peel ratio than the female parent Nendran (2.97). Whereas maximum pulp peel ratio of 5 was recorded in NOP 46. Maximum fruit length was recorded in NCR 2 (29 cm) followed by NRC 21 (28 cm) which was more than the female parent (26 cm), whereas all the hybrids except NCR 12, NCR 19 and NOP 47 (16) recorded low fruit girth than cv. Nendran (16 cm).

To develop nematode resistant Nendran progenies (phase II), cv. Nendran was crossed

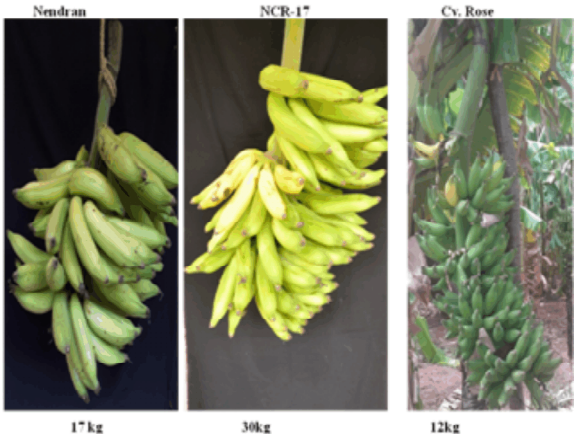


Fig. 10a. High yielding Nendran based progenies

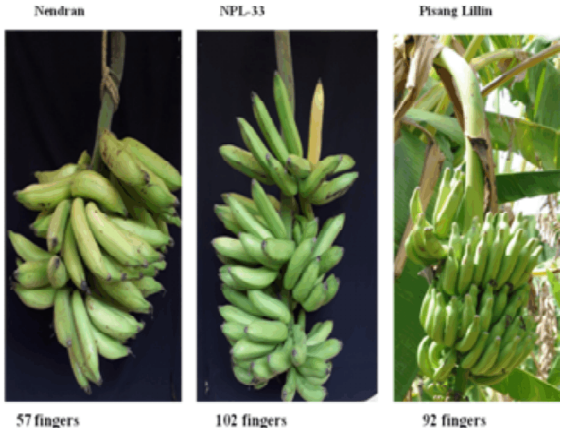


Fig. 10b. Promising Nendran based progenies for number of fingers

with various male parents namely Calcutta 4, *M. microcarpa*, Pisang Jajee and SH 3436-9 and maximum number of seed set (211) and embryos (31) was obtained in Nendran x Calcutta 4. Whereas, only two embryos could be obtained from the cross combinations namely Nendran x cv. Rose and Nendran x Pisang Jajee.

Pyramiding of resistant genes through three way crosses

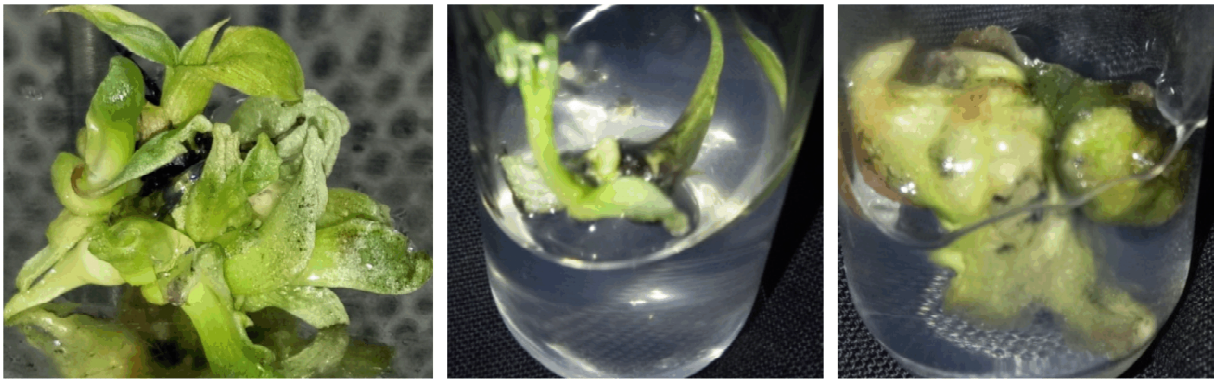
Three way crosses have been made in seven progenies using Pisang Lilin as male parent and seed set was observed in all combinations. But none of the embryos of these cross combinations developed into plantlets. At the same time, three and 19 progenies could be developed from the cross combinations, progeny 148 x Lairawk and progeny 207 x cv. Rose respectively.

Regeneration and evaluation of open pollinated progenies

Open pollinated seeds were obtained from 33 accessions which includes six progenies. Of which, more number of seeds were extracted from Chinia followed by Progeny No. 690. Interestingly, first time seed setting was observed in Chinese Cavendish and only one embryo could be extracted from 15 seeds. This information suggested that among the Cavendish types, Chinese Cavendish is having residual female fertility and could be used as female parent for improving the Cavendish group of bananas. Maximum number of embryos could be obtained from Chinia (69) and Enna Benian (61) whereas, no embryo was obtained from cv. Manoranjitham. A total of 28 plantlets have been regenerated from open pollinated seeds with maximum number of plantlets (7) from Kothia and Nepali Chinia.

Development of multiple shoots from embryo culture

To develop true to type and more number of plantlets from single embryo, media



Poovan x Pisang Lilin | Nendran x Calcutta 4 | Karpuravalli x Pisang Jajee

Fig. 11. Development of multiple shoots from embryos of various cross combinations

composition was modified. A total of 44 embryos developed multiple shoots from 10 cross combinations and 7 open pollinated accessions (Fig. 11). Cross combinations involving Calcutta 4 either as female or male recorded the best results for developing multiple shoots.

Identification of improved diploids

Diploid x Diploid crosses

Progeny No 97 (Pisang Jajee x Matti)

Parthenocarpic fruit development was observed with a bunch of 5-6 hands with an average bunch weight of 5-6 kgs. Fruits are shorter with 9-10 cm in length, tapering towards the distal end having persistent style.

Fig. 12. Progeny No 97 (Pisang Jajee x Matti)

Pulp is creamy white and slightly acidic in taste. It produces profuse pollen grains which are highly viable in nature (98 - 99%) (Fig. 12).

Triploid x Diploid crosses

Progeny No 792 (Udhayam -ABB x Pisang Lilin -AA)

An unique diploid (AA) progeny has been developed. This has fertile pollen and aromatic fruits. Duration is 350 days. Pseudostem is 1.6 –1.7 m height, bunch is cylindrical, fruit hands are compactly placed and the fruits completely turned towards the peduncle. It takes 120-130 days for bunch maturation. Fruits are completely parthenocarpic in nature with a bunch weight of 7 kg and the pulp is sweet with aromatic flavor (Fig. 13).

Fig. 13. Progeny No 792 (Udhayam -ABB x Pisang Lilin -AA)

Evaluation of starchy hybrids

Progeny No 685 (Saba x Pisang Lilin) and Progeny No 690 (Saba x Pisang Lilin) which were identified for their high yield and good cooking quality. They were evaluated further during the reporting period and recorded an yield of 42.5 kg and 38.5 kg respectively which is 81 and 64% higher over the female parent (Saba) (Fig. 14a & b).

Fig. 14a. Progeny No 685 Fig. 14b. Progeny No 690

Evaluation of banana hybrids for *Fusarium* wilt, race-1 (*Foc*) resistance under pot culture conditions

A) Kothia based progenies

A total of 43 Kothia (ABB) based progenies were evaluated against *Foc* under pot culture (Table 10), of which progeny number 528 (Kothia x Calcutta 4) was found to be resistant as it recorded '0' score followed by progeny number 515 (Kothia x Pisang Lilin), 538 (Kothia x Calcutta 4) and 567 (Kothia x Pisang Jajee) which recorded a disease score of '2'.

Table 10. Disease scores of Kothia based progenies tested against *Foc*

Progeny No.	Parents		Average score
	Female	Male	
515	Kothia	Pisang Lilin	2
528	Kothia	Calcutta -4	0
538	Kothia	Calcutta -4	2
567	Kothia	Pisang Jajee	1
91	*M. laterita*	Pisang Jajee	1

B) Improved diploids (AA)

Three improved diploids namely progeny 21, 97 and 148 were screened against *Foc*, of which progeny 21 (*Musa laterita* x Pisang Jajee) was found to be moderately resistant as it scored '1' (Table 11).

Table 11. Disease scores of improved diploids against *Foc*

Progeny No.	Parents		Average Score
	Female	Male	
21	*M. laterita*	Pisang jajee	1
97	Pisang jajee	Matti	3
148	Pisang jajee	Lairawk	3

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

A total of 72 core collection accessions representing various genomic groups namely AA (6), BB (7), AB (9) AAA (15), ABB (5) and AAB (30) were established in pots with five replications each. Out of 64 accessions screened for *Fusarium* wilt resistance (VCG 0124) under pot culture conditions, none were found to be resistant.

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

Cv. Grand Naine

Totally 140 numbers of male flower buds have been initiated in callus induction medium towards the establishment of ECS. LD_{50} has been determined for sodium azide using shoot tip explants (0.01% for 3 hrs) of cv. Grand Naine. The mutated plants of cv. Grand Naine derived from different mutagens and explants are presented in the Table 12 & Fig. 15.

Table 12. Status of putative mutants of cv. Grand Naine

Mutagen	Explants	No. of plants in *in-vitro*	No. of plants in primary hardening	No. of plants in secondary hardening
EMS	Shoot tip	-	120	-
	ECS	360	260	300
DES	Shoot tip	-	100	-
	ECS	240	210	210
Sodium Azide	Shoot tip	140	-	-
	ECS	15	-	-
	Total	755	690	510

Fig. 15. Primary hardening of cv. Grand Naine mutants derived from EMS

Cv. Rasthali

Sick plot screening of 35 putative mutants of cv. Rasthali at Muthalapuram, Theni, Tamil Nadu indicated that NRCB RM 217 and NRCB RM 100 yielded a normal bunch of 10 kg and 12 kg despite internal disease score of 5 and 6 respectively. They are under *in vitro* multiplication for large scale field evaluation (Fig. 16a & b).

a) NRCB RM 100 b) NRCB RM 217

Fig. 16 a&b. Fusarium wilt resistant mutants in bearing under sick plot conditions at Theni, Tamil Nadu

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

Developed methodology to identify highly vacuolated uninucleate stages in 10 banana cultivars / lines for anther culture

Identification of microspore developmental stages *viz*. PMC, dyad, tetrad, highly vacuolated uninucleate stage and matured pollen stages are a pre-requisite in anther culture for the production of haploids. We have identified the highly vacuolated uninucleate stage in 10 banana cultivars (Fig. 17) which were usually located with bract with

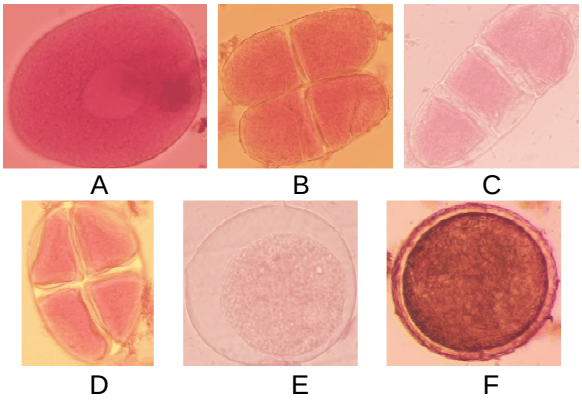


Fig. 17. Developmental stages of highly vacuolated uninucleate microspore stages in banana (a) PMC, (b) Diad, (c) Triad, (d) Tetrad, (e) Highly vacuolated uninucleate microspore and (f) Matured pollen grain

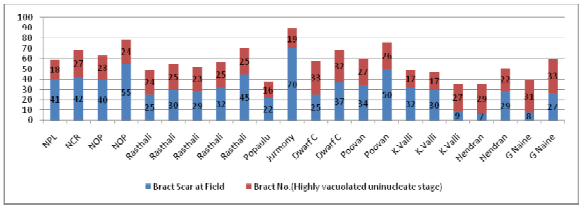


Fig. 18. Highly vacuolated uninucleate microspore stages in different banana cultivars/lines

No. 16 (Popoulu) to No. 32 (Grande Naine) (Fig. 18). This stage varied according to the clones/lines as follows NPL (18), NCR (27), NOP (23), Rasthali (23), Jurmony (19), Poovan (26), Karpuravalli (17), Nendran (22). Further, this stage also varied with environmental conditions and number of bract scar after which the flower buds was collected from the plant. Usually the uninucleate stage was observed in older bracts when flower bud was collected from a peduncle having less number of bract scars.

4.1.7 Identification and evaluation of superior clones of cvs. Ney poovan (AB) and Grand Naine (AAA)

Survey and collection of elite clones

Surveys were made in Nagercoil and Tirunelveli districts of Tamil Nadu and Malapuram districts of Kerala for the collection of elite clones of cvs. Ney Poovan (AB – 2 Nos.) and Nendran (AAB – 17 Nos.). The elite clones of cv. Nendran *viz.*, high yielding Nendran, Quintal Nendran, Attu Nendran, Swarnamukhi and cv. Ney Poovan *viz.*, dwarf and high yielding clones have been established at ICAR-NRCB farm (Fig. 19 a&b and 20 a&b).

a. Dwarf Ney Poovan (5.5 feet) b. Clone No.13 (22 Kg)

Fig. 19a & b. Dwarf Ney Poovan (AB)

a. Clone No. 73 (1.20 m.) b. Clone No. 75 (1. 25 m.)

Fig. 20a & b. Dwarf clones of cv. Grand Naine (AAA)

First crop evaluation of the elite clones of cvs. Ney Poovan and Grand Naine indicated that their performance was superior for the traits for which they were identified. All the dwarf clones of Grand Naine exhibited plant heights less than 1.8 m and their yield ranged from 25-35 kg while the high yielding Ney Poovan clones produced bunches of 16-28 kg. The ratoon crop was significantly better than the first crop in both the varieties. The boxplot analysis (Fig. 21) showed that Ney Poovan collections were skewed towards lower yield,

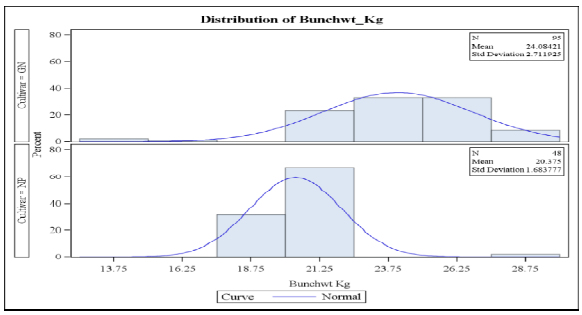


Fig. 21. Boxplot analysis

so further survey should emphasize more on the collection of high yielding clones. Similarly the Grand Naine collections were skewed towards dwarfness therefore, there is enormous potential to select dwarf Grand Naine clones from the present collections with moderate yield. Principal component analysis (PCA) grouped the elite clonal selections into three groups *i.e.,* 1. Dwarf / dwarf and high yielding clones of Grand Naine, 2. high yielding clones of Grand Naine and 3. high yielding clones of Ney Poovan.

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

4.2.1 Studies on nutrient dynamics in banana

Ney Poovan (Ratoon-2)

At harvesting stage in Ney Poovan (ratoon-2), a gradual increase in dry matter production (DMP) was observed in increasing levels of RDF of NPK from control to 150%. The highest DMP of 12622g was recorded at 150% RDF while control recorded 10665g. The total DMP in a plant was distributed in the order of bunch (3722g) > stem (2780g) > corm (1785g) > leaf (1502g) > peduncle (887g) > petiole (319g) > root (297g) > malebud (118g) (Fig. 22a). At harvesting stage, the total nutrient uptake (kg/ha), nutrient removal through bunch harvest (kg/ha) and nutrient recycled (kg/ha) by Ney Poovan were worked out (Table 13).

Rasthali (Ratoon-2)

At harvesting stage in Rasthali (ratoon-2), a gradual increase in DMP was observed in increasing levels of RDF of NPK from control to 150%. The highest DMP of 18564g was recorded at 150% RDF while control recorded 13909g. The total DMP in a plant was distributed in the order of bunch (5013g) > stem (3607g) > corm (3052g) > leaf (1946g) > peduncle (1014g) > root (494) > petiole

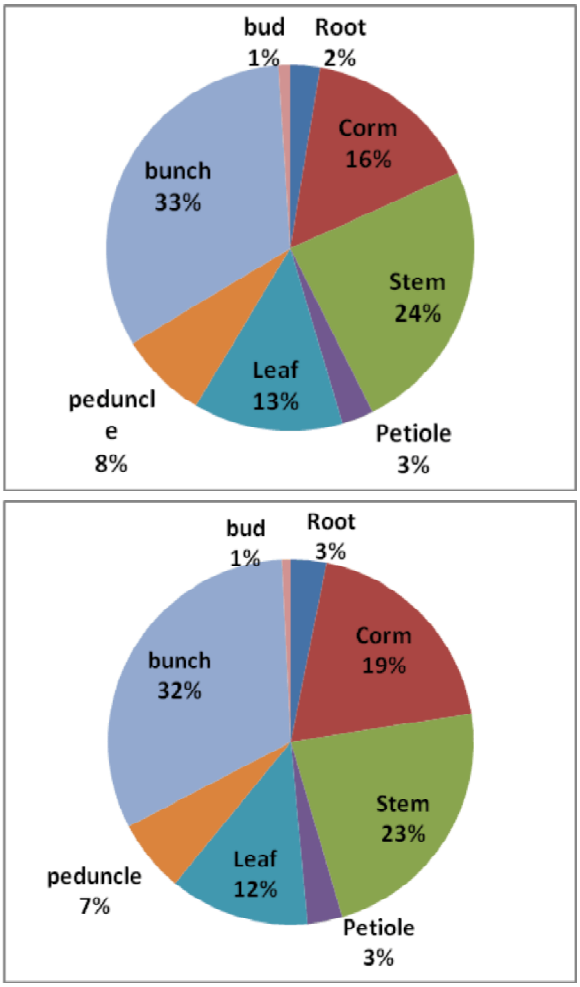


Fig. 22a & b. DMP fraction of Ney Poovan (r-2) and Rasthali (r-2) at harvest, respectively

Table 13. Uptake – Removal - Recycle of nutrients in ratoon-2 of Ney Poovan and Rasthali

Nutrients (kg/ha)	Ney Poovan (Ratoon-II)			Rasthali (Ratoon-II)		
	Total Uptake	Removed through bunch harvest	Recycled	Total Uptake	Removed through bunch harvest	Recycled
Nitrogen	393	124	269	394	157	237
Phosphorus	57	20	37	75	26	49
Potassium	943	488	455	1069	596	473
Copper	2.06	0.43	1.63	2.49	0.60	1.89
Manganese	6.36	0.59	5.77	4.77	0.44	4.33
Zinc	2.74	1.29	1.45	3.56	1.83	1.73
Iron	4.66	1.22	3.44	4.82	1.52	3.30

(485g) > malebud (124) (Fig. 22b). At harvesting stage, the total nutrient uptake (kg/ha), nutrient removed through bunch harvest (kg/ha) and nutrients recycled (kg/ha) by Rasthali were worked out (Table 13).

Vermicomposting of residues

After bunch harvesting, the residues were vermicomposted. The average nutrient concentrations (%) and nutrient contents (g/plant) in vermicompost generated from a single plant of Ney Poovan and Rasthali after harvest of bunch were estimated (Table 14).

Using Microsoft Excel software, cubic polynomial curves were generated nutrient uptake with respect to 3 leaf stage, 10 leaf stage, 20 leaf stage, shooting and harvesting for assessing nutrient accumulation pattern in Ney Poovan (r-2) and Rasthali (r-2). These cubic polynomial curves were used for predicting nutrient uptake and accumulations with respect to dry matter production, in different segments of Ney Poovan (r-2) and Rasthali (r-2) during these growth stages. The adjusted R^2 values between the predicted and observed values are high and ensure statistical integrity of the curve.

Nutrient budgeting based on these data, revealed that except potassium, the nutrient removal through bunch harvest is 2 to 10 times less than the nutrient recycling and only that much nutrient replenishment is sufficient for next banana cropping season but, 52-56% K replenishment is required. At shooting, ratoon-2 crop soil recorded Potential Buffering Capacity for K ($cmol.kg^{-1}(M/L)^{-0.5}$) of 50.68 while at harvesting, it was 49.88, which indicated significant K-mining, cautioning sufficient K-replenishment, during successive cropping season.

4.2.2 Organic banana farming for sustainable soil health and nutritional security

Under organic banana farming, highest leaf nutrient concentrations (%) and the highest nutrient uptakes (g/plant) were recorded in cv. Grand Naine at 20 leaf stage and shooting stage, with application of poultry manure + groundnut cake + rural compost + wood ash + VAM + PSB + KSB and were on a par with that 100% inorganically fertilised. The leaf nutrient concentrations (%) and uptakes (g/plant) (Table 15).The same treatment declined soil pH from 8.2 to 7.5, increased EC (dS/m) from 0.21 to 0.25 and organic carbon (%) from 0.12 to 0.69, at 20 leaf stage. The 'r' values for soil available nutrients (SAN) at 10 leaf stage vs. nutrient uptakes (NU) at 20 leaf stage were N=0.86**, P=0.77**, K=0.67*, Ca=0.64*, Mg=0.51*, while that of SAN at 20 leaf stage Vs. NU at shooting were N=0.84**, P=0.68*, K=0.76**, Ca=0.77**, Mg=0.74**, indicating

Table 14. Nutrients in vermicompost of residues of Ney Poovan and Rasthali after bunch harvest

Nutrients in vermicompost	Ney Poovan (Ratoon-II)		Rasthali (Ratoon-II)	
	Concentration	Contents (g/plant)	Concentration	Contents (g/plant)
Nitrogen	1.19%	101	0.70%	89
Phosphorus	0.17%	14	0.14%	18
Potassium	2.06%	177	1.36%	174
Copper	73.37ppm	0.63	53.13ppm	0.69
Manganese	259.97ppm	2.22	125.88pm	1.63
Zinc	63.26ppm	0.53	52.33ppm	0.67
Iron	146.28ppm	1.25	92.23ppm	1.23

Table 15. Leaf nutrient concentrations and nutrient uptake by Grand Naine at different growth stages.

Nutrients	20-leaf stage		Shooting stage	
	Leaf nutrient concentration (%)	Nutrient uptake (g/plant)	Leaf nutrient concentration (%)	Nutrient uptake (g/plant)
Nitrogen	2.78	96.3	2.65	174.9
Phosphorus	0.29	14.4	0.29	28.7
Potassium	3.12	196.6	3.21	317.8
Calcium	0.65	75.1	0.72	142.6
Magnesium	0.39	36.1	0.34	67.3

significant matching of nutrient releasing and uptake patterns in organic banana farming.

4.2.3 Development of clump management technology for enhanced productivity in Banana

In first ratoon of banana cv. Ney Poovan graded doses of fertilizers @ 125%, 150% and 175% recommended dose of fertilizer (RDF) per clump were imposed on four different plant populations of maintaining 1 or 2 or 3 or 4 suckers per clump along with the mother plant. A control treatment by adopting traditional farmers' practice of planting single sucker per pit at 2.0m X 2.0m spacing and allowing one sucker per plant after flowering of mother plant with 100% RDF was maintained. Observations recorded on various plant growth parameters, flowering, yield and yield attributes as well as plant nutrient status revealed significant differences among the treatment plants (Fig. 25).

In the ratoon crop of cv. Ney Poovan, plant growth parameters, yield and fruit characteristics were found significantly different among the treatment plants. The plants allowed with more number of suckers per clump at different stages of growth recorded taller plants with higher pseudostem girth as compared to the control plants of allowing one sucker after flowering of the mother plant. Treatment T6 (Mother plant + allowing one sucker each at 4th and 6th month after planting + application of 175% of RDF per clump) recorded the tallest plants (325 cm) while the pseudostem girth was highest in T7 (Mother plant + allowing one sucker each at 5th, 7th and 8th month after planting + application of 125% of RDF per clump) (72.3 cm) (Fig. 23 & 24).

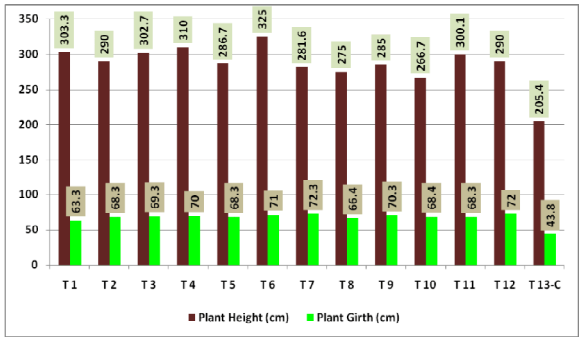


Fig. 23. Effect of number of plants per clump and fertilizers dosage on plant height and girth (cm) in cv. Ney Poovan (I Ratoon)

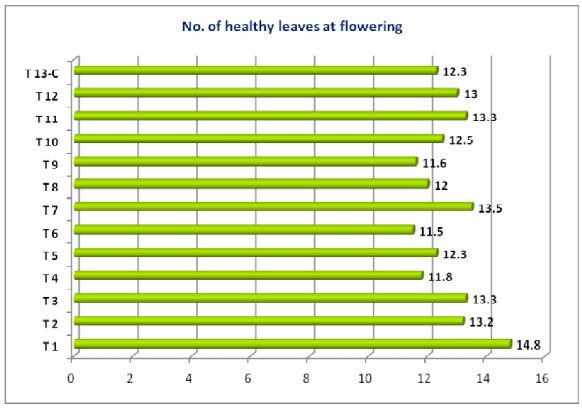


Fig. 24. Effect of number of plants per clump and fertilizers dosage on no. of healthy leaves in cv. Ney Poovan (I Ratoon)

Fig. 25. Mother plant with daughter suckers at different stages of growth in clump management trial in cv. Ney Poovan

The leaf growth characteristics in terms of leaf length and leaf breadth was found to be more in the tratment plants than control plants. Besides, the leaf length and breadth was the highest in the ratoon plants as compared to the mother plants.

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

Number of suckers on leaf production of banana

A trial was laid out in cv. Poovan to study the effect of number of suckers on leaf production by involving farmers' practices. First crop was allowed for fruits and the bunches were harvested. The yield of the first crop ranged from 9 to 13 kg per bunch during May to July 2017. The first ratoon was allowed for leaf purpose. In cv. Poovan, three suckers per hill produced maximum number of harvestable leaves, followed by four and five suckers per hill. Three suckers per hill produced 20.08 harvestable leaves per month with a leaf production ranging from 13 to 33 leaves, while four suckers per hill produced 17.0 harvestable leaves per month with leaf production of 12 to 19. However, 13.16 harvestable leaves per month were produced by five suckers per hill varied from 8 to 20. Similarly, total leaf area also varied from three (7.876 to 18.377 m^2) to five suckers per hill (4.977 to 13.569 m^2). Three suckers per hill produced leaf area of 0.743m^2 per month, while four suckers per hill produced 0.705m^2 per month and five suckers per hill produced 0.562 m^2per month.

4.2.5 Development of modified atmosphere packaging techniques in banana and plantain for domestic and export markets

Active packaging on extending the shelf-life of banana

Among the various treatment combinations (active packing materials *viz*., ethylene absorber, O_2 remover, moisture remover and CO_2 remover) employed, improved post-harvest handling treatments, followed by packing in polybag and kept at cold storage at 13.5^{0}C extended the shelf-life of banana cv. Grand Naine for 108, 94 and 60 days with respect to 75, 85 and 95% maturity, when compared to control, respectively without deterioration of quality parameters. Nendran harvested at 80-85% maturity with improved postharvest treatments and stored at 13.5^{0}C extended the shelf-life up to 32 days compared to control at room temperature (7 days). Among the various methods employed for ripening of banana cv. Grand Naine, fruits treated with ethylene gas (100 ppm for 24 hours) gave uniform colour development with shelf-life of six days at room temperature and 12 days at 22^{0}C storage temperature.

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

Standardization of driers for dehydration of banana slices

The removal of water from the banana slices was faster with vacuum drier (300 min.) whereas solar drier took 600 min. to complete the drying. In the sensory descriptors, the colour, texture, flavour and after taste was superior with vacuum drying conditions. Colour value of L: 62.42; a: -2.09 and b: 13.18

were recorded with vaccum oven drying. Solar direr tend to make the slices a bit darker with the value of 55.93. The swelling power of the cultivars Monthan, Saba, Nendran and Grand Naine was also studied. With the increase in temperature the swelling also increased. The order of increase was Monthan (13.27 %) > Saba (12.93 %) > Nendran (11.33 %) > and Grand Naine (10.85 %). The FTIR analysis of various flour revealed that Nendran flour has higher accumulation of bioactive compounds than the other flours.

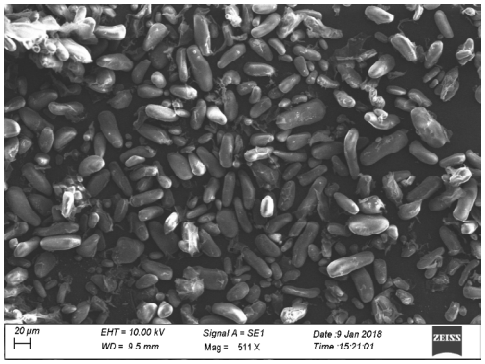
Functional properties of starch from banana

The scanning electron micrographs of the banana starch granules are presented in Fig 26. The banana starch granules exhibited similar shapes with oval appearances. Cultivar Grand Naine showed irregular oval shaped granules with smooth surfaces with more dense congregation of starch. Cultivar Monthan banana exhibited average rod shaped, irregular oval shaped granules and cv. Nendran revealed long rod shaped granules with smooth surfaces. The percentage of amylose displayed significant difference in selected banana cultivars that ranged between 19.87 and 22.32%. In this study, the highest water absorption capacity (WAC) was observed in cv. Monthan (3.25%) when compared with cv. Nendran (2.93%) and cv. Grand Naine (3.03%) and cv. Saba (2.87%).

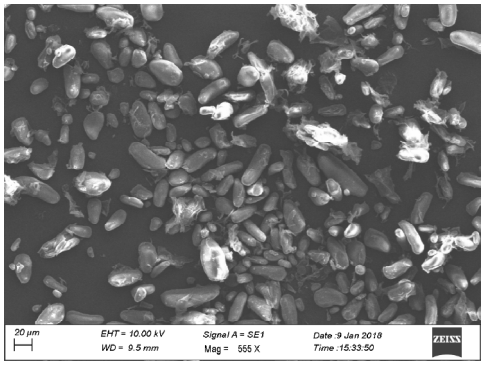
The colour parameters (*L**, *a** and *b**) of banana starches revealed that *L** value of banana starches ranged from 71.98 to 84.88. Higher *L** value reflects the colour (whiteness) and purity of starches. *a** value of the banana starches was low and ranged from -2.60 to -0.38. Higher *a** value indicates redness of the samples. In our study all the samples had a lower value which indicated that samples were pure to the character of the starch. The *b** value of starches ranged from 9.06 to 16.79.

Process developments for starch modification

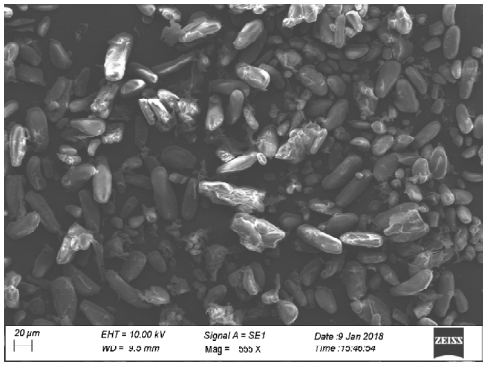
The starch extracted using enzymatic method was subjected to modification using various methods. As the starch tend to loose its resistant starch content when it was used for making processed products. The methods like, autoclaving, autoclaving + debranching, chemical methods like phosphorylation, carbonylation and acetylation were used to produce the modified starches. After retrogradation, the modified starches were specifically analyzed for resistant starch content. It was observed that phosphorylated starch produced the modified starch with higher



cv. Monthan



cv. Nendran



cv. Grand Naine

Fig. 26. Images of banana starch granules of different cultivars under SEM

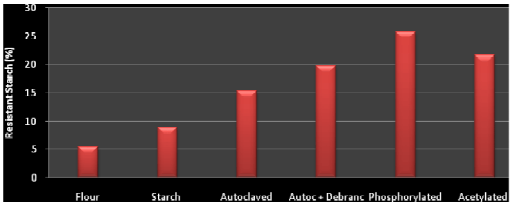


Fig. 27. Influence of different methods of starch modification in resistant starch content (%)

retention of resistant starch (25.7%) than other methods (Fig. 27).

Process standardization for *in vitro* starch hydrolysis and glycemic index of products

Glucose adsorption assay for the products were analyzed. It was observed that the starch and modified starches of the banana recorded less amount of glucose adsorption than the banana flour. The pasta prepared with the ratio of 65:25:10 to maida: banana flour and modified starch also recorded the lesser glucose adsorption. Similarly the *in vitro* starch hydrolysis data revealed the significant reduction in hydrolysis pattern of cv. Grand Naine modified starch than the white bread and Grand Naine starch after the incubation for 150 min. (Fig. 28).

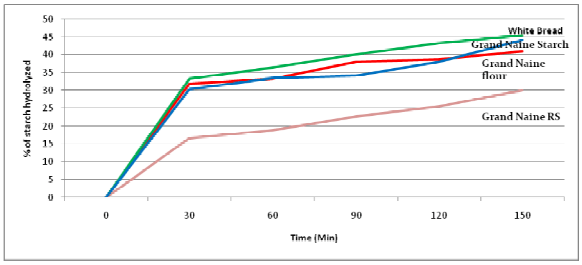


Fig. 28. *In vitro* starch hydrolysis patern of Grand Naine starches compared to white bread starch

Characterization of banana fibre and standardization of degumming procedures

Pseudostem of five cultivars *viz*., Grand Naine, Poovan, Popoulu, Red Banana and Karpuravalli were taken for extraction of fibre. The highest pseudostem fibre recovery was obtained from Karpuravalli (2.49%) and lowest from Grand Naine (1.1%). Properties like breaking strength, breaking extension, tex and tenacity were found to be good in fibres of Red Banana (975.97 gf, 3.17 %, 33.7 tex, 28.40cN/tex and 180.25 MPa). Cellulose is the major component of the fibre. The highest cellulose content was recorded with Karpuravalli fibre (55.84%) followed by Poovan fibre (54.57%).

Non-cellulosic gummy material deposited on the surface of fibre has to be removed for using fibre for various applications. Fibres are treated with Pectinase, Laccase, combination of both enzymes and also with sodium hydroxide at varying concentrations. Results showed that Laccase treatment on fibres recorded with good physic-mechanical properties as well as chemical composition.

Screening of microorganism for the ferulic acid production

Six organisms namely, Fungal spp - CDF1, CDF2, CDF3 and Bacterial spp – PN1, Cd2, Cd6 isolated from cow dung was taken for screening. The selected inoculum of PN1, CDF2 and Co-culture were then inoculated in the substrates. Samples were then incubated in incubator shaker at 35°C and at 150 rpm. From the analysis, ferulic acid was found to be produced by all the organisms. The results after 72 hrs incubation showed the presence of ferulic acid in both PN1, CDF2 and Co – culture inoculated samples with the highest production of ferulic acid using the coculture (394.76 mg/kg). Hence co-culture of organisms would be efficient for ferulic acid production.

Enrichment of banana flour based extruded products

Banana flour based extruded products (noodles) enriched with carrot (antioxidant) and beet root juices (70 to 100% each) were standardized and developed by using pasta making machine. Among the various combinations, banana flour based extruded product (noodles) enriched with 70% carrot juice in combination with 70:30 (all purpose flour (refined wheat flour: banana flour) was at acceptable level (Hedonic scale: 8.33).

4.3 PHYSIOLOGY AND BIOCHEMISTRY

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

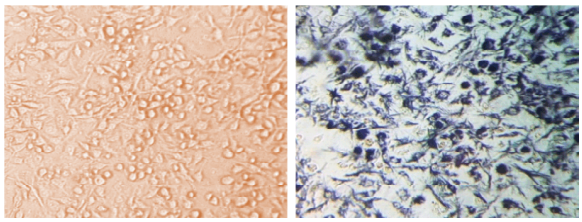
In banana cv. Grand Naine, the photosystem healthiness and function was analysed under drought stress with and without drought alleviation chemicals. The Quantum Yield (YII) of PS II under steady state in field grown banana plants subjected to drought stress alleviation chemicals [Acetyl Salicylic Acid (ASA) + Butylated Hydroxy Toluene (BHT)] recorded higher (0.47 to 0.53) than untreated drought plants (0.37 to 0.41). The photosynthesis decreased in all drought treatments (0.89 to 2.03µmol of CO_2 m^{-2} s^{-1}) compared to irrigated control (18.07 µmol of CO_2 m^{-2} s^{-1}) after the soil water potential reached to -0.8 to -0.9 MPa. However, the plants primed with ASA+BHT recorded 65% more photosynthesis than non-primed drought plants. The Quantum Yield (YII) and Fv/Fm ratio of soil moisture stressed banana under natural light recorded lesser than low light (50% of natural light) condition.

In another field experiment of drought stress in banana cv. Grand Naine at floral primordial initiation stage and PPFM (Pink Pigmented Facultative Methylotrops) and Acetyl Salicylic Acid (ASA) were applied before the drought stress treatment. The irrigated treatment recorded bunch weight of 27.25 kg, compared to 7.75 kg in drought stressed treatment. However, in PPFM primed and drought imposed plants recorded 9.75 kg and 12.32 kg in ASA treated one.

Application of potassium sulphate (1.5%), a growth regulator, as bunch spray in soil moisture stressed banana plants increased the fruit weight 17.35% more than drought stressed plants in cv. Grand Naine. The ABB cultivars recorded chlorophyll pigments in the range of 5.11 to 9.72 mg g^{-1} fw. of leaves.

The ripened banana fruits are having higher anti-cancer properties than unripened fruits. The *in vitro* assay of hill banana (Virupakshi) fruit juice revealed that, it has higher potential to inhibit growth the colorectal cancer cells HT 29 (Fig. 29).

CONTROL HT 29 LINE CELLS (0 / ml) ug



HILL BANANA FRUIT JUICE TREATED HT 29 LINE CELLS (200 ug / ml)

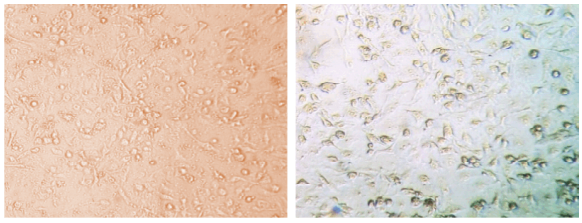


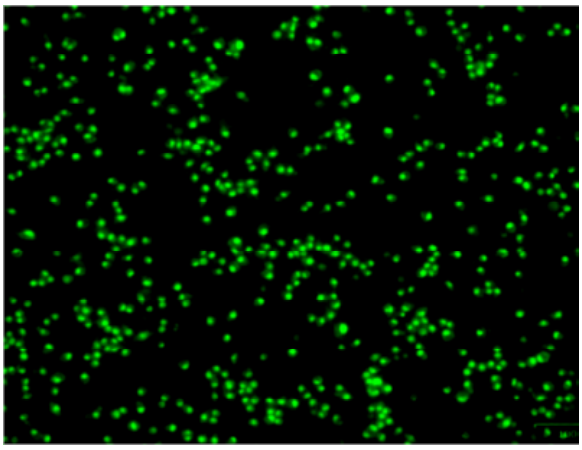
Fig. 29. Hill banana juice inhibits the proliferation of colon cancer cells (HT 29)

The pre-amendment of Biomix (microbial consortium), developed by ICAR-CSSRI, in the soil before imposing drought in banana plants protect the cell machineries and functions compared to non-amended soil. The Biomix protect the banana cv. Rasthali, from drought damage through sustaining photosynthesis and increased production of free amino acids and reducing sugars. Similar, Biomix amendment in the salt stressed soil (100 mM NaCl) also increased the gas exchange parameters, free amino acids and reducing sugars and plants are thriving under salt stress ever after three weeks of salt stress.

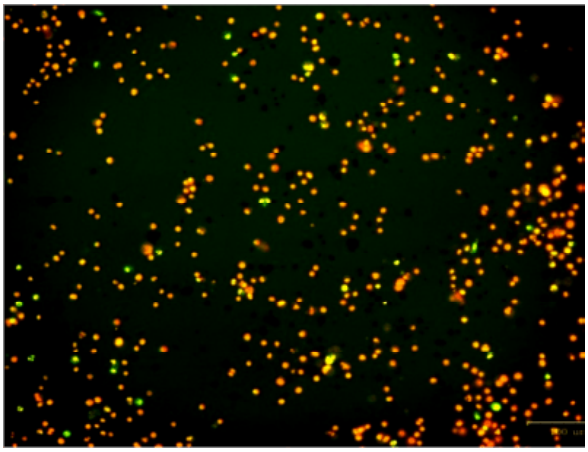
Efficacy of banana peel against breast cancer cells

This study aimed to evaluate the antioxidant, anti-tumor activities and

phytochemicals of methanolic banana peel extracts (var. Nendran). Free radical scavenging activity of the peel extracts was evaluated by using the DPPH (1, 1-Diphenyl-2 -picryl hydrazyl) method and FRAP (Ferric Reducing Antioxidant Power) assay. The anti-tumor activity of breast cell line (MCF-7) was determined by the MTT and ETBr AO staining assay. Nendran peel is more potent in reducing ferric (18.40%) and involves in 55.10 (IC_{50}) free radical inhibition. In phytochemicals investigation, the flavonoids content was high with Nendran peel extract (51.47µg/ml) that attribute to its antioxidant activity. Moreover, they showed highest tumor inhibition of the breast cell line. The obtained results suggest that banana (var. Nendran) extract have the highest antioxidant and antitumor activities and thus could be significant in therapeutic treatments (Fig. 30).



Control



120.6 ìg/ml of Nendran extract

Fig. 30. Efficacy of var. Nedran peel extract on control of MCF-7 cancer cell culture lines

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

Pre-harvest life enhancement of Grand Naine bananas

Grand Naine bunches with full maturity (100%) were treated by fumigation with 1-methylcyclopropene (1-MCP) at a concentration of 1 ìl/L for 12 hr. Before treatment, first two top hands of bunches were allowed to ripe and the ripe hands were excised and removed to make sure that bunches were fully matured. Immediately after of excision of ripe hands, fumigation was carried out by placing the 1-MCP inside the polythene sleeves and covering of bunches using polythene sleeves air-tight (Fig. 31a). Mature bunches of Grand Naine was treated with distilled water as control and treated and control bunches were allowed to ripe. The water treated control bunches started colour breaking from the next day and fifty percent of the hands of bunches were ripe within two days. The 1-MCP treated Grand Naine bunches remained green without initiation of colour breaking and ripening for

Fig. 31. Enhancement of pre harvest green life of bananas. a) Treatment of 1-MCP on full mature Grand Naine bunch, b) 1-MCP treated Grand Naine bunch after 30 days, c) Grand Naine bunches with peel splitting

30 days (Fig. 31b). Beyond that bunches showed maturity browning and cracking and peel-splitting (Fig. 31c). The treatment full mature Grand Naine bananas with 1-MCP enhanced the *in planta* green life for 30 days.

Evaluation of ripening behavior of pre-harvest Grand Naine bananas revealed that 1-MCP treated bananas with ethylene spray ripened within three days, but the 1-MCP treated bananas on self-ripening took seven days for ripening. The ethylene evolution rate in self-ripening and induced-ripening of 1-MCP treated bananas was 2.32 and 2.46 ppm/hr, respectively against 4.80 ppm/hr of control bananas during colour breaking stage and 4.64 and 4.83 ppm/hr, respectively against 6.92 ppm/hr of control bananas at ripening stage 6. Measurement of polygalacturanase activity in self-ripening and induced-ripening of 1-MCP treated bananas was 0.047 and 0.051 Unit activity/g fresh weight, respectively against 0.113 U/g in control bananas at colour breaking stage and 0.40 and 0.44 U/g, respectively against 0.71 U/g in control bananas at ripening stage 6. The lower levels of ethylene release in 1-MCP treated Grand Naine bananas and correspondingly lower level activities of main cell wall depolymerizing enzyme, polygalacturonase, imply that 1-MCP treatment blocked ethylene synthesis and consequently lower enzymes activities. The total soluble solids (TSS) and acidity of the 1-MCP treated pre-harvest Poovan bananas were analysed after self-ripening and induced ripening treating with ethylene were in the range of 20.14-23.4°B and acidity were 0.36-0.38 % and were in the acceptable levels similar to untreated control fruits.

Glycemic index of bananas

Glycemic index (GI) of stages 5 (green at the tips) and 6 (full yellow, edible stage) of ripening of nine commercial banana genotypes were analysed by *in vitro* starch hydrolysis method after by estimating total starch and resistant starch enzymatically, estimating amylase and glucose by starch digestion, preparing starch hydrolysis index curve and calculating GI from it. Among the cultivars analysed, Monthan had the lowest GI of 35 and 48 at stages 5 and 6 of ripening and Karpuravalli had the highest GI with 52 and 68 in stages 5 and 6, followed by Ney Poovan with GI of 54 and 67 in stages 5 and 6. Grand Naine had the GI of 50 and 64 in these two stages. Udhayam and Red banana had the GI similar to Ney Poovan. In all the genotypes tested by *in vitro* method, GI of stage 5 (green at the tips) was relatively in lower levels compared to stage 6 (full yellow) (Table 16 & Fig. 32a & b).

Table 16. Glycemic indices of commercial banana cultivars evaluated *by in vitro* starch hydrolysis

Cultivar	Stage 5 (Green in tips)	Stage 6 (Full Yellow)
Grand Naine (AAA)	50 ± 3.5	64.0 ± 4
Red Banana (AAA)	51 ± 2.5	66 ± 3.5
NeyPoovan (AB)	54 ± 3.5	67 ± 4
Poovan (AAB)	52 ± 3	63 ± 3
Rasthali (AAB)	51 ± 2.5	62 ± 3.5
Nendran (AAB)	38 ± 3	52 ± 3.5
Monthan (ABB)	35 ± 2	48 ± 3
Karpuravalli (ABB)	52 ± 2.5	68 ± 3
Udhayam (ABB)	52 ± 3	66 ± 3.5

Fig. 32a. Cv. Grand Naine at Stage 5

Fig. 32b. Cv. Grand Naine at Stage 6

Characterization of banana flower bract anthocyanins

Anthocyanin pigment contents in flower bracts of male flower buds of eleven commercial banana cultivars were estimated. The average contents of six bracts of male flower bud varied between 57.8 mg in Ney Poovan and 22.2 mg in Grand Naine per 100 g of pigment yielding bracts. Other higher yielding cultivars were Hill banana (57 mg), Poovan (55), Rasthali (54.7), Pachanadan (53) and Nendran (52.5). The number of anthocyanin yielding bracts of male flower bud among the cultivars varied with maximum of ten in Nendran and five in Monthan and Karpooravalli. Udhayam, Hill banana and Monthan yielded higher amount of monomeric anthocyanins from the first outermost bract of male flower bud; Pachanadan, Rasthali and Karpooravalli yielded maximum pigment in second bract and in varieties like Ney Poovan, Grand Naine and Saba as well as Nendran contained the highest pigment in fourth, fifth and sixth bracts.

The composition of anthocyanin compounds in bracts of three cultivars namely, Poovan, Ney Poovan and Rasthali were analysed by HPLC in comparison with standards. The Poovan bract anthocyanins composed of five compounds (Fig. 33) with retention time of 2.5, 2.7, 5.9, 10.0 and 10.4 min in 3, 7, 26, 28 and 36%.

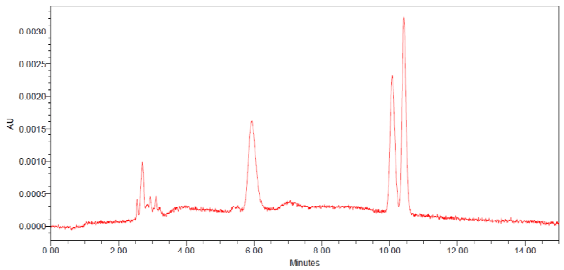


Fig. 33. Chraomatogram of anthocyanin compounds in male flower bract of Poovan

Encapsulation of anthocyanin pigments

Anthocyanin pigments were extracted from flower bracts of Nendran using ethanol:water (1:1 v/v) and yield of anthocyanins from Nendran bract was 52 mg / 100 g fresh weight. The extracted pigment was made into powder form by low pressure concentration and freeze drying. The powdered anthocyanin was mixed with maltodextrin (~20 DE) in 10:1 ratio and spray dried to obtain final powder. The powder was encapsulated in '0' size capsules with capacity of 400 mg. The quantity of anthocyanin in each capsule was 40 mg (Fig. 34).

Fig. 34. Macro-encapulated anthocyanin pigments from banana flower bracts

4.4 CROP PROTECTION

4.4.1 Identification of pheromones of Banana stem weevil, Odoiporus longicollis for the management of the pest

Collection and isolation of Banana stem weevil volatiles

Volatiles released from male and female banana weevils were collected and analysed by Gas Chromatography/ Mass Spectrophotometry (GC-MS). Synthetic analogues of the identified compounds were tested under *in vitro*. Results indicated that some of the chemicals showed 30% weevil attraction in wind tunnel bioassay.

Insect behavioural assay using host plant volatiles

In vitro assay of host plant volatiles from susceptible banana cultivars (Karpuravalli, Nendran and Poovan) were analysed by GC-MS. Synthetic analogues of susceptible host plant volatiles (α-pinene, β-pinene, β-caryophylene and limonene (0.5 to 2%) indicated 10 - 30% of male and female attraction while stem trap alone indicated 70% of attraction. The synthetic chemicals in combinations tested in the field failed to attract weevils.

Insect behavioural assay using Kairomones

In vitro test of kairomone compounds Heptane, 2-methyl-4-pentanal, Heptadecane, Octadecane, 4-ethyl-acetophenone and Tetradecane at 0.5 to 2% concentration recorded 20-40% of male and female attraction and more attraction was in female stem weevils. Banana stem weevil calling behaviours like raising abdomen to full extent of the hind leg, vibrant antennal beating, protrusion of the ovipositor etc were also observed. However, the above compounds did not attract the weevils under field conditions.

Collection of volatiles from healthy and aphid infested plants

Volatiles were collected from the healthy and aphid infested banana plants of cv. Grand Naine and analysed by GC-MS. The result revealed that presence of 28 compounds in control plants belonging to 16 functional groups and 24 compounds belonging to 11 functional groups in the aphid infested plant released volatiles. Studies indicated that there are eleven functional groups in the healthy and five functional groups are common to healthy and aphid infested and six functional groups are specifically belong to aphid induced volatiles. This study recorded more number of aromatic compounds and herbivore in duced plant volatiles (Table 17).

Observations on banana weevil infestation in Fusarium wilt infected germplasm field

Banana weevil infestation was recorded in *Musa* germplasm lines grown in fusarium wilt sick field. The results indicated that the basal splitting of the pseudostem due to fusarium wilt disease invites banana stem weevil (*Odoiporus longicollis)* infestation. Banana

Table 17. Variations in the volatiles released by healthy and aphid induced banana cv. Grand Naine

Volatiles (functional groups) specific to banana healthy plant	Aldehyde (2), Alkaloid (1), Heterocyclic compound (1), Alkonic acid (1), amide (1), Fatty acid ester (FAE: 1), Steriod (1), Ether (1), Aromatic (7), Phenol (1), Fatty acid (3), Cycloalkane (2), Carbohydrate (1), Alkane (3), Carboxylic acid (1), Phthalate (1)
Volatiles (functional groups) present in aphid infested plant	Cyclodiene (1), Cycloalkane (2), Alkene (4), Fumarate (1), Pyridine (1), Cholrine derivatives of alkyn ester (1)

stem weevil infestation was noticed in all 315 accessions, whereas the corm weevil (*Cosmopolites sordidus*) infestation was recorded only in 163 out of 315 accessions. In general, the wilt infected plants succumb to stem weevil infestation through the basal split caused due to wilt infection.

Collection and analysis of volatiles from the fusarium wilt infected and healthy plant

Volatiles from the healthy and wilt infected plants of cv. Ney Poovan were collected and analysed by GC-MS. The results recorded 58 compounds in control plants belong to 26 functional groups and 51 compounds belong to 22 functional groups in the wilt infected plant leaf sheath. Sixteen compounds present in both healthy and wilt infected banana plants. The following functional groups are exclusively present in the wilt infected leaf sheath, Aldehyde(1), Dicarbomide (1) and fatty acid ester (FAE: 9). The compounds present in the healthy plant leaf sheath are Alkanol (2), Alkene(2), Aminoacid (1), Fluorine derivatives(1) and Biphenyl(1).

4.4.2 Pest mapping in bananas and plantains in India

Field surveys were carried out in Pollachi, Thadiyankudisai and nearby areas (Tamil Nadu), and Palakkad (Kerala) for the collection of banana insects and their natural enemies. The reference collection of insect pests of banana, their natural enemies and other insects associated with banana ecosystem was strengthened further with the addition of specimens from different geographical locations. The CO1 gene was sequenced from *Kophene cuprea, Aleurolobus musae* and *Basilepta subcostata.* Molecular characterization of fruit scarring beetle complex from North East India indicated the presence of at least two species. *Acropimpla*sp nr. *nigroscutis* (Cameron), a parasitoid on banana skipper (*Erionota torus*), new mymarid egg parasitoid, *Anagrus* sp. (from Manipur) in addition to *Erythmelus panis* (from Tamil Nadu) were identified from lacewing bug. Both parasitoids and predators of banana mites, fruit mealybugs, root mealybugs and scales were documented for the first time. New parasitoids of minor pests of banana including *Olene mendosa, Olepariciniand Kophene cuprea* were identified. The rugose spiralling whitefly, *Aleurodicus rugioperculatus* (Hemiptera: Aleyrodidae), a recently reported invasive pest, was monitored for further spread in and around Pollachi and Aliyarnagar in Tamil Nadu and the extent of its severity on banana was greater than last year. *Encarsia guadeloupae* Viggiani (Hymenoptera: Aphelinidae), an exotic parasitoid, was found to be very active on the pest with up to 80% parasitism and three coccinellid predators, *Axinoscymnus puttarudriahi, Scymnus saciformis* and *Anegleis cardoni,* were found to feed on the whitefly. A web photo gallery of insect pests of banana, their symptoms of damage and natural enemies with over 1000 high resolution color photographs was constructed to enable easy visual identification of insect pests by researchers and field workers (Fig. 35a & b).

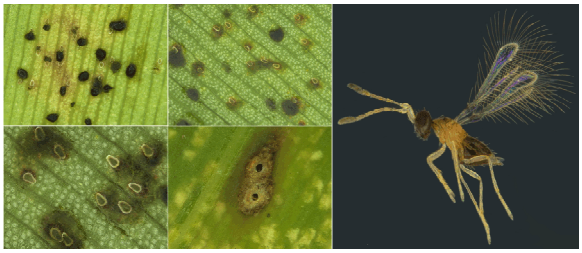


Fig. 35a. *Anagrus* on lacewingbug

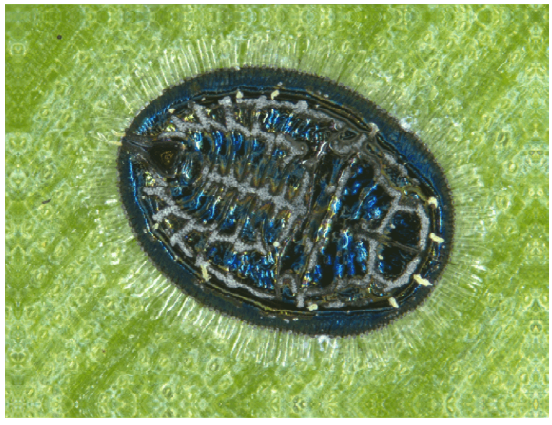


Fig. 35b. Banana whitefly

4.4.3 Investigation on fungal and bacterial diseases of banana and their management

Detection of *Mycosphaerella eumusae* from crude DNA of fungal mycelium and *Eumusae* leaf spot tissues by LAMP method

Rapid and cheaper method of isolating DNA for the diagnosis of *Eumusae* leaf spot pathogen

Crude DNA was isolated from the leaf spot tissues of different banana cultivars belong to various genomic groups *viz*., Rasthali (AAB), Grand Naine (AAA) and Monthan (ABB), by adding five ml of extraction buffer to powdered leaf and incubated at 65ºC for 5 min. DNA obtained was precipitated by adding 0.5 volume of 7.5M potassium acetate and 0.7 volume of 100% isopropanol. After 5 mins, DNA was precipitated again by centrifugation. The obtained DNA pellet with 70% ethanol was resuspended in TE buffer. The time taken for the extraction of DNA was only 2 hours as against 18hrs in the normal method of isolating DNA for PCR analysis. The method was applicable for isolating DNA from the fungal mycelium as well.

Validation of crude DNA of fungal mycelium and leaf spot tissues for the diagnosis of eumusae leaf spot pathogen by LAMP method

The LAMP method was validated with the crude DNA extracted from infected leaf tissues and mycelium. Specific amplification of target pathogen through positive reaction in the tubes containing crude DNA.

Testing the specificity of LAMP method using closely related *Mycosphaerella* species and their mixtures of DNA

The specificity of LAMP primer was individually tested with the genomic DNA of closely related *Mycosphaerella* species [*M. fijiensis* (10 nos.) and *M. musicola* (10 nos)] and 17 other leaf spot causing fungal pathogens resulted in amplification of only DNA of *M. eumusae* by turning the color of the LAMP amplified product into yellowish green and produced a ladder DNA pattern in gel electrophoresis. The specificity of the LAMP method checked using different combinations of mixtures of DNA (*M. eumusae* + *M. musicola, M. fijiensis* + *M. musicola, M. eumusae* + *M. fijiensis* and *M. eumusae* + *M. fijiensis* + *M. musicola*) revealed that the LAMP primers were highly specific to *M. eumusae.*

Isolation and identification of bioactive compounds from effective bio-control agents against eumusae leaf spot disease

The total ethyl acetate crude extracts (EACE) of *Penicillium pinophilum* (12DF) and *Emericella nidulans* (9DF) were isolated through TLC and 18 compounds were identified and evaluated *in vitro* for their antifungal activity against *M. eumusae.* The results indicated that, only 7 out of 18 compounds proved to be antifungal. Further these seven compounds were analysed through GC-MS and among them only two compounds showed 100% mycelial inhibition of *M. eumusae* pathogen at all the concentrations (0.01, 0.05, 0.25 and 0.5 g ml^{-1}) and the compound isolated from *E. nidulans* (9DF) showed 100% inhibition at 0.25 and 0.5 g ml^{-1} concentration. However, all three compounds recorded 100% inhibition of spore germination under *in vitro* condition (Fig. 36).

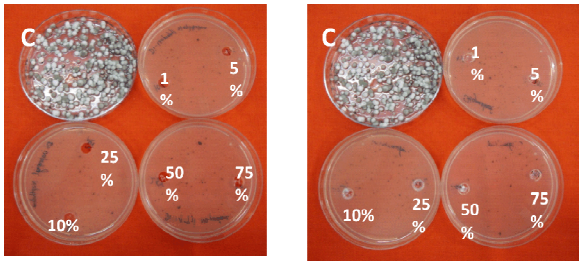


Fig. 36. Effect of different bioactive compounds on the mycelial growth of *Mycospharella eumusae* A. Inhibition of mycelial growth of *M. eumusae* by a principle compound isolated from *P. pinophilum.* B. Inhibition of mycelial growth of *M. eumusae* by a principle compound isolated from *Emericella nidulans*

Characterization of toxin compounds isolated from *M. eumusae* pathogen through GC-MS

Ethyl acetate crude extract (EACE) was extracted from culture filtrate of *M. eumusae* and partially purified using TLC.

The spots appeared (7 spots) in TLC were extracted individually and *in vitro* bioassay test was carried out using *M. eumusae.* The results indicated that only one band out of 7 bands caused necrosis (T1). The toxin T1 analyzed through GC-MS resulted in identification of three different compounds *viz.,* Trimethoxy flavone, Quinizarin, *p*-Benzoquinone dioxime. Among these, only two compounds *viz.*, Quinizarin and p-Benzoquinone dioxime (similar to juglone) caused necrosis of 10 mm diameter at 100 ppm and 27 mm diameter at 50 ppm after 72 hrs. respectively (Fig. 37).

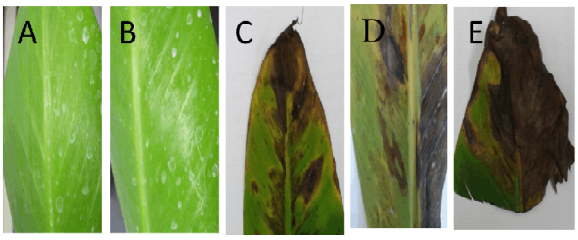


Fig. 37. Effect of toxin compounds from *M. eumusae* on banana leaves after 15 days of spraying. A. Control, B. DMSO, C. Juglone -50 ppm, D. Quinizarin-100 ppm, E. *p*-Benzoquinone dioxime (PBD) - 50 ppm

Isolation and characterization of pathogen causing tip and pedicle rot disease in banana cv. Nendran

Three fungal isolates (TP, TR and PR) were isolated from fruit tip and pedicle rot infection in banana fruit (cv. Nendran). These fungal isolates identified based on the ITS–rDNA sequence analysis. The two isolates (TP and PR) belong to a new type of fungi *Fusarium chlamydosporum* (not reported in India) and isolate (PR) belongs to *Lasiodiploidia theobromae*.

The phylogenetic analysis was done with these sequences of *Fusarium chlamydosporum* (TP, PR) by comparing with the similar sequences retrieved from NCBI database revealed that the two sequences of *F. chlamydosporum* (TP, PR) showed 99.9% homology with the other sequences of *F. chlamydosporum* by grouping in same cluster.

In vitro evaluation of different fungicides against *Fusarium chlamydosporum* causing tip and pedicle rot infection in banana

Evaluation of six different fungicides [Tebuconazole + Trifloxystrobin (Nativo), Carbendazim, Thiophanate methyl (Roko), Difenoconazole (Score), Propiconazole (Tilt) and COC (Fytolan)] against *F. chlamydosporum* at five different concentrations (0.05, 0.1, 0.25, 0.5 and 1%) by poison food technique. All the fungicides tested have inhibited the mycelial growth of the pathogen *F. chlamydosporum* in the range of 72.2 to 100%. However, three fungicides Nativo, Carbendazim and Propiconazole (Tilt) have recorded 100% inhibition of the mycelial growth of the pathogen *F. chlamydosporum* at all the concentrations tested.

In vitro evaluation of different fungicides against *Lasiodiplodia theobromae* causing tip rot infection in banana

Evaluation of six different fungicides [Tebuconazole + Trifloxystrobin (Nativo), Carbendazim, Thiophanate methyl (Roko), Difenoconazole (Score), Propiconazole (Tilt) and COC (Fytolan)] against *L. theobromae* at five different concentrations (0.05, 0.1.0.25, 0.5 and 1%) by poison food technique resulted in inhibition of mycelial growth of the pathogen in the range of 38.8 to 100%. However, two fungicides Carbendazim and Thiophanate methyl (Roko) has recorded 100% inhibition of the mycelial growth.

4.4.4 Survey, etiology and management of rhizome rot of banana

A survey conducted for rhizome rot of banana in Tiruchirapalli and Theni (Tamil

Nadu), Anantapuramu (Andhra Pradesh) and, Hoogly and Nadia (West Bengal) revealed 8-10% of the disease incidence in Poovan, Red banana, Grand Naine and Ney Poovan cultivars. The incidence was high in tissue cultured banana seedlings (cv. Grand Naine). The incidence was noticed during early stage of plants (2-5 months after planting). Thirty six different isolates of rhizome rot pathogen were isolated and prepared glycerol stock of the cultures and stored in 80°C.

Characterization of the isolates using crystal violet pectate assay and bioassay on potato showed that two isolates were highly virulent and one of the isolates expressed a typical rhizome rot/head rot symptom in tissue cultured banana cv. Ney Poovan (Fig. 38a & b). Fifteen plant growth promoting bacterial isolates from banana rhizospheric soil samples were isolated.

Fig. 38a. Symptom of bacterial rhizome rot expressed in TC Ney Poovan plant

Fig. 38b. Un-inoculated healthy plant

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

Complete genome of banana bract mosaic virus (BBrMV) North Eastern Hill isolate was compared with three other isolates and the variation was distinguishable in phylogenic tree. Out of 49 BBrMV isolates analyzed, isolate TN11 showed evidence of recombination by seven recombination detection algorithms. The BBrMV was found to be seed transmitted and it was confirmed by detecting and quantifying the virus using RT-PCR and growing-out test. The viral copies were quantified in different parts of the seed using real time PCR which revealed that 27-631copies of virus in them. Lace wing bug *Stephanitis typica* has been proved to be an additional vector for BBrMV based on molecular evidence. Occurrence of CMV in *Musa ornata* was recorded for the first time and confirmed using ELISA, PCR and pathogenicity test by mechanical sap inoculation to *Nicotiana* spp. Using MVR-RNAi and hairpin-rep (BBTV) constructs, 22 putative transgenic lines of Hill banana (Virupakshi, AAB) were developed and planted in the transgenic net house. ECS derived banana bunchy top virus (BBTV) free Hill banana plants showed significant differences in growth and yield parameters compared to sucker grown plants in second ratoon crop and on par with tissue culture raised plants. Preliminary field evaluation data on endogenous banana streak mysore virus (BSMYV) free elite tissue culture derived Poovan banana plants, showed significant difference in the growth and yield parameters compared to sucker grown plants. Screening of fifty diploid banana germplasm accessions (AA and BB) for the resistance against BBTV was done with sucker grown plants and transmitted the virus into the plants using viruliferous aphids. Twelve diploid accessions including Hill banana and Grand Naine plants have expressed the symptoms till date.

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

Protein-protein interactions of host and virus

Through *in–silico* analysis, six eIF4E were identified in cv Nendran. Gene specific primers were designed and PCR conditions were standardized. All six eIF4E genes from cv. Nendran were amplified with gene specific

primers, cloned, sequenced and submitted in NCBI genbank. Further these six genes were sub-cloned in bait and prey vectors for studying the direct interaction of these gene with VPg of BBrMV in yeast system.

Time course study - infectious cycle of BBTV in hill banana

To study the BBTV infectious cycle in Hill banana, the viruliferous aphids were fed onto the secondary hardened plants of Hill banana. After feeding with 30 viruliferous aphids, the leaf tissue was collected for analysing the changes in the proteins at 10 different time intervals. The proteins were separated using IPG strips by isoelectrophoresis

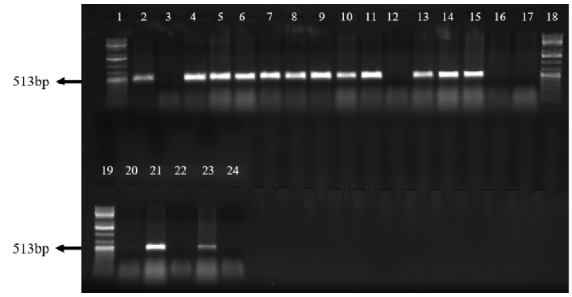
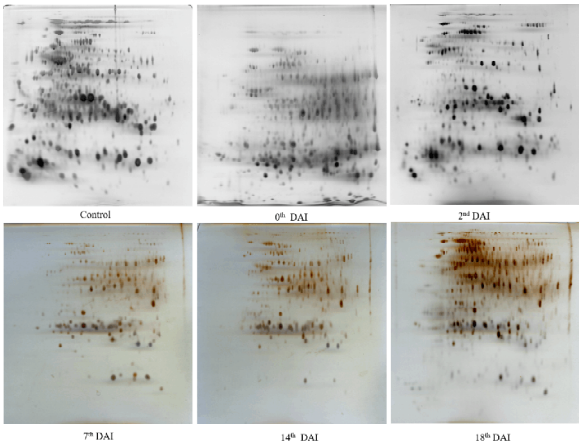


Fig. 39. PCR confirmation of BBTV infection in hill banana plants

Amplified fragments of BBTV coat protein gene (Samples are pooled by row/column method). Lane-1, 18 &19 = 1 kb DNA ladder plus (MBI Fermentas); Lanes 2-11 = R1-R10 samples; Lanes12-17, 20-24 = C1-C9 samples.



in IEF100 Isoelectric Focusing Unit - Hoefer®, followed by second dimension separation of proteins (Fig. 39 & 40).

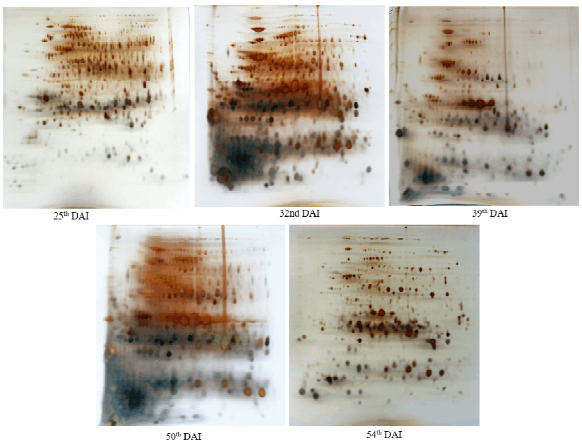


Fig. 40. Silver stained gels of hill banana plants after aphid inoculation of BBTV at different time intervals (control, 0th, 2nd, 7th, 14th, 18th, 25th, 32nd, 39th, 50th and 54th day after infection)

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

Survey and sampling of banana for nematodes

The soil and root samples collected from different banana growing regions revealed higher populations of spiral nematodes (*Helicotylenchus* spp.) in Kasaragod and Kannara (Kerala); root-lesion nematodes (*Pratylenchus* spp.) in Malappuram District (Kerala); root-knot nematodes (*Meloidogyne* spp.) in Arabhavi (Karnataka); Kovvur, Anantapur (Andhra Pradesh); Gandevi (Gujarat); Patkapura (Orissa).

Molecular diversity studies on banana nematodes

Nematode DNA was extracted from 31 nematode isolates comprising root-knot nematode (11), spiral nematode (10), root lesion nematode (4), reniform nematode (2) and entomopathogenic nematodes (EPN) (3). Amplification by PCR with different set of random primers and sequencing were done for

Table 18. List of nematode isolates submitted to NCBI

	Location	Primer	Gen Bank Accession No.
	Root-lesion nematode (*Pratylenchus coffeae*)		
1	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	D3A – D3B	MF 996768
2	Theni, Tamil Nadu	D3A – D3B	MG 020110
3	Thottiyam, Tamil Nadu	D2A – D3B	MH087065
	Spiral nematode (*Helicotylenchus multicinctus*)		
4	Theni, Tamil Nadu	D3A – D3B	MF 996772
5	Thottiyam, Tamil Nadu	D3A – D3B	MG 020141
6	Yercaud, Tamil Nadu	D2A – D3B	MH087066
7	Theni, Taml Nadu	D2A – D3B	MH087063
8	Kasaragod, Kerala	D2A – D3B	MH087064
9	Bangalore, Karnataka	D2A – D3B	MH084946
	Root-knot nematode (*Meloidogyne* sp.)		
10	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	D3A – D3B	MG 020140
11	Theni, Tamil Nadu	D3A – D3B	MG 022136
12	Theni, Tamil Nadu (*Meloidogyne graminicola*)	D2A – D3B	MH087061
	Reniform nematode (*Rotylenchulus reniformis*)		
13	Thadiaynkudisai, Tamil Nadu	D2A – D3B	MH100897
	***Rhabditis rainai* (EPN)**		
14	Thayanur, Tiruchirappalli, Tamil Nadu	D3A – D3B	MF996767
	***Steinernema siamkayai* (EPN)**		
15	Thayanur, Tiruchirappalli, Tamil Nadu	18S – 28S	MH091330
16	Podavur, Tiruchirappalli, Tamil Nadu	18S – 28S	MH091332
	***Heterorhabditis indica* (EPN)**		
17	Thayanur, Tiruchirappalli, Tamil Nadu	TW81-AB28	MH299879

DNA samples of 40 nematode isolates. Sequencing of 17 nematode isolates were submitted to NCBI and genebank accession numbers were obtained (Table 20).

Interaction between root-lesion nematode, *Pratylenchus coffeae* and entomopathogenic nematode, *Heterorhabditis indica* on banana cv. Nendran

Inoculation of root-lesion nematode, *Pratylenchus coffeae* and entomopathogenic nematode, *Heterorhabditis indica* alone and in combination. The results showed that plant growth parameters of combined inoculation of both the nematodes and *H. indica* alone were on par with un-inoculated control. Significant reduction in population of *P. coffeae* was observed in combined inoculation with *H. indica*.

Evaluation of botanicals, biocontrol agents against root-lesion nematode, *Pratylenchus coffeae*

Promising botanicals (Nano formulations of Quercetin and Zimmu) and biocontrol agents (*Trichoderma asperellem*, *Penicillium*

pinophilum, *Trichoderma* sp., *Bacillus* sp.) were tested against root-lesion nematode on banana cv. Nendran. Results showed that *Bacillus* sp. was most effective in reducing nematode population and improving plant growth.

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

Nine promising diploid and triploid banana genotypes *viz*., cv. Rose (AA), Pisang Jari Buaya (AA), Bainsa (ABB), Manoranjitham (AAA), Pacha Bontha Batheesa (ABB), Cuba (ABB), Kanai Bansi (AA), Nutepong (ABB) and Ash Monthan (ABB) was screened against root knot nematode (*Meloidogyne incognita*). The results showed that Kanai Bansi and Nutepong were moderately resistant. The Pisang Jari Buaya, a resistant reference genotype for lesion forming nematodes was highly susceptible.

Isolation, identification and evaluation of entomopathogenic nematode isolates against banana stem weevil

Four entomopathogenic nematode (EPN) isolates were obtained from soil samples collected from ICAR-NRCB. Using molecular markers they were identified as *Rhabditis rainai*, *Steinernema siamkayai* (Two isolates) and *Heterorhabditis indica*. *In vitro* inoculation of *R. rainai* on grubs of banana stem weevil, *Odoiporus longicollis* recorded 100% mortality after third day of inoculation @ 10,000 nematodes / grub and 40% mortality of adult weevils after ten days of inoculation. With respect to *H. indica*, 100% mortality of grubs was observed at 48 hrs after inoculation with a minimum population of 250 nematodes / grub, while 100% mortality of adult weevils was observed one week after inoculation with a minimum population of 10000 nematodes / weevil (Fig. 41a & b).

Fig. 41a. Cadavers of grubs of banana stem weevil killed by *Heterorhabditis indica*

Fig. 41b. Cadaver of adult stem weevil killed by *Heterorhabditis indica*

4.5 EXTERNALLY FUNDED PROJECTS

4.5.1 IITA – collaborative project: Improvement of Banana For Smallholder Farmers in The Great Lakes Region of Africa - Enhancing Banana Production by Developing Fusarium Wilt-Resistant Varieties and Benefit Sharing with African Smallholder (S. Uma, S. Backiyarani, M. S. Saraswathi and A. Thirugnanavel)

In vitro polyploidization was attempted in BB, AA and AB accessions by treating different explants *viz.,* seed, embryo and shoot tip with oryzalin at different concentrations for doubling their chromosome. ECS has been developed for Kunnan (AB) type for use in *in vitro* polyploidization. Pisang Awak (ABB) accessions were crossed with different male parents and a total of 456 seeds were obtained. Existing five Karpuravalli tetraploids developed at ICAR-NRCB were crossed with different diploid male parents and a total of 400 seeds were obtained. Work package (WP3) is aimed at developing molecular markers for *Foc* resistance, for which DNA of 130 mapping population have been isolated and kept ready for marker studies. WP5 is aimed at improvement of dual purpose Pisang Awak types through the use of breeding database, for the purpose of which banana breeding tracker has been developed and breeding data are being maintained in this database for easy retrieval of breeding information.

Banana breeding tracker (BBT)

To facilitate the breeders a Banana Breeding Tracker (BBT) has been developed (Fig. 42) with integration of four outsource platforms such as wix.com, Google Sheets, Jotform (https://www.jotform.com) and the QR-code generators wherein breeding information and phenotypic data can be entered. All the information fed in BBT will be coded as Quick Responsive code (QR) which can be decoded and breeding information can be retrieved by the decoder using QR scanner. The BBT developed by ICAR-NRCB is being used and facilitates the development of new hybrids and mapping population.

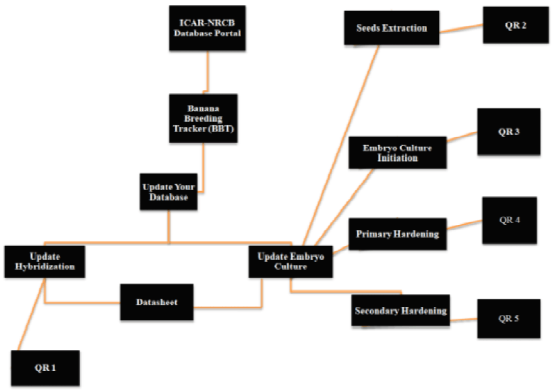


Fig. 42. Architecture of the database

4.5.2 Network project on Transgenic in crops – Banana functional genomics (Sigatoka & Drought component) (S. Uma, S. Backiyarani, R. Thangavelu and M. S. Saraswathi)

Functional Genomics

Musa long Non-coding RNA database (*Musa*LncRNADB) has been developed from the 905 novel lncRNAs from 8471 drought-responsive, novel transcripts of RNA-Seq reads from two banana cultivars, a drought-tolerant cv. 'Saba' (ABB) and -susceptible cv. 'Grand Naine' (AAA). This database was developed using HTML, Java and PHP, datasets are stored in MySQL database. This consists of long non-coding RNA expression, natural antisense RNAs and microRNA decays. Search options are provided in this database, which enables to search and retrieve the results by giving the query (by LncRNA name or genome id) in the search box. This will be more useful for the scientific community who are working in the field of long non-coding RNAs and miRNA in fruit crops (Fig. 43).

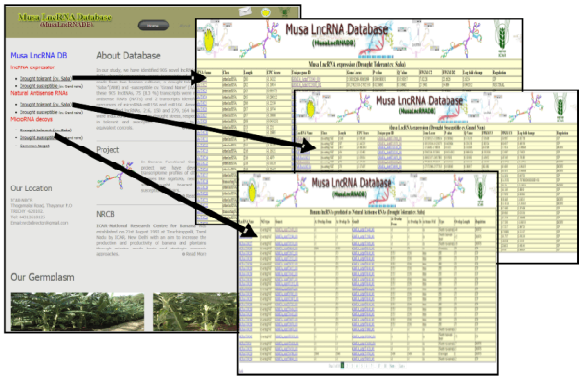


Fig. 43. *Musa* long Non-coding RNA database (*Musa*LncRNADB)

Cloning of candidate gene of *Eumusae* leaf spot disease resistance

Based on the differential expression profiling, two genes (Dirigent 11 and Pathogenesis related protein) were identified as over expressed in resistant cultivar under challenged condition (Table 19). These genes were validated through expression analysis and found that DIR11 Protein was upregulated on 3rd day after inoculation in *eumusae* leaf spot

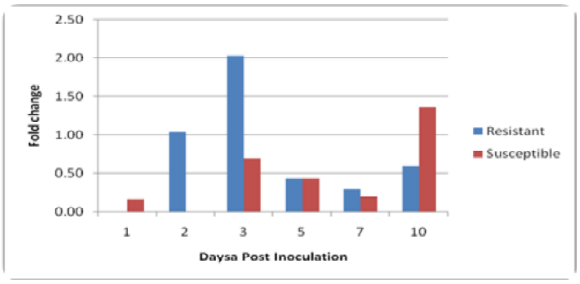


Fig. 44. Validation of DIR protein gene using gene expression studies against resistant and susceptible cultivars of *Eumusae* leaf spot disease at different time intervals

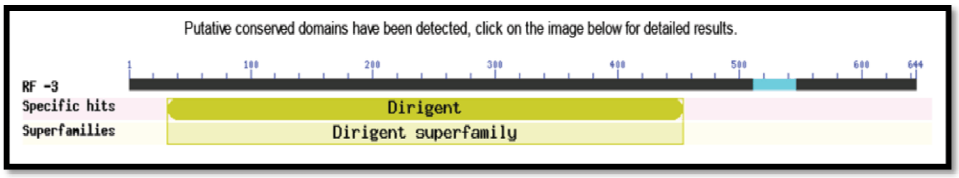


Fig. 45. Dirigent 11

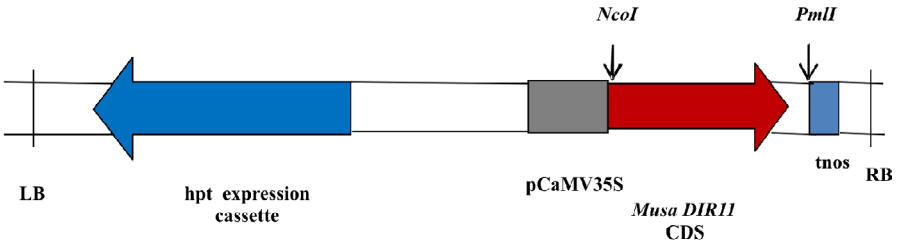


Fig. 46. DIR11 construct development in pCAMBIA vector

Table 19. Genes identified in *Eumusae* leaf spot resistant banana cultivar

Gene of Interest / Insert	Size of full length CDS	Fold change in expression at transcript level	Role / Likely Function in stress response
Dirigent 11	536 bp	17.95	Over expression is expected to result in the development of resistance to fungal pathogens by inducing phenolics
Pathogenesis related protein (PR)	957 bp	6.0	Selectively disrupt the membrane system of pathogen through formation of transmembrane pores

inoculum in disease resistant cultivar and whereas in susceptible cultivar it was upregulated only on 10th day (Fig. 44). Hence full length gene of Dirigent 11 has been isolated and cloned (Fig. 45 & 46) for developing transgenic plants in cv. Grand Naine.

DBT-QUT Project

4.5.3 Biofortification and development of disease resistance in banana

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

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

To quantify the expression of psy2a gene in leaf tissues of 10 randomly selected transgenic plants of each constructs (pBMGF-DC-34, pBMGF-DC-32, pBMGF-DC-12, pBMGF-DC-35, and pBMGF-DC-49) in two cultivars *viz.,* Grand Naine and Rasthali. RNA sample used for semi quantitative RT PCR were used for quantitative real time PCR analysis (qRT PCR). The RPS 2 gene was used as reference gene for normalizing the value of psy 2a gene. It was observed that irrespective of the promoter, mostly all the transgenic plants showed over expression of the Psy 2a gene than control plants. But, the constructs DC 32 followed by DC 12 showed less expression in leaf tissues compared with that of other constructs. This revealed that both the fruit specific promoters (Musa Expansin and 1-aminocyclopropane-1-carboxylate oxidase) are showing leaky expression in leaf tissues. But the expression of Psy2a gene which are driven by the Maize Ubiquitin promoter (DC 34) and Banana bunchy top virus (BBTV) DNA-4 promoter DC 35) are higher than the non transgenic plants. This revealed that Psy2a gene which are driven by these promoters are expressed constitutively in all parts of the plants including leaf and root tissues. For the quantification of beta caroteniod, as per the QUT SOP the fruit pulp non - transgenic cv. Rasthali and cv. Grand Naine at ripened stage were collected and subjected to HPLC analysis preparation. The β-Carotenoid content were 199.1ng/g and 182.3 1ng/g pulp in cvs. Rasthali and Grand Naine respectively.

Component-II: Transfer and evaluation of Indian bananas with iron gene constructs

(M. Mayil Vaganan , I. Ravi and K.J. Jeyabaskaran)

Fifty numbers each of independent transgenic event, Rasthali and Grand Naine plants transformed with iron construct *p*BMGF-DC-53 carrying *Os*NAS1 gene along with 10 untransformed control plants were primary and secondary hardened in glass house conditions and plants were field-planted in transgenic net house for confined field trials (Fig. 47). The transformed plants were PCR-confirmed and also screened for *Agrobacterium* contamination using VirC gene specific primers. The

Fig. 47. Rasthali and Grand Naine plants transformed with *Os*NAS1 in transgenic net house under confined field trials

differential expression of *Os*NAS1 gene in the leaf tissues of some of the transgenic plants of Rasthali and Grand Naine were studied with Reverse Transcriptase-PCR. Out of 34 each of Rasthali and Grand Naine transgenics tested by RT-PCR, 16 and 18 respectively showed higher transcript levels (Fig. 48a & b). The accumulation of iron in the leaf tissues of *Os*NAS1 transformed plants were quantified by the biochemical estimation of total iron using Iron Assay Kit (Sigma) and the iron content in leaf tissues were at higher levels compared to untransformed wild plants. The higher iron levels were comparable with of transcript levels analysed by RT-PCR in the transgenics.

With the second gene construct of *p*BMGF-DC-68 carrying *Os*NAS2 gene, more than 200 transgenic events of Rasthali and Grand Naine were developed. All the transformed plants were subjected individually to PCR analysis with the gene specific primers for confirming the presence of transgene (Fig. 49). The transgenic plants are now under primary hardening process.

Rasthali and Grand Naine transgenic plants transformed with *Os*NAS1 received from Bhabha Atomic Research Centre, Mumbai as part of the programme for field confined trials were primary hardened and are now being secondary hardened in green house conditions.

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

Efficient ECS of cvs. Rasthali and Grand Naine has been provided to the Indian partners based on their requirements. A total of SCV of 31ml and 28 ml cv. Rashali and cv. Grand Naine respectively have been distributed to other Indian partners.

Field evaluation of ECS derived plants of cv. Grand Naine

Comparison of the data of both first crop and ratoon crop of cv. Grand Naine showed

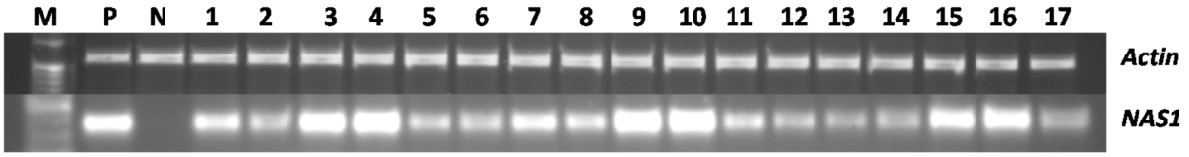


Fig. 48a. Reverse transcriptase-PCR analysis of transgenic Rasthali plants for the differential expression of *Os*NAS1 gene

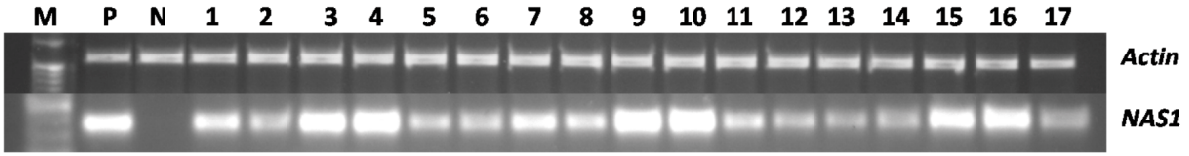


Fig. 48b. Reverse transcriptase-PCR analysis of transgenic Grand Naine plants for the differential expression of *Os*NAS1 gene

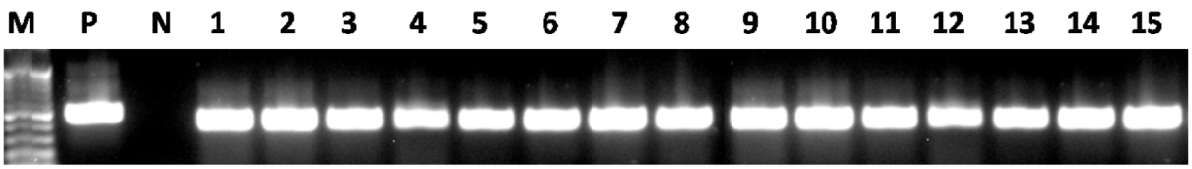


Fig. 49. PCR confirmation of plants transformed with *Os*NAS2 iron gene with nptII gene specific primers; Lane 1-8: Rasthali and lane 9-15: Grand Naine

that the bunch yield of ECS and shoot tip (32 kg) derived plants were on par with each other whereas, the sucker derived plants gave an yield of only 28 kg (Fig. 50a & b). Ratoon plants of ECS showed better yield (33 kg) when compared to the first crop bunch (32 kg) (Fig. 51).

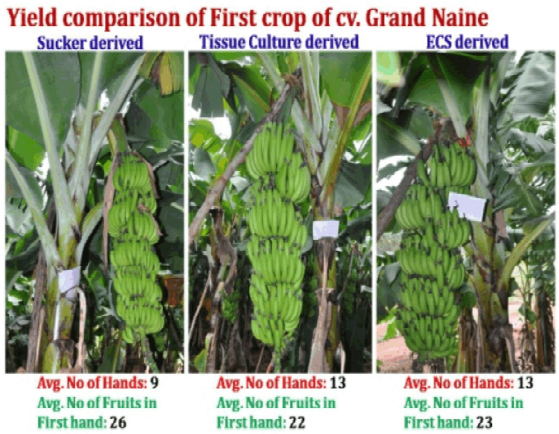


Fig. 50a. ECS derived plants of cv. Grand Naine - First crop

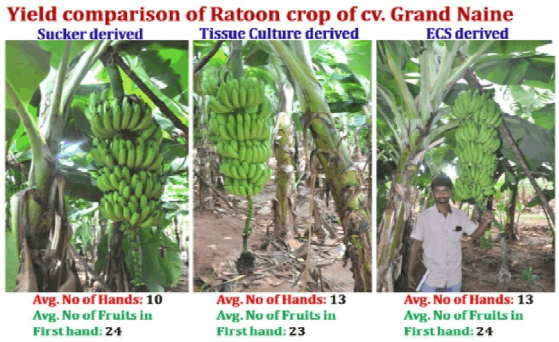


Fig. 50b. ECS derived plants of cv. Grand Naine - Ratoon crop

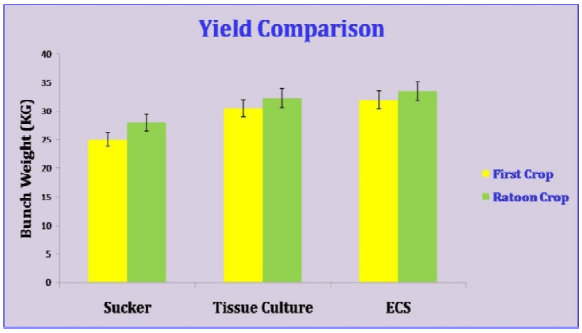


Fig. 51. Yield comparison between first crop and ratoon crop of cv. Grand Naine

DAE Project

4.5.4 Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis (M. S. Saraswathi, S. Uma, S. Backiyarani and R. Thangavelu)

For ECS, lethal dose LD50 has been determined for the chemical mutagens, EMS (0.1% for 2 hours), DES (3mM for 1 hour), Sodium azide (0.005% for 1 hour) and gamma irradiation (35Gy) based on fresh weight gain (FWG), SCV and regeneration efficiency. These mutated cultures after regeneration in MA3 were germinated in MA4 containing fusaric acid (0.1 mM) or culture filtrate (6%) or Beauvericin (5µM). The germinated plants after hardening were established in pots for challenge inoculation. Totally four batches of putative mutants derived from EMS, DES and Gamma irradiation were challenged with the pathogen *Fusarium oxysporum* f. sp. *cubense*. This led to the identification of 20 resistant lines with no disease symptoms (EMS 16; DES 3; Gamma irradiation 1) (Fig. 52).

Fig. 52. Pot screening of putative mutants of cv. Rasthali for fusarium wilt resistance

PPV & FRA project

4.5.5 Framing crop specific DUS guidelines for banana (*Musa spp.*) (S. Uma, M. S. Saraswathi and S. Backiyarani)

About 39 accessions inclusive of 33 reference accessions, 2 new accessions and 4 farmers' varieties have been planted.

Four awareness programmes about registration of farmers variety under PPV

&FRA was conducted at Tandalwadi, Balawadi and Ainpur of Jalgaon district, Maharashtra and Erumbukadu, Nagercoil, Kanyakumari district wherein about 220 farmers participated and they were benefitted. Further, a radio talk has been delivered through All India Radio about the importance of registration of banana varieties.

The farmers were assisted in filing the application for registration of eight landraces under PPV&FRA for the landraces like Manoranjitham and Numaran from Kolli Hills, Namakkal district; Matti from Tirunelveli district; Semmati, Chingan, Thottu Chingan, and Kudiraivali Chingan from Erumbukadu, Nagercoil, Kanyakumari district.

Kamal Vikas 1 is a farmer's variety bred by the farmer Mr.Mahajan Vikas Dattatray, Ainpur of Jalgaon district, Maharashtra from the existing cv. Grand Naine which has been acquired lawfully. Plant height ranged from 320-330 cm, with the bunch shape being cylindrical and fruit colour being yellowish green with more internodal space when compared to cv. Grand Naine. The famer has already filed his registration with PPV and FRA, New Delhi and he has supplied the suckers to ICAR-NRCB for evaluation. Planting was done in August, 2017 and the crop is in the shooting stage.

ICAR-AICRP Project

4.5.6 Assessment of Post-harvest losses in Banana under AICRP on Fruits

ICAR-NRCB as the nodal centre is co-coordinating the programme on as assessing the post-harvest losses across five AICRP Centers located at Tamil Nadu, Karnataka, Kerala, Andhra Pradesh and Maharashtra. A survey was conducted in Theni and Erode districts in banana cv. Grand Naine and in Tiruchirappalli and Tuticorin districts in cv. Poovan, to estimate the post - harvest losses in banana at various levels *viz.,* field level, transport level, assembly/wholesale market, storage and ripening level. The results showed that the losses estimated at ICAR-NRCB, Tiruchirappalli was 18.96% and 19.12% in Theni and Erode districts, respectively in cv. Grand Naine and 14.81% and 14.46% in Tiruchirappalli and Tuticorin districts, respectively in cv. Poovan. Tamil Nadu registered the minimum post –harvest losses in both the cultivars compared to other states. Jalgaon center is recorded 31.25% post-harvest losses in cv. Grand Naine. As a lead center/ lead presenter, compiled the surveys carried out by the four different centers namely, Bengaluru, Jalgaon, Kannara, Kovvur including Tiruchirappalli (ICAR-NRCB). The results revealed that the average post–harvest losses of banana were 21.97, 25.09, 16.83 and 31.25% at Kannara, Kovvur, ICAR-NRCB, Tiruchirappalli and Jalgaon centers, respectively. Among the centers, ICAR- NRCB, Tiruchirappalli recorded the least value of post –harvest loss of 16.83%, while Jalgaon center recorded the highest value of post-harvest losses of 31.25%.

ICAR–Extramural project

4.5.7 On-site diagnostics for insect pests of selected horticulture crops to enable timely pest management decision making (J. Poorani)

Stethorus forficatus Poorani (Coccinellidae) was described as a new species of predator on citrus and compared with other *Stethorus* spp. on banana, citrus and coconut. This species was identified as a potential predator of mite pests on citrus.

4.5.9 Survey, characterization and management of a most virulent strain of *Fusarium oxysporum* f. sp. *cubense* – Tropical Race 4 (*Foc*-TR4) infecting banana in India (R. Thangavelu and S. Backiyarani)

Pot culture evaluation of commercial cultivars of banana against *Foc*-TR4

The screening of ten different commercial cultivars against *Foc*-TR4 under pot culture conditions showed that the cvs. Red Banana (AAA), Nendran (AAB) and Saba (ABB) exhibited a disease score of 3 compared to other varieties which showed a score of more than 4 on a disease scale of 1-6. None of the varieties found to be resistant to *Foc*-TR4.

In vitro evaluation of bio-agents and botanicals against *Foc*-TR4

The *in vitro* evaluation of different bioagents and botanicals against *Foc*-TR4 indicated that the endophytic *Trichoderma asperellum* and botanical Zimmu at 50% conc. recorded 60 and 70% inhibition of mycelial growth of *Foc*-TR4 respectively. However, *T. asperellum* (CD1) isolated from cow dung showed 100% *in vitro* inhibition of spore germination as well as mycelial growth of *Foc*-TR4 (Fig. 53).

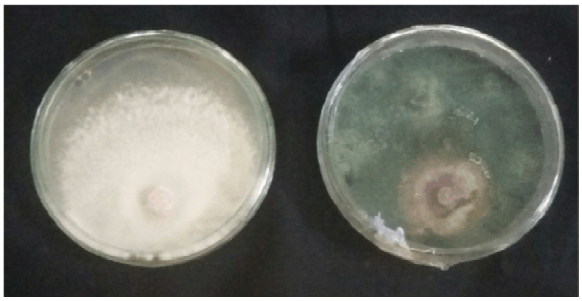


Fig. 53. *In vitro* mycelial growth inhibition of *Foc*-TR4 by *Trichoderma asperellum*

Survey for the occurrence of *Foc*-TR4 in different states of India

Status of *Foc*-TR4 in Uttar Pradesh

In collaboration with ICAR-CISH, Lucknow survey was conducted in Katrauli, Mangalsi and Muksoonganj villages of Sohawal block, Faizabad district, Uttar Pradesh indicated the presence *Fusarium* wilt disease in cv. Grand Naine and the incidence was ranged from 30 - 45% and about 95% of the area under banana was affected. Analysis of the infected samples confirmed that the *Fusarium* wilt in cv. Grand Naine grown in Uttar Pradesh was due to Tropical race 4 (*Foc*-TR4) (Fig. 54).

Fig. 54. Banana field (cv. Grand Naine) devastated by Tropical Race 4 of *Fusarium* wilt in Faizabad district of Uttar Pradesh

Status of *Foc*-TR4 in Madhya Pradesh and Gujarat

Survey conducted in Burhanpur (25ha), Madhya Pradesh and Surat district (20 ha), Gujarat revealed the occurrence of *Fusarium* wilt incidence of about 10 - 50% in cv. Grand Naine. The pathogen was identified as *Foc* race 1 (Fig. 55).

Fig. 55. Eradication of *Fusarium* wilt (*Foc* race 1) infected banana plants (cv. Grand Naine) in Surat district of Gujarat

Status of *Foc*-TR4 in West Bengal

Survey conducted in major banana growing districts of West Bengal revealed the incidence of *Fusarium* wilt in cv. Grand Naine particularly in tissue cultured derived banana (more than 80%). Characterization of *Foc*

pathogen by molecular method resulted that the *Foc* belongs to race 1.

Status of *Foc*-TR4 in Karnataka

Survey made in Karnataka (Chikkeballapura and Bengaluru districts) revealed incidence of *Fusarium* wilt disease in banana cv. Ney Poovan (more than 50%) and no wilt incidence was noticed in cv. Grand Naine.

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

Lateral flow immunostrip was developed for the onsite detection of banana bract mosaic virus (BBrMV) has been released by Shri Radha Mohan Singh, Union Agriculture and Farmers Welfare Minister, during 89th ICAR Foundation Day. The BBrMV immunostrip detected the virus from 10 ng of expressed protein. A method of ELISA was developed to simultaneously detect two viruses namely BBrMV and cucumber mosaic virus (CMV). Different parameters were standardized and developed lateral flow assay for the detection of CMV. Recombinase polymerase amplification (RPA) based detection system for DNA viruses *viz*., banana bunchy top virus (BBTV) and banana streak mysore virus (BSMYV) was standardized and Multiplex reverse transcription-recombinase polymerase amplification-based detection system for DNA and RNA viruses (BBTV and CMV) was standardized.

DBT-ATL Project

4.5.11 Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants (R. Selvarajan and M. S. Saraswathi)

Mother cultures and tissue culture raised plants of different banana cultivars received from twenty-three DBT recognized tissue culture production units were tested for banana viruses. Totally 18192 banana plant samples were tested for the presence of four banana viruses. This year certificate of quality was issued for 57.72 million TC plants.

During the reporting period, as expertise of the 'Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants' 979 batches of tissue culture plants (Grand Naine, Williams, Robusta, Ney Poovan, Red Banana, Quintal Nendran, Sabri etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports issued. This generated an income of Rs.17.32 lakhs to the Institute during 2017-18.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Radio talks

Name of the Scientist	Topic	Date of broadcast
R. Selvarajan	Disease management in banana	1 April, 2017
K. J. Jeyabaskaran	Banana for livelihood	25 April, 2017
I. Ravi	Banana and livelihood of banana farmers	11 July, 2017
A. Thirugnanavel	Genetic diversity and importance of registration of landraces of banana under PPV&FRA	13 September, 2017
V. Kumar	Water, nutrient and weed management in banana	10 October, 2017
B. Padmanaban	Eco-friendly insect pest management in banana	29 November, 2017
R. Thangavelu	Protection of banana from various diseases	2 February, 2018
K. N. Shiva	Post-harvest technology in banana	9 February, 2018

5.2 Television talks

Name of the Staff	Topic	Date of broadcast
P. Ravichamy	Value addition of banana (Captain TV & Polimer TV)	14 July, 2017
P. Ravichamy	Varieties of banana (Makkal TV & Puthiyathalamurai TV)	13 October, 2017
K. N. Shiva	Value added products of banana & Role of ICAR-NRCB in entrepreneurship development (DD-Malayalam)	28 December, 2017

5.3 Exhibitions conducted / participated

Name of the event	Organizer	Venue	Date
Agri Intex - 2017	TNAU; CII; ICAR and Govt. of Tamil Nadu	CODISSIA Trade Centre, Coimbatore, Tamil Nadu	14-15 July, 2017
National banana festival, 2017	CII and TNAU	AC & RI (TNAU), Madurai, Tamil Nadu	21-23 July, 2017
24th ICAR-NRCB foundation day & Kisan Mela	ICAR-NRCB	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	21 August, 2017
AGRI EXPO - 2017	Pasumai Vikatan	St. John's Vestry School, Tiruchirappalli, Tamil Nadu	1-4 September, 2017

Name of the event	Organizer	Venue	Date
International Symposium on Horticulture: Priorities and Emerging trends	ICAR-IIHR	ICAR-IIHR, Bengaluru, Karnataka	5-8 September, 2017
3rd India International Science festival-2017 (IISF-2017)	DST, New Delhi; IIT, Chennai and Govt. of Tamil Nadu	Anna University, Chennai, Tamil Nadu	13-16 October, 2017
World Soil Day	ICAR-KVK, Sirugamani and ICAR-KVK, Karur	ICAR-KVK, Sirugamani, Tiruchirappalli, Tamil Nadu	5 December, 2017
International exhibition and workshop on agro-processing and value addition (VAIGA 2017)	Govt. of Kerala	KAU, Thrissur, Kerala	27-31 December, 2017
Agri Expo-2017 *'Uzhavar Thiruvizha'*	News7 Media, Chennai	Thanjavur, Tamil Nadu	24-26 January, 2018
ICAR-NRCB Silver Jubilee Celebration	ICAR-NRCB Tiruchirappalli, Tamil Nadu	ICAR-NRCB,	17 February, 2018
National Banana Festival 2018, Kerala	CISSA and Govt. of Kerala	Thiruvananthapuram, Kerala	17-21 February, 2018
National Horticulture Fair -2018	ICAR-IIHR	ICAR-IIHR, Bengaluru, Karnataka	15-17 March, 2018
Krishi Unnathi Mela - 2018	ICAR-NRCB	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	17 March, 2018

5.5. Publicity

A total of 25 press releases on ICAR-NRCB activities / meets / technological information (popular articles) were featured in different national and state level newspapers, magazines, journals, radio, television, etc. for the benefit of banana farmers.

5.6. Training

More than 3400 farmers including agricultural & horticultural officers, SHG, entrepreneurs, students and stakeholders were visited at ICAR-NRCB (for getting first-hand information about ICAR-NRCB developed technologies on banana) from different places of the country and they were explained about ICAR-NRCB activities/ technologies for benefit of the farmers/ students. Under the outreach programmees, ICAR-NRCB scientists have trained more than 5000 farmers across the country.

6. EDUCATION AND TRAINING

6.1 Students guided

Student Name	Degree	Project title	Chairperson
M. Gopi	Ph. D. (Microbiology)	Identification and evaluation of antagonistic microbes and botanicals for the management of Fusarium wilt disease (*Fusarium oxysporum* f. sp. *cubense*) in banana cv. Grand Naine	R. Thangavelu
S. Sumathi	Ph.D. (Biotechnology)	Biotechnological approaches for the development of banana specific Arbuscular Mycorrhizal Fungi against Fusarium wilt disease	R. Thangavelu
P. Ganga Devi	Ph.D. (Biotechnology)	Genetic diversity analysis of Sigatoka leaf spot pathogens and its management through microbial	R. Thangavelu
A. Hemavathi	B. Tech. (Biotechnology)	Transmission of banana bract mosaic virus by insect vectors	R. Selvarajan
P. Priyanka	M. Sc. (Biotechnology)	Molecular detection of banana bract mosaic virus in different tissues of banana flower and seed	R. Selvarajan
R. Suman	M. Sc. (Biochemistry)	Biochemical characterization and macro-encapsulation of banana flower bract anthocyanins	M. Mayil Vaganan
K. Kalaimathi	M. Sc. (Biochemistry)	Biochemical and molecular characterization of Rasthali and Grand Naine banana plants genetically transformed with *Os*NAS1 gene	M. Mayil Vaganan
M. Praveena	M. Sc. (Biochemistry)	Alleviation of salinity stress in banana cv. Grand Naine (AAA) by microbial consortium	I. Ravi
M. Surya Prabha	M. Sc. (Biochemistry)	Effect of microbial consortium on soil moisture deficit stress alleviation in banana cv. Rasthali (AAB)	I. Ravi

Student Name	Degree	Project title	Chairperson
Priya Elizebeth Francis	M. Sc. (Food Technology & Quality Assurance)	Physico-chemical changes as affected by ripening agents in banana	K. N. Shiva
Teena Joseph	M. Sc. (Food Technology & Quality Assurance)	Standardization and development of banana flour based snack food (Murukku)	K. N. Shiva
Anaga	M. Sc. (Agricultural Engineering)	Development of a hybrid drying system for drying banana slices	K. N. Shiva
K. Karthickeyan	M. Sc. (Bioinformatics)	*In silico* functional annotation of differentially expressed hypothetical proteins during biotic and abiotic stresses in banana	S. Backiyarani
S. Usharani S. Arthi	B. Tech. (Biotechnology)	Identification of genes responsible for seediness in banana	S. Backiyarani
Keerthiga	M. Sc. (Biotechnology)	Somatic embryogenesis receptor kinase (SERK) gene expression in banana (*Musa* spp.) cv. Rasthali (Silk- AAB)	M. S. Saraswathi
S. Priyanka	B. Tech. (Biotechnology)	Effect of culture media on improving anther culture response in three different commercial cultivars of banana (Karpooravalli, Rasthali and Poovan)	D. Ramajayam
S. Durgadevi	M. Sc. (Biochemistry)	Ferulic acid production from banana fiber	P. Suresh Kumar
Boby George Bhagya Vijayan	M. Sc. (Food Technology & Quality Assurance)	Ripening stage dependent colour chart development for the traditional varieties of banana at room temperature	P. Suresh Kumar
Jain Sarah Jacob	M. Sc. (Food Technology & Quality Assurance)	Development of pasta from banana flour and vinegar from banana peel	P. Suresh Kumar
Manija Madhu	M. Sc. (Food Technology & Quality Assurance)	Development of pre-biotics from banana peel and utilization of ripened banana flour as functional replacement in doughnut	P. Suresh Kumar

6.2 Trainings

6.2.1. On-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	Date
'Hi-tech Banana Cultivation for Enhancing the Production and Productivity of Quality Bananas' to officials of Bayer Crop Sciences Ltd., Mumbai	S. Uma V. Kumar	21-23 June, 2017
'Production of banana fig and banana flour based baby food'	K. N. Shiva	8 September, 2017
'Production of banana flour and flour based baby food'	K. N. Shiva	1-2 March, 2018
'Post-harvest handling, packing and storage of banana flower'	K. N. Shiva	2 March, 2018
'Production of value added products from banana'	S. Uma K. N. Shiva P. Suresh Kumar	12-16 March, 2018
'Cutting edge molecular diagnostics techniques for the viruses affecting banana and plantain' to African Nationals under India-Africa Forum Summit -III	R. Selvarajan	15-29 March, 2018
Internship program for 2nd year students of B. Sc. (Biotechnology), Dr. N. G. P. Arts and Science College, Coimbatore	All Scientists	11-26 May, 2017
Internship program for students of B. Tech. (Food technology) of J. C. T. College of Engineering and Technology, Coimbatore on 'Processing and value addition in banana'	K. N. Shiva P. Suresh Kumar	21-23 June, 2017
Internship program for students of B. Tech. (Biotechnolgy) of Sree Sastha Institute of Engineering and Technology, Chennai and Bannari Amman Institute of Technology, Sathyamangalam	All Scientists	20-27 November, 2017

International Trainees at ICAR-NRCB

6.2.2. Off-Campus Trainings

Title of the Training Program	Course Co-ordinator(s)	Venue	Date
'Post harvest handling, processing and packing of Nendran bananas' to the officials of Fair Exports Ltd., Kochi for export of Nendran to Dubai via Seaport	S. Uma R. Thangavelu K. N. Shiva P. Suresh Kumar	Aroma Exports cold storage, Cumbum, Tamil Nadu	16 June, 2017
'Good harvesting, handling, packaging and storage techniques for export of Nendran banana' to staff of Fair Exports (India) Pvt. Ltd., Kochi	V. Kumar R. Thangavelu K. N. Shiva P. Suresh Kumar	Banana fields in Chamaraja Nagara, Karnataka; Pack house, Angamali, Ernakulam and Kochi port, Kerala	11-12 July, 2017 & 19-22 October, 2017
'Post-harvest management and value addition in banana' to staff of Lulu group	R. Thangavelu K. N. Shiva	Dubai, UAE	9-10 August, 2017
'Importance of registration of indigenous landraces of banana under PPV&FRA' to farmer communities	A. Thirugnanavel	Erumbukadu, Nagercoil, Tamil Nadu	13 September, 2017
Hands-on training on 'Macropropagation'	M. S. Saraswathi	ICAR-KVK, Puzhutheri, Karur, Tamil Nadu	21 September, 2017

Dr. Uma, Director, ICAR-NRCB receiving Indo-Japan best bioresource utilization award

7. AWARDS AND RECOGNITIONS

7.1 Awards

Name	Award details
ICAR-NRCB	'Special Appreciation Award' as knowledge partner at National Banana Festival - 2018 held at Kalliyoor, Tiruvananthapuram, Kerala from 17-21 February 2018
S. Uma	'Indo-Japan best bioresource utilization award'. Awarded jointly by IIT, Guwahati and Gifu University, Japan on 2 February, 2018 at IIT, Guwahati
R. Selvarajan	'Jeersannidhi Award' by Indian Phytopathological Society, Division of Plant Pathology, IARI, New Delhi
I. Ravi	'Fellow of Bose Science Society' - Bose Science Society was established under the Charter of TNSRO (Tamil Nadu Scientific Research Organisation, TNSRO), Affiliated with Vigyan Prasar, DST, Govt. of India, New Delhi
K.N. Shiva	'Best Poster Award' for the paper entitled 'Entrepreneurship development through package of equipment for rope making from outer sheath of banana pseudostem' by Indian Society of Agricultural Engineers, New Delhi on8 January, 2018
D. Ramajayam	'Best Poster Award' for the research paper entitled 'Chipping bucket-A feasible approach for oil palm trunk disposal' at 'International Symposium on Horticulture: Priorities & Emerging Trends' held at ICAR-IIHR, Bengaluru from 5-8 September, 2017
C. Anuradha	'Endeavour Fellowship-2018' by Department of Education and Training, Australian Government
R. Thangavelu S. Backiyarani C. Anuradha B. Sathish	'Outstanding Performer Award' during Swachh Bharat Mission Anniversary for contribution in Swachh Bharat Program

7.2 Recognitions

Name of the Scientist	Details
S. Uma	Member - State Coordination Committee, Tamil Nadu Member - Governing body of Indian Institute of Food Processing Technology, Thanjavur Member - Andhra Pradesh food processing task force Member - District horticulture mission, Tiruchirappalli Co-partner in organizing 'National Banana Festival' jointly organized by the Govt. of Tamil Nadu , TNAU, CII and ICAR-NRCB at AC&RI (TNAU), Madurai during 21-22 July, 2017 Member - Selection committee for the selection of Dean, TNAU, Coimbatore Special invitee to deliver a lecture in the 'International Symposium on Horticulture' held at ICAR-IIHR, Bengaluru during 6-7 September, 2017

Name of the Scientist	Details
S. Uma	Invited speaker in the 'FAO Global Banana Workers Symposium' held at Geneva, Switzerland during 7-11 November, 2017
	Invited member - QRT Meeting on ICAR-AICRP (Fruits), held at ICAR-NRCB, Tiruchirappalli during 19-20 December, 2017
	Invited to deliver a special lecture and chair a technical session in the 'Indo-Japan Bilateral Symposium on Bioresources Utilization' held at IIT, Guwahati, Assam during 1-3 February, 2018
	Chairperson of the organising committee for successful conduct of the 'Group Discussion of ICAR-AICRP (Fruits)' held at ICAR-NRCB, Tiruchirappalli during 15-18 February, 2018
	Invited to deliver a special lecture in the 'Indo-African Summit Training programme' at ICAR-CPCRI, Kasaragod on 20 February, 2018
	Invited to deliver a special lecture on 'Biodiversity in banana' in the ICAR sponsored Short Course held at HC&RI (TNAU), Coimbatore on 5 March, 2018
S. Uma R. Thangavelu	Coordinators for one day 'Consultative meeting on Fusarium wilt disease - Tropical Race – 4 in banana' held at ICAR-NRCB, Tiruchirappalli on 21 December, 2017
J. Poorani	Invited member, 'Ladybird Specialist Group' under the International Union for Conservation of Nature (IUCN) species survival commission, Global species programme
R. Thangavelu	Deputed by ICAR as a country representative to attend 3rd Global Conference of World Banana Forum held at Geneva, Switzerland from 7 to 10 November 2017
	Convener, 5th Annual Group Meeting of AICRP (Fruits) held at ICAR-NRCB, Tiruchirappalli, 15-18 February, 2018
	Co-Chairman, Technical Session on 'Good Agricultural Practices in Banana' at National Banana Festival 2017 held at AC & RI (TNAU), Madurai during 21-23 July, 2017
	Rapporteur for the consultative meeting on "Quarantine and biosafety issues relating to Fusarium wilt Tropical race - 4: An emerging threat to banana cultivation in India" held at ICAR-NRCB, Tiruchirappalli on 21 December, 2017
R. Thangavelu K. N. Shiva	Deputed to Dubai to monitor and inspect the packed 'Nendran' bananas sent from Kochi port to Dubai by sea shipment from 6-12 August, 2017
R. Selvarajan	Developed dip-stick test kit for virus detection which was released by the Union Minister of Agriculture and Farmer's Welfare, Government of India at ICAR foundation day, New Delhi
	Nominated and elected as Zonal President (Southern Zone) of the Indian Phytopathological Society for 2018
	Member, Organizing Committee and Chairperson for technical session held at 26th Annual conference of Indian Virological Society (VIROCON-2017) held at Nitte University, Mangalore from 7-9 December, 2017

Name of the Scientist	Details
R. Selvarajan	Convener, 5th Annual Group Meeting of AICRP (Fruits) held at ICAR-NRCB, Tiruchirappalli from 15-18 February, 2018
	External expert, IBSC committee of ICAR-IIHR, Bengaluru
M. Mayil Vaganan	Associate Editor of journal *International Journal of Agricultural Sciences*
I. Ravi	Special invitee, Global *Musa* genetic resources network's workshop on 'Evaluation of *Musa* genetic resources' held at Montpellier, France, 12-15 December, 2017
	Member of selection committee in Central University of Tamil Nadu, Tiruvarur for recruiting faculty of History & Hindi Officer in 2017
V. Kumar	Member, Conference committee, National Banana Festival-2017 held at AC & RI (TNAU), Madurai, 21-23 July 2017
	Co-Chairman, Technical Session on 'Good Agricultural Practices in Banana' at National Banana Festival 2017 held at AC & RI (TNAU), Madurai, 21-23 July, 2017
	Panel member, Technical session on "Knowledge sharing workshop on tropical fruits - Banana and Pomegranate" held at Anantapuramu, Andhra Pradesh on5 November, 2017
	Convener, 5th Annual Group Meeting of AICRP (Fruits) held at ICAR-NRCB, Tiruchirappalli, 15-18 February, 2018
K. N. Shiva	Co-Chairperson, 'International Exhibition and Workshop on Agro-Processing and Value addition' (VAIGA-2017) held at KAU, Vellanikkara, Thrissur, Kerala on 28 December, 2017
D. Ramajayam	Awarded certificate for outstanding contribution in reviewing the articles for the journal *Scientia Horticulturae*, Elsevier, Amsterdam, The Netherlands
	Membership certificate as a valued Associate Editor for the journal *International Journal of Agriculture Sciences*
C. Anuradha	Honorary life membership from International Society of Root Research (ISRR).
	Life Member, Indian Virological Society
	Editorial member - *International Journal of Current Research and Development*
P. Giribabu	Certificate of excellence in peer reviewing for *Indian Journal of Plant Protection*
	Rapporteur for the session on 'Appraisal of QRT team on ICAR-AICRP on fruits held at ICAR-NRCB, Tiruchirappalli on 20 December, 2018
	Rapporteur, consultative meeting on 'Quarantine and biosafety issues relating to Fusarium wilt Tropical race - 4: An emerging threat to banana cultivation in India' held at ICAR-NRCB, Tiruchirappalli on 21 December, 2018

8. LINKAGES AND COLLABORATIONS

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

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

Project Title	Collaborating Institute(s)
Consortium for managing Indian banana genetic resources	Mizoram University, Aizwal, Mizoram Assam Agricultural University, Jorhat, Assam
Collection, evaluation, documentation and conservation of banana genetic resources from NE region	Indian Institute of Technology, Guwahati, Assam

Project Title	Collaborating Institute(s)
Diversity assessment, germplasm conservation and database development on banana resources in NE India	Tamil Nadu Agricultural University, Coimbatore
Whole genome and transcriptome study to stress tolerant banana cultivars	ICAR-Indian Institute of Horticulture Research, Bengaluru
Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system	Institute of Advanced Study in Science and Technology (IASST), Guwahati, Assam
Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	ICAR Research Complex for NEH region, Umiam, Meghalaya
Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	N.V.Patel Collge of Pure and Applied Science, Guajarat
Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	Utkal University, Bhuaneshwar, Odisha
Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	Tripura University, Suryamaninagar, Tripura
In vitro mass propagation of high value hill area banana	National Botanical Research Institute, Lucknow
Characterization of high value phyto-chemicals of anti-diabetic and immune-modulatory properties in NE banana varieties	Jawaharlal Nehru Tropical Botanic Garden & Research Instt., Thiruvananthapuram
Development of pre & post harvest bunch care management methods for fresh banana	Kohima Science Collge, Jotsoma, Nagaland
Genetic resource assessment, *in situ* conservation and impact of banana waste as a feed for animals in NE region of India	Nagaland University, Medzhiphema, Nagaland
Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal
Management of low temperature and soil moisture deficit stresses in banana growth in NE India	Patkai Christian College, Dimapur, Nagaland
Downstream processing for utilization of banana wastes for natural fiber extraction, fiber	North Eastern Regional Instt. Of Science and Technology, Nirjuli, Arunachal Pradesh
	Nagaland University, Lumami, Nagaland
	Gauhati University, Guwahati, Assam
	TERI School of Advanced Studies, New Delhi
	The Energy and Resource Institute, New Delhi
	ICAR – National Bureau of Plant Genetic Resources, New Delhi
	PSG College of Technology, Coimbatore
	College of Agriculture, Lembucherra, Tripura
	Regional Plant Resource Centre, Bhubaneshwar, Odisha
	ICAR- Research Complex for NEH Region, Nagaland
	Centre – Dimapur, Nagaland
	Jawaharlal Nehru University, New Delhi
	West Bengal State University, Kolkata

Project Title	Collaborating Institute(s)
based products, biomass briquettes and utility compounds	ICAR Research Complex for NEH Region, Manipur Centre, Imphal, Manipur Sikkim University, Gangtok, Sikkim Guru Nanak Dev University, Amritsar, Punjab North East Hill University, Tura Campus, Meghalaya Translational Health Science and Technology Institute, Faridabad Assam down Town University, Guwahati, Assam Institute of Life Science, Bhubaneshwar, Odisha Indian Institute of Technology, Kharagpur Tezpur University, Naapam, Assam College of Veterinary Science, Khanapara, Guwahati National Bureau of Plant Genetic Resources – Regional Station, Shillong National Bureau of Plant Genetic Resources – Regional Station - Hyderabad

9. PUBLICATIONS

9.1 Research Papers

International

Mostert, D., Molina, A.B., Daniells, J., Fourie, G., Hermanto, C., Chao, C.P., Fabregar, E., Sinohin, V.G., Masdek, N., Thangavelu, R., Li, C., Yi, G., Mostert, L. and Viljoen, A. 2017. The distribution and host range of the banana Fusarium wilt fungus, *Fusarium oxysporum* f. sp. *cubense*. *Asia PLoS One.* **12**(7): e0181630. doi: 10.1371

Nandakumar, A., Mayil Vaganan, M., Sundararaju, P. and Udayakumar, R. 2017. Phytochemical analysis and nematicidal activity of ethanolic leaf extracts of *Datura metel*, *Datura innoxia* and *Brugmansia suaveolensis* against *Meloidogyne incognita*. *Asian Journal of Bio Sciences* **2**(4): 1-11.

Nandakumar, A., Mayil Vaganan, M., Sundararaju, P. and Udayakumar, R. 2017. Nematicidal activity of aqueous leaf extracts of *Datura metel*, *Datura innoxia* and *Brugmansia suaveolensis*. *American Journal of Entomology*. **1**(2): 39-45.

Narayana, C. K., Jeyabaskaran, K. J. and Mustaffa, M. M. 2017. Chemical and mineral composition of four cultivars of banana (*Musa* sp.) belonging to different genomic groups grown in India. *International Journal of Current Microbiology and Applied Sciences*, **6**(9): 2862-67.

Poorani, J. 2017. *Stethorus* spp. (Coleoptera: Coccinellidae) predatory on *Schizotetranychus hindustanicus* (Hirst) (Acari: Tetranychidae) from South India, including a new species and a new synonymy in Indian *Stethorus*. *Zootaxa*, **4277**(4), DOI: http://dx.doi.org/10.11646/zootaxa.4277.4.9J.

Venkataraman, S., Prasad, B. V. L. S. and Selvarajan, R. 2018. RNA Dependent RNA Polymerases: Insights from Structure, Function and Evolution. *Viruses*, **10**(2): 76. http://doi.org/10.3390/v10020076.

Yadav, S. K. U., Singh, J., Padmanaban, B. and Kumar, L. S. 2017. Genetic variability in Indian populations of banana corm weevil, *Cosmopolites sordidus* (Coleoptera: Curculionidae) assessed by RAPDs and AFLPs. *International Journal of Tropical Insect Science.* **37**(3), 149-162.

National

Elayabalan, S., Subramaniam, S. and Selvarajan, R. 2017. Construction of BBTV rep gene RNAi vector and evaluate the silencing mechanism through injection of *Agrobacterium tumefaciens* transient expression system in BBTV infected hill banana plants cv. Virupakshi (AAB). *Indian Journal of Natural Sciences*, **7**(42): 12395-12403.

Poorani, J. and Thanigairaj, R. 2017. First report of *Encarsia dispersa* Polaszek (Hymenoptera: Aphelinidae) as a parasitoid of rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin (Hemiptera: Aleyrodidae), a recent invasive pest in India, with notes on its predators. *Journal of Biological Control*, **31**(1): 1–4, DOI: 10.18311/jbc/2017/16263.

Ravichamy, P., Nandakumar, S. and Sivabalan, K. C. 2017. Television for effective dissemination of farm information to banana growers: A study from Tamil Nadu. *Progressive Research – An International Journal.* **12**(1):1146-1149.

Ravichamy, P., Sivabalan K. C., Subramanian, A. R. and Nandakumar, S. 2017. An explorative study on communication

behaviour of banana growers in Tiruchirapalli district of Tamil Nadu. *Journal of Pharmacognosy and Phytochemistry.* **6**: 319-323.

Selvarajan, R., Balasubramanian, V., Jeyabaskaran, K. J. and Mustaffa, M. M. 2017. Yield loss management through fertilizers in banana bract mosaic virus affected French plantain cv. Nendran (AAB). *Indian Journal of Agricultural Sciences*, **87**(8): 1055-61.

9.2 Popular articles

Anuradha, C. and Lakshmi, K. 2017. CRISPR-CAS 9 – A new genome editing tool. https://www.scribd.com/document/372426499/7-CRISPR.

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9.6.1 International

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10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

Consultancy Services / Contract Research / Commercialization of Technologies

I Consultancy Services / Contract Research

S. No.	Date	Name of the Technology	Address of the Client	Revenue (Rs. in Lakhs)
1	20 April, 2017	Technical guidance for trial shipment of 'Nendran' banana for export to Dubai from Kochi Seaport.	Agricultural and Processed Food Products Export Development Authority (APEDA), 3rd Floor, NCUI Building, Opp. Asiad Village, August Kranti Marg, New Delhi - 110 016	6.70
2	4 July, 2017	Evaluation of Metadichol for the *in vitro* inhibition of *Mycosphaerella eumusae* pathogen causing eumusae leaf spot diseases of banana.	M/s. Mac Ojus, 1757, East End 'A' Main, 36th Cross, 9th Block Jayanagar, Bengaluru - 560 069, Karnataka	2.05
3	31 July, 2017	Evaluation of farmer's banana variety – Kamal Vikas A1	National Innovation Foundation – India (Autonomous Body of Department of Science & Technology), Government of India, Satellite Complex, Jodhpur Tekra, Premchand Nagar Road, Satellite, Ahmedabad – 500 082, Gujarat	4.14

II Commercialisation of Technologies

1	8 September, 2017	Banana fig	Mr. Jose Joseph Mathew, Varickamakkal House, Pindimana Post, Kothamangalam - 686 692, Kerala	0.10

S. No.	Date	Name of the Technology	Address of the Client	Revenue (Rs. in Lakhs)
2	8 September, 2017	Banana fig	Mr. Kaushik Selvam, No. 53, West 50 Feet Road, Ramakrishnapuram, Karur - 639 001, Tamil Nadu	0.10
3	8 September, 2017	Banana flour based baby food	Mr. Mager Guilbert Loze T, 39, 29th Street, Shanthinagar, Palayamkottai - 627 002, Tamil Nadu	0.10
4	2 March, 2018	Banana flour and flour based baby food	Mrs. Sethu Viswanathan, Director, Mitraniketan, Vellanad, Trivananthapuram - 695 543, Kerala	0.20
5	2 March, 2018	Post harvest handling, packing and storage of banana flower	Mr. V. Arumugam, 1/65 A, North Street, Athichchanallur, Srivaikundam Taluk, Tuticorin - 628 621 Tamil Nadu	0.10
III	**Other Services**			
1.	Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants (Virus indexing)		Virus indexing of mother plants and mother cultures and tissue culture raised banana plants	282.00
2.	Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants (Genetic fidelity)		979 batches of tissue culture plants of banana cvs. Grand Naine, Williams, Robusta, Ney Poovan, Red Banana, Quintal Nendran, Sabri etc. have been tested for their genetic fidelity using SSR and ISSR markers and reports issued	17.32
3.	Supply of Antisera		Production and sale of polyclonal antiserum for banana viruses *viz*., cucumber mosaic virus (CMV), banana bract mosaic virus (BBrMV)	2.15

S. No.	Date	Name of the Technology	Address of the Client	Revenue (Rs. in Lakhs)
			and banana bunchy top virus (BBTV) to various State Agricultural Universities	
4.		International training Programmes	'Cutting edge molecular diagnostics techniques for the viruses affecting banana and plantain' to nine African Nationals under India-Africa Forum Summit -III	6.69
5.		Supply of mother cultures	Supply of supplied mother cultures of banana cvs. Udhayam and Grand Naine to M/s. Aranya Biotech, Gujarat	0.20
			Supply of 5949 plants (5375 tissue cultured plants + 574 suckers) of banana cv. Udhayam to banana growers of various districts of Tamil Nadu	
	Total			**321.85**

Signing of MoUs / MoCs / MoAs

Date	MoUs / MoCs / MoAs	Details
20 April, 2017	Signing of Memorandum of Understanding for Nendran export	ICAR-NRCB has signed MoU with APEDA & M/s. Fair Exports India Ltd., Kochi for export of banana cv. Nendran to Dubai by sea
26 July, 2017	Signing of Memorandum of Agreement with NIT, Tiruchirappalli, Tamil Nadu	ICAR-NRCB signed MoA with NIT, Tiruchirappalli for developing technologies and postgraduate research programmes
11 October, 2017	Signing of Memorandum of Agreement with KNCET, Thottiyam, Tamil Nadu	ICAR-NRCB has signed MoA with Kongu Nadu College of Engineering and Technology, Thottiyam for developing various machineries for banana production and value addition

Date	MoUs / MoCs / MoAs	Details
16 October, 2017	Signing of Memorandum of Co-operation with Government of Andhra Pradesh	ICAR-NRCB has signed MoC with Government of Andhra Pradesh for developing technologies towards value chain management, supporting banana export, organic production and waste utilization

Signing of MoC by Director, ICAR-NRCB with Chief Minister of Andhra Pradesh

Signing of MoA by ICAR-NRCB with NIT, Tiruchirappalli

11. RAC/ IRC / IMC MEETS

IRC Meet

Mid term Institute Research Council (IRC) meet was held on 18, 22 and 29 September, 2018. All Scientists presented the achievements of on going institute as well as externally funded projects and the technical programme for 2018-19. Few new projects were also presented and discussed in detail.

IMC Meet

The 23rd Institute Management Committee (IMC) meet of ICAR-NRCB was held under the Chairmanship of Dr. S. Uma, Director, ICAR-NRCB on 23 May, 2017. The members were Dr. Vikramaditya Pandey, Principal Scientist, ICAR, KAB-II, New Delhi; Dr. N. Bakthavatsalam, Principal Scientist & Head (Division of Insect Ecology), ICAR-NBAIR, Bengaluru; Dr. (Mrs.) Anuradha Agrawal, Principal Scientist, ICAR-NBPGR, New Delhi; Dr. S. Sriram, Principal Scientist, ICAR-IIHR, Bengaluru; Dean (Horticulture), TNAU, Coimbatore; The Commissioner of Horticulture & Plantation Crops, Government of Tamil Nadu, Chennai; The Additional Director of Horticulture (Fruits), Department of Horticulture, Government of Karnataka, Bengaluru; Finance & Accounts Officer, ICAR-CIBA, Chennai; Mr. M. N. Vaithiyanathan and Mr. S. P. Rajendran. Various institute related financial issues were discussed and deliberated.

IMC members at ICAR-NRCB

RAC Meet

The 19th Research Advisory Committee (RAC) meet of ICAR-NRCB was held on 18-19 January, 2018. The RAC members visited the research farm and experimental plots and had fruitful discussions with the Scientists. Dr. S. Uma, Director, ICAR-NRCB made a detailed presentation on the research achievements of ICAR-NRCB for the last year. This was followed by the presentation of action taken report on the recommendations of 18th RAC meet by Dr. B. Padmanaban, Member Secretary, RAC. Salient achievements of research projects were presented by the Scientists of ICAR-NRCB and discussed. The RAC team expressed happiness over the maintenance of the experimental fields and research output of the Institute.

RAC members of ICAR-NRCB and scientists of ICAR-NRCB

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

Human Resource Development

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

Name of the Staff	Name of the program	Venue	Date
R. Selvarajan Principal Scientist	Transcriptome analytics (Re-sequencing and *De Novo*)	Genome Education Centre, Bionivid Technology, Bengaluru, Karnataka	26-27 April, 2017
D. Ramajayam Principal Scientist	Recent Advances of Bioinformatics in Agricultural Research: A Practical Perspective	ICAR – IASRI, New Delhi	1-21 December, 2017
P. Suresh Kumar Senior Scientist	Advances in applications of nanotechnology	ICAR-CIRCOT, Mumbai, Maharastra	11-15 September, 2017
P. Giribabu Scientist	Capacity building program on 'Technologies for utilization of entomopathogenic nematodes for sustainable management of soil insect pests'	ICAR-NBAIR, Bengaluru, Karnataka	28 August–1 September, 2017
P. Durai Assistant Chief Technical Officer	MusaNet Asia regional workshop on '*Musa* characterization and documentation'	MARDI, Jeranganu, Terengannu, Malaysia	13-17 November, 2017
D. Ramachandra moorthi V. Selvaraj Technical Officers	Competence enhancement programme on soft skills and personality development for technical staff of ICAR	ICAR-NAARM, Hyderabad, Telangana	15-24 June, 2017
K. Kamaraju Technical Officer	Experimental data analysis	ICAR-IASRI, New Delhi	26 July-August 8, 2017
K. Kamaraju Technical Officer R. Pitchaimuthu Senior Technical Assistant	Agrometeorological data collection, analysis and management	ICAR-CRIDA, Hyderabad, Telangana	11-23 December, 2017

Name of the Staff	Name of the program	Venue	Date
M. Bathrinath Senior Technical Assistant	Propagation and nursery management for production of quality planting material	ICAR-IIHR, Bengaluru, Karnataka	13-22 November, 2017
V. Manoharan, Technical Assistant	Automobile maintenance, road safety and behavioral skills	ICAR-CIAE, Bhopal, Madhya Pradesh	18-22 July, 2017
P. Murugan Assistant	Training programme on reservation in services	ISTM, New Delhi	13-15 November, 2017
R. Neela Mega Shyamala Kannan Steno Gr. III	Training programme on efficiency and enhancing behavioural skills	ICAR - NAARM, Hyderabad	25-31 October, 2017
P. Kamaraj V. Ganesan V. Pandian Skilled Supporting Staff	Rain water harvesting and water management techniques	ICAR-KVK Kulithalai, Karur Tamil Nadu	7 October, 2017

12.2 Workshop / Seminar / Conference / Symposia / Scientific meet etc. attended by the Scientists and other staff

Name of the Staff	Event	Organizer / Venue	Date
All staff of ICAR-NRCB	National Banana Festival	AC&RI, TNAU Madurai, Tamil Nadu	21-23 July, 2017
	ICAR-NRCB foundation day	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	21 August, 2017
	Overview of IPR & what you need to know about Patents by Mrs. Girija Sriram, Bengaluru		30 October, 2017
	Interactive Meet on 'Application of nanotechnology for enhancing production and productivity of banana'		25 November, 2017
	Appraisal to quinquennial review team of ICAR-AICRP (Fruits)		19-20 December, 2017
	Consultative meet on "Quaranine and bio safety issues relating to *Fusarium* wilt tropical race-4 - An emerging threat to banana cultivation in India"		21 December, 2017

Name of the Staff	Event	Organizer / Venue	Date
	Fifth group discussion on ICAR-AICRP (Fruits)		15-18 February, 2018
	Krishi Unnati Mela- Awareness on *Fusarium* wilt and mitigation of drought		17 March, 2018
S. Uma B. Padmanaban R. Thangavelu V. Kumar k. J. Jeyabaskaran K. N. Shiva P. Suresh Kumar	Workshop on "Hi-tech cultivation of banana for export"	Organized by Agri Search (India) Pvt. Ltd., Nashik, Maharashtra and ICAR-NRCB, Tiruchirappalli at Jalgaon, Maharashtra	7-8 January, 2018
S. Uma R. Thangavelu	Third global conference of World Banana Forum	FAO, Geneva, Switzerland	10 November, 2017
S. Uma V. Kumar	National Banana Festival steering committee meet	CII Southern region head quarters, Chennai, Tamil Nadu	9 May, 2017 & 19 June, 2017
S. Uma V. Kumar	National Banana Festival steering committee meet	AC&RI (TNAU), Madurai, Tamil Nadu	31 May, 2017
S. Uma V. Kumar	National Banana Festival steering committee meet	Directorate of Horticulture, Chennai, Tamil Nadu	7 July, 2017
S. Uma R. Thangavelu S. Backiyarani M. S. Saraswathi	IITA project – Annual action plan meet	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	23 June, 2017
S. Uma R. Thangavelu	DAC interface meet on Fusarium wilt – Tropical race 4	New Delhi	16 December, 2017
S. Uma R. Thangavelu M. Loganathan	ICAR-Bioversity International collaborative project meet	Bioversity International, Bengaluru, Karnataka	28 December, 2017
S. Uma R. Thangavelu R. Selvarajan M. Mayil Vaganan I. Ravi S. Backiyarani M. S. Saraswathi C. Anuradha	Tenth Institute biosafety committee meet (IBSC)	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	31 October, 2017

Name of the Staff	Event	Organizer / Venue	Date
S. Uma M. Mayil Vaganan S. Backiyarani M. S. Saraswathi D. Ramajayam S. Palanichamy	International symposium on horticulture - priorities and emerging trends	ICAR-IIHR, Bengaluru, Karnataka	4-8 September, 2017
S. Uma M. Mayil Vaganan I. Ravi S. Backiyarani M. S. Saraswathi	Annual BIRAC review meet	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	16 September, 2017
S. Uma I. Ravi S. Backiyarani M. S. Saraswathi A. Thirugnanavel C. Anuradha	Interim review meet of Bioversity / IITA project entitled 'Improvement of banana for smallholder farmers in the great lake regions of Africa	ICAR-NRCB, Tiruchirappalli, Tamil Nadu	19-23 August, 2017
R. Thangavelu V. Kumar	24th Zonal workshop of KVKs (Zone IX) - Sensitization meet on Fusarium wilt – Tropical race 4	KVK, Burhanpur, Madhya Pradesh	24-26 November, 2017
M. Mayil Vaganan I. Ravi	National conference on plant physiology - emerging role of plant physiology for food security and climate resilient agriculture	IGKVV, Raipur, Chhattisgarh	23-25 November, 2017
V. Kumar K. N. Shiva P. Suresh Kumar P. Durai	National seminar on banana	Organized by Centre for Innovation in Science and Social Action (CISSA), Kerala at Kalliyoor, Thiruvananthapuram	17-19 February, 2018
V. Kumar M. Loganathan	Knowledge sharing workshop on tropical fruits-banana and pomegranate	Anantapuramu, Andhra Pradesh	5 November, 2017
K. N. Shiva D. Ramajayam	IIFPT open day on the theme 'Food processing-New way of make in India'	IIFPT, Thanjavur, Tamil Nadu	16 September, 2017

Name of the Staff	Event	Organizer / Venue	Date
K.N. Shiva P. Suresh Kumar	Workshop on Agro-processing and value addition (VAIGA-2017)	Organized by Dept. of agriculture development & farmers' welfare, Govt. of Kerala, at KAU, Thrissur, Kerala	27-31 December, 2017
S. Backiyarani M. S. Saraswathi	Workshop on Indo-German bilateral co-operation in seed sector	Organized by PPV& FRA at NASC, New Delhi	21 November, 2017
R. Thangavelu	Second state coordination committee meet on doubling farmers' income by 2022	TNAU, Coimbatore, Tamil Nadu	7 April, 2017
R. Selvarajan	VIROCON-2017 - Viruses to viromes in health and disease	Nitte University, Mangalore, Karnataka	7-9 December, 2017
	Institute bio safety committee meet (IBSC)	ICAR-IIHR, Bengaluru, Karnataka	9 August, 2017
	Review meet on CRP on vaccine diagnostics	ICAR-IVRI, Bengaluru, Karnataka	6 October, 2017
	Stakeholder meet on "National certification system for tissue culture raised plants (NCS-TCP)	SCOPE Convention Centre Auditorium, Lodhi Road, New Delhi	14 November, 2017
M. Mayil Vaganan	World Soil Day	CREED-KVK, Ariyalur District, Tamil Nadu	5 December, 2017
I. Ravi	Workshop on 'Evaluation of *Musa* genetic resources'	Bioversity International, Montpellier, France	12-15 December, 2017
	National seminar on 'Abiotic stress in Agriculture – Constraints and strategies' (UGC-SAP sponsored)	Annamalai University, Chidambaram	6-7 March, 2018
V. Kumar	Banana stakeholders meet	Organized by CII & Dept. of Horticulture at Salem	19 April, 2017

Name of the Staff	Event	Organizer / Venue	Date
V. Kumar	Consultation meet with scientists of TNAU and KNCET, Thottiam on 'Conveyor system for transport of harvested bunches'	Coimbatore	5 September, 2017
	VIII Scientific advisory committee meet	ICAR-KVK, Dharmapuri	3 November, 2017
	XI Scientific advisory committee meet	ICAR-KVK, Namakkal	7 November, 2017
	IX Scientific advisory committee meet & Awareness programme on 'Safe use of pesticides'	ICAR-KVK, Perambalur	7 December, 2017
K. J. Jeyabaskaran	Brainstorming workshop on yield modeling for horticultural crops under CHAMAN project	MNCFC, New Delhi	18 August, 2017
K. N. Shiva	National conclave on scientific co-operation on food safety and applied nutrition	FSSAI, FDA Bhawan, Kotla Road, New Delhi	5 February, 2018
S. Backiyarani	Annual meet of the East Africa Banana Breeding Project - 'Improvement of banana for smallholder farmers in the Great lakes region of Africa'	Kampala, Uganda	24-27 April, 2017
	Workshop on state level biosafety capacity building	TNAU, Coimbatore	23 March, 2018
D. Ramajayam	VIII Scientific advisory committee meet of ICAR-KVK	ICAR-KVK, Virinjipuram, Vellore	9 November, 2017
	XIX Scientific Advisory Committee meet of ICAR-KVK (CENDECT)	ICAR-KVK (CENDECT) Kamatchipuram, Theni	31 March, 2017
P. Suresh Kumar C. Anuradha	India international science festival – 2017	Anna University, Chennai	13-16 October, 2017
P. Giribabu	International Conference on Biocontrol and Sustainable Insect Pest Management (ICBS-2018)	AC & RI (TNAU), Killikulam, Tamil Nadu	29-31 January, 2018

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

24th ICAR-NRCB foundation day & Kisan Mela

ICAR-NRCB celebrated its 24th Foundation day as 'Kisan Mela' with the theme 'Banana and Plantains for Nutritional Security' on 21 August, 2017. Dr. S. Uma, Director, ICAR-NRCB, presided over the function and Dr. C. Anandaramakrishnan, Director, Indian Institute of Food Processing Technology (IIFPT), Govt. of India, Thanjavur was the Chief Guest of the Function. International scientists, Dr. Rony Swennen, IITA & KUL, Belgium; Dr. Allan Brown, IITA, Tanzania & Dr. Robooni, NARO, Uganda were guests of honour. Dr. S. Uma briefed about last year's achievements of the centre. Dr. C. Anandaramakrishnan, Director, IIFPT urged the farmers to use the facilities available at IIFPT and have collaborative research with ICAR-NRCB. Dr. Rony Swennen, IITA & KUL, Belgium, gave a special lecture on 'Role of banana and plantains in meeting food and nutritional security of people in Africa'. Technical lectures were delivered by Drs. R. Thangavelu and K. N. Shiva. An exhibition was arranged with 20 stalls displaying various inputs and technologies for banana farming.

Release of publications during ICAR-NRCB Foundation day & Kisan Mela

QRT meet of ICAR - AICRP (Fruits)

The Quinquennial Review Team Meet (QRT) of ICAR- All India Co-ordinated Research Project (Fruits) was held during 19-20 December, 2017. The meeting was presided over by Padmashri Dr. K. L. Chadha, Chairman, and Drs. H. K. Senapathi, Satyabrata Maiti, V. S. Thakur and B. M. C. Reddy, members of QRT team. Scientific delegates from various state agricultural universities (SAU) participated in the meet. Presentations were made by Drs. Prakash Patil, Project Coordinator AICRP (Fruits), S. Uma, Director, ICAR-NRCB and other scientists of SAUs. A banana stakeholders' meet was also organized as part of the QRT and the meet was attended by farmers, innovators, entrepreneurs and delegates from SAUs, ICAR-KVKs etc.

Members of QRT team at ICAR-NRCB

Consultative meet on *Fusarium* wilt, Tropical race – 4

A consultative meet on 'Quarantine and biosafety issues relating to *Fusarium* wilt Tropical race - 4: An emerging threat to banana cultivation in India' was held at ICAR-NRCB on 21 December, 2017 where Scientists from different centers *viz*., Dr. N. K. Krishna Kumar, Regional Coordinator - Bioversity International, New Delhi; Dr. Rajan Sharma, Head (Quarantine Unit), ICRISAT, Hyderabad; Dr. N. Sathyanarayana, Joint Director (PP, DPPQS), Faridabad; Dr. M. Anand Raj, Former Director, ICAR-IISR, Calicut; Dr. S. C. Dubey, Head, Plant Quarantine Division, ICAR-NBPGR, New Delhi; Dr. B. K. Pandey, Principal Scientist, ICAR, SMD(Hort. Sci.),

New Delhi; Dr. A. S. Krishnamurthy, Head, Plant Pathology, TNAU, Coimbatore and Dr. K. Soorianathasundaram, Professor, Horticulture, TNAU, Coimbatore participated and issues related to research, biosafety and quarantine of tropical race 4 of *Fusarium* wilt disease were discussed.

Fifth group discussion of ICAR-AICRP (Fruits)

The fifth annual group discussion of ICAR-AICRP (Fruits) was hosted by ICAR-NRCB, Tiruchirappalli during 15-18 February, 2018. Delegates from 37 SAUs and 17 ICAR institutes participated and presented their centre's achievements. Research achievements and technical programmes for each centre were discussed in detail under the chairmanship of Dr. Prakash Patil, Project Coordinator, ICAR-AICRP (Fruits).

The silver jubilee celebration of ICAR-NRCB was formally inaugurated by Dr. Anand Kumar Singh, DDG (Hort. Sci. & Crop Sci.), ICAR on 17 February, 2018. Dr. S. Nagoor Ali Jinnah, CGM, NABARD, Chennai and Dr. B. M. C. Reddy, ICAR, Special Invitee & Ex-Vice Chancellor,YSRHU attended as guests of honours. Directors of various ICAR institutes namely, Dr. M. R. Dinesh, ICAR-IIHR, Bengaluru; Dr. S. Rajan, ICAR-CISH, Lucknow; Dr. M. S. Ladaniya, ICAR-CCRI, Nagpur; Dr. S. D. Sawant, ICAR-NRCG, Pune and Dr. Vishal Nath, ICAR-NRCL, Muzzafarpur attended the meet. Dr. H. P. Maheswarappa, Project Co-ordinator (Palms),

Dr. Anand Kumar Singh, DDG (Hort. Sci. & Crop Sci.), ICAR addressing the gathering at Silver Jubilee Celebrations of ICAR-NRCB

Dr. Manish Das, ICAR-HQ and Dr. S. K. Malik, DG representative, also participated.

Inauguration of Bioversity International – IITA - ICAR-NRCB collaborative megaproject

A pre-launch discussion meet of an International collaborative megaproject titled 'Improvement of banana for small holder farmers in the Great Lake Region of Africa' with research component for ICAR-NRCB titled 'Breeding for improved banana with fusarium wilt resistance' was launched on 1 April, 2017. Dr. N. K. Krishnakumar, Bioversity International - Regional Representative, South & Central Asia, Dr. W. S. Dhillon, ADG (Horti. Sci.), ICAR, New Delhi, Dr. S. Uma, Director, ICAR-NRCB, Tiruchirappalli and scientists from ICAR-NRCB and other state and ICAR institutes attended the meet. The project envisages developing *Fusarium* wilt disease resistant bananas to cater to the needs of Indian farmers. On this occasion, an exhibition showcasing bunches of 75 different varieties of banana was arranged.

Dr. N. K. Krishna Kumar, Regional Coordinator, Bioversity International addressing the gathering at the inaugural session of Bioversity International – IITA - ICAR-NRCB collaborative mega project

Interactive meet on 'Application of Nanotechnology for enhancing productivity of banana'

A one-day interactive meeting was organized at the centre on 'Applications of

nanotechnology for enhancing the production and productivity of banana' with the objective of elucidating the benefits of Nanotechnology and exploring the possibilities of using this technology in banana production, protection and processing system. Dr. K. S. Subramanian, Professor, Nano Science & Technology, TNAU, Coimbatore; Dr. Sarat Chandra Babu, Department of Chemical Engineering, NIT, Tiruchirappalli; Dr. K. Ruckmani, Centre for Excellence in Nano-bio Translational Research, BIT, Anna University, Tiruchirappalli; Dr. G. J. Janavi, Prof & Head, Nano Science & Technology, TNAU, Coimbatore and the scientists of ICAR-NRCB participated in the meet.

Special lecture on IPR

Mrs. Girija Sriram, an eminent Patent agent, IP Solutions, Bengaluru delivered a lecture on 'Overview of IPR and all you need

Participants in Interactive meet on 'Application of Nanotechnology for enhancing productivity of banana'

to know about Patents' at ICAR-NRCB on 30 October, 2017.

Special lecture from visiting faculty

Dr. Jayasankar Subramanian, Professor (Tree Fruit Breeding and Biotechnology), University of Guelph-Vineland, Canada delivered a talk on 'New advances in fruit science' at ICAR-NRCB on 16 March, 2018.

Krishi Unnati Mela - 2018

The ICAR-NRCB organized Krishi Unnati Mela - 2018 on 17 March, 2018. The farmer's meet was attended by over 300 banana farmers from nearby districts such as Tiruchirappalli, Karur, Namakkal, Pudukottai, Perambalur and Ariyalur. Address by the Prime Minister of India was telecast live at the venue and the gist of his speech was translated to the farmers and other participants. Mr. N. Ravichandran, Commissioner, Tiruchirappalli City Corporation was the Chief Guest of the event. Mr. Manikantan Nair, Deputy General Manager, State Bank of India, Tiruchirappalli and Mr. K. Natarajan, Programme Director, All India Radio, Tiruchirappalli also addressed the meet. Dr. S. Uma, Director, NRCB, explained the importance of the programme to the farmers and stressed upon the adoption of improved technologies of drip irrigation, low input agriculture and soil health management for sustainable farming to attain the goal of doubling the farmers' income. Drs. I. Ravi and R. Thangavelu, scientists, ICAR-NRCB delivered lectures on management of Fusarium wilt disease and drought in banana respectively.

Dr. S. Uma, Director, NRCB, explained the importance of the programme

14. DISTINGUISHED VISITORS

Name	Date
Dr. W. S. Dhillon, ADG (Hort.), ICAR, New Delhi	1 April, 2017
Dr. N. K. Krishnakumar, Bioversity International - Regional Representative for South & Central Asia, New Delhi	1 April, 2017
Mr. R. Ravindra, Deputy General Manager, APEDA, Bengaluru	20 April, 2017
Dr. Jawaharlal, Dean, HC&RI, TNAU, Coimbatore	23 May, 2017
Dr. Rony Swennen, IITA & KUL, Belgium	20 & 21 August, 2017
Dr. Allan Brown, IITA, Tanzania	20 & 21 August, 2017
Dr. Robooni, NARO, Uganda	20 & 21 August, 2017
Dr. C. Anandharamakrishnan, Director, IIFPT, Thanjavur	21 August, 2017
Mrs. Girija Sriram, Patent agent, IP Solutions, Bengaluru	30 October, 2017
Dr. (Mrs.) G. J. Janavi, Professor & Head, Department of Nano Science & TechnologyTNAU, Coimbatore	25 November, 2017
Dr. K. S. Subramanian, NABARD Chair Professor, Department of Nano Science & Technology, TNAU, Coimbatore	25 November, 2017
Dr. J. Sarat Chandra Babu, NIT, Tiruchirappalli	25 November, 2017
Dr. K. Ruckmani, Dept. of Pharmaceutical Tech., Anna University, Tiruchirappalli	
Dr. S. N. Pandey, Former ADG (Hort. Sci.)	18 & 19 January, 2018
Dr. W. S. Dhillon, Assistant Director General (Hort. Sci.), ICAR, New Delhi	18 & 19 January, 2018
Dr. P. Ananda Kumar, Former Director, ICAR-NGCFP, Hyderabad	18 & 19 January, 2018
Dr. A. K. Misra, Former Head, CISH, Lucknow	18 & 19 January, 2018
Dr. N. Kumar, Former Dean, TNAU, Nagerkovil	18 & 19 January, 2018
Dr. Anand Kumar Singh, DDG (Hort. Sci. & Crop Sci.), ICAR, New Delhi	17 February, 2018
Dr. S. Nagoor Ali Jinnah, CGM, NABARD, Chennai	17 February, 2018
Dr. B. M. C. Reddy, ICAR, Special Invitee & Ex-Vice Chancellor, Dr. YSRHU	17 February, 2018
Dr. M. R. Dinesh, Direcor, ICAR-IIHR, Bangalore	17 February, 2018
Dr. S. Rajan, ICAR-CISH, Lucknow	17 February, 2018
Dr. M. S. Ladaniya, ICAR-CCRI, Nagpur	17 February, 2018
Dr. S. D. Sawant, ICAR-NRCG, Pune	17 February, 2018
Dr. H. P. Maheswarappa, Project Co-ordinator (Palms), Kasaragod	17 February, 2018
Dr. Manish Das, ICAR-HQ, New Delhi	17 February, 2018
Dr. Jayasankar Subramanian, Professor (Tree Fruit Breeding and Biotechnology), University of Guelph-Vineland, Canada	16 March, 2018

Name	Date
Mr. N. Ravichandran, Commissioner, Tiruchirappalli City Corporation, Tiruchirappalli	17 March, 2018
Mr. Manikantan Nair, Deputy General Manager, State Bank of India, Tiruchirappalli	17 March, 2018
Mr. K. Natarajan, Programme Director, All India Radio, Tiruchirappalli	17 March, 2018

15. EMPOWERMENT OF WOMEN

Training Details	Date
Banana fiber and its products – Importance and scope to 19 rural women of M/Gramalaya, Tiruchirappalli at ICAR-NRCB, Tiruchirappalli, Tamil Nadu	30 May, 2017
Banana fiber and its products – Importance and scope to 24 rural women of M/s Gramalaya, Tiruchirappalli at ICAR-NRCB, Tiruchirappalli, Tamil Nadu (sponsored by NABARD)	3 July, 2017
Value addition in banana to 25 self help groups (SHG) for women, Ariyalur Dist., Tamil Nadu at ICAR-NRCB, Tiruchirappalli, Tamil Nadu	23 November, 2017

16. PERSONNEL

16.1 Staff News

Name	Event	Date
Dr. D. Ramajayam, Principal Scientist	Promoted from Senior Scientist (Fruit Science) to Principal Scientist (Horticulture)	w.e.f. 10 October, 2016
Dr. A. Thirugnanavel, Scientist	Transferred to ICAR-Central Citrus Research Institute, Nagpur	3 November, 2017
Mr. B. Sathish, Senior Administrative Officer	Transferred to ICAR-Indian Institute of Rice Research, Hyderabad	22 April, 2017
Dr. P. Ravichamy Senior Technical Officer	Awarded Ph.D. degree	17 November, 2017
Mr. V. Selvaraj, Senior Technical Assistant	Promoted to Technical Officer	w.e.f. 5 March, 2017
Mr. T. Sekar, Senior Technical Assistant	Promoted to Technical Officer	w.e.f. 10 March, 2017

Name	Event	Date
Mr. K. Kamaraju, Senior Technical Assistant	Promoted to Technical Officer	w.e.f. 10 March, 2017
Mr. V. Manoharan, Technical Assistant	Promoted to Senior Technical Assistant	w.e.f. 18 June, 2017
Mr. R. Mohanraj,	Promoted to Lower Division Clerk	w.e.f. 21 April, 2017
Mr. P. Mohan, Senior Technical Assistant (Driver)	Superannuation	31 July, 2017

16.2 Staff position

Scientific Staff

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

Technical Staff

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

Administrative, Audits & Accounts and Supporting Staff

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

17. OTHER INFORMATION

National Banana Festival - 2017

The ICAR-NRCB participated in the 'National Banana Festival' held at AC&RI, Madurai, Tamil Nadu from 21-23 July, 2017. The event was organized by Confederation of Indian Industry, Chennai in collaboration with TNAU, ICAR-NRCB, NHB, NABARD and other industry partners. The festival was inaugurated by five state ministers including Agriculture, Forestry, Co-operative, Revenue and Education. Other dignitaries included Mr. Shakil P. Ahammed, Joint Secretary, Ministry of Agriculture and Farmers' welfare, Govt. of India; Mr. Gagandeep Singh Bedi, Agriculture Production Commissioner & PS, Dept of Agriculture, Govt. of Tamil Nadu; Mr. K. Veera Raghava Rao, Collector; Dr. K. Ramasamy, Vice Chancellor, TNAU, Dr. S. Uma, Director, ICAR-NRCB; Mr. S. Nagoor Ali Jinnah, CGM, NABARD; Mr. P. Ravichandran, Chairman, Tamil Nadu State Council, CII. ICAR-NRCB displayed bunches of more than 100 banana varieties and more than 25 value added products like banana fig, flower pickles, extruded snacks, flour based baby powder, cookies and banana fiber based handicrafts.

Director, ICAR-NRCB with Ministers Tamil Nadu at National Banana Festival- 2017

National Banana Festival - 2018

The ICAR-NRCB participated in 'National Banana Festival-2018', organized by Centre for Innovation in Science and Social Action (CISSA), Kerala from 17-21 February 2018 at Thiruvananthapuram, Kerala. A 'National Seminar on Banana' was organized in which scientists and students of the centre gave lead presentations and research abstracts. In the exhibition, the centre displayed bunches of 50 banana varieties and value added products.

Dr. Radha Mohan Singh, Hon'ble Union Minister for Agriculture and Farmers Welfare, GoI visit to ICAR-NRCB stall

World Soil Day

The ICAR–NRCB celebrated 'World Soil Day' in collaboration with ICAR-KVK, Sirugamani and ICAR-KVK, Karur on 5 December, 2017. Dr. S. Uma, Director, ICAR-NRCB inaugurated the exhibition and distributed soil health cards to farmers. Scientists of the centre delivered lectures on banana cultivation and soil health management. About 800 farmers of Tiruchirapalli, Karur and Namakkal districts of Tamil Nadu participated.

Signing MoC with State Government of Andhra Pradesh

A 'Memorandum of Cooperation' was signed between ICAR-NRCB and State Government of Andhra Pradesh on 16 October, 2017. Dr. S. Uma, Director, ICAR-NRCB and Shri M. Girija Shankar, Secretary to Government, Industries and Commerce Department, Government of Andhra Pradesh signed the MoC in the presence of Mr. N. Chandrababu Naidu Chief Minister of Andhra Pradesh. ICAR-NRCB will act as 'Knowledge Partner' in developing technologies towards value chain management, supporting banana export, organic production and waste utilization. The centre also provides training to farmers and entrepreneurs to promote indigenous and commercial varieties for domestic and export market.

Signing of MoA with NIT, Tiruchirappalli

A 'Memorandum of Agreement' was entered between ICAR-NRCB and NIT, Tiruchirapalli on 26 July, 2017. Dr. S. Uma, Director, NRCB and Dr. Mini Shaji Thomas, Director, NIT signed the MoA at NIT, Tiruchirapalli, on behalf of the respective institutes. Both the institutions have agreed to exchange ideas and expertise for developing imaging systems, electronic devices, solar energy applications in agriculture, nanotechnology and other fields by enlisting the students for internship and postgraduate research programmes for the benefit of farming community.

Signing MoA with KNCET

A 'Memorandum of Agreement' was signed between ICAR-NRCB, Tiruchirapalli and Kongunadu College of Engineering & Technology (KNCET), Thottiyam, Tamil Nadu on 11 October, 2017. Dr. S. Uma, Director, ICAR-NRCB and Dr. P. S. K. R. Periyasamy, Chairman, KNCET signed the MoA at the centre. The agreement focussed on developing biosensors and imaging technology for pest detection, portable cable car conveyor system for the transportation of harvested bunches and to promote green technology through utilization of solar power and other fields. This agreement also supports enlisting the students for internship and post graduate research programmes at ICAR-NRCB.

Dr. S. Uma, Director, ICAR-NRCB and Dr. PSK R. Periyasamy, Chairman, KNCET, Trichy exchanging the MoA on for collaborative research programmes

Signing MoU for the export of Nendran Banana to Dubai

The ICAR-NRCB and (APEDA) entered into a 'Memorandum of Understanding' for the export of Nendran Banana to Dubai in

Dr.S.Uma, Director, ICAR-NRCB, Trichy handing over the MoU to Mr. R. Ravindra, Dy. General Manager, APEDA, Bengaluru for the project on the export of Nendran Banana to Dubai

partnership with M/s. Fair Exports India Ltd., Kochi through Sea port on 20 April, 2017. Dr. S. Uma, Director, ICAR-NRCB and Mr. R. Ravindra, Deputy General Manager, APEDA, Bengaluru signed the MoU. The MoU intends to develop a sea protocol for the export of Nendran Bananas initially, followed by Ney Poovan.

Agricultural Education Day

The ICAR-NRCB celebrated the birth anniversary of Bharat Ratna Dr. Rajendra Prasad, former President and Union Minister of Agriculture, India as 'Agricultural Education Day' on 4 December, 2017. Various events including quiz competition, essay writing and debate were conducted to school children and college students and prizes were distributed.

Students with ICAR-NRCB staff at Agricultural Education Day

ISO 9001: 2015

The ICAR-NRCB upgraded to ISO 9001: 2015 from ISO 9001: 2008, as part of the continual improvement and to keep the systems in place to follow the Quality Management Systems (QMS) procedures. ISO certification body auditors Mr. B. Karthikeyan, Director & Lead Auditor and Mr. V. Sivakumar, Auditor, Quest Certification (P) Ltd, Chennai visited the Institute and certified ICAR-NRCB ISO 9001: 2015 compliant on 21 April, 2018.

International training on 'Cutting edge molecular diagnostics techniques for the viruses affecting banana and plantain'

The ICAR-NRCB hosted an international training programme under Indo-African Forum Summit-III on 'Cutting edge molecular diagnostics techniques for the viruses affecting banana and plantain' during 15-29 March, 2018. Nine trainees from Kenya, Comoros, Sudan, Ethiopia and Malawi participated. Totally 18 lectures on various aspects of diagnostic techniques were delivered by resource persons from the centre as well as experts from outside. Hands-on training was imparted on different detection techniques developed at our accredited test laboratory for four banana viruses. The trainees were highly satisfied with the exposure that they had at the centre on diagnostics.

'Swachh Bharath' Activities

The ICAR-NRCB conducted various activities for promotion and popularization of the cleanliness drive initiated by the Government of India.

Distribution of Tree guard to Government School by ICAR-NRCB

ICAR-NRCB staff at staff quarters during Swachch Bharat mission

Activity	Month
Celebration of 'Sewa Diwas'; Celebration of 'Samagra Swachhta Diwas'; Celebration of 'Sarwatra Swachhta'	September, 2017
Cleaning of nearby 'Tourist Spots' of Tiruchirappalli; Launching of special cleaning drive at ICAR-NRCB premises	October, 2017
Creation of awareness on the importance of planting and aftercare of trees, proper upkeep and use of school toilets among primary school children by the Director and Scientists; Distribution of stainless steel drinking water container fitted with tap for providing safe and clean drinking water to the Anganwadi children of the adopted village – Keerikalmedu; Distribution of floor mats for hygienic sitting of Anganwadi children; Provision of tree guards to protect the small plants from wind and animal grazing	November, 2017
Cleaning and weeding at the Office premises; Pit digging, planting and fixing of tree guards; Comprehensive campaign through distribution of T-shirts containing Swachh Bharat slogans; Special cleaning drive on 31 December, 2017 involving local peoples of nearby villages, staff and their family members including SRF, RA, PhD Scholars, Contractual staff, *etc*.	December, 2017
Special drive on cleaning and weeding experimental blocks at ICAR-NRCB's Research Farm	January, 2018
Tree planting at Research Farm by RAC Chairman and Members; Special cleaning drive and Pongal Celebration by RAC members and Staff of ICAR-NRCB	February, 2018
Distribution of dustbins to collect bio-degradable and non-degradable wastes generated from Primary Govt. School of the Centre's adopted village; Distribution of bio-degradable bags to Primary school children to purchase household grocery items; Administration of Swachhta pledge to school children; Practicals on segregation of bio-degradable and non-degradable wastes generated from the school/Class rooms; Distribution of bio-degradable bags to petty shop owners in the adopted village.	March, 2018

International Yoga Day

'International Yoga Day' was celebrated on 20 June, 2017. Members from Jai Ranga Nature Cure Hospital and Yoga Research Centre, Tiruchirappalli demonstrated various yogas to ICAR – NRCB staff.

Sports meet

ICAR – NRCB participated in the ICAR Inter-Institutional Sports meet for South zone held at Coimbatore from 9-13 October, 2017. A contingent of 10 members participated in the events, *viz.*, Badminton, Javelin, Disc Throw, Chess and Carrom.

Independence Day and Republic Day celebrations

Independence Day and Republic Day were celebrated at ICAR-NRCB on 15 August, 2017 and 26 January, 2018 respectively. Dr. S. Uma, Director, ICAR - NRCB hoisted the National flag and addressed the staff.

Constitution Day

The Staff of ICAR-NRCB read the preamble of the constitution of India as a part of the 125th birth anniversary celebration of Dr. B. R. Ambedkar on 27 November, 2017.

Hindi Pakhwara

ICAR–NRCB celebrated '*Hindi Pakhwara*' from 14 – 28 September, 2017. Various competitions *viz.,* singing, quiz, news reading, etc. were held and prizes were distributed.

Joint Hindi Competition - TOLIC 2017

The Staff of ICAR-NRCB actively participated in 'Joint Hindi Competitions – TOLIC 2017', held at Tiruchirappalli from 21 November, 2017 to 12 December, 2017. R. Pitchaimuthu and P. Giribabu won first prize and third prize for Audio-Visual Quiz respectively.

ANNEXURE – I

I Institute projects

	Name of the Project	Principal Investigator
	Crop Improvement	
1.	Improvement and management of banana genetic resources in Indian subcontinent	S. Uma
2.	Improvement of banana through conventional breeding	S. Backiyarani
3.	Development of trait specific markers for fusarium wilt resistancethrough association mapping studies in banana (*Musa* spp.)	M. S. Saraswathi
4.	Improvement of cv. Grande Naine (Cavendish – AAA) for Fusarium wilt resistance through non-conventional breeding	M. S. Saraswathi
5.	Production of doubled haploids for improvement of bananas (Musa spp.)	D. Ramajayam
6.	Identification and evaluation of superior clones of cv. Ney Poovan (AB) and Grand Naine (AAA)	R. Natarajan
	Crop Production & Post Harvest Technology	
7.	Studies on nutrient dynamics in banana	K. J. Jeyabaskaran
8.	Organic banana farming for sustainable soil health and nutritional security	K. J. Jeyabaskaran
9.	Development of clump management technology for enhanced productivity in banana	V. Kumar
10.	Development of pre and post harvest techniques for leaf production in banana	K. N. Shiva
11.	Development of modified atmosphere packaging techniques in banana and plantain for domestic and export markets	K. N. Shiva
12.	Functions of resistant starch and designer food development from banana flour	P. Suresh Kumar
13.	High temperature and soil moisture deficit stresses in banana: Mechanism of high temperature tolerance and management of high temperature and soil moisture deficit stresses in banana	I. Ravi
14.	Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower	M. Mayil Vaganan
	Crop Protection	
15.	Identification of pheromones of Banana stem weevil, *Odoiporus longicollis* for the management of the pest	B. Padmanaban
16.	Pest mapping in bananas and plantains of India	J. Poorani

	Name of the Project	Principal Investigator
17.	Investigation on fungal and bacterial diseases of banana and their management	R. Thangavelu
18.	Survey, etiology and management of rhizome rot of banana	M. Loganathan
19.	Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	R. Selvarajan
20.	Proteomic analysis of host-BBTV interaction in banana	C. Anuradha
21.	Investigations on *Musa* nematode's diversity, biology, behavior and their interactions	P. Giribabu

II ICAR funded projects

	Name of the Project	Principal and Co-Investigator(s)
1.	Network project on Transgenics in crops – Banana functional genomics (Sigatoka & Drought component)	S. Uma R. Thangavelu S. Backiyarani M. S. Saraswathi I. Ravi
2.	Survey, characterization and management of a most virulent strain of *Fusarium oxysporum* f. sp. *cubense* infecting banana	R. Thangavelu S. Backiyarani
3.	Consortium research platform on vaccines and diagnostics	R. Selvarajan C. Anuradha
4.	Assessment of post-harvest losses in banana	K. N. Shiva

III Other agencies funded projects

	Name of the Project	Funding Source	Principal and Co-Investigator(s)
1.	Improvement of Banana For Smallholder Farmers in The Great Lakes Region of Africa - Enhancing Banana Production by Developing Fusarium Wilt-Resistant Varieties and Benefit Sharing with African Smallholder	IITA	S. Uma S. Backiyarani R. Thangavelu M. S. Saraswathi
2.	Biofortification and development of disease resistance in Banana	DBT - QUT	
	Component - 1: Biofortification and evaluation of Indian banana with pro Vitamin A (PVA) constructs		S. Backiyarani S. Uma M. Mayil Vaganan
	Component - 2: Biofortification and evaluation of Indian banana with Iron constructs		M. Mayil Vaganan I. Ravi K. J. Jeyabaskaran

	Name of the Project	Funding Source	Principal and Co-Investigator(s)
	Component - 3: Development of efficient ECS for Rasthali and providing authentic virus free IMFC to Indian Partners		S. Uma S. Backiyarani M. S. Saraswathi
3.	Twinning programme on 'Molecular characterization of *Fusarium oxysporum* f.sp. *cubense* causing Fusairum wilt on banana and its sustainable management'	DBT	R. Thangavelu S. Backiyarani
4.	National certification system for tissue culture plants	DBT-ATL	R. Selvarajan M. S. Saraswathi
5.	Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali through induced mutagenesis	DAE	M. S. Saraswathi R. Thangavelu S. Uma S. Backiyarani
6.	Framing crop specific DUS guidelines for banana (*Musa spp*.)	PPV & FRA	S. Uma M. S. Saraswathi S. Backiyarani
7.	Consortium for managing Indian banana genetic resources	DBT - NER	S. Uma M. S. Saraswathi S. Backiyarani
8.	Genetic resource assessment, *in-situ* conservation and impact of banana waste as a feed for animals in NE region of India	DBT - NER	M. S. Saraswathi S. Uma
9.	Whole genome and transcriptome study to stress tolerant banana cultivars	DBT - NER	S. Backiyarani S. Uma I. Ravi
10.	Collection, evaluation, documentation and conservation of banana genetic resources from NE region	DBT - NER	M. S. Saraswathi M. Mayil Vaganan
11.	*In vitro* mass propagation of high value hill area banana	DBT - NER	M. S. Saraswathi R. Thangavelu I. Ravi
12.	Diversity assessment, germplasm conservation and database development on banana resources in NE India	DBT - NER	M. S. Saraswathi S. Backiyarani
13.	Characterization of high value phyto-chemicals of anti diabetic and immune-modulatory properties in NE banana varieties	DBT - NER	M. Mayil Vaganan I. Ravi P. Suresh Kumar
14.	Management of low temperature and soil moisture deficit stresses in banana growth in NE India	DBT - NER	I. Ravi M. Mayil Vaganan M. S. Saraswathi
15.	Development of pre & post harvest bunch care management methods for fresh banana	DBT - NER	P. Suresh Kumar K. N. Shiva

Name of the Project	Funding Source	Principal and Co-Investigator(s)
16. Value addition of banana and creating small scale enterprises of Meghalaya tribal community through minimal processing technology	DBT - NER	P. Suresh Kumar V. Kumar K. N. Shiva
17. Downstream processing for utilization of banana wastes for natural fiber extraction, fiber based products, biomass briquettes and utility compounds	DBT - NER	P. Suresh Kumar K. N. Shiva
18. Exploring diversity, genomic and transcriptome profiling and phyto semiochemicals of banana pest complex in NE Region	DBT - NER	B. Padmanaban S. Backiyarani J. Poorani
19. Molecular dissection of defense against Sigatoka infection in banana - Exploitation of *Musa* germplasm of NE for development of Sigatoka resistant hybrid	DBT - NER	R. Thangavelu
20. Screening of banana germplasm from the NE for Fusarium wilt resistance and molecular characterization in contrasting genotypes	DBT - NER	R. Thangavelu
21. Knocking out the virus – Elimination of the endogenous banana streak viral sequences from banana through genome editing with CRIPSPR – Cas9 system	DBT - NER	R. Selvarajan C. Anuradha
22. Biotechnological interventions through RNAi approach for management of banana bunchy top virus in NE region of India	DBT - NER	R. Selvarajan C. Anuradha

IV. Contract research projects

1. Evaluation on the effect of foliar spray of Pronos and Dormulin for the suppression of *Eumusae* leaf spot disease of banana (Dr. R. Thangavelu).
2. Evaluation of Paraffinic oil for the management of leaf spot diseases of banana cv. Grand Naine. M/S Raj Petro specialities Pvt. Ltd., Chennai, Tamil Nadu (Dr. R. Thangavelu).
3. Evaluation of Metadichol for the *in vitro* inhibition of *Mycoshaerella eumusae* pathogen causing *Eumusae* leaf spot disease of banana (Dr. R. Thangavelu).

ANNEXURE – II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Relative Humidity (%)	Rainfall (mm)
April 2017	40.43	27.3	34	0
May 2017	40.6	28.3	39.22	65
June 2017	37.96	27.9	49.56	46.4
July 2017	39.4	29.2	47.2	45
August 2017	36.76	27.5	54.56	174.1
September 2017	34.2	25.6	58.5	261.2
October 2017	34.93	26.8	58.26	216.4
November 2017	30.96	24.2	65.26	93.2
December 2017	31.06	23.3	65.9	31.5
January 2018	30.45	21.6	50.16	0
February 2018	32.75	22.5	44.64	8.4
March 2018	35.77	22.4	41.54	0
Total				941.2

भाकृअनुप
ICAR

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तायनूर पोस्ठ तोगमलै रोड
तिरूच्चिरापक्कि ६२० १०२ए तमिल नाडु भारत

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