NRC BANANA

NRCB

Annual Report
2012 - 2013

वार्षिक प्रतिवेदन
२०१२ - '१३

भाकृअनुप
ICAR

NATIONAL RESEARCH CENTRE FOR BANANA
TIRUCHIRAPALLI

NATIONAL RESEARCH CENTRE FOR BANANA

राष्ट्रीय केला अनुसंधान केंद्र

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भारतीय कृषि उनुसंधान पर्षद
तायनूर पोस्ठ तोगमलै रोड तिरूच्चिरापक्कि ६२० १०२ तमिल नाडु

NATIONAL RESEARCH CENTRE FOR BANANA

(Indian Council of Agricultural Research)
Thayanur Post, Thogamalai Road, Tiruchirapalli - 620 102, Tamil Nadu

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PREFACE

Banana and plantain serves not only as staple food and nutritious fruit to the world population but also serves as vegetable, a source of natural fiber and bio-plate. Besides, it provides basic raw material for several value added products from fruits, fiber and leaves. The research activities at the National Research Centre for Banana, Tiruchirapalli during the last two decades are focused on to improve the productivity and to mitigate the constraints posed by biotic and abiotic stresses under the changing climatic conditions. In this endeavor, research, education and extension activities continued as in the past years by the scientists of the Centre and I take great pride in presenting the outcome of research activities in the areas of Improvement, Production and Protection in the Annual Report 2012-'13.

In the research year of 2012-'13, several milestone research activities were carried out and completed. In Improvement, embryo rescue for direct regeneration and indirect organogenesis through somatic embryogenesis and multiple shoot formation were successfully standardized. "Formosona" (high yielding Cavendish variety and resistant to *Fusarium* wilt (race-4)) from Taiwan Banana Research Institute, Taiwan was added. Fingerprinting of 14 unique landraces using ISSR and SSR markers was done. PCR conditions have been standardized for EST derived primers in Sigatoka challenged cDNA-SSH library and also developed two markers to identify the banana genome.

In Production section, which includes production, physiology, biochemistry and post-harvest technology, significant research achievements were made which include application of recommended dose of NK fertilizers in the ratio of 7:2:1 N and 4:3:3 K_2O at vegetative, flowering and bunch development stages respectively was standardised for Udhayam first ratoon crop. Validation of the fertilizers adjustment equations developed for different banana varieties by NRCB at different banana growing areas in AICRP Centres revealed a high level of fitness under Coimbatore (Tamil Nadu) conditions for Ney Poovan; Mohanpur (West Bengal) conditions for Martman; under Kerala conditions for Nendran and under Arabhavi (Karnataka) conditions for Ney Poovan.

Reduction by leaf pruning of photosynthate source in cvs. Poovan, Ney Poovan and Karpuravalli on flowering and fruit yield lead to production of more photosynthesis as a compensation mechanism. Study indicated salt injury percentage could be used as a trait for phenotyping for salt tolerance among banana genotypes. Protein isolation protocol for 2-DE proteomic analysis of banana roots, using phenol as extractant and ammonium acetate as precipitant was found suitable. A banana pulp based ready-to-drink beverage was developed which was on par with banana RTS beverage with consumer preference.

Important research achievements in protection indicated toxins from the NRCB *Beauveria bassiana* isolate had high mortality rate on stem weevil. Using GC/MS, 23 volatile compounds were identified from leaf sheath of cv. Karpuravalli which has the potential as pheromone. Biopriming by application of different entophytes with botanical combinations gave complete control of Fusarium

wilt in Grand Naine plants. A highly sensitive method of Loop mediated Isothermal Amplification for detection of BBTV in non-symptomatic samples was standardized.

In the HRD area, scientists were deputed to 10 national training programmes to upgrade skills in their respective areas. Under transfer of technology, various banana value added products technologies were transferred to entrepreneurs and Self Help Groups for commercialization. Also, a National Conference was organised on 'Adaption to Climate Change for Sustained Production of Banana' at Jalgoan, Maharastra and many collaborative and linkages with different national agencies have been imitated. About 4500 banana farmers, Agricultural & Horticultural officers, self-help groups and students visited the Centre and were appraised on the activities of the Centre.

It is my privilege to congratulate and also thank Dr. B. Padmanaban, Chairman and Drs. M. Mayil Vaganan, C. Anuradha and Mr. P. Ravichamy members of the Publication Committee for their good works in compiling, editing and bringing out this report of the Centre in time.

I place on record my sincere gratitude to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for his valuable guidance and Dr. N. K. Krishna Kumar, Dy. Director General (Hort.), ICAR for his constant inspiration and encouragement.

(M.M.Mustaffa)
Director

2. EXECUTIVE SUMMARY

In Red Banana (AAA) a short duration accession and a high yielding Ash coated Monthan (ABB) were identified from farmer's field and Formosona variety (a Cavendish mutant with high yield and resistance to *Fusarium* wilt (race – 4) from Taiwan Banana Research Institute (TBRI), Taiwan were added. Elite clones of Ney Poovan and Grand Naine were collected through survey. NRCB selection - 08 proved its superiority in respect to yield and crop duration in all the AICRP centers tested. Six introduced banana accessions were morphotaxonomically characterized using IPGRI Banana descriptor and their identity confirmed. DNA fingerprints for 14 indigenous landraces have been developed using SSR and ISSR markers and documented. *In vitro* screening of 30 banana hybrids against root-lesion nematode and root-knot nematode revealed 15 and 4 hybrids were resistant to *P. coffeae* and *M. incognita* respectively.

Field evaluation of two *M. balbisiana* clones collected from Nagaland *viz.,* Paglapahad and Prima *Wild* were found promising for leaf industry. Cultivar Saba based progeny (No.183) was found promising in terms of fruit qualities like firm pulp, good cooking quality and suitability to chips making. Namwakhom (Pisang Awak, ABB) a dwarf and exotic introduction was found promising and was suitable for high density planting.

Embryo rescue for direct regeneration and indirect organogenesis through somatic embryogenesis and multiple shoot formation have been successfully standardized. For the first time, somatic embryos of Marabale x Pisang Jajee hybrid has been developed which were shifted to suspension culture. Embryo rescue has been standardized for Rhodochlamys based hybrids (*M. ornata* and *M. laterita*). Protocol has been standardized for the direct regeneration of plants from immature male flower buds of cv. Rasthali.

PCR conditions have been standardized for EST derived primers in Sigatoka challenged cDNA –SSH library. Ubiquitin has been identified as the house keeping genes and will be used as reference in expression studies for Sigatoka and drought. Full length genes of NBS-LRR R genes and chitinase, which were upregulated during nematode infection, were isolated and characterized.

In the first ratoon crop of cv. Udhayam, application of recommended dose of NK fertilizers (RDF) (300:400g N&K plant^{-1}) in the ratio of 7:2:1 N and 4:3:3 K_2O at vegetative, flowering and bunch development stages recorded the earliest fruit maturity, whereas, application of RDF in the ratio of 7:3:0 N and 6:2.5:1.5 of K_2O significantly delayed the fruit maturity by ten days**.** Among different plant densities, 2.4 X 2.4m spacing (1736 plants/ha) recorded the earliest fruit maturity while 3.6 X 3.6m spacing with three suckers per pit (2315 plants/ha) delayed the fruit maturity. Among three levels of nutrients, application of RDF in ratio of 7:2:1 N and 4:3:3 K_2O recorded the highest bunch weight (30.2 kg) with more number of hands and fingers. Among the five plant populations, the highest bunch weight was recorded (1736 plants/ha) and the highest total yield of 78.1 t/ha was recorded in planting of two suckers per pit at a spacing of 2.4 X 2.7m (2778 plants/ha) which recorded a bunch weight of 28.1 kg.

The fertilizer adjustment equations developed at NRCB were validated at different banana growing areas in Tamil Nadu, West Bengal, Kerala and Karnataka through AICRP Centers. A high level of fitness of these equations under Coimbatore and Mohanpur conditions indicated highly significant (r) value between the yield target and actual yield obtained under Kerala conditions, the equation indicated no need of P application to the soil for Nendran banana. Soil under Arabhavi conditions is more responsive to applied potassium and also need less N and P than the blanket recommendation followed in this region.

Impact of source reduction (leaf pruning) on flowering and fruit yield studies indicated in cvs. Poovan, Ney Poovan and Karpuravalli, reduction in source area produced more photosynthesis as a compensation mechanism. Complete defoliation after full bunch opening indicated reduction in bunch weight by 23% and 70% in cvs. Saba and Monthan respectively. Spraying of growth regulators during the first two months after bunch opening (during second to third weeks) improved the bunch size in cvs. Nendran, Peyan and Rasthali.

The effect of soil moisture deficit stress on banana cv. Grand Naine produced less number of leaves (0.77 leaves/ week). Plant height (0.7 - 0.8 cm/ day) did not show variation due to irrigation or moisture stress. But, stress imposed plants including ASA primed plants significantly reduced the plant growth (0.28 to 0.3 cm/ day) over control (0.63 cm / day). Reduction of soil moisture to 65% of field capacity did not affect the gas exchange parameters of photosynthesis in cv. Grand Naine. The Karpuravalli, Saba, Poovan and Ney Poovan varieties recorded significantly less cell injuries.

The phenol-ammonium acetate protocol was found suitable for banana proteomics studies. Proteomic analysis indicated 80 differentially expressed proteins (up-regulated, down-regulated, newly appeared and disappeared) due to the *P. coffeae* infection. Phenolic metabolites were recorded in roots of nematode-resistant banana cv. Yangambi Km5 and susceptible cv. Nendran. A proanthocyanidin metabolite and two phenolic metabolites were correlated with infection of *P. coffeae* in banana. The contents of vanillic, caffeic acid and procyanidin showed elevated accumulation in roots of bananas infected with *P. coffeae* and were more in resistant variety Anaikomban than in susceptible cv. Nendran by metabolomic approach.

The post-harvest storage treatments to extend the shelf-life of Red Banana indicated that, the hands of 80% mature fruits packed in $KMnO_4$ impregnated polybag and stored at 13.5°C with RH 95% increased the shelf-life of fruits up to 145 days with better quality and organoleptic characters. Banana flowers of cv. Karpuravalli packed in 200 gauge polybag kept at 20° C can be stored up to 10 days without affecting the quality. Banana central core stem of three types (full length, slices and cubes) treated with 0.1% citric acid, packed in polybags and stored under refrigeration extended the shelf-life up to 32 days. Banana pulp based ready-to-drink beverage of cv. Robusta, with the dilution of pulp juice at 1:4 revealed high TSS and moderate acidity with acceptance (7.41 Hedonic scale), which was on par with banana RTS beverage. Among the varieties, Gandevi registered maximum cellulose content of 55.63%. Basrai recorded the highest lignin content of 11.40% and a minimum pectin content of 2.37%. Basrai was found to be the best variety and 0.5% NaOH was the best treatment for extraction of fiber, based on chemical parameters studied.

Maximum reduction of 90% nematode population with 50% increase in plant growth and bunch weight was recorded in plants treated with *P. linacinus* + *P. flourescens* + Neem cake + Marigold as intercrop. Endophytic fungi *(Alternaria tenuis, Trichosporium nigricans, Curvularia lunata and C. geniculata*) at 50 and 100% concentration enhanced plant growth (30%) and significant reduction (30%) in root-lesion and root-knot nematodes in cvs. Rasthali and Nendran raised in cement rings contained root-lesion nematode infested soil.

Endophytic fungi strains (42 nos.) isolated from banana leaf and mid rib, resulted in 35 isolates of *Metarhizium anisopliae*, two *Beauveria bassiana* and two *Lecanicillium lecanii*.

The toxins extracted from the *Beauveria bassiana* NRCB isolate caused 83% weevil mortality on the 10th day of application. Whereas the liquid formulation, rice chaffy grain formulation and insecticide caused 100, 78 and 100% weevil mortality on 6th, 6th and 2nd day after application, respectively. Fraction

no. 3 from cv. Nendran and fraction no. 4 from cv. Poovan recorded 60% and 39% attraction of stem weevils respectively. The GC/MS profile of leaf sheath of cv. Karpuravalli indicated 23 volatile components having RT values ranging from 2.621 to 21.372. The volatile components include Alkanes-10, Alcohol-1, Aldehyde-1, Ketone-1, Phenol-1, Fatty acids-6.

The evaluation of different VCGs in cv. Grand Naine under *in vitro* screening indicated that the VCG 0124 only caused the wilt disease. Phylogenetic analysis of *Mycosphaerella eumusae* indicated three different major groups of *M. eumusae* isolates in India and each group was further categorized into separate clades showing the presence of wide genetic diversity. RAPD analysis of *M. eumusae* isolates indicated a unique band specific to *M. eumusae* which can be used as a specific marker to *M. eumusae*.

The combined application of rhizospheric and endophytic fungal antagonists along with or without fungicide application under field condition significantly increased the bunch weight (up to 74.8%) and suppressed the Fusarium wilt disease compared to untreated plants.

The biopriming of banana plants with combined application of *Pseudomonas putida* + Alpinia, *Pseudomonas putida* + *Hibiscus* sp., *Pseudomonas putida* + Zimmu, *Bacillus* sp. + Zimmu combinations resulted in complete control (100 %) and significantly increased the plant growth parameters.

Liquid formulation application of *Trichoderma* sp. (which was stored for 13 months at 25±2°C) at 5, 10 and 15% conc. in cv. Grand Naine indicated that application of all the concentrations resulted in the control of Fusarium wilt disease even after six months of planting.

Irrespective of the source of origin *i.e.* endophytic or rhizosperic *T. harzianum* and *T. longibrachiatum* endophytically colonized only in the root and corm tissues and maintained the same population level (10^6 CFU/g of soil) till 7th week of sampling.

VAM isolates isolated from banana cultivars were identified as *Glomus etunicatum, Archaeospora leptoticha, G. trimurales* and *Pacispora scintinallans*. The genetic diversity analysis indicated that *Glomus etunicatum, A. leptoticha, G. trimurales* were clustered together in group A and *P. scintinallans* in a separate group B.

DAC-ELISA with polyclonal antiserum detected the streak virus in the virus infected leaf samples of cv. Poovan. Best combination of primers was identified for the multiplex PCR in order to detect all the six genomic components of BBTV. A Loop mediated Isothermal Amplification (LAMP) based highly sensitive method for non-symptomatic samples was standardized for the detection of BBTV. RCA based approach was standardized for the detection of BBTV and BSMYV. Rolling Circle Amplification (RCA) was observed only from the DNA isolated from infected but was absent in healthy. The Restriction Fragment Length Polymorphism (RFLP) pattern obtained, differentiated BSV species infecting the variety. The presence of a new BSV species in cv. Hill banana based on RCA-RFLP is to be confirmed.

Endophytic bacterial inoculation on tissue culture banana plants of cv. Grand Naine indicated increase in the plant growth and the bacterial load was higher in the bio-primed plants especially those treated with *Bacillus subtilis* and *Pseudomonas fluorescens* compared to the non-treated Grand Naine TC plants. Transmission efficiency of banana aphid was compared under four different ranges of Relative Humidity (RH) *i.e.* 35-40%; 40- 45%, 50-55% and 60-65%. A single aphid could transmit the BBTV disease but with less percentage (15%) and the disease rate was increased when the aphid per plant increased to 5, 10 and 30, the transmission percentage was 55, 65 and 80 respectively.

2-DE analysis of proteins indicated 40 differentially regulated proteins and the spots were mass fingerprinted and 32 were annotated. Upregulated (15) and downregulated (17) protein spots were observed in the infected samples. Plant metabolism and growth related proteins were upregulated, whereas, protein synthesis, photosynthesis and cell division related proteins were downregulated.

Transfer of Technology

During 2012-13, Scientists gave four radio talks in All India Radio, Tiruchirapalli, and 50 lectures in different aspects of banana. NRCB had participated / organized 9 exhibitions at regional / national levels and organized 13 on-campus training programmes on Production and Post-harvest technology of banana. 15 Research papers, 10 book chapters, 37 popular articles, 2 technical bulletins / 6 extension folders / handouts were published. One document film on hill banana and 40 research papers were also presented in National and International conferences / Symposia / workshop / meetings. As many as 20 VIPs and about 4500 banana farmers, Agricultural & Horticultural officers, self-help groups and students visited the Centre and were appraised on the activities of the Centre. Technologies on value - added products such as *thokku*, banana flour and banana centre core stem were transferred to entrepreneurs for adaption.

Mother cultures of tissue culture banana plants received from DBT recognized tissue culture production units were tested for four known banana viruses under DBT – ATL. During 2012-13, out of 2986 samples virus indexed, 69 were positive for BBTV and 27 were positive for CMV.

HRD and Education

Scientists were deputed to international and national trainings to improve their skill and knowledge in the latest developments in Agricultural Sciences. Under education and training programme, 19, M.Sc, M.Tech, M.Phil, Ph.D students from different Universities were guided for their project / thesis work in various aspects of banana. Totally 97 seminars / conference/ symposia / workshop / meetings were attended by the Scientists at Regional / National / International levels.

Revenue Generation

A total of Rs.30.18 lakhs was realized as revenue by the Centre during the year 2012-13.

3. INTRODUCTION

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

The Centre works on four major thrust areas of research *viz.*, Improvement, Production, Postharvest Management and Protection. It has well-equipped research laboratories for tissue culture, biotechnology, soil science, nutrient management, physiology and biochemistry, entomology, nematology, fungal, bacterial, viral pathology and postharvest technology.

The NRC for banana has been identified as National Repository for banana. It has a field gene bank consisting of wild banana germplasm from the North - Eastern states, Western Ghats and Andaman and Nicobar islands and also exotic banana accessions from International Transit Centre (ITC), Belgium through NBPGR, New Delhi. The Centre has completed seven in-house research projects and 15 are in progress. In addition to Centre's in-house projects, 26 externally funded projects funded by NATP, DBT, NHB and INIBAP were completed. The Perspective Plan and Vision 2030 document on the research priorities and also reports by QRT and RAC were published. The Centre conducts every year two meetings of Institute Research Council to review the on-going research projects and also monitor the progress of RAC with QRT recommendations. The vision of the Centre is to increase the production and productivity of bananas and plantains so to meet the growing needs in India. Quinquennial Review team under the Chairmanship of Dr. S. D. Shikhamany, visited the Centre and reviewed the progress.

The mandates of the Centre are :

- To undertake the basic and strategic research for developing technologies to enhance the productivity and utilization of banana
- To develop improved cultivars through traditional and biotechnological methods and conserve the diversity
- To serve as national repository of germplasm and information related to banana and plantain and also to disseminate the knowledge to improve the production and productivity
- To provide leadership and coordinate the network research for generating location specific variety technology and for solving specific constraints on banana and plantain production
- To collaborate with relevant national and international agencies in achieving the above objectives

Salient Achievements

Crop Improvement

A field gene bank with 360 core accessions have been assembled from both indigenous and exotic sources, maintained in the Centre's gene bank repository at Tiruchirapalli. Among the collections, 92 accessions are highly resistant and 25 are resistant to Sigatoka leaf spot disease. SSH library consisting of 850 clones has been created for the Sigatoka resistant cv. Manoranjitham challenged with *Mycophaerella eumusae* and 0.5% of genes were hit with the defense genes. Embryogenic cell suspensions (ECS) for five different commercial varieties

viz., Rasthali, Nendran, Ney Poovan, Robusta and Grand Naine have been developed and regeneration protocol from ECS for Nendran and Rasthali has been standardized. Picloram based medium was found more efficient in the formation of somatic embryos in cvs. Rasthali and Nendran. A simple and efficient protocol has been developed for regeneration of plantlets from matured and immature embryos of cultivar *M. acuminata* ssp. *burmannica* (AA) and this will facilitate the *Musa* improvement programme through conventional approaches. NRCB has developed a DNA Bank for *Musa* germplasm with 225 accessions. A farmers' friendly method of mass production of banana planting material by 'Macro propagation' technique has been standardized to meet the need of small and marginal farmers in multiplication of disease free traditional varieties of banana locally.

Crop Production

Poovan plants supplied with 20 l water/ day/plant with 75% N (150 g N/plant) as fertigation increased the yield by 20% and recorded maximum net profit with a benefit cost ratio of 1.96. A combination of distillery sludge 2.5 kg + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure per plant recorded the maximum growth and yield parameters in Rasthali and Karpuravalli bananas. Application of gypsum 2 kg/ plant + FYM 15 kg/ plant + 120% recommended K in saline sodic soil increased the yield by 51 % over control in Nendran and Rasthali bananas. Paired row planting system, which accommodated 4,500 - 5,200 plants/ha, increased the productivity and fruit quality with 75% recommended fertilizers dose as fertigation in Robusta, Grand Naine and Red Banana. The study on the effect of organics on the BSV and BBMV infected Poovan showed that plants applied with 100 % RDF or 125 % RDF as inorganic sources produced more vigorous plants. Wider spacing (2.1 X 2.4m) and applied with 300:400g N &K per plant in Udhayam recorded the lowest fruit acidity (0.45 %) and highest pulp: peel ratio (6.69). Besides, wider spacing plants also exhibited early flowering as compared to closer spacing. In the case of root knot nematode population, the widest spacing (2.1 X 24 m) recorded the least nematode (32.3/250g of soil) population compared to closest spacing. Application of 15 kg rice husk ash + 25g VAM + 80% recommended NPK gave an additional profit of Rs. 32,500/ha. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, increased the bunch weight of Ney Poovan banana by 43.5% over control, resulting in an additional net profit of Rs. 38,000/ha. Fertilizer adjustment equations for Poovan and Karpuravalli bananas were developed by following the Soil Test Crop Response and Targeted Yield Concept. Under high soil pH conditions, application of bentonite sulphur 20g/plant at three month after planting improved the plant height, number of leaves, total leaf area, number of fruits, bunch weight and leaf N, P, K, Ca, Mg and S content of Nendran banana. Effect of micronutrients with and without sulphur application on banana under high pH soil condition in cv. Ney Poovan indicated that the application of sulphur 20g/plant reduced the soil pH from 8.6 to 7.8 in the rhizosphere soil and increased the plant growth (up to 12.5 %) and yield parameters (up to 14%) significantly over the control.

Postharvest Technology

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

Crop Protection

Mass production technique for *Paecilomyces lilacinus,* (an egg parasite of root-knot nematode) using banana petiole and pseudostem has been developed. Integration of *P. lilacinus* with either neem cake or *Tagetus* or *Solanum torvum* is useful for effective management of root-knot nematode. The combined application of *Bacillus subtilis* and B. *cereus* in cv. Ney Poovan resulted in 60% increase in plant growth with 90% reduction of root lesion nematode populations than individual treatments. The screening of *Musa* germplasms against major nematodes resulted in the identification of 5 diploids and 8 triploids resistant to both root-lesion and root-knot nematodes. Swabbing 0.06% Chlorpyrifos 20 EC on the pseudostem of 1.2 m height during 5 to 8 months completely controlled BSW incidence. Treating suckers with Monocrotophos 36 EC (14 ml/liter) followed by soil application of Carbofuran 3G at the rate of 30 g per plant each at 4th and 7th month after planting found effective against corm weevil. Pseudostem split trap swabbed with chaffy grain formulation of *Beauveria bassiana* trapped the stem and corm weevils better than traps swabbed with maize flour formulation. Of the 37 semiochemicals tested, maximum olfactory response by corm weevil was recorded to bisabol-ol, which found effective for banana corm weevil monitoring under field conditions. The weevil attraction was maximum (80%) in the treatment of Semiochemical No. 1 + host plant volatile extract obtained from cv. Nendran. Cross reaction between race 1 and race 2 of *Foc* has been observed in VCG analysis. Diversity of *Foc* isolates has been studied using RAPD, PCR-RFLP analysis of IGS region and the sequence analysis of rDNA-ITS region. Use of Carbendazim (0.1 %) for dipping the suckers before planting followed by soil drenching in root zone (@ 1-2 lit at 2,4 & 6 month after planting) and stem injection(@2ml at 2,4 &6 MAP) effectively controlled the Fusarium wilt disease in Ney Poovan cultivar under field conditions. Combined application of either endophytic *Trichoderma* strain BC2 + rhizospheric *T. koningii* (or) endophytic *Trichoderma* spp. strain Dsr1 + rhizospheric *T. koningii* (or) endophytic *Trichoderma* strain prr2 + rhizospheric *T. harzianum* isolate @ 30g/ plant as rice chaffy grain formulation completely controlled the *Fusarium* wilt disease under green house condition. Microscopic examination and molecular analysis of 96 isolates of *Mycospharella* spp. isolated from different cultivars of banana grown in different regions of India revealed the presence of *M. eumusae* indicating that the leaf spot in India is caused by *M. eumusae.* Endophytic bacterial inoculation on tissue culture banana plants of cv. Grand Naine indicated increase in the plant growth and the bacterial load was higher in the bio-primed plants. Soil application of increased dose of fertilizer (150% of RDF) in cv. Poovan has compensated the yield loss due to BBrMV. Polyclonal antiserum to BBTV was produced and ELISA technique has been standardized for detection. NA probe and PCR based diagnostic techniques have been developed for all the banana viruses. A multiplex PCR technique has been developed for detecting three banana viruses simultaneously. Complete genome of BSV infecting Poovan has been cloned and sequenced. Promoter sequences from BBTV were cloned and sequenced. Duplex PCR for all the four viruses CMV, BBrMV, BBTV and BSV has been standardized. Real Time-PCR technique for simultaneous detection of banana viruses was standardized. Rolling circle amplification (RCA) approach which uses bacteriophage Phi29 DNA polymerase has been standardized to detect episomal virus of BSMysV in Poovan and BBTV in Hill banana. Primers and probe have been designed for rep gene of BBTV and assessed the quantity of its transcripts in latent and severely infected plants using real time-PCR.

Transfer of Technology

In 2012 - '13 year, four radio talks through All India Radio, Tiruchirapalli and fifty lectures on various aspects of banana cultivation were

delivered by the scientists. Thirteen on-campus trainings on production, biotechnology and post-harvest technology of banana were conducted. Research papers (14), book chapters (8), popular articles (33) and technical bulletins / extension folders (7) were published by the scientists of the Centre. A film document on NRCB was made and released. Scientsts have presented 48 research papers at Regional / National and International Conferences / Symposia / Seminars / Workshop /Meetings.

As many as 20 VIPs and about 4500 banana farmers, Agricultural and Horticultural officers, Self help groups and students were appraised of the activities of the centre on their visit. Technologies on value added products of banana *viz.*, thokku and banana core stem were transferred to entrepreneurs.

Linkages and Collaboration

The Centre has developed good linkages with international institutes *viz.*, Bioversity International, France and QUT, Australia. Collaborated with different national research institutions for different activities *viz.*, NBPGR, New Delhi; BARC and CIRCOT, Mumbai; IIHR, Bangalore; Coffee Board, Bangaluru; NHB, DST and DBT New Delhi; NCL Pune and all SAUs. Tissue culture industries involved in banana mass propagation, farmers, exporters, banana federations, State Horticulture and Agriculture departments and self-help groups are linked with the Centre for various research and developmental activities. NRCB also co-ordinates with AICRP (Tropical Fruits) Centres working on banana. The Centre has collaborated with CTCRI, Trivandrum (Kerala) and CPRI, Shimla (H. P.) for development of extruded product by blending banana, cassava and potato flours.

Revenue Generation

A total of Rs.30.18 lakhs was realized as revenue generation by the Centre during the year 2012-13.

BUDGET DETAILS (REVISED ESTIMATE) FOR THE YEAR 2012-'13

Sl.No	Head of Account	PLANAmount (Rs. In lakhs)	NON-PLAN Amount (Rs. In Lakhs)
1	Estt. Charges	0.00	328.57
2	OTA	0.00	0.05
3	Travelling Allowances	6.00	3.50
4	Other charges	124.00	80.86
5	HRD	1.98	1.70
6	Equipments	16.98	10.00
7	Works	0.00	0.00
8	Furniture & Fixtures	0.00	0.00
9	Library books	0.49	0
10	Information Technology	0.48	0
	Total	**149.93**	**424.68**

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

4.1.1 Genetic Resource Management

Collection

Short duration and high yielding clones of Red Banana (AAA) and Ash Monthan (ABB) were identified and collected from a secondary source in Chennampatti area of Bhavani Taluk of Tamil Nadu and added to NRCB field gene bank. A core collection of 364 accessions representing the maximum genetic diversity of the Indian subcontinent is being maintained at NRCB field gene bank. Apart from the indigenous collections, 88 introductions received from ITC, Belgium through NBPGR are being maintained at NRCB. Field evaluation of two *M. balbisiana* clones collected from Nagaland *viz.,* Paglapahad wild and Phirima wild were found promising for leaf industry due to its big, green and flexible leaves (2.6 x 0.65m). Formosona a Cavendish variety with high yield and resistance to *Fusarium* wilt (race – 4) collected from TBRI, Taiwan was added. Saba based progeny (No.183) was found promising in terms of fruit qualities like firm pulp, good cooking quality and suitability to chips making.

Characterization

During this period, five introduced banana accessions were morphotaxonomically characterized using IPGRI banana descriptor and their identity has been confirmed. Kayinja, Dole, Pisang Berangan, Kasaka and Robusta were identified to be the members of Pisang Awak, Ash Monthan, Unique, cooking ABB of unique nature and Dwarf Cavendish respectively (Table 1).

Molecular characterization of unique land races

ISSR markers

A total of 10 primers were tested to assess the ISSR polymorphism in 12 unique landraces of *Musa* representing AAA, AAB, ABB and AB genome. All the 10 primers (100%) showed amplified products resulting in discrete, repeatable amplicons and were considered for the genetic diversity analysis.

Using ten primers 173 alleles were identified with a mean of 17.3 per primer based on presence (1) and absence (0) of alleles. Maximum 29 alleles were observed in UBC 841 and minimum 9 alleles was produced by UBC 808. Hundred per cent polymorphism was observed in 70 per cent of the primers tested (Table 2). Polymorphism as high as 95.68 was observed in this study which was helpful in distinguishing the individuals at intra species level.

PIC values ranged from 0.31 (UBC 842) to maximum 0.50 (UBC 868) with an average of 0.37. Effective multiplex ratio (EMR) ranged from 9.00 (UBC 808) to 29.00 (UBC 841) with an average of 16.1 and the marker index (MI) ranged from 3.10 (UBC 808) to 10.50 (UBC 841) (Table 3). No specific relation existed among PIC, EMR and MI in the present study.

Table 1. Identity confirmation of introduced accessions from ITC, Belgium

Sl. No.	ITC No.	NRCB. No.	Name	Genome	Sub group (as per ITC)	NRCB clarifications
1	0087	2177	Kayinja	ABB	Pisang Awak	Pisang Awak
2	0767	2153	Dole	ABB	Ash Monthan	Ash Monthan
3	1287	2151	Pisang Berangan	AAA	Unique	Similar to Pisang Berlin (AA)
4	0591	2219	Kasaka	AA	-	Belongs to ABB but unique
5	0574	2215	Robusta	AAA	Cavendish	Dwarf Cavendish

Table 2. ISSR diversity of unique land races

S. No.	Primer	Total No. of bands	No. of polymorphic bands	% polymorphism	Polymorphic Information content (PIC)	Effective multiplex ratio (EMR)	Marker Index (MI)
1.	UBC 811	17	17	100.00	0.33	17.00	5.62
2.	UBC 807	21	21	100.00	0.34	21.00	7.22
3.	UBC 808	9	9	100.00	0.34	9.00	3.10
4.	UBC 834	13	11	84.60	0.42	9.30	3.98
5.	UBC 812	18	17	94.40	0.32	16.05	5.27
6.	UBC 842	17	17	100.00	0.31	17.00	5.33
7.	UBC 840	16	16	100.00	0.42	16.00	6.72
8.	UBC 868	18	14	77.78	0.50	10.88	5.51
9.	UBC 841	29	29	100.00	0.36	29.00	10.50
10.	UBC 818	15	15	100.00	0.38	15.00	5.84
	Total alleles	173	166	956.78	3.72	160.1	63.5
	Average	**17.3**	**16.6**	**95.68**	**0.37**	**16.1**	**6.35**

Table 3. Unique bands produced by different ISSR markers used for DNA fingerprinting

Accession Name	Primer Allele	size in bp
Manoranjitham	UBC 811	481
	UBC 807	355
	UBC 812	411
	UBC 840	475
Thellachakkarakeli	UBC 834	1782
	UBC 868	826
Matti	UBC 807	1780
	UBC 808	395
Sannachenkadali	UBC 807	2022
	UBC 818	1583
	UBC 841	2186
Anaikomban	UBC 834	708
	UBC 812	556, 742
	UBC 868	658
Poovillachundan	UBC 808	1065
	UBC 812	1059
Kunnan	UBC 811	458, 820
Kullan	UBC 842	464
Namwakhom	UBC 811	2055
	UBC 868	2739
Saba	UBC 841	1253
	UBC 818	3291
Bangrier	UBC 842	1394, 2560, 3190
Goukar	UBC 812	493
	UBC 842	933, 1526

In the present study, bands unique to specific landraces were reported for all the land races except Hill banana and Amritsagar.

Primer UBC 808 produced bands unique to Matti (395 bp) and Poovillachundan (1065 bp) while primer UBC 834 produced bands unique to Anaikomban (708 bp) and Thellachakkarakeli (1782 bp) (Fig. 1a and 1b respectively). These unique bands could be converted into SCAR markers for use in varietal identification.

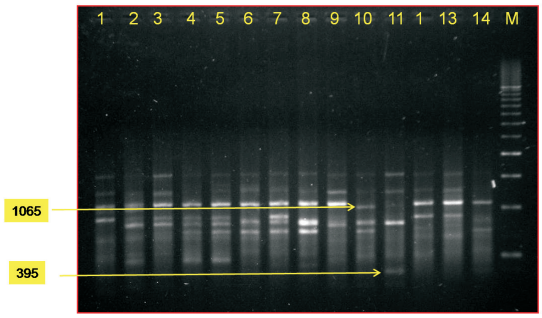


Fig. 1a. Profile of unique landraces using ISSR marker UBC 808

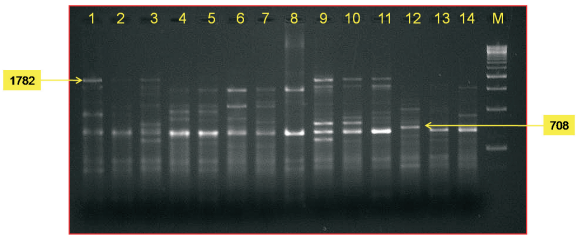


Fig. 1b. Profile of unique landraces using ISSR marker UBC 834

SSR markers

A total of 10 primer pairs were tested to assess the polymorphism in 14 unique landraces of banana representing AAA, AAB, ABB and AB genome. Only nine primer pairs (90%) has amplified products resulting in discrete, repeatable amplicons and were considered for the genetic diversity analysis. The nine primer pairs recorded 75 alleles with a mean of 8.33 alleles per primer based upon the presence (1) and absence (0) of alleles. The maximum 15 alleles were observed in AGMI 133/134 and the minimum 5 alleles were produced by two primer pairs *viz.,* AGMI 191/192 and Mb SSR 1-100.

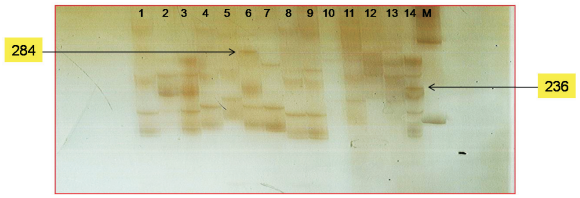
For most of the primer pairs, the expected and the observed product size were almost the same except for AGMI 113/114 and AGMI 129/130, Mb SSR 1-100, where the observed product range was more than the expected product size. (Table 4). Similarly the observed and the expected number of alleles were not same for all the primer pairs tested except for primer pair AGMI 99/100. The observed number of alleles was less than the expected number of alleles for the two AGMI primer pairs tested namely 35/36, 129/130 and Mb SSR 1-100 and vice-versa for the rest of the primer pairs tested.

PIC value was comparatively higher for the genome specific primer (0.43 for B- genome specific primer namely Mb SSR 1-100) as against AGMI series of primers used. The

Table 4. Influence of SSR markers on polymorphism, allele no. and size, Polymorphic Information content

Accn. No.	Product range in bp		Number of alleles		Polymorphic Information content
	Expected	Observed	Expected	Observed	
AGMI 35/ 36	106	100-150	10	7	0.35
AGMI 95/ 96	240	150-250	4	9	0.37
AGMI 99/ 100	164	150-200	6	6	0.33
AGMI 113/ 114	210	150-200	3	10	0.33
AGMI 129/ 130	221	150-200	10	8	0.29
AGMI 133/ 134	239	250-350	3	15	0.25
AGMI 191/ 192	164	150-200	2	5	0.27
AGMI 197/ 198	173	150-200	4	10	0.28
Mb SSR 1-100 F/ 1-100 R	190-235	200-250	6	5	0.43
Total alleles			**75**	**2.90**	
Mean			**8.33**	**0.32**	

unique alleles could be converted into genetic probes for varietal identification. PIC values are correlated with the polymorphism level and the present study indicates the need for inclusion of more number of primers to arrive at a meaningful conclusion. AGMI primer pair 133/134 generated alleles unique to Saba and Goukar at 284 and 236 bases respectively (Fig. 2).



1. Thellachakkarakeli
2. Amritsagar
3. Manoranjitham
4. Hill banana
5. Kullan
6. Saba
7. Bangrier
8. Namwakhom
9. Kunnan
10. Poovillachundan
11. Matti
12. Anaikomban
13. Sannachenkadali
14. Goukar

Fig. 2. Profile of unique land races of banana using SSR marker AGMI 133/134

Phylogenetic relationships and diversity analysis of *Musa balbisiana* accessions

Musa balbisiana diversity is spread in all the natural habitats of banana growing states of India *viz.,* Tamil Nadu, Kerala, Andhra Pradesh, Karnataka, Bihar, Orissa, West Bengal, North-Eastern states and Andaman and Nicobar Islands. Though morphotaxonomically characterized using INIBAP *Musa* descriptor (1996), molecular characterization is an authenticated analysis to study the extent of diversity and phylogenetic relationships.

A total of 10 primer pairs of SSR markers were tested to assess the microsatellite polymorphism among 20 *M. balbisiana* accessions using *M. acuminata*, Nendrakunnan, Borchampa and Bangrier as controls. All the ten primer pairs (100%) had amplified products resulting in discrete, repeatable amplicons and were considered for the genetic diversity analysis (Fig. 3).

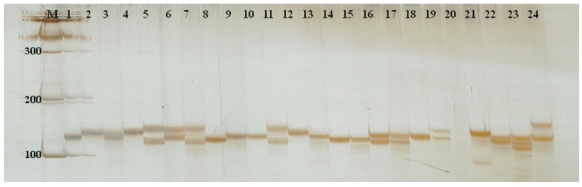


Fig. 3. Mb SSR 1-100 showing the variability among *M. balbisiana* accessions

From the ten primer pairs, 90 alleles were identified with a mean of 9.00 alleles per primer based on the presence (1) and absence (0) of alleles. The maximum 22 alleles were observed in STMS 7 and the minimum 4 alleles were produced by Ma SSR 8a/8b. PIC values ranged from 0.13 (STMS 7) to 0.27 (MAOCEN 1) (STMS) with an average of 0.21. (Table 5) and the per cent polymorphism was high.

Table 5. No. of alleles and Polymorphic information content (PIC) of SSR markers

Sl. No	Primer Name	Standardized annealing temp.	No. of alleles observed	PIC
1	MaSSR-8a/8b	60 °C	4	0.16
2	Mb 1-100	60-50°C	7	0.26
3	AGMI 133/134	55°C	6	0.18
4	AGMI 197/198	55°C	9	0.22
5	AGMI 191/192	55°C	9	0.24
6	AGMI 189/190	55°C	12	0.23
7	STMS 7	52°C	22	0.27
8	STMS 10	52°C	2	0.15
9	MAOCEN 1	55°C	10	0.13
10	MAOCEN 15	55°C	9	0.21
		Average	9.00	0.21

Evaluation of NRCB selection (sel-09)

A newly identified dwarf statured Pisang Awak member *viz.,* Namwakhom, an introduced accession from ITC was evaluated with local Pisang Awak member, Karpuravalli as check/ reference. Namwakhom has proven its superiority over local Karpuravalli in terms

Table 6. Comparative evaluation of NRCB selection - 09 with local Karpuravalli

Name	Height (cm)	Girth (cm)	Days taken for flowering	Days for maturity	Duration (days)	Bunch Weight (kg)	No. of hands	No. of fruits hand	Total no. of fruits
Karpuravalli	411.8b	87a	361.2b	140.2b	501.4b	17.65a	14.7a	15.9b	238.1a
Namwakhom	211.7a	82.45b	279.4a	123.2a	393a	11.55b	10.1b	16.4a	170.1b
SEd	4.0134	1.6338	2.2608	0.973	10.0036	0.4802	0.2789	0.1915	6.0183
CV%	2.88	4.31	1.58	1.65	5	7.35	5.03	2.65	6.59
Level of significance	**	**	**	**	**	**	**	*	**

of dwarf stature (40- 50%) and short duration (about 70-80 days). These two traits make the accession promising for high density planting (Table 6).

Utilization

Two *Musa balbisiana* clones *viz.,* Phirima wild (Acc. No.1186) and Paglapahad wild (Acc. No.1182) were identified for their very long leaf (260-270 cm length) with about 65cm breadth at the middle and had very good keeping quality at room temperature. (4-5 days).

Standardization of various mass multiplication protocols in banana

Macropropagation of cv. Rasthali and Nendran

In cv. Rasthali, the earliest bud formation (14 days) was observed in the bed method with an average of 2.6 primary buds/sucker, followed by pot method (16 days) with an average of 1.8 primary buds / sucker and *in situ* decapitation where 3.3 primary buds/ sucker were produced within 17 days of decapitation. Similar response was observed in cv. Nendran, but the bud formation was delayed by 7 days in pot method, 4 days in bed method and 3 days *in situ* decapitation. *In situ* decapitation method produced a total of 13 shoots in 23 days of decapitation with an average of 1.3 shoots/ plant. The earliest shoot formation was observed on the 19th day of decapitation.

In situ macropropagation of Udhayam

In situ macropropagation was attempted in Udhayam using Ethrel at three different concentrations namely 300, 400 and 500 ppm on three months old mother plants and the results indicated that removal of apical meristem followed by application of Ethrel at 300 ppm induced 3 shoots per corm in 15.3 days during primary decortication and 4 shoots in 11.5 days during secondary decortications (Table 7).

Direct shoot organogenesis from immature male flower buds for cv. Rasthali

Six different initiation media with different concentrations of BAP and TDZ for direct

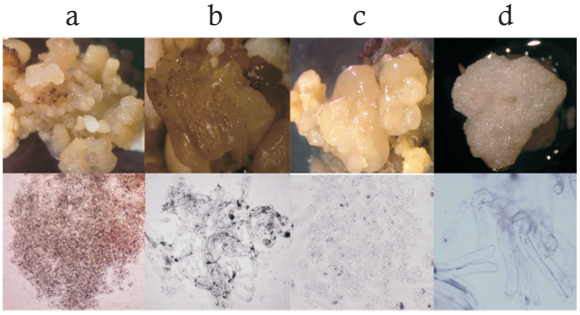
Table 7. Effect of various concentrations of Ethrel on *in situ* macropropagation of Udhayam

Ethrel concn. in ppm	No. of primary buds formed per corm	Days taken for primary bud initiation	No. of secondary buds formed per corm	Days taken for secondary bud initiation
300	3.0	15.3	4.0	11.5
400	2.4	15.8	1.4	8.0
500	0.6	8.4	3	12.3

shoot regeneration from immature male floral hands were tried. The treatment (TDZ-0.5mg/l) and (BAP-8mg/l+TDZ-0.5mg/l) recorded better response with proliferation of multiple clump like structures. Among the ten shoot regeneration media with different hormonal combinations, treatment (T9) MS medium supplemented with BAP (22.5mg/l) and IAA (1.75mg/l) followed by T10 (MS+ 22.52mg/l BAP + 3.5mg/l IAA) and (MS+ 11.26 mg/l BAP + 1.75 mg/l IAA) recorded better response for direct shoot regeneration (Table 8). All other treatments showed no shoot development even though the explants produced proliferating floral meristem. Direct regeneration of shoots were observed after 2-3 weeks from the proliferating multiple meristem clump like structures. After 2-3 weeks in subculture medium, M9 supplemented with BAP (100µM) and IAA (10 µM) produced ~14 shoot buds.

Embryogenic cell suspension cultures from immature male flower buds in cv. Rasthali

Male flower buds of cv. Rasthali (100 nos.) were initiated on callus induction medium and maintained in optimum conditions. The proembryos emerged on the surface of the callus after 5-6 month of initiation. The cells beneath the proembryos are the pro-embryogenic cells mass (PEM) which are friable (Fig.4 a) in nature. Those friable PEM were transferred to liquid suspension medium for cell multiplication. Analysis of results indicated that only the floral hands from 8 to 16 position has the ability to produce embryogenic callus from which suspension culture was possible with homogenous granules with better response for cell multiplication whereas the hands from



a. Creamy white friable callus
b. Brown compact callus
c. Creamy white compact callus
d. Watery callus

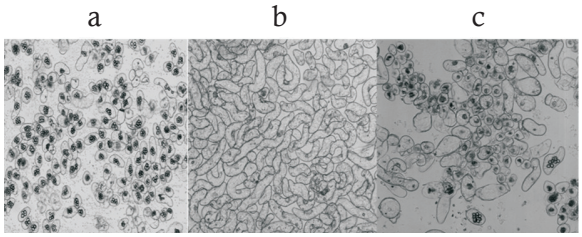
Fig. 4. Types of callus

Table 8. Influence of different media in the direct shoot organogenesis from immature floral hands of cv. Rasthali

Treatments	Basal Medium	Growth Regulators (m/l)					Mode of Response		
		BAP	TDZ	GA3	KIN	IAA	Proliferation of floral meristem	Shoot development	No. shoot/ Explant
T1	MS	3mg/1	-	1mg/1	-	-	+	-	0
T2	½ MS	-	-	-	-	-	-	-	0
T3	MS	3mg/1	-	0.5mg/1	1mg/1	-	+	-	0
T4	MS	2mg/1	0.5mg/1	-	-	-	++	-	0
T5	½ MS	3mg/1	-	-	-	1mg/1	+	-	0
T6	MS	3mg/1	-	-	-	1mg/1	+	-	0
T7	MS	11.26mg/1	-	-	-	1.75mg/1	++	+	10
T8	MS	11.26mg/1	-	-	-	3.50mg/1	++	-	0
T9	MS	22.52mg/1	-	-	-	1.75mg/1	+++	++	14
T10	MS	22.52mg/1	-	-	-	3.50mg/1	+++	++	12.5

- : No proliferation/ shoot development + : better proliferation/ / shoot development
++ : good proliferation/ shoot development

1-7 and 17-23 position turns into non-embryogenic calli (Fig. 4b,c&d) of various types (Creamy white friable, white and brown compact, white and brown spongy calli, etc.) which failed to produce cell suspension. Also the physical state of the cells was studied and observed that except friable calli all the others were carrying empty and heterogenous (Fig. 5b&c) (round and vacuolated, rod shaped, elongated cells.

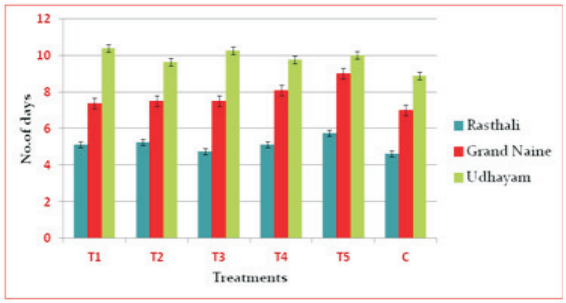


a. Homogenous embryogenic cells
b. Homogenous non embryogenic cells
c. Heterogenous cell complex

Fig. 5. Cell structure of different types of embryogenic callus

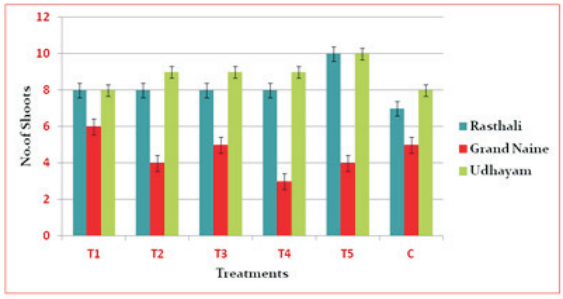
Development of low cost tissue culture protocols for mass multiplication

Attempts were made to develop low cost tissue culture protocols for mass multiplication of three commercial varieties of banana *viz.,* Udhayam, Rasthali and Grand Naine. Reverse osmosis water and table sugar were used as the water and carbon sources respectively. Six different treatments *i.e.,* Sago alone, Isabgol alone, Sago + Agar, Isabgol + Agar, Sago + Isabgol including control were studied. The results indicated that blend of Sago and Isabgol (T5) produced the maximum shoots (10.00) in varieties like Udhayam and Rasthali and T1 (sago alone) produced the maximum shoots (6.00) in Grand Naine (Fig. 6a&b).



T1 - Sago 10%
T2 - Isabgol 3%
T3 - Sago 9% + Agar 0.04 %
T4 - Isabgol 3% + Agar 0.08%
T5 - Sago 5% + Isabgol 1.5%
T6 - Control (Agar 0.7 %)

Fig. 6a. Effect of gelling agents and their combinations on days taken for greening in various commercial varieties



T1 - Sago 10%
T2 - Isabgol 3%
T3 - Sago 9% + Agar 0.04 %
T4 - Isabgol 3% + Agar 0.08%
T5 - Sago 5% + Isabgol 1.5%
T6 - Control (Agar 0.7 %)

Fig. 6b. Effect of gelling agents and their combinations on shoot proliferation in various commercial varieties

Development of variety specific protocol

Among the various combinations of hormones tested for initial establishment of cv. Ney Poovan, MS medium with BAP + IAA + CW was found optimum which induced early greening in 5.00 days followed by BAP + KIN, TDZ + IAA and BAP + IAA as against the control (6.3 days).

4.1.2 Improvement of banana through conventional breeding

Development of superior clones through survey and collections

Elite clones of Ney Poovan and Grand Naine were collected through survey from clonal plantations in Bhavani and Theni respectively.

Evaluation of superior introductions

An ITC accession, Maia Popuolu (AAB) was multiplied and was planted at BRS, Kannara during 2009-2010. Plants produced 17-20kg bunch weight with 4-5 hands and 8-12 fruits per hand. The plants have been

initiated under *in-vitro* for large scale multiplication and evaluation (Fig. 7)

Fig. 7. Exotic introduction Maia Popuolu

Conventional breeding

A total of 181 bunches produced seed set in 2012-'13 involving different cross combinations of AA x AA, AAB x AA, ABB x AA and ABBB x AA. A total of 26,601 seeds were obtained, of which 22,217 were fully developed good seeds and the remaining (4386) were immature seeds. All the hybrid seeds were initiated under *in vitro* for embryo culture and the highest germination was recorded in ABB x AA cross combination.

Improvement of Pisang Awak group of bananas

For improving Pisang Awak cultivars, 34 bunches of 14 different accessions belonging to Pisang Awak subgroup were crossed resulting in 6934 hybrid seeds which were initiated *in vitro*. Enna Benian was the best female parent exhibiting an average of 438 seeds per bunch while Bhurkel produced only per bunch. Only three combinations exhibited *in vitro* germination. At Agali, 55 Pisang Awak group plants were crossed with potential male parents.

Karpuravalli (ABB) banana as female parent was crossed with four different male parents two each with parthenocarpic (Rose and Pisang Lilin) and non-parthenocarpic (Calcutta-4 and Pisang Jajee) diploid male parents. Pisang Lilin as male parent yielded the highest number of seeds (505) while the least was with cv. Rose (133 seeds). Triploid Udhayam as male parent (3x X 3x) also resulted in 13 seeds of which 66.1% exhibited germination (Table 9).

Improvement of Cooking Bananas

For the improvement of cooking bananas, Pisang Lilin, Pisang Jajee, Anaikomban, Sennachankadali (SCK), cv. Rose and Calcutta-4 were used as male parents. 20,556 seeds were obtained in 255 bunches of Saba, Kothia, Monthan and Bangrier exhibiting an average of 80 seeds per bunch. All the hybrid seeds were taken for embryo culture.

Under improvement of cooking bananas for Fusarium wilt resistance 68 bunches of Kothia were crossed with seven diploid (AA) male parents, four parthenocarpic (SCK, Anaikomban, Cultivar Rose and Pisang Lilin) and three non parthenocarpic (Calcutta-4,

Table 9. Effect of various diploid male parents on seed set and related parameters in Karpuravalli

Male Parents	Average no. of days taken for bunch maturation	Total no.of seeds	% good seeds	% seeds with embryo	% embryo germination
Cultivar Rose (AA)	133.0	132.0	94.6	43.2	0.0
Calcutta-4 (AA)	112.7	222.0	93.2	45.4	1.1
Pisang Jajee (AA)	111.5	278.0	95.6	49.2	12.9
Pisang Lilin (AA)	117.7	505.0	96.6	38.1	0.0
Udhayam (ABB)	118.0	13.0	84.6	27.2	66.1

Chengdawt and Pisang Jajee) parents resulting in 17,809 seeds with an average of 262.2 seeds per bunch. Maximum seed set was observed with Pisang Lilin (6185 seeds) and least with Chengdawt (35 seeds). Hybrids from Anaikomban failed to germinate while Chengdawt exhibited maximum germination (18%).

Seed set in tetraploid cv. Bhat Manohar (ABBB)

Open pollinated bunch of tetraploid Bhat Manohar exhibited seed set to an extent of 668 seeds, of which 400 seeds were fully developed and 268 were immature seeds. First set of 200 good seeds have been initiated *in vitro*, of which only 138 seeds had well developed embryos and the rest had no embryo but with rich endosperm. 98 embryos germinated under *in vitro* conditions.

Improvement of Kothia

In Kothia improvement programme, among six diploid male parents, seed set ranged from 35 to 6185 and percent good seeds from 57.1 – 87.7% (Table 10).

Improvement of Saba for Fusarium wilt resistance was initiated by crossing with four diploid male parents of which three were non parthenocarpic (Calcutta-4, Chengdawt and Pisang Jajee) and a parthenocarpic (Pisang Lilin). 64 bunches were crossed and 2372 seeds with an average of 38 seeds per bunch was obtained. Maximum seed set was observed in Pisang Lilin crosses (1132) while the lowest was in Calcutta - 4 (122). Chengdawt based crosses exhibited the highest germination (57%) while Pisang Lilin based crosses recorded the lowest germination (16.5%) (Table 11).

Improvement of NRCB selection 08

Bangrier (Bluggoe – ABB) is a shy seed setter group with less than 2% seed set. During last year, 58 bunches of NRCB selection - 8 was crossed with three male parents (Pisang Jajee, Pisang Lilin and Chengdawt) which produced 372 seeds with an average of 6.5 seeds per bunch. The highest seed set was recorded in Pisang Lilin cross (269) along with the highest germination percent (61.9%) while, Chengdawt based crosses failed to germinate (Table 12). Similarly, 65 bunches of Monthan (ABB) was crossed with three male parents (cv. Rose, Pisang Lilin and Pisang Jajee). Only one bunch crossed with Pisang Jajee resulted in two seeds.

Improved germination through seed priming in *Ensete superbum*

For the first time, seed priming protocol was standardized for germination and regeneration of *Ensete superbum* seeds through embryo culture. Seed priming in GA3 for 10

Table 10. Effect of various diploid male parents on seed set and related parameters in Kothia

Male Parents	Average no. of days taken for bunch maturation	Total no.of seeds	% good seeds	% seeds with embryo	% embryo germination
Cultivar Rose (AA)	124.0	2190.0	84.5	46.5	9.6
Calcutta-4 (AA)	124.0	3964.0	81.2	53.8	11.2
Pisang Jajee (AA)	106.5	2917.0	87.7	54.8	11.1
Pisang Lilin (AA)	113.6	6185.0	82.8	24.1	11.0
SCK (AA)	126.0	396.0	77.0	43.2	1.5
Chengdawt (AA)	121.5	35.0	57.1	55.0	18.1
Anaikomban (AA)	120.5	2413.0	85.0	34.1	0.0

Table 11. Effect of diploid male parents on seed set and related parameters in cv. Saba

Male Parents	Average no. of days taken for bunch maturation	Total no.of seeds	% good seeds	% seeds with embryo	% embryo germination
Pisang Jajee (AA)	122.7	739.0	44.2	46.1	16.5
Pisang Lilin (AA)	119.1	1132.0	50.8	59.0	34.4
Chengdwat (AA)	122.4	379.0	43.2	42.6	57.1
Calcutta-4 (AA)	90.0	122.0	74.5	49.4	22.2

Table 12. Effect of various Diploid male parents on seed set no. in NRCB Selction-08

Male Parents	Days taken for bunch maturation	Total no.of seeds	% good seeds	% seeds with embryo	% embryo germination
Pisang Jajee (AA)	92.9	86.0	68.6	5.0	33.3
Pisang Lilin (AA)	102.5	269.0	49.4	15.7	61.9
Chengdawt (AA)	87.0	16.0	68.7	36.3	0.0

days on shaking platform enhanced embryo regeneration by more than 50%. Presently, 38 plantlets have been regenerated through embryo culture and are being maintained *in-vitro* for shifting to primary hardening.

Histological studies were made in cross combination of Saba (ABB) x Calcutta-4 (AA), Alpon (AAB) x Calcutta-4 (AA) and Kozhikodu (AAB) x Calcutta-4. After pollination, the samples were collected at different time interval such as 6, 12, 24, 36 and 48 hrs. The samples were fixed in the fixatives (Carnoy's reagent) and embedded in the ratio of 8:2 paraffin and bees wax. Thin sections of 15 microns were made with help of microtome. Pollen germination on the stigmatic surface and tube penetration through the stylar region was observed (Fig. 8).

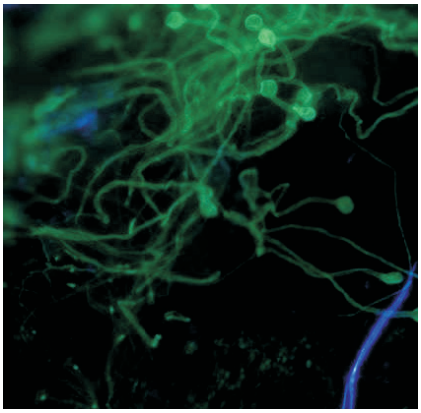


Fig. 8. Pollen germination at stylar region in cv. Kozhikodu

Seed storage studies in hybrids

Normally seeds of Bankela based progenies were viable upto 60 days beyond which it declined. Anaikomban crossed progenies showed viability upto 40 days while Pisang Jajee extended upto 120 days. Kothia based progenies using various male parent also showed viability upto 120 days (Fig. 9). Only Calcutta -4 based progenies (as male parents) showed germination even after 200 days.

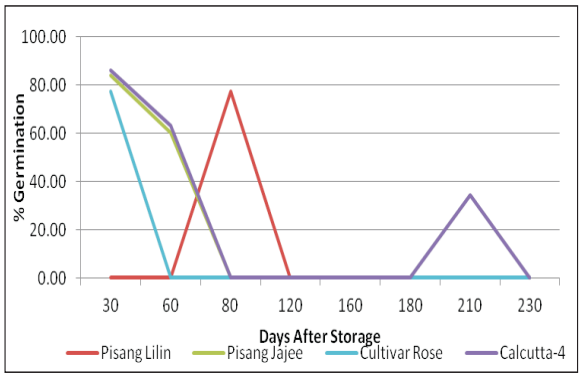


Fig. 9. Effect of seed storage on hybrid embryo germination (cv. Kothia)

Multiple hybrid plantlet development through somatic embryogenesis

Multiple plantlets from single hybrid embryo have been developed through callus and ECS. Somatic embryos developed 60 days after initiation in MA-1 medium with 2-4D and IAA. Best regeneration of somatic embryos into plantlets was observed in medium augmented with IAA (0.1mg/lit. Approximately 20-30 plantlets could be developed from a simple hybrid embryo in 6-7 months. (Fig. 10a-e)

Multiple hybrid plantlet development through ECS

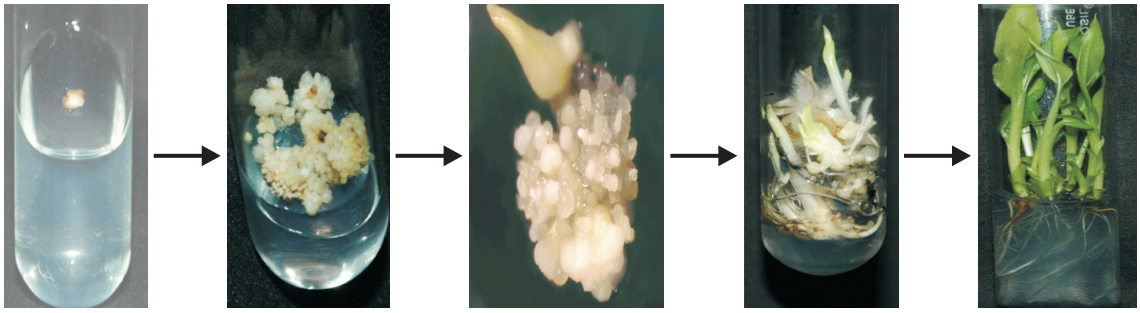
For the first time, somatic embryogenesis in hybrid embryos of Marabale x Pisang Jajee (AAB x AA) was established in MA1 medium (Fig. 11a-d). Proembryos have been initiated in liquid culture to establish the embryogenic cell suspension cultures. Six months old cultures were initiated in the MA3 medium and maintained in complete darkness for 45 days which resulted in secondary somatic embryos.

4.1.3 Improvement of Rasthali through induced mutagenesis

Around 500 each of shoot tips and proliferating buds of cv. Rasthali were treated with three different mutagens namely ethyl methane sulfonate, diethyl sulphate and sodium azide and were screened *in vitro* with Fusaric acid and culture filtrate and the shoots survived are in various stages of micropropagation (Table 13).

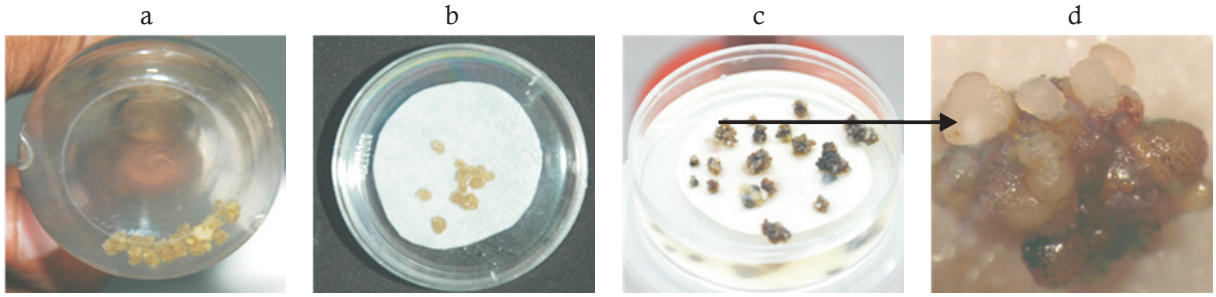
Effect of addition of chemical mutagens to the initiation media

Studies were made to find out the effect of addition of chemical mutagens namely EMS 1% (T1), Sodium azide 0.01% (T2) and



a. Embryo | b. Embryogenic callus initiation | c. Formation of multiple somatic embryos | d. Regenaration of embryos into plantlets | e. Multiple plantlets from single hybrid embryo

Fig. 10. Multiple hybrid plantlet development through somatic embryogenesis



a: 6 months old culture | b: Transferred to MA3 | c: After 45 days | d: Secondary somatic embryos

Fig.11 ECS development in hybrid embryos

Status of mutated cultures of cv. Rasthali

Table 13. Screening of mutagens in various stages of micropropagation

Treatments	No. of plantlets under *in vitro* screening	Primary hardening	Secondary hardening	Pot screening	Wilt resistant mutants
Shoot tips EMS – 2%	464	20	12	14	4 (Pot screening)
Proliferating buds EMS - 0.6%	172	-	20	9	30 (Secondary hardening)
Shoot tips NaN3 - 0.02%	444	12	17	10	-
Proliferating buds NaN3 - 0.01%	284	-	14	20	-
Shoot tips DES - 10mM	512	13	35	14	-
Proliferating buds DES – 4mM	256		13	20	-
Total	2132	45	111	87	34

DES 5 mM (T3) to the initiation media on the establishment of shoot tips of cv. Rasthali. It was found that no greening of shoot tips was observed in T1, shoot tips died on the very next day of initiation in T2 and greening was observed after five days of initiation in T3.

4.1.4 Identification and characterization of nematode resistant genes in banana

Isolation of full length genes

R gene

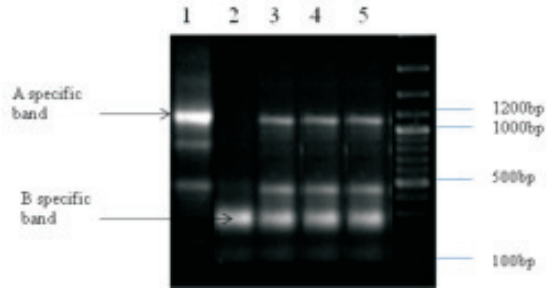
One R gene upregulation during nematode infection was identified and isolation was carried out by using RACE PCR. To get the full length of this gene, two forward and two reverse primers were designed and obtained 2800bp length nucleotide sequences after overlapping the sequences. The presence of conserved domain such as ATPase domain, P-loop, RNBS-A nonTIR, kinase 2, RNBS, GLPL and leucine rich repeat were observed and this was confirmed as CC-NBS LRR family R gene.

Chitinase gene

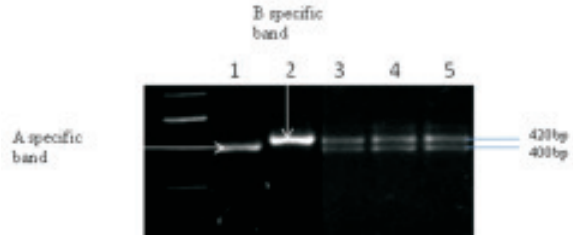
Among the SSH derived clones putative gene of acidic chitinase was found to be upregulated in the nematode inoculated resistant cultivar. The isolated full length of chitinase gene encoded a polypeptide of 343 aminoacid residues. The annotation result revealed that this belongs to acidic chitinase III family. The alignement of the most conserved region of glycosyl hydrolase family 18 from different organism indicated that the region of MLSIGG was highly conserved among the chitinase gene.

Identification of genome specific marker

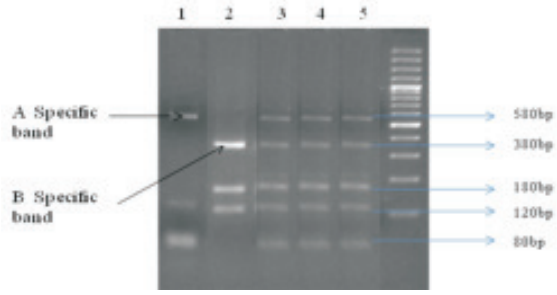
All banana genomic groups namely AA (8), AAA (8), AB (4), AAB (4), ABB (6) and BB (10) were tested with SSR 4 (obtained from EST-SSR marker), chitinase (obtained from SSH clones) primers and compared with already available genome specific ITS marker. The results suggested that SSR 4 and chitinase could clearly differentiate B and AA genome (Fig 12a-b). All the diploid accessions of AA, BB and AB genome available in the germplasm



a) Chitinase primer



b) SSR 4 primer



c) ITS primer

1. Cv rose – AA
2. Bhimkol – BB
3. Monguthamg – BB/AB
4. Borkal Baista – BB/AB
5. Srisailam - BB / AB

Fig 12. Three genome specific markers (a-c) showing different banding pattern in three B genome accession

accessions were tested with SSR4, chitinase and ITS markers to confirm their genomic status. The results revealed that except three accessions of BB genome, all the accessions were confirmed to their respective genomic group. While three BB accessions viz., Monguthamg, Borkal Baista and SriSailam produced both A and B specific bands which indicated that these three accessions could be of inter specific hybrid of A and B genome. These results revealed suggested that SSR4 and Chitinase primers could be used as genome specific markers to identify the AA, BB specific genome or hybrids.

Identification of nematode resistant marker by using EST-SSR markers

To identify the candidate genes, EST-SSR primers were used for identifying the nematode resistant markers. To know the function of the SSR containing ESTs, all the SSR containing ESTs were subjected to BLASTGO analysis. On an average 2407 SCMUs showed homology to genes having known function and the remaining sequences (440) did not hit with any of the genes.

To predict the protein domain, InterPro analysis was carried out which resulted in 2518 SSR containing ESTs were matched with InterProscan with 4452 gene ontology terms and the KEGG pathway analysis resulted in 59 metabolic pathways, and five pathways namely carotenoid, phenylpropanoid, phenylalanine, flavanoid and terpenoid biosynthesis metabolosim involved in resistance mechanism were identified.

A total of 23 candidate genes were selected which are in the open reading frame and tested against *Musa* accessions of which only one primer could differentiate the nematode resistant and susceptible accessions.

Musa EST-SSR database

Simple sequence repeats (SSR) containing expressed sequence tags (ESTs) were identified from the Musa ESTs available in the public domain (NCBI) by using WEBSAT software. A total of 5137 SSR containing ESTs were identified and primers were designed in the flanking region by using Primer3 software. A database has been created with primer sequence, annealing temperature, repeat details, product size, primer length, etc.

4.2 CROP PRODUCTION

4.2.1 Standardization of agro-techniques for banana production and productivity

Standardization of stage wise nutrient requirement in Udhayam banana

In the first ratoon crop of cv. Udhayam, application of recommended dose of N & K fertilizers (RDF) (300:400g N & K plant^{-1}) in the ratio of 7:2:1 N and 4:3:3 K_2O at vegetative, flowering and bunch development stages recorded the earliest fruit maturity (116.3 days), whereas, application of RDF in the ratio of 7:3:0 and 6:2.5:1.5 of K_2O (N3) significantly delayed the fruit maturity (125.2 days). Among different plant densities, 2.4 X 2.4m spacing (1736 plants/ha) recorded the earliest fruit maturity in 116.8 days while planting of three suckers per pit at 3.6 X 3.6m spacing (2315 plants/ha) took 125.5 days for fruit maturity. Among three levels of nutrients, application of RDF in the ratio of 7:2:1 N and 4:3:3 K_2O (N1) recorded the highest bunch weight (30.2 kg) with of more number of hands (18.1) and fingers (314.0) while, the lowest bunch weight 27.1 kg was recorded in N3. Among the five plant populations, the highest bunch weight of 30.8 kg was recorded in T2 (1736 plants/ha) and the lowest bunch weight (26.8 kg) was recorded in T5. However, the highest total yield of 78.1 t/ha was recorded in planting of two suckers per pit at a spacing of 2.4 X 2.7m (2778 plants/ha) (S3) with a bunch weight of 28.1 kg (Table 14). Application of recommended dose of fertilizers (300:400g N&K plant^{-1}) in ratio of 7:2:1 N and 4:3:3 K_2O at vegetative, flowering and bunch development stages also recorded the highest number of hands (18.1) and fingers per bunch (314.0).

In the second ratoon crop, nutrient ratio of 7:2:1 N and 4:3:3 K_2O (N1) recorded the highest plant height (365.1 cm), pseudostem circumference (84.8 cm), more healthy leaves (16.7) and least phyllochron (7.2 days).

Leaf nutrient concentrations (Table 15) indicated significant differences between three levels of nutrition as well as five different planting densities. Among the three nutrient levels, N1 recorded the highest leaf nitrogen (2.63%), phosphorus (0.51%) and potassium (3.14%) concentrations. Among the planting densities, S2 recorded the highest N (2.73%) while, the highest P (0.59%) and K (3.18%) were recorded in S3 and S5 respectively. The leaf calcium content as significant among the

Table 14. Effect of stage wise nutrition on fruit maturity and bunch weight in cv. Udhayam (I ratoon)

Treatments	Days taken for Maturity				Bunch weight (kg)			
	N1	N2	N3	Mean	N1	N2	N3	Mean
S1 (1984 pl./ha)	114.4	116.7	123.3	118.1	31.7	28.9	27.4	29.3
S2 (1736 pl./ha)	115.5	114.8	120.3	116.8	33.6	30.4	28.5	30.8
S3 (2778 pl. /ha)	118.2	121..8	126.8	122.3	28.8	28.1	27.3	28.1
S4 (2057 pls./ha)	116.5	119.1	124.4	119.9	29.7	29.2	28.1	29.0
S5 (2315 pl./ ha)	121.4	125.3	129.7	125.5	27.9	27.3	25.2	26.8
Mean	116.3	119.4	125.2		30.2	28.8	27.1	
	S. Ed.	C.D.	C.V. %		S. Ed.	C.D.	C.V. %	
Spacing (S)	1.856	5.129**	3.48		0.715	1.977**	5.99	
Nutrition (N)	1.438	3.973**			0.554	1.531**		
S X N	3.215	NS			1.239	NS		

Table 15. Effect of stage wise nutrition on leaf nutrient concentrations in cv. Udhayam

Treatments	Nitrogen (%)				Phosphorous (%)				Potassium (%)				Magnesium (%)				Calcium (%)			
	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean	N1	N2	N3	Mean
S1 (1984 pl./ha)	2.63	2.52	2.48	2.54	0.42	0.35	0.58	0.45	3.09	2.89	2.78	2.92	2.3	2.1	2.6	2.33	2.8	2.6	2.9	2.77
S2 (1736 pl./ha)	2.87	2.67	2.65	2.73	0.47	0.50	0.43	0.47	3.12	2.96	2.83	2.97	2.3	1.9	2.1	2.10	3.9	2.9	3.5	3.43
S3 (2778 pl./ha)	2.46	2.40	2.51	2.46	0.61	0.53	0.64	0.59	3.20	2.96	2.67	2.88	1.8	1.4	2.2	1.80	3.0	2.7	2.9	2.87
S4 (2057 pls./ha)	2.69	2.35	2.59	2.54	0.48	0.38	0.35	0.40	3.01	3.12	2.89	3.07	2.3	2.3	1.7	2.10	3.6	3.2	3.4	3.40
S5 (2315 pl./ha)	2.51	2.21	2.32	2.35	0.59	0.49	0.42	0.50	3.28	3.29	2.98	3.18	1.6	1.4	1.2	1.40	4.2	3.8	4.0	4.00
Mean	2.63	2.43	2.45		0.51	0.45	0.48		3.14	3.02	2.83		2.06	1.82	1.96		3.51	3.04	3.34	
	S.Ed.	C.D.	C.V. %		S.Ed.	C.D.	C.V.%		S.Ed.	C.D.	C.V. %		S.Ed.	C.D.	C.V. %		S. Ed.	C.D.	C.V. %	
Spacing (S)	0.117	0.253* 0.315**			0.042	0.091*			0.174	0.372*			0.106				0.339	0.728*		
Nutrition (N)	0.091	0.197* 0.176*	11.97		0.032	0.068*	12.71		0.134	0.290*	10.81		0.082				0.263	NS	14.36	
S X N	0.204	0.438* 0.546**			0.072	NS			0.290	NS			0.183				0.588	1.69**		

three levels of nutrition; N1 recorded the highest Ca content of 3.51%. However, N1 recorded the highest leaf Mg of 2.06% whereas; both were the least (3.04% and 1.82%) in N2. Among the plant spacing/densities S5 and S1 (1984 plants/ha) recorded the highest calcium and magnesium 4.00%, 2.33 % respectively.

Effect of organics on the BSV and BBrMV infected Poovan banana

In the first ratoon crop of BSV and BBrMV infected Poovan banana, application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake / plant recorded the highest bunch weight. Plants raised from the healthy suckers recorded the

Table 16. Effect of organics on soil bulk density in BSV and BBMV infected Poovan banana

Treatments	Bulk density (g cc-1)- Vegetative stage							Bulk density (g cc-1)- Flowering stage						
	N1	N2	N3	N4	N5	N6	Mean	N1	N2	N3	N4	N5	N6	Mean
M1-BSV	1.35	1.33	1.28	1.27	1.38	1.39	1.33	1.34	1.30	1.27	1.25	1.39	1.38	1.32
M2-BBMV	1.37	1.35	1.31	1.29	1.40	1.43	1.36	1.32	1.31	1.26	1.25	1.41	1.41	1.33
M3-Healthy	1.38	1.33	1.23	1.26	1.39	1.41	1.33	1.32	1.28	1.24	1.24	1.40	1.39	1.31
Mean	1.37	1.34	1.27	1.27	1.39	1.41		1.33	1.30	1.26	1.25	1.40	1.39	
	S. Ed.			C.D.		Significance	C.V. %				S. Ed.	C.D. (5%)	Significance	C.V. %
Material (M)	0.009			-		NS	2.17				0.011	-	NS	2.46
Nutrition (N)	0.014			0.037	**						0.016	0.043	**	
M X N	0.023			-	NS						0.027	-	NS	

Table 17. Effect of organics on soil porosity in BSV and BBMV infected Poovan banana

Treatments	Porosity (%)- Vegetative stage							Porosity (%)- Flowering stage						
	N1	N2	N3	N4	N5	N6	Mean	N1	N2	N3	N4	N5	N6	Mean
M1-BSV 41.3	41.23	42.59	42.13	39.67	39.50	41.14	42.27	42.76	43.20	43.62	41.05	41.34	42.36	
M2-BBMV 40.86	41.65	43.35	42.71	40.58	40.47	41.60	42.00	42.41	43.77	44.28	41.40	41.18	42.51	
M3-Healthy 40.72	41.28	42.29	42.01	38.92	38.85	40.68	41.84	42.69	43.88	43.76	39.06	39.17	41.73	
Mean 40.96	41.53	42.74	42.28	39.72	39.61		42.04	42.62	43.62	43.85	40.50	40.56		
	S. Ed.		C.D.	Significance		C.V.%					S. Ed.	C.D. (5%)	Significance	C.V. %
Material (M)	0.418		-	NS		2.17					0.641	-	NS	4.45
Nutrition (N)	0.591		1.612	**							0.907	2.474	**	
M X N	1.023		-	NS							1.570	-	NS	

highest bunch weight of 21.9 kg and the lowest bunch weight (19.7 kg) was recorded in BSV infected suckers. Application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake / plant also recorded the highest number of hands (12.7), fingers (201.2), fruit TSS (25.2° B) and pulp: peel ratio (5.21). In the second ratoon crop, the plant height was the maximum at 100 and 125% RDF inorganic fertilizers. Among the organics, application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake / plant recorded more height (289.5 cm) and plant girth (67.7 cm).

Studies on the effect of organics on soil physical properties indicated influence on bulk density, porosity/ pore space and particle density. In the second ratoon crop of Poovan banana, the lowest bulk density of 1.27 and 1.25 gm/cc or mg/m3 was recorded in the rhizosphere soil applied with 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake (N3). Whereas, the highest bulk density of 1.41 and 1.39 g $cc^{-1}$was recorded with application of 100% and 125% RDF inorganic fertilizers respectively (Table 16). Application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake (N3) and other organic treatments significantly improved the porosity as well as particle density at both stages of growth. The highest porosity of 43.85% and 43.62% was recorded at vegetative stage in N4 and N3 respectively while the lowest porosity of 39.61% was recorded in treatment T6 (Table 17).

Table 18. Effect of organics on soil microbial population in BSV and BBMV infected Poovan banana

Bacterial population (CFU g^{-1})							
Treatments	**N1**	**N2**	**N3**	**N4**	**N5**	**N6**	**Mean**
M1-BSV	15.7	15.8	16.8	15.9	12.2	13.7	15.02
M2-BBMV	18.2	17.4	18.7	18.8	12.9	13.4	16.55
M3-Healthy	19.5	21.7	23.6	22.7	16.2	16.9	20.10
Mean	17.8	18.3	19.7	19.1	13.8	14.5	
		S. Ed.		C.D.	Significance		C.V.%
Material (M)		0.916		2.656	**		13.61
Nutrition (N)		1.296		3.757	**		
M X N		2.245		-	NS		
Fungal Population (CFU g^{-1})							
M1-BSV	12.1	12.6	13.0	13.5	9.88	10.3	11.89
M2-BBMV	15.8	15.4	16.2	15.4	11.2	12.9	14.40
M3-Healthy	17.0	17.8	19.8	19.0	13.6	14.6	16.97
Mean	14.96	15.26	16.33	15.97	11.56	12.60	
		S. Ed.		C.D.	Significance		C.V. %
Material (M)		0.725		2.099	**	11.53	
Nutrition (N)		1.024		2.969	**		
M X N		1.774		-	NS		

Application of 20 kg FYM + 0.9 kg neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake/ plant recorded significantly higher bacterial count (19.7 x 10^5 CFU g^{-1}) and fungal population (16.3 x 10^3 CFU g^{-1}) than in both 125% and 100% RDF inorganic fertilizers. Application of 20 kg FYM + 0.9 kg Neem cake + 2.0 kg Vermicompost + 0.9 kg groundnut/plant registered the highest leaf contents of chlorophyll 'a' (0.962 mg g^{-1}), chlorophyll 'b' (0.614 mg g^{-1}) and total chlorophyll (1.576 mg g^{-1}). (Table 18).

4.2.2 Fertilizer tailoring for targeted banana yield and sustainable soil health

The following fertiliser adjustment equations for Grand Naine (Ratoon-I) were developed. FN = 7.85*T – 0.77*SN – 0.36*ON; FP = 0.85*T – 0.72*SP – 0.56*OP and FK = 13.13*T – 0.83*SK – 0.51*OK, where, FN, FP & FK are NPK requirement through fertilizer (kg/ha), SN, SP & SK are NPK available in the soil (kg/ha), ON, OP & OK are NPK requirement through organic manure (kg/ha), and T – yield target (t/ha).

Requirement of N, P_2O_5, K_2O for producing one ton of Grand Naine (ratoon-I) banana was estimated as 5.38, 0.3 and 7.98 kg, respectively (Table 19). The computer softwares were developed in MS-Excel and BASIC for Grand Naine (Ratoon-I). These softwares are very useful to farmers to quantify the NPK fertilizer input for achieving a targeted yield from his land with specific initial soil NPK contents.

Fertilizer adjustment equations

The fertilizer tailoring equations for different varieties of banana was validated in different AICRP (TF) centers to find out the location specific equations/responses. Under Coimbatore (Tamil Nadu) condition, in Ney Poovan, the NPK dosages for targeting yield upto 44 t/ha produced actual yield more than the target. After a target of 44 t/ha, the actual yield started declining. From this, it was inferred that the fertilizer adjustment equations for Ney Poovan banana is applicable up to the yield target of 44 t/ha. At Coimbatore condition, as per the fertilizer adjustment equations, 207:32:286g NPK per plant was enough to produce 47.07 t/ha in contrast to TNAU's blanket recommendation of 110:35:330g NPK per plant produced only 39.21 t/ha. The fertilizer schedule as per these

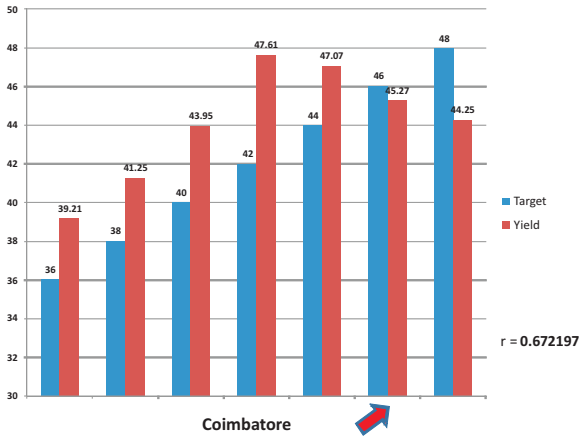


Fig. 13. Target and yield (t/ha) Ney Poovan under Coimbatore condition

Table 19. STCR studies for developing fertilizer tailoring equations for Grand Naine banana (Ratoon I)

	Nutrient Requirement (NR) (kg/ ton)	Contribution from soil in control plot (CS) (kg)	Contribution from fertilizer in treatment plot (CF) (kg)	Contribution from organic fertilizer in treatment plot (CO) (kg)
Nitrogen (N)	5.38	1.45	3.41	0.52
Phosphorus (P_2O_5)	0.3	0.1	0.16	0.04
Potassium (K_2O)	7.98	2.87	4.70	0.41

equations, for the target of 42 t/ha the highest B:C ratio was 2.5 but in the blanket recommendation, the B:C ratio was 1.97. The high level of fitness of these equations under Coimbatore conditions was also proved with highly significant r value of 0.672** between the yield target and actual yield obtained (Fig. 13).

Under Mohanpur (West Bengal) condition, in Martaman banana, the NPK dosages for a target yield up to 38 t/ha produced the actual yield, which was more than the target. After this target, the actual yield started declining. The blanket recommendation under Mohanpur condition was 200:40:200g NPK per plant recorded, which recorded an actual yield of 28.7t/ha (B:C ratio 1.55), while the fertilizer schedule (186:32:553g NPK per plant) as per the fertilizer adjustment equations targeting 38t/ha recorded an actual yield of 38.1 t/ha (B:C ratio 1.80). The very high level of fitness of these equations under Mohanpur condition is evidenced by the highly significant r value of 0.971** (Fig. 14).

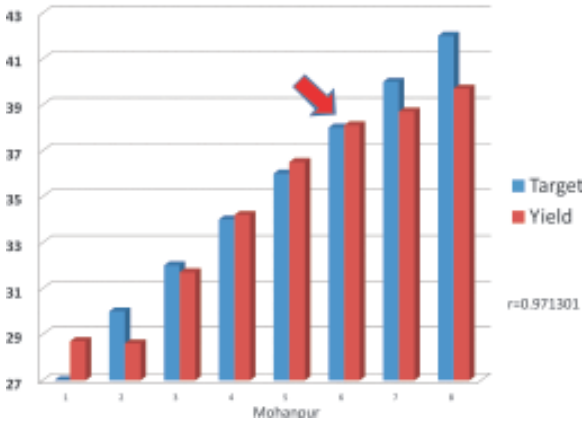


Fig. 14. Target and yield (t/ha) in Martaman banana

Under Kannara (Kerala) condition, in Nendran banana, the NPK dosages for targeting yield upto 30 t/ha produced actual yield, which is more than the target yield. After this target, the actual yield started declining. The blanket recommendation is 190:115:300g NPK per plant, which produced an actual yield

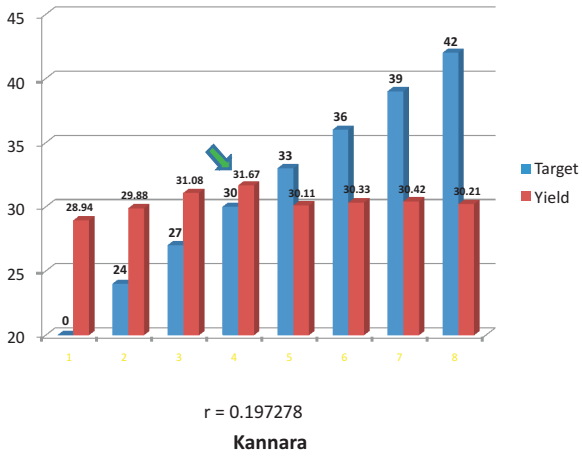


Fig. 15. Target and yield (t/ha) in Nendran banana under Kannara condition.

of 28.94 t/ha (B:C ratio 2.32), however with the adjustment equations, 282:0:519g NPK per plant produced an actual yield of 31.67 t/ha (B:C ratio 2.4) for a target of 30 t/ha. It is inferred that under Kannara soil condition, no P application is required for Nendran banana (Fig. 15).

Under Arabhavi (Karnataka) condition, the blanket recommendation of 200:50:200g NPK per plant recorded an actual yield of 26.89 t/ha (B:C ratio 3.42). The fertilizer schedule (150.75: 17.81:344.5g NPK) targeting 38 t/ha produced an actual yield of 33.68 t/ha (B:C ratio 4.14), which is 25.3% more than that of the blanket recommendation of NPK. The soil under Arabhavi is more responsive to applied potassium and also needs less N and P than that of the blanket recommendation for Ney Poovan banana.

4.3 PHYSIOLOGY, BIOCHEMISTRY AND POSTHARVEST TECHNOLOGY

4.3.1 Physiology

Physiology of flowering at fruit development

Apical 4, 6 and 8 functional leaves were maintained along with control (no leaf pruning) from fifth month to study the impact of source reduction (leaf pruning) on flowering and fruit yield in cvs. Poovan, Ney Poovan and Karpuravalli. The flowering was prolonged by 58-75 days in plants maintained with reduced sources (4-6 leaves) over control (>12 leaves). To study the real time function of source (leaves), the gas exchange parameters were measured in cv. Ney Poovan with fewer sources (4 leaves) exhibited higher photosynthesis (20.32 µmol $CO_2 s^{-1} m^{-1}$) than plants with six leaves (14.10 µmol $CO_2 s^{-1} m^{-1}$) and control (12-14 leaves) (12.98 µmol CO_2 $s^{-1} m^{-1}$) (Fig. 16). Similar trend was observed in transpiration and stomatal conductance also. Plants with four leaves recorded higher transpiration (7.12 mmol m^{-2} s^{-1}) than six leaves (5.32 mmol m^{-2} s^{-1}) and control (5.24 mmol m^{-2} s^{-1}). The plants with 4 leaves recorded higher stomatal conductance (0.31 mmol m^{-2} s^{-1}) than six leaves (0.17 mmol m^{-2} s^{-1}) and control (0.16 mmol m^{-2} s^{-1}). The results indicated that plants with lesser source are manufacturing more photosynthate as a compensation mechanism.

Current photosynthetic contribution towards bunch development due to complete defoliation, after full bunch opening was studied in cvs. Saba, Monthan and Poovan. In cv. Poovan fruit length was reduced and in Saba fruit circumference was significantly reduced by complete removal of source (leaves) (Table 20). By complete defoliation, bunch weight was reduced to 23% and 70% in cvs. Saba and Monthan respectively.

The relative growth rate (RGR) of fruit length and girth for first two months after bunch emergence in Nendran, Peyan, and Rasthali was higher during second to third weeks (0.16 cm/ day). Subsequently the RGR of fruit was reduced (0.04 - 0.07 cm/day). Therefore, first 2-3 weeks after bunch opening is crucial for growth of fruit length and girth as it reflects the log phase of fruit development. Application of external growth regulators for fruit development, during this log phase time will improve the bunch size.

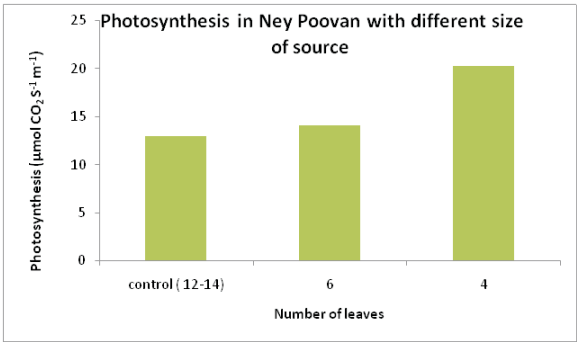


Fig. 16. Photosynthesis in Ney Poovan with different size of source

Drought stress tolerance

Studies were conducted to find the effect of soil moisture deficit stress on banana cv.

Table 20. Effect of source (leaves) at flowering on finger growth in banana cultivars

Banana cultivars	Treatments	Finger Girth(cm)	Finger Length (cm)
Monthan	T1	12.50 A	13.81 A
Monthan	T2	10.14 BC	11.01 C
Saba	T1	10.82 B	12.00 B
Saba	T2	10.54 B	11.29 BC
Poovan	T1	9.12 CD	10.07 CD
Poovan	T2	9.07 D	8.92 D

The treatments with same letters are not significant

Table 21. Grand Naine plant growth parameters under soil moisture stress treatments

Treatments	Height(cm/ day)	Girth (cm/day)	Leaves/day	Leaves/ week
Irrigated	0.73	0.63	0.145	1.015
Stressed	0.70	0.30	0.11	0.770
ASA primed + stress	0.80	0.28	0.11	0.770
Mean	0.74	0.40	0.12	0.85

Grand Naine. Soil moisture stress was imposed by withholding irrigation to reach at 60-75% on volume basis and stress was relieved by irrigation. In the soil moisture stressed plants, the leaf production was around 0.77 leaves/ week as compared to 1.05 leaves/week in irrigated plants. Banana plants primed with acetyl salicylic acid (ASA) (100 µM) and subsequently soil moisture stress imposition also produced similar number of leaves (0.77 leaves/week). Plant height (0.7 - 0.8 cm/day) did not show variation due to irrigation and moisture stress. But, stress imposed plants including ASA primed plants had significantly decreased plant girth (0.28 to 0.3 cm/day) than control (0.63 cm/day) (Table 21).

In cv. Grand Naine plants at soil moisture at 75% field capacity (in volume basis), the gas exchange parameters of photosynthesis (19.68%), stomatal conductance (12.08%) was significantly reduced but transpiration increased (12.25%). The leaf temperature was increased (6.45%) over irrigated control. The transpiration was recorded 5.61 mmol m^{-2} s^{-1}, 2.99 mmol m^{-2} s^{-1} and 0.09 mmol m^{-2} s^{-1} in irrigated control, at 75% soil moisture and 65% soil moisture respectively. The stomatal conductance of irrigated control, at 75% and 65% soil moisture levels were recorded as 0.17 mmol m^{-2} s^{-1}, 0.05 mmol m^{-2} s^{-1} and 0.00 mmol m^{-2} s^{-1} respectively. Therefore, when the soil moistures reduced to 65% of field capacity, gas exchange parameters were reduced to nil.

Grand Naine tissue culture plants were subjected to water stress by PEG 8000 (- 0.59 MPa and -0.82 MPa) with nutrient solution in controlled conditions. Higher level of water deficit stress (-0.82 MPa) reduced the leaf elongation and accelerated the leaf senescence.

In a pot study, soil moisture stress was imposed to reach 65% of soil moisture (volume basis) in 3-4 month old banana cultivars *viz.,* Karpuravalli, Saba, Poovan, Ney Poovan, Nendran and Rasthali. The chlorophyll content reduced drastically in all stress imposed treatments, but the level of chlorophyll content reduction was less in cvs. Karpuravalli, Poovan and Saba (Fig. 17). In terms of cell injury, Nendran (24.05%) and Rasthali (37.77%) suffered more due to soil moisture stress. The cvs. Karpuravalli, Saba, Poovan, Ney Poovan recorded significantly less cell injuries (12.88 to 18.77%). Similarly, the photosynthesis and its associated parameters also drastically reduced. Some of the susceptible banana cvs. like Nendran, Rasthali recorded negative photosynthesis under stress condition.

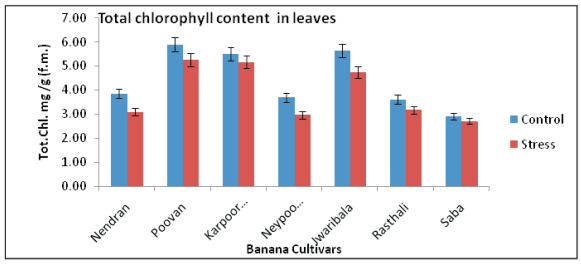


Fig. 17. Effect of soil moisture stress on total chlorophyll content

A dehydrin gene was amplified from genomic DNA of banana cv. Saba. This gene

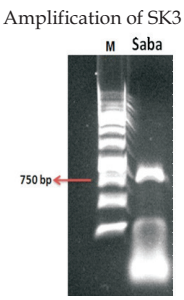


Fig. 18. *Sk3 dehydrin* amplified in cv. Saba

was amplified by primer designed from ESTs of *Sk3 dehydrin* available from NCBI site. The amplicon size was 750 kb (Fig. 18).

Salt stress tolerance

Banana cvs. Nendran, Ney Poovan, Saba, Rasthali, Karpuravalli and Grand Naine were phenotyped for salt stress tolerance. These plants were subjected to salt stress after three months of planting at different concentrations of NaCl (0, 50,100 and150 mM of NaCl). The salt tolerant banana genotype Saba exhibited less salt injury (5.78 to 9.71%) and Nendran and Red banana exhibited more than 80% salt injury under 150 mM NaCl treatment. The percentage of salt injury could be used as a phenotypic trait for identifying salt tolerant genotype. In case of growth parameters, plant height, circumference and leaf dry matter production, could distinguish salt tolerant genotypes (Saba, Karpuravalli and Ney Poovan) from susceptible banana genotypes (Nendran, Rasthali and Grand Naine) (Table. 22).

Banana cv. Grand Naine was phenotyped for salt stress tolerance (50, 100 and 150 mM of NaCl with nutrient solution). After three weeks of treatment, relative water content (RWC) of leaves was significantly reduced (75.84%) in all salt treatment compared to control (80.30%). Mild salt stress (50mM of NaCl) not affected the total chlorophyll content (1.98 ug/cm^2) compared to control (2.02 ug/cm^2), whereas in higher salt concentrations (100 mM and 150 mM), the total chlorophyll reduced significantly (1.93 & 1.86 ug / cm^2) compared to control (Table 23). In salt treated plants, plant height, girth and number of green leaves (16.88 cm, 3.50 cm, 3.38 respectively) decreased significantly as compared to control (17.78 cm, 4.5 cm and 3.5 respectively).

Table 23. Effect of NaCl on RWC and chlorophyll content of banana cv. Grand Naine

NaCl (mM)	RWC (%)	Total Chl (ug/cm2)
0	80.30^{A}	2.02^{A}
50	77.54^{A}	1.98^{AB}
100	71.25^{C}	1.93^{BC}
150	74.27^{B}	1.86^{C}
General Mean	75.84	1.95
CV(%)	1.35	1.37
SE(d)	0.836	0.022
Tukey HSD at 5%	2.8941	0.0755

Table 22. Effect of NaCl stress on plant growth parameters of banana cultivars

Treatment Name	Pseudo stem DM (g/plant)	Leaves DM (g/plant)	Root DM (g/plant)	Plant height (cm)	Circumference (cm)
V1 - Ney Poovan	118.85^{B}	72.84^{A}	14.64^{A}	79.75^{A}	21.17^{BC}
V2 - Nendran	89.37^{BC}	45.43^{B}	4.90^{D}	81.00^{A}	18.67^{CD}
V3 - Saba	102.06^{BC}	76.31^{A}	9.90^{C}	76.33^{AB}	22.46^{AB}
V4 -Poovan	70.60^{C}	55.73^{B}	10.81^{BC}	54.46^{C}	17.04^{D}
V5 – Grand Naine	86.47^{BC}	54.68^{B}	3.18^{D}	54.67^{C}	17.96^{D}
V6 - Rasthali	223.55^{A}	73.22^{A}	12.73^{AB}	71.67^{B}	24.38^{A}
General Mean	115.15	63.03	9.36	69.65	20.28
LSD at 5%	38.209	14.701	2.501	7.0023	3.0695

The treatments with same letters are not significant

Table 24. Effect of foliar priming of acetyl salicylic acid (0.1mM) in Grand Naine plants and antioxidative enzymes under NaCl stress.

Treatments	APX (specific activity)	CAT (specific activity)	SOD (Units)
0 mM NaCl	1.96^{D}	11.27^{B}	15.61^{D}
50 mM NaCl	2.35^{C}	15.89^{A}	18.02^{C}
100 mM NaCl	2.74^{B}	16.13^{A}	49.47^{B}
150 mM NaCl	8.37^{A}	11.40^{B}	54.36^{A}
General Mean	3.85	13.92	34.36
CV(%)	2.75	0.61	0.75
LSD at 5%	0.212	0.3265	0.5117

The treatments with same letters are not significant

Higher salt concentration interferes with banana plant growth by affecting leaf water status and photosynthetic pigments. Tissue cultured Grand Naine plants were primed with 0.1mM acetyl salicylic acid (ASA) and subsequently treated with salt treatment (50, 100 and 150mM NaCl). The plants treated with ASA recorded higher ascorbate peroxidase and superoxide dismutase activities but no significant activities of catalase. The alleviation effects of ASA were more pronounced at higher salt concentration (100 and 150 mM) (Table 24)

Proteomic studies in bananas in response to NaCl-stress

For identification of differentially expressed proteins due to salt (NaCl) stress, proteomic analysis was performed on total proteins extracted by phenol-ammonium acetate protocol from roots of salt-tolerant cv. Saba and susceptible cv. Grand Naine plants treated with 1 mM (control) and 150 mM NaCl for 15 days. The analysis was carried out with 13 cm non-linear pH 4-7 IPG strips and silver staining of the 2-DE gels particularly of Grand Naine developed darkening in upper portion due to the reaction of nonprotein materials with silver nitrate masking the middle and high molecular weight proteins. Overnight staining with colloidal Coommassie Blue of gels produced proteomic profiles of Saba and Grand Naine banana roots around 350 and 400 protein spots respectively (Fig. 19a&b and 20a&b). By analysis using Melanie7 software, a total of 80 differentially regulated proteins from both genotypes were identified.

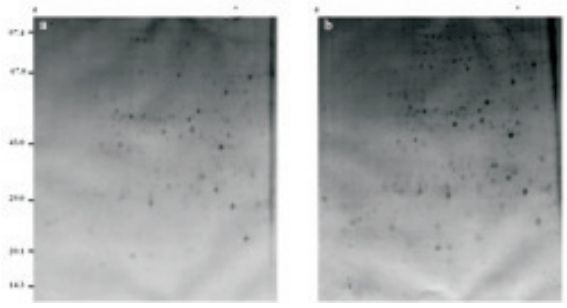


Fig. 19. 2-DE patterns of Saba root proteins: (a) treated with 1 mM NaCl (control) and (b) treated with 150 mM NaCl concentrations

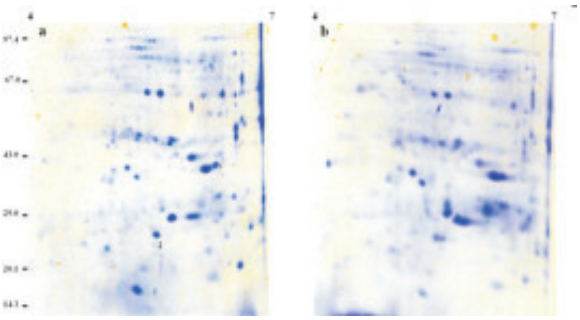


Fig. 20. 2-DE patterns of Grand Naine root proteins: (a) treated with 1 mM NaCl (control) and (b) treated with 150 mM NaCl concentrations

4.3.2 Biochemistry

Biochemical mechanism of resistance of banana to *Pratylenchus coffeae*

Protein extraction method for banana root proteomics analysis by 2-DE was standardized by comparing four protocols *viz.*, Trichloroacetic acid-acetone (TCA), Phenol-ammonium acetate (PAA), Phenol/SDS-ammonium acetate (PSA) and Tris base-acetone (TBA) with modifications. Among the four methods, the phenol-ammonium acetate protocol (PAA) yielded the highest protein concentration of 0.42 mg/0.1 ml from 0.89 mg of proteins yield from one g of root tissues followed by TCA protocol of 0.34 mg/0.1 ml from 0.86 mg of proteins yield from one g of root tissues. The SPA and TBA protocols yielded very protein concentrations (Table 26). Comparison of total number of resolved protein spots by 2-DE in identical conditions in the pH 3-10 range from 250 µg proteins isolated by four methods showed that PAA protocol produced highest number of proteins with 584 spots followed by the TCA protocol, which showed 546 protein spots (Fig. 21 a&b). This is approximately 100% more protein spots yield than the PSA and TBA protocols, which produced only 261 and 258 spots respectively in 2-D gels. Comparison of protocols for number of proteins resolved in different p*I* range revealed that more than two-third of the total spots were distributed in 4-7 p*I* in PAA and TCA protocols (Fig. 22).

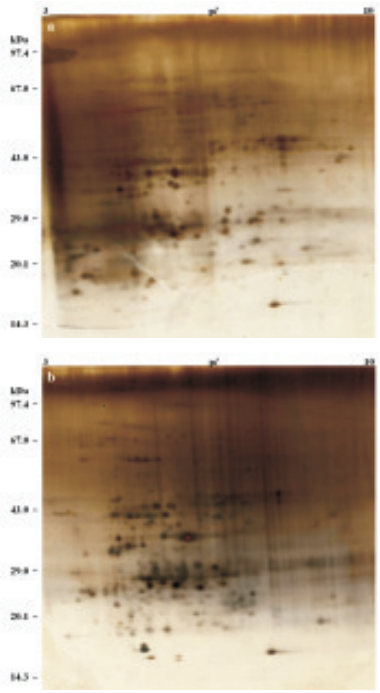


Fig. 21. 2-DE patterns of Grand Naine banana root proteins: (a) trichloroacetic acid-acetone protocol and (b) phenol-ammonium acetate protocol

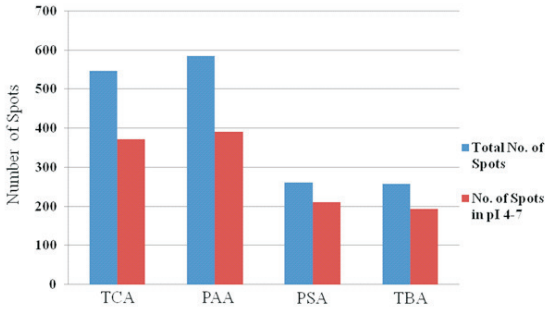


Fig. 22. Total protein spots resolved in the narrow 4-7 p*I* range

Table 25. Protein concentration and number of spots from banana roots by four different extraction protocols.

Extraction method	Protein concentration* (mg/100 µl lysis buffer)[a]	Number of protein spots*
TCA-acetone (TCA)	0.34 ± 0.028	546 ± 25.3
Phenol-ammonium acetate (PAA)	0.42 ± 0.037	584 ± 20.6
Phenol/SDS-ammonium acetate (PSA)	0.28 ± 0.025	261 ± 32.7
Tris buffer-acetone (TBA)	0.20 ± 0.022	258 ± 14.1

Mean (± SD) of four replications.

[a]Quantity of protein solubilised when total protein extracted from one g of root tissue was solubilised in 0.1 ml lysis buffer

The PAA and TCA protocols produced better spots resolution free from any streaking and distortion of proteins. The sum of quantity and intensity of proteins from the gels were analysed using Melanie7 software. The sum of protein spots quantity was highest by the PAA protocol followed by the TCA protocol and the other two protocols had very low sum of proteins quantity (Fig. 23). Similarly, PAA protocol showed highest average protein spot intensity followed by the TCA protocol (Fig. 24). This indicated PAA method was found most suitable for banana rooteomics analysis by 2-DE. In addition, one g root tissue, 1:3 ratios of roots to extraction buffer and overnight storage at -20°C for protein precipitation were found best to obtain maximum protein yield. Extraction of proteins from more amounts of root tissues yielded proportionately higher amount of proteins. Lower and higher ratios of tissue to extraction buffer resulted in lower yield of proteins from root tissues particularly by PAA protocol. Incubation for 2 or 6 hr was found insufficient for complete precipitation of proteins but overnight incubation yielded significantly higher quantity of proteins.

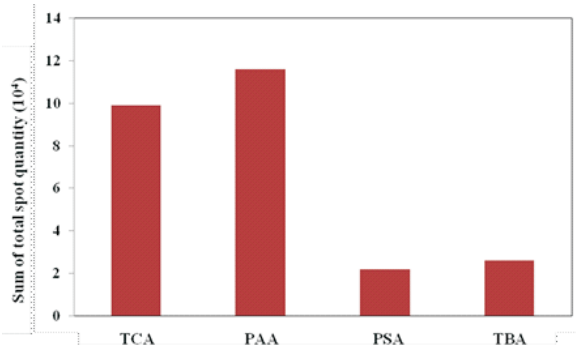


Fig. 23. Comparison of extraction protocols for sum of total spot quantity

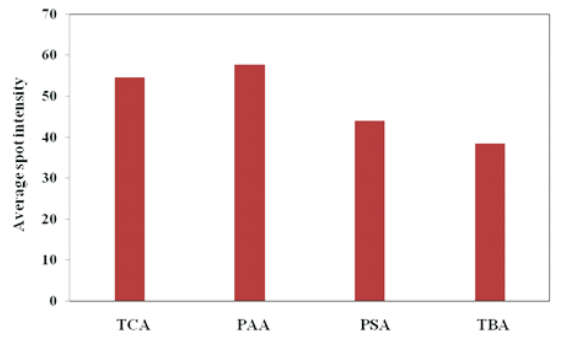


Fig. 24. Comparison of extraction protocols for average intensity of total spots

Studies on differentially expressed proteins in response to *Pratylenchus coffeae* infection

Proteomic analysis for identification of differentially expressed proteins by infection of root lesion nematode was carried out from the total proteins isolated from one g root tissues of Anaikomban and Nendran at seven days after inoculation with *P. coffeae* and control (uninoculated) by phenol-ammonium acetate protocol using 18 cm IPG strips of pH 3-10 for first dimension and 12% SDS-PAGE for second dimension. The results showed 580 and 586 peptide spots respectively from uninoculated control and nematode-inoculated Anaikomban roots (Fig. 25 a&b) and 563 and 571 peptides from uninoculated control and nematode-inoculated Nendran. From both genotypes, 80 differentially expressed proteins (up-regulated, down-regulated, newly appeared and disappeared) due to the *P. coffeae* infection were identified and out of these, 40 were sent for fingerprinting by GC-MS/MS and the biological functions of 19 of these proteins included defense and stress-related protein, proteins involved in energy metabolism, oxidative species scavenging, signal transduction and cell wall remodelling upon nematode infection.

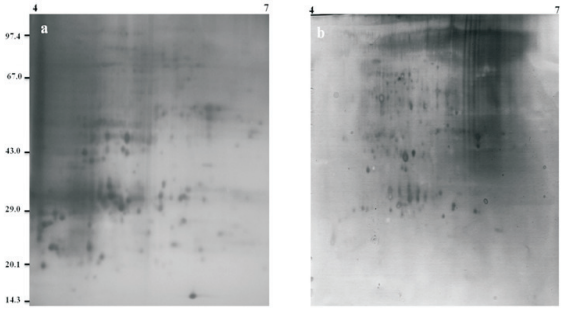


Fig. 25 a&b. 2-DE patterns of banana root proteins of Anaikomban: (a) control (uninoculated) and (b) inoculated with *P. coffeae*

Identification of phenolic metabolites in bananas in response to *P. coffeae* infection

Identification and quantification of phenolic metabolites from two fractions *viz.*, total methanol-soluble phenolics including non-conjugated, glycoside-bound and ester-bound phenolics and cell wall-bound (ester-bound phenolics incorporated in the cell wall) prepared from the roots of nematode-resistant banana cv. Yangambi Km5 and susceptible cv. Nendran were performed by HPLC. The identification of metabolites was carried out by comparing retention times and quantification of the compounds by comparing with areas of peaks of authentic standards. Six phenolic metabolites *viz.*, protocatechuic acid, vanillic acid, caffeic acid, *p*-coumaric acid, ferulic acid and sinapic acid from methanol soluble fraction (Fig. 26) and five major phenolic metabolites *viz.*, protocatechuic acid, vanillic acid, *p*-coumaric acid, ferulic acid and sinapic acid and with traces of caffeic acid from wall-bound phenolic fraction were detected (Fig. 27).

The percentage composition of phenolic metabolites did not differ much between controls and nematode-infected roots of both Yangambi Km5 and Nendran. The quantity of vanillic, *p*-coumaric, ferulic and sinapic acids from total soluble phenolics fraction of nematode-inoculated roots of resistant cv., Anaikomban, were 3.70-, 2.86, 2.97- and 3.19-times higher compared to the corresponding control. From cell wall-bound fraction, the induction of protocatechuic, *p*-coumaric and sinapic acid were 3.3-, 2.9- and 4.2-times higher in inoculated roots of resistant cv. Anaikomban compared to the corresponding control. The induction of soluble and wall-bound phenolics in infected roots of Nendran was also less than 2-times compared to control and the content of caffeic acid in the cell wall was only 2-6% of total phenolic acids (Table 26).

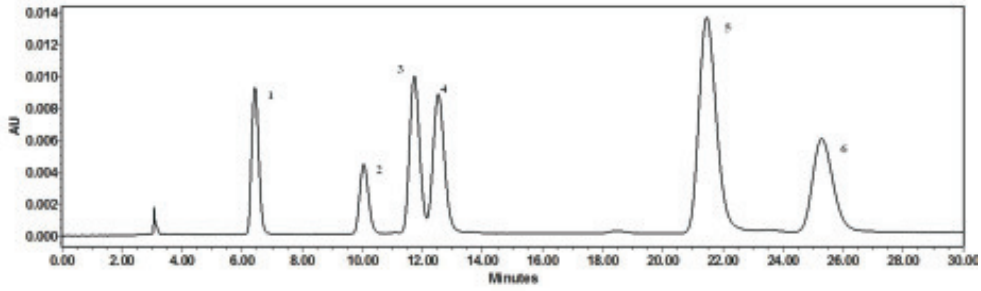


Fig. 26. HPLC chromatogram of total methanol soluble phenolic acids eluted from roots of resistant banana cv. Yangambi Km5 following infection with *Pratylenchus coffeae*. 1, Protocatechuic acid; 2, Vanillic acid; 3, Caffeic acid; 4, p-Coumaric acid; 5, Ferulic acid and 6, Sinapic acid

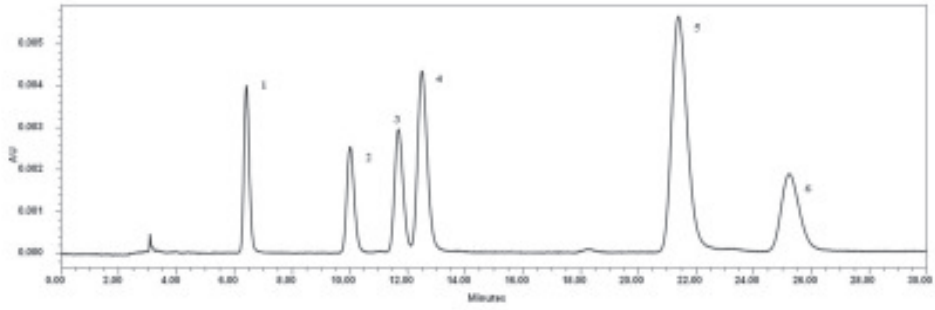


Fig. 27. HPLC chromatogram of cell wall-bound phenolic acids eluted from roots of susceptible banana cv. Nendran following infection with *Pratylenchus coffeae*. 1, Protocatechuic acid; 2, Vanillic acid; 3, Caffeic acid; 4, p-Coumaric acid; 5, Ferulic acid and 6, Sinapic acid

Table 26. Individual phenolic acid metabolites (ig/g root fresh weight) in resistant (Yangambi Km5) and susceptible (Nendran) banana roots in response to *Pratylenchus coffeae* infection

Phenolic metabolites	Total soluble acids				Cell wall-bound acids			
	Yangambi Km5 (Control)	(Inoculated)	Nendran (Control)	(Inoculated)	Yangambi Km5 (Control)	(Inoculated)	Nendran (Control)	(Inoculated)
Protocatechuic acid	9.90	26.22	7.37	12.25	4.91	16.32	3.43	6.47
Vanillic acid	7.43	27.53	7.26	11.40	5.72	14.33	5.24	8.01
Caffeic acid	15.83	41.32	8.58	16.62	1.22	1.74	1.12	1.61
p-Coumaric acid	12.44	35.53	10.39	14.25	7.14	21.04	5.85	8.74
Ferulic acid	16.54	49.21	14.98	22.04	10.26	26.49	8.76	16.07
Sinapic acid	14.83	47.37	9.74	17.37	5.22	21.81	4.72	6.71

Metabolomic analysis in banana roots in response to *P. coffeae* infection

Metabolomic approach was applied for studying biochemical changes in susceptible and resistant bananas in response to root lesion nematode infection. Total metabolites were extracted from 100 mg roots of *P. coffeae* inoculated and uninoculated Anaikomban and Nendran bananas at seven days after inoculation using solvent system of methanol: water: chloroform (1:1:0.5 v/v) and analysis of total metabolites using GC-MS (LECO-PEGASUS III) was carried out. Analysis of the total ion chromatogram was carried out for Ion Mass Spectrum, Retention Index and Similarity Index by LECO® ChromaTOF™ and for number of metabolites by Binbase, a local database coupled to NIST and Fiehn's metabolites libraries showed around 850 metabolites with 200 known metabolites by chemical name from banana roots (Fig. 28). A proanthocyanidin metabolite and two phenolic metabolites could be correlated with infection of *P. coffeae* in banana. The comparative analysis of contents of vanillic and caffeic acids and procyanidin indicated elevated accumulation in roots of bananas infected with *P. coffeae* and induction of these metabolites was more in resistant variety Anaikomban than in susceptible cv. Nendran (Fig. 29 a&b).

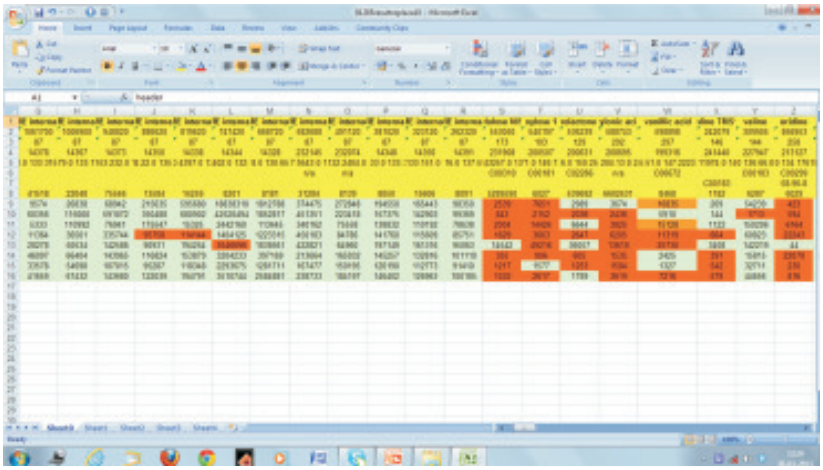


Fig. 28.The Print Screen of Excel Sheet of Binbase results of metabolites analysis

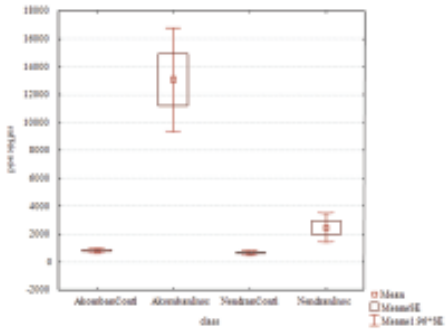


Fig. 29 a. Caffeic acid concentrations in the resistant and susceptible banana roots

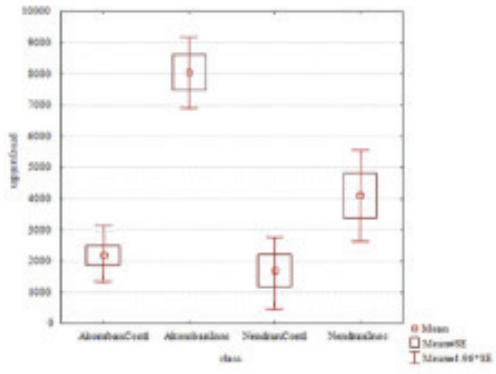


Fig. 29 b. Procyanidin (a proanthocyanidin compound) concentrations in the resistant and susceptible banana roots

Mining metabolites: Extracting banana metabolome from the literature

The metabolite recognition tool of Chemical Abstract Service (CAS) Database was performed to the literatures covering 'banana', '*Musa acuminata*' and '*Musa balbisiana'* as search cases to ascertain the 'size' of banana metabolome in literatures up to 2012. A total of 299 metabolites were listed with CAS Registry Number (CASRN) from published literatures on banana, which were indexed by name and curated by ChemSpider, the free chemical database and the Identification Number of 26 metabolites were not found and CASRN of 91 metabolites had more than one hits. By further search and curation of banana metabolites with SciFinder, a chemical/metabolite abstracting database of University of California, Davis, USA, all the 299 metabolites names were indexed from the CASRN in ChemSpider and SciFinder databases without any ambiguity. Many of the metabolites found in literatures *vis-à-vis* banana were common compounds such as amino acids, minerals, enzymes, polymer compounds like lignin and starch, *etc.* and only a small number metabolites (around 30) were of typical of banana metabolome.

Metabolomic analysis during ripening of banana

Banana peel and pulp tissues are recalcitrant for metabolomic analysis due to abundance of sugar metabolites. A solvent system and quantity of tissue required for metabolomic analysis were standardized for extraction of maximum metabolites without interference of sugar metabolites from tissues of banana fruit. Of the various solvents tested for peel and pulp including the standard solvent system of methanol:chloroform:water (5:2:2 v/v) used for plant tissues, the methanol:chloroform:acetonitrile (2:1:1 v/v) solvent system produced maximum number of metabolites with optimum concentrations by GC-MS (LECO-PEGASUS III) analysis. Analysis of total ion chromatogram through Binbase, a local mass-spectral analysis software, the solvent system produced maximum of around 1500 metabolites with 250 known metabolites from NIST and Fiehn libraries. Of the different quantity of tissues examined, metabolites extraction from 10 mg peel and pulp tissues in one ml of extraction buffer, derivatization of 250 µl metabolites and injection of 0.5 µl was found optimum for metabolomic analysis of banana fruit tissues (Fig. 30 a,b&c).

Analysis for metabolic changes was carried out in peel and pulp tissues of Grand Naine (*Musa* sp., AAA) fruit during seven stages of banana fruit ripening *viz.*, Stage1: Full green; Stage2: Traces of yellow; Stage3: More green than yellow; Stage4: More yellow than green; Stage5: Green in tips; Stage6: Fully yellow and Stage7: Yellow flecked with brown spot. The total metabolites were extracted using the solvent system of methanol:

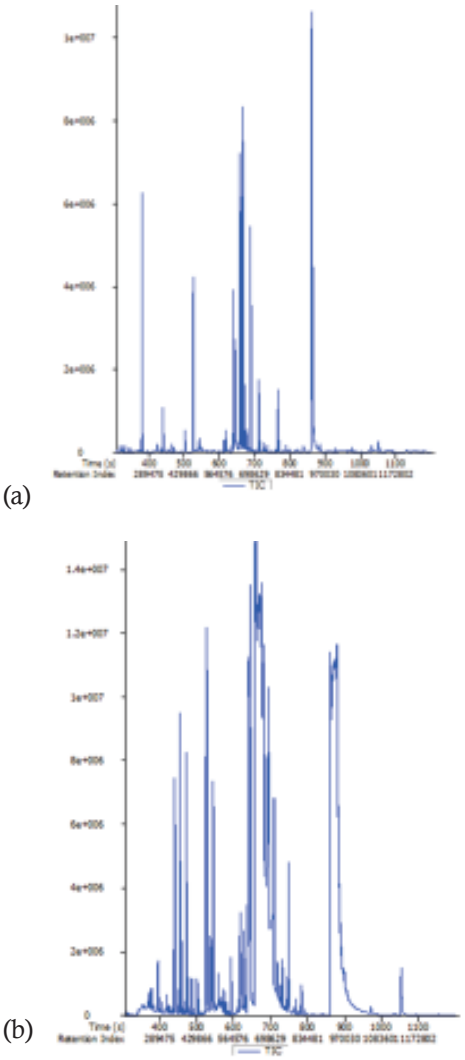


Fig. 30 a&b. Total ion chromatogram from LECO-PEGASUS-III GC-MS; banana fruit ripe peel (10 mg) and fruit ripe pulp (50 mg) samples

chloroform: acetonitrile (2:1:1 v/v) were analyzed by GC-MS. The results of analysis by Binbase to NIST and Fiehn metabolites libraries clearly indicated gradual increase in concentration of pectin and hemicellulose catabolites like galacturonic acid, arabinose (Fig. 31 a&b) and xylose during ripening of

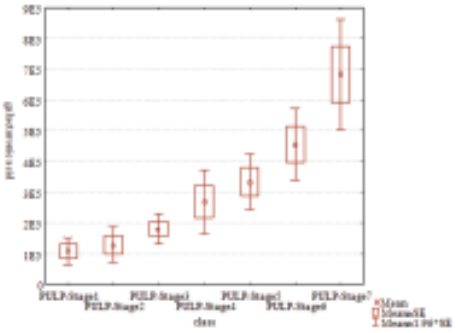


Fig. 31a. Accumulation of galacturonic acid in banana pulp during different stages of ripening

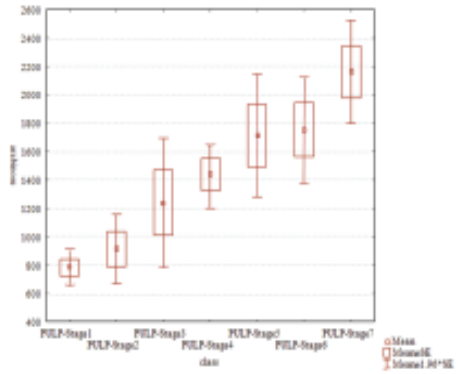


Fig. 31b. Accumulation of arabinose in banana pulp during different stages of ripening

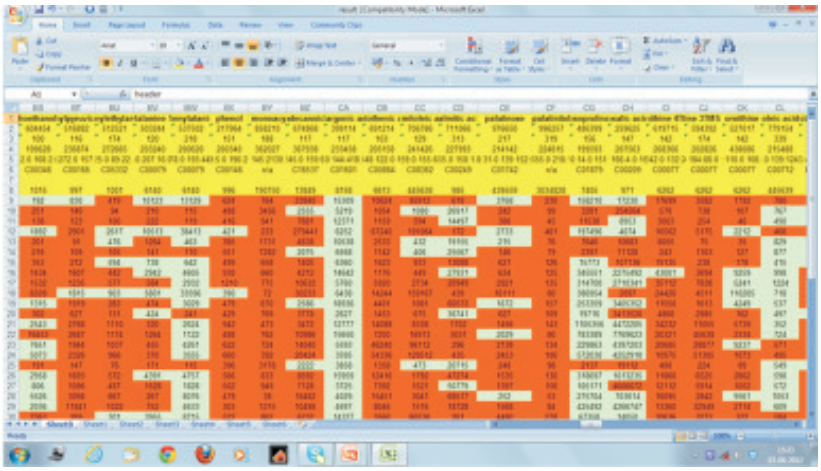


Fig. 30c. The Print Screen of Excel Sheet of Binbase results of metabolites analysis during ripening of banana

the fruit and higher content of flavonoids like catechin in initial stages of ripening and decrease of such compounds in later stages of ripening and decrease of organic acids like malic acid content during ripening. This implies that metabolomic analysis can be applied to banana for discovery of novel metabolites, new metabolic pathway and metabolite marker and also for functional genomics studies.

4.3.3 Postharvest Technology

Survey on banana leaf industry

A survey in Tiruchirappalli area revealed that cv. Karpuravalli is mainly cultivated for leaf purpose with 1000 to 1200 plants/acre. Fertilizer is applied on 3rd, 5th and 7th month after planting, maintaining is done at half- or 3/4th unfurled stage. Harvesting is done six months onwards at regular intervals.

Postharvest management of Red Banana

Among the post-harvest treatments to extend the shelf-life of Red Banana, 80% maturity hands packed in KMnO4 impregnated polybag and stored at 13.5°C with RH 95% increased the shelf-life of fruits up to 145 days with better postharvest quality (high pulp peel ratio, TSS and total sugar) and organoleptic characters (Fig. 32).

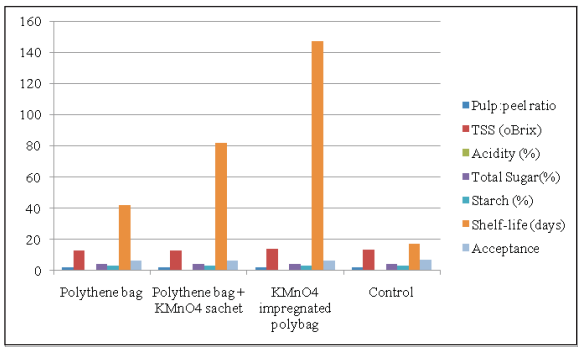


Fig. 32. Effect of packaging and cold storage on quality of Red Banana

Postharvest management of banana flower

An experiment was conducted to extend the shelf-life of banana flowers (male buds) by storing at various temperatures in polybags in order to utilize the flowers for various preparations. Banana flowers of cv. Karpuravalli could be stored up to 10 days in 200 gauge polybags kept at 20°C without affecting the quality followed by vacuum packing, In vacuum packing discoloration and rotting of flowers were observed. However, the control had maximum loss in weight of 21% (Fig. 33.).

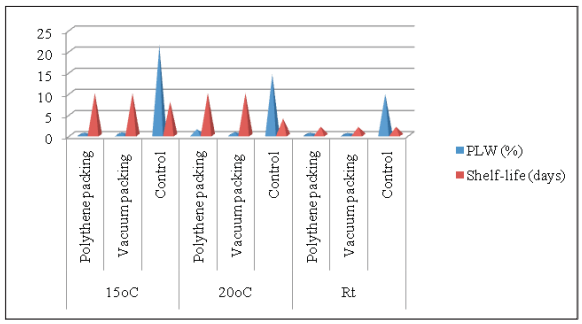


Fig. 33. Effect of packaging and cold storage on shelf-life of banana flower

Postharvest management of Central core stem of banana

In a trial to extend the shelf-life of banana central core stem by preventing discoloration, full-length (30 cm length with 30 mm dia.), slice (5 mm thickness with 30 mm dia.) and cubes (7.5 cm thickness with 1.5 cm dia.) were tied. Among them, cubes and slices of central core stem can be stored up to 32 days each under refrigeration (5-6°C) after treating them with 0.1% each of KMS and citric acid for half-an-hour and sealing in 200 gauge polybag, when compared to seven days at room temperature (Fig. 34).

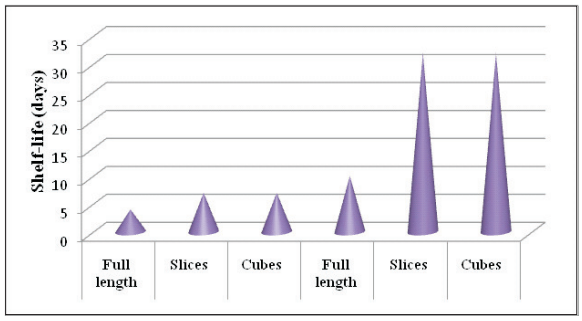


Fig. 34. Effect of packaging and cold storage on shelf-life of banana central core stem

Standardization and development of banana pulp based juice

Among the various combinations tried for banana pulp based ready-to-drink beverage of cv. Robusta, dilution of pulp with water at 1:4 glended well with high acceptance (7.41 Hedonic scale), which was on par with banana RTS beverage (Fig. 35 a&b).

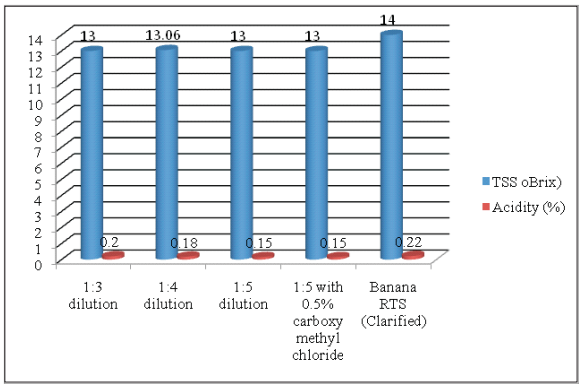


Fig. 35a. Effect of banana pulp based juice on quality

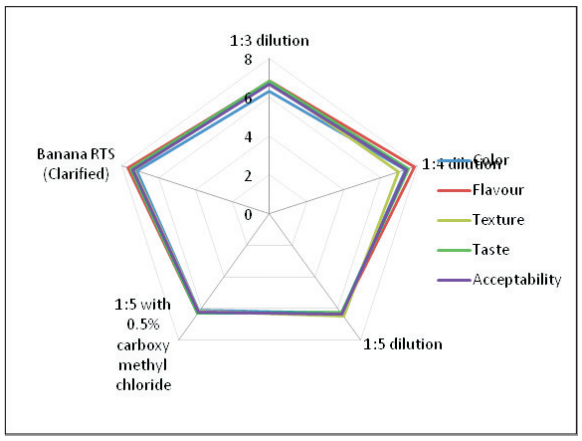


Fig. 35b. Sensory evaluation of banana pulp based juice

Evaluation of commercial banana varieties for fiber extraction and quality

Among three cavendish banana cv. Gandevi registered maximum cellulose content (55.63%). Basarai recorded the highest lignin content of 11.40% and minimum pectin content 2.37%, followed by Grand Naine, irrespective of the treatments. Among the treatments, 0.1% NaOH recorded the highest cellulose (59%) and lignin content (13%) in the fibre. However, minimum pectin content was registered with 0.5% NaOH, irrespective of the varieties. Overall, 'Basarai' was found to be the best variety and 0.5% NaOH was the best treatment for extraction of fiber, based on chemical parameters studied (Fig. 36).

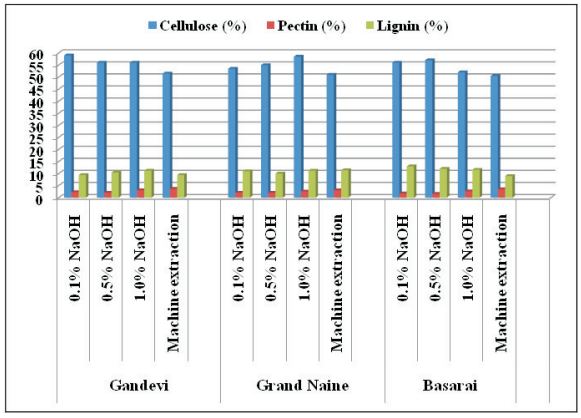


Fig. 36. Chemical properties of fibers extracted by various processes in banana varieties

4.4 CROP PROTECTION

4.4.1 Nematode management

Effect of endophytic bacteria against root-lesion nematode

In vitro screening of endophytic isolates viz., *Bacillus sp.*, *Clostridium* sp., *Sporolacto bacillus,* and *Lactococcus* sp., at two concentrations against *P. coffeae* in cvs. NeyPoovan and Poovan revealed that 100 % concentration of all isolates exhibited maximum plant height (40 cm to 133 cm), pseudostem girth (8 to 31 cm) and number of leaves (5 to 7). But significant reduction in nematode population (<10 nematodes/g root) was recorded in the treatments *Clostridium* sp., *Bacillus sp.*, and *Lactococcus* sp., compared to *Sporolacto bacillus* and control plants. Similar results were obtained with respect to root parameters also.

Effect of endophytic fungi against root-lesion nematode

Endophytic fungi *(Alternaria tenuis, Trichosporium nigricans, Curvularia lunata and C. geniculata*) were imposed at 50 and 100% concentration in cvs. Rasthali and Nendran raised in cement rings contained root-lesion nematode infested soil resulted in 30 % enhanced plant growth and significant reduction in root-lesion and root-knot nematodes in both cultivars.

Diversity studies on *Musa* nematodes through molecular characterization.

Among the four methods of DNA extraction tried (warm lysis, phenol, freeze thaw and CTAB methods), phenol method (modified from Pastrick *et* al.,1995) is found suitable for isolating pure DNA from *M. incognita* and *P. coffeae.*

Primer sequence was designed for three major types of nematodes *viz. Radopholus similis, P. coffeae, and M. incognita.*

Among the seven ITS primers used for diversity studies of *M. incognita,* five primers (M11, M12, M13, Mel, MiITS1), amplified with the expected size which will be further used for diversity analysis (Fig. 37).

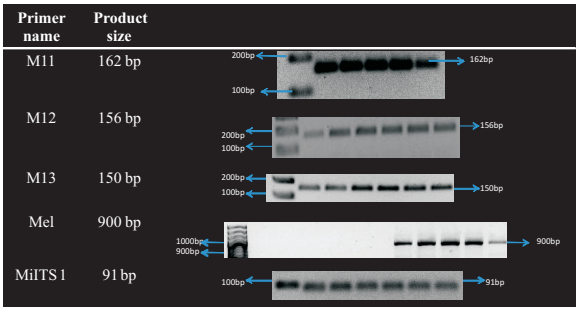


Fig. 37. ITS primer standardization for *Meloidogyne incognita*

4.4.2 Management of banana weevils

Isolation of endophytic fungi for the management of insect pests

Endophytic fungi strains (42) were isolated from banana leaf mid rib and coffee leaves which consisted of 35 isolates of *Metarhizium anisopliae* , two isolates of *Beauveria bassiana* and two isolates of *Lecanicillium lecanii* from banana leaf midrib and three isolates of *Metarhizium anisopliae* from coffee leaves.

Evaluation of entomopathogenic fungi

Rhizospheric isolates of *Beauveria bassiana* (NRCB, CCRI, and RCRS) and three endophytic isolates of *Metarhizium anisopliae* (Ma-CI 1, Ma-CI 2, and Ma-CI 3) were evaluated against banana stem weevil under

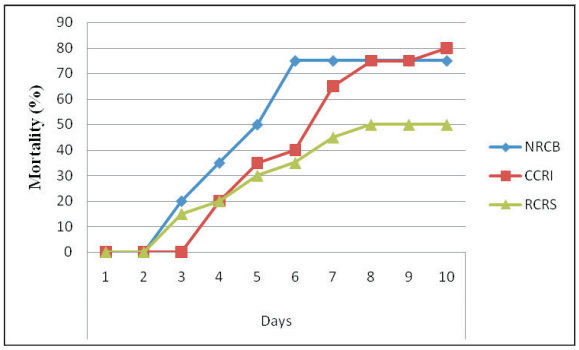


Fig. 38. Banana stem weevil mortality due to *Beauveria bassiana* isolates

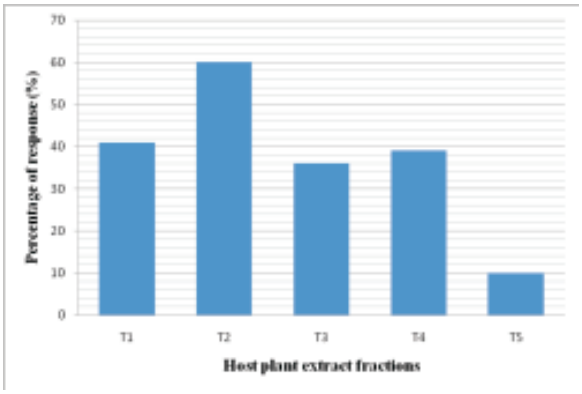
laboratory conditions. *Beauveria bassiana* NRCB isolate recorded 80% mortality of stem weevils whereas CCRI and RCRS isolates of *Beauveria bassiana* and endophytic *M.anisopliae* (Ma-CI 2) recorded only 40 % mortality on 6th day after application under *in vitro* conditions. Ma-CI 1 and Ma-CI 3 registered 20 % mortality (Fig. 38).

Isolation and evaluation of toxins from promising isolates of microbial fungi

The toxins extracted from the *Beauveria bassiana* NRCB isolates were compared with other formulations of *B.bassiana.* NRCB isolate such as liquid, rice chaffy grain formulations along with insecticide Chlorpyriphos for their efficacy against stem weevil under laboratory conditions. The results showed that the toxins caused 83.0% weevil mortality on the 10 th day of application, where as the liquid formulation, rice chaffy grains formulation and insecticide caused 100, 78 and 100 % weevil mortality on 6th, 6th and 2nd day after application respectively. No weevil mortality was recorded in the check control.

Improving the efficacy of semiochemical lure for banana weevils

In order to improve the efficacy of semiochemical lure instead of using the whole extract, the banana leaf sheath extracts of cvs. Nendran and Poovan were fractioned by column chromatography and tested against banana stem weevil by wind tunnel method. Among 10 fractions tested, the fraction no.3 from cv. Nendran and fraction no.4 from cv. Poovan recorded 60% and 39% attraction of stem weevil respectively (Fig. 39).

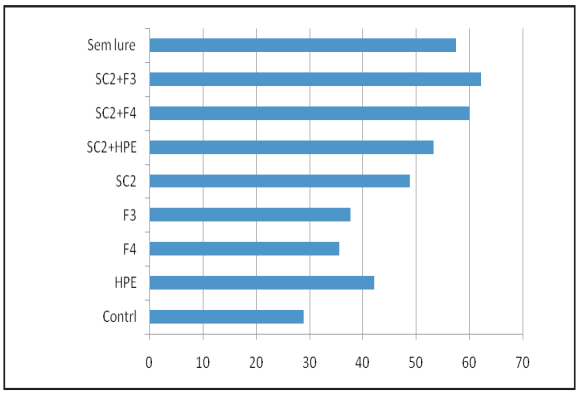


T1 – Nendran (Fraction No.3), T2 - Nendran (Fraction No.4), T3 - Poovan (Fraction No.3), T4 - Poovan (Fraction No.4), T5 - Control.

Fig. 39. Response of stem weevil to fraction No.3 and 4 of extracts of cvs. Nendran and Poovan by Wind tunnel studies.

Evaluation of leaf sheath volatile fractions with semiochemical No.2

Among the treatments, the fraction 3 in combination with SC No.2 attracted a maximum of 62.22 ± 3.85 percent of weevils followed by fraction 4 along with SC No.2 60.00 ± 6.67. The semiochemical lure which is a combination of crude extract of host plant along with SC No.2 and with an antioxidant attracted 57.5 ± 3.19 percent weevils. The crude extract collected from banana leaf sheath alone attracted a maximum 42.22 ± 3.85 percent weevils. All the treatments attracted more weevils than control. These results showed that addition of either crude extract or its fractions enhanced the attraction of SC No.2 by 12 percent (Fig. 40).



Percent of weevil atraction

Sem lure = Semio chemical lure
SC2 = Semio chemical lure no. 2
F3 = Fraction no. 3
F4 = Fraction no. 4
HPE = Host plant extract

Fig. 40. Stem weevil attraction to semiochemicals and Host Plant Extract fractions

Identification of volatiles from leaf sheath and corm of banana

Banana leaf sheath of cv. Karpuravalli was extracted by cold extraction method and the GC/MS profile indicated 23 volatile components having RT values ranging from 2.621 to 21.372. (Fig. 41). The volatile components include Alkanes- 10, Alcohol-1, Aldehyde-1, Ketone-1, Phenol-1, Fatty acids-6. The volatile components were identified (Fig. 42).

Identification of effective volatile component from the total volatile components of leaf sheath extract of susceptible cultivar. GC-EAD analysis was carried out at NBAII Bangalore.The results showed that out of seven

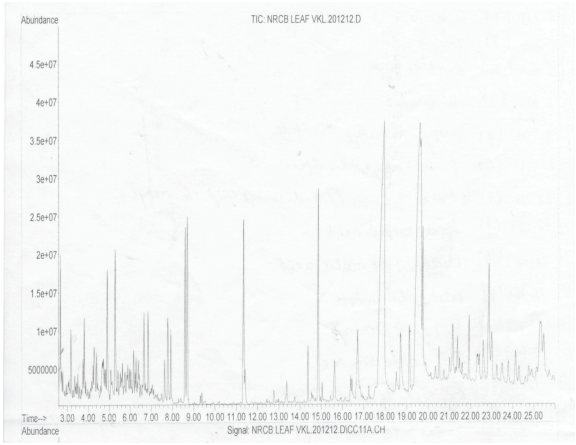


Fig. 41. GC/MS Profile of leaf sheath extract of a susceptible cultivar.

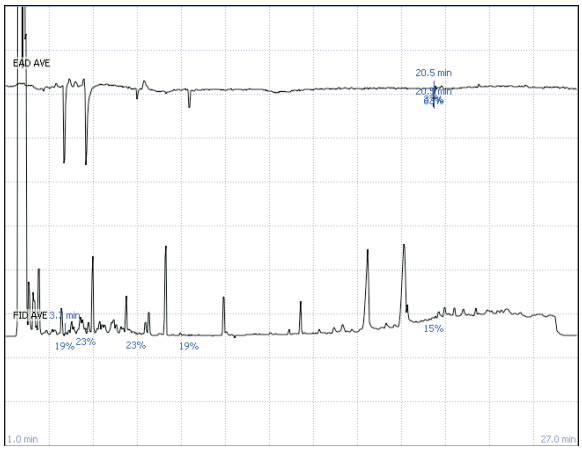


Fig. 42. GC-EAD response of banana stem weevil (female) to leaf sheath extract of a susceptible cultivar

volatile components, three components having RT values of 17.5, 19.1 and 19.8 indicated response to male weevils. The female stem weevil response were noticed at RT values 3.7 and 20.5. Corm weevil response was recorded at RT values 5.8 and 6.9 while female corm weevil did not show any response to the same volatile extract.

4.4.3 Fungal and Bacterial disease Management

a. Fusarium wilt

Evaluation of biocontrol agents for the suppression of Fusarium wilt disease

Soil application of endophytic fungi viz., *T. harzianum, Penicillium pinophilum* and *Penicillium* sp. in combination with botanical extracts such as *Alpinia* sp., *Hibiscus* sp. and Zimmu in different combinations under pot culture condition indicated that the treatments viz., *T. harzianum* + Zimmu*; T. harzianum* + *Hibiscus* sp., *P. pinophilum* + *Alpinia* sp.; *P. pinophilum* + *Hisbiscus* sp., and *P. pinophilum* + Zimmu recorded total suppression (100%) of Fusarium wilt disease in cv. Grand Naine.

Field evaluation of wilt infected suckers in cv. Rasthali

Field evaluation of effective fungal and bacterial endophytic and rhizospheric antagonists for the suppression of planting material already infested with *Foc* pathogen in cv. Rasthali (Mortaman) showed that plant growth parameters such as height, girth, no. of leaves and leaf area increased significantly compared to control plants without any biocontrol agents. Besides, the number of plants flowered and harvested till date were significantly higher in the bio-control agents applied plants the experiment is in progress.

Evaluation of different VCGs in cv. Grand Naine

The evaluation of different VCGs on their ability to cause wilt disease in cv. Grand Naine

under pot culture condition indicated that none of the VCGs group other than VCG 0124 caused wilt disease in cv. Grand Naine.

b. Eumusae leaf spot disease

Genetic diversity of *Mycosphaerella eumusae* of India

i) Sequencing of rDNA-ITS region

Diversity analysis of *Mycosphaerella eumusae* causing leaf spot disease in India was studied. The rDNA-ITS region of 99 isolates of *M. eumusae* and one isolate each of *M. fijiensis* and *M. musicola* were amplified, purified, and sequenced. The phylogenetic analysis showed that presence of three different major groups of *M. eumusae* isolates in India (Fig.43) and each group was further categorized into separate clades showing the presence of wider genetic diversity among the *M. eumusae* isolates in India. These different major groups were not based either on host source or genomic status of the host or geographical region of the isolates from where these were isolated. Besides, this analysis has clearly distinguished all the three major species of *Mycosphaerella* such as *eumusae, fijiensis* and *musicola* which is more important for the quarantine as well as for management purpose. It was also observed that all the three *Mycosphaerella* species originated from a same cluster indicating all belongs to a same ancestral group sharing a close genetic relatedness with a bootstrap value of 99%.

ii) RAPD Analysis

Initial screening of 40 operon primers (OPA 1-20 and OPB 1-20 series) tested using the genomic DNA of representative isolates of *M. eumusae* isolates indicated only eleven primers generated reproducible and scorable bands, and only five primers produced maximum number of bands with high degree of polymorphism (25 to 83.3%). These five primers were further used for molecular analysis using genomic DNA of 99 isolates of *Mycosphaerella eumusae* available at NRCB and

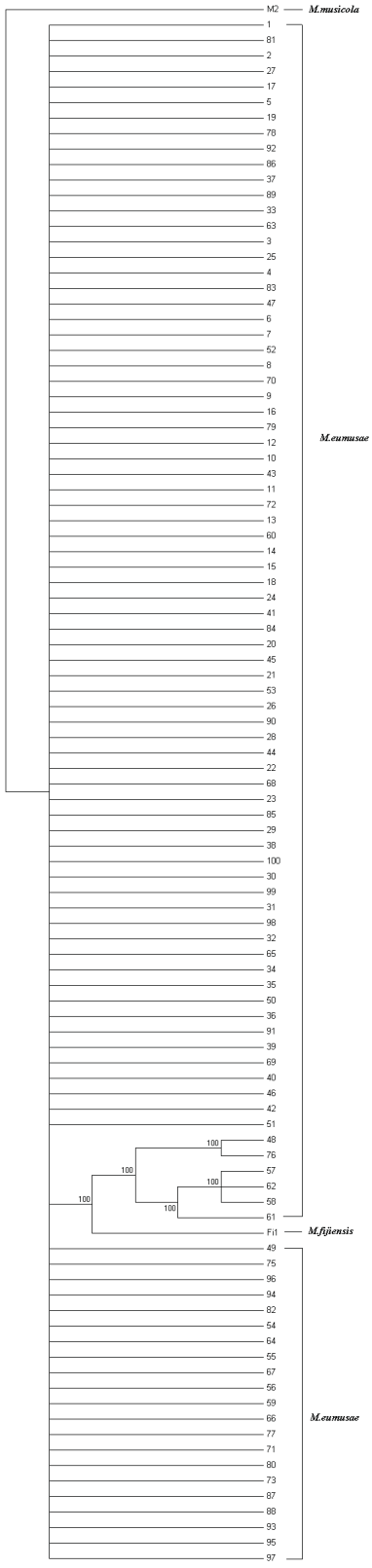
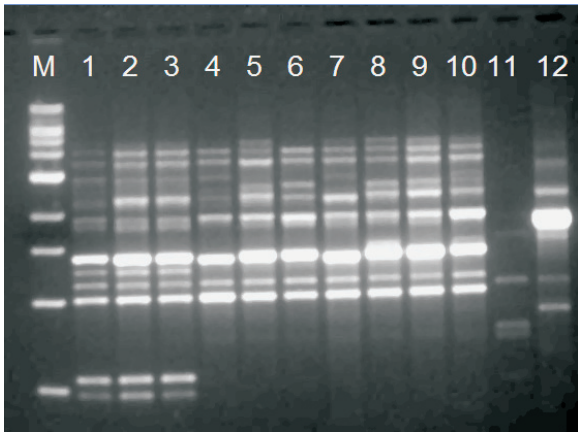


Fig. 43. Dendrogram of *Mycosphaerella* species using ITS-rDNA sequences based on UPGMA method

one isolate each of *M. fijiensis* and *M. musicola*. The results of the RAPD analysis indicated that the size of RAPD fragments ranged from 300 to 350 bp. The primers produced 105 different fragments among 101 isolates of *Mycosphaerella* spp. and were scored based on the presence or absence of bands (Fig. 44).



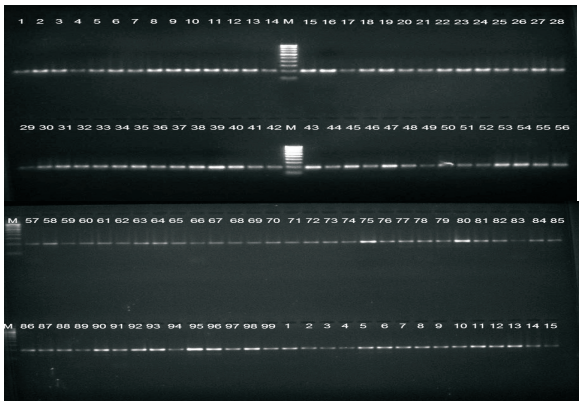
M-500bp marker (Genei), 1-10- *M.eumusae* isolates, 11- *M. musicola,* 12- *M. fijiensis*

Fig. 44. Fingerprint patterns produced by RAPD primer for *Mycosphaerella* spp. isolates

The genetic diversity analysis carried out using the RAPD bands clearly indicated the presence of two major groups among the *M. eumusae* isolates of India (cluster C). However, among these two major groups, there was a wide genetic diversity and among the 99 eumusae isolates, the genetic similarity ranged between 25 to 86%. Similar to rDNA-ITS sequencing analysis, RAPD analysis also clearly distinguished *eumusae* species from the other two major species such as *fijiensis* and *musicola*. All the isolates of *eumsae* including *fijiensis* and *musicola* shared a distance matrix of about 0.04-0.96. The three *Mycosphaerella* spp. shared a very close genetic relatedness and also showed that the other two species viz. *fijiensis* and *eumusae* might have evolved from *M. musicola*.

Development of molecular markers specific to *M. eumusae* pathogen

During the RAPD analysis of M. *eumusae* isolates, a unique band specific to *M. eumusae* isolates were observed. These specific bands were cut from the gel, purified, cloned and sequenced for the development of Sequence Characterized Amplified Region (SCAR) markers. Primers (12) designed were validated using genomic DNA of 115 isolates of *M. eumusae* obtained from different parts of India, and also DNA of five isolates of *M. eumusae,* 11 isolates of *M. musicola* and 11 isolates of *M. fijiensis* obtained from different banana growing regions of the world. Besides, DNA of 27 other leaf spot fungi of India was also used. The results of validation indicated that, only one primer pair viz. 5f & 5r have amplified all the *M. eumusae* isolates which can be be used as a specific marker to *M. eumusae* (Fig. 45).



M-100bp marker (Genei), 1-99 &1-15 – DNA from 115 isolates of *M. eumusae*

Fig. 45. Validation of *Mycosphaerella eumusae* specific primer 5f & 5r using DNA of *M. eumusae* isolates

In vitro screening of native antagonistic microbes for the management of Eumusae pathogen

A total of 112 bacteria and 14 fungi isolates were isolated from different banana germplasm accessions and screened for the inhibition of spore germination and mycelial growth of eumusae leaf spot pathogen under *in vitro* conditions. Among 33 epiphytic and 79 endophytic bacterial antagonists screened, 17 bacterial isolates showed 100% inhibition of spore germination and a maximum of 95.1% inhibition of mycelial growth. Among fungal antagonists screened, two epiphytic and eight endophytic isolates recorded 100%

inhibition of spore germination and 32.8 - 90.3% inhibition of mycelial growth. All the effective bacterial (17) and fungal (10) isolates were further tested for their compatibility. The results indicated that 153 combinations of bacterial isolates and 79 combinations of fungal isolates exhibited 100% compatibility and these compatible combinations will further be tested under field conditions.

4.4.4 Studies on viral diseases and their management

Survey for viral diseases

Survey undertaken in 28 plantations in Theni district for banana viral diseases indicated the incidence of BBTV upto 100% in cv. Grand Naine and a higher incidence of BBrMV was recorded in cv. Red banana. The average incidence of BBTV, BBrMV and CMV was 21.86%, 5.06%, and 2.61 % respectively (Table 27).

Molecular characterization of banana viruses

HC-Pro gene of BBrMV was amplified from ten banana isolates collected from different regions were cloned and sequenced. The results revealed 96-100% nt and aa sequence identity with the known sequences. Phylogenetic analysis revealed that all the Indian isolates were clustered together and only Philippines isolate clustered separately. By recombination analysis four potential recombination events and putative recombination sites were identified. Selection analysis revealed that the isolates are under

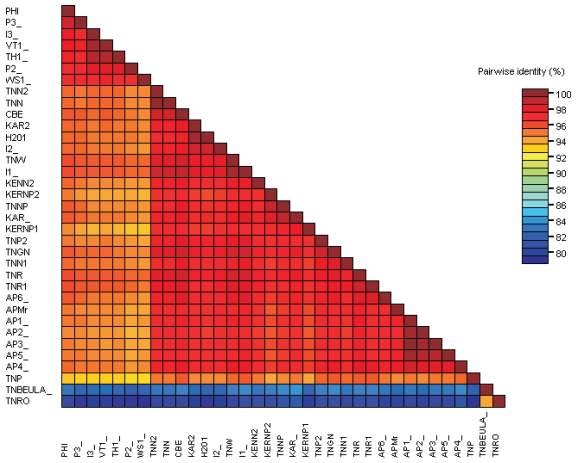


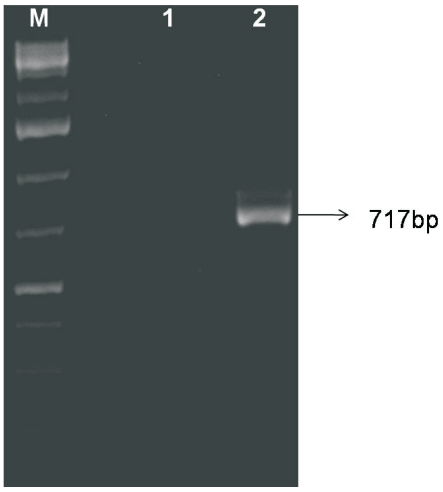
Fig .46. Graphical representation of percentage pairwise genome scores and nucleotide identity plot of coat protein gene of BBrMV infecting banana and plantain species demarcation tool SDTv1.0 program.

Table 27. Survey for viral diseases in different parts of Theni District, Tamil Nadu.

Name of the Location	Variety	Percentage of Disease incidence		
		BBTV	BBrMV	CMV
Chinnamanur	Grand Naine	3	1	-
Vaikalpatti	Grand Naine	30	5	-
K.K.Patti	Grand Naine (I Crop)	-p-	2-9	1- 4
K.K.Patti	Grand Naine (III Crop)	93.5-100	1-9.5	2.4-5.4
K.K.Patti	Red banana	10	5	-
Muthalapuram	Grand Naine	1-15	2-4	3-4
Gokilapuram	Grand Naine	10-40	3-9	2-4
Surulipatti	Grand Naine	1-18	5-8	3-4
Gudaloor	Grand Naine (I Crop)	10-40	5-8	2-7
Gudaloor	Grand Naine (III Crop)	60	10.5	2
Average		21.86	5.06	2.61

predominantly purifying selection and evidence of positive selection was identified at the N-terminal of HC-Pro .

Coat protein gene of BBrMV infected cv. Monthan (TKP-TN), Grand Naine and Red banana (Theni-TN), Beula, (NRCB), Nendran, Neypoovan (Kerala), Mortaman (Andhra Pradesh) and Grand Naine (Karnataka) were cloned and sequenced. The sequence analysis revealed 82-99% similarity at the nucleotide level and more than 88-99 identity at the amino acid level among the isolates that were compared in this study (Fig. 46).



Lane M-1 kb ladder plus DNA ladder ; Lane 1- Healthy control; Lane 2- BaMMV CP gene

Fig .47. PCR amplification of BaMMV coat protein gene in banana cv. Udayam.

Complete coat protein coding gene of BaMMV was amplified from banana cv Udayam, cloned and sequenced.The sequence had 86-87% homology with a BaMMV isolate (Accn. No. AY730748) (Fig. 47).

Expression of recombinant master REP protein of BBTV and a viral associated protein of BSMYV in *E. coli*

Full length master replication gene was cloned into pCOLD-I expression vector and expressed upon IPTG induction. The expressed protein was 34kDa in size and the same was purified and its antiserum was raised. The antisera was cross reacted in ELISA with proteins of healthy plants and the same was confirmed through western blot analysis with a healthy plant protein of a size approx 60 kDa. Polyclonal antiserum was raised against viral associated proteins of BSMYV-TRY isolate. DAC-ELISA was performed with this antiserum which detected the streak virus in the virus infected leaf samples of cv. Poovan.

Diagnostic techniques for banana viruses

Immuno-Capture Reverse Transcription PCR (IC-RT-PCR) was standardized by trapping the virus from different parts of the banana plant *viz.,* leaf, leaf sheath and bract with the polyclonal antiserum raised against BBrMV. An expected fragment of 507 bp length was amplified only from infected samples. Sensitivity of Real Time PCR was assessed by SYBR® Green chemistry and TaqMan® probes for the detection of BBrMV. Among the two methods, TaqMan® probe was more sensitive than SYBR® Green chemistry and the same was validated using infected samples. Best combination of primers was identified for multiplex PCR to detect all the six genomic components BBTV. A Loop Mediated isothermal Amplification (LAMP) based highly sensitive method was standardized for the detection of BBTV with an addition of a loop primer in the reaction. Advantage of this method is that non-symptomatic samples can be analyzed for BBTV. Using RCA based approach, standardized the detection of BBTV and BSMYV which was validated by testing large number of infected samples collected during surveys. Amplification has not been obtained from healthy samples which confirmed the specificity of the technique. This technique will be highly useful for the detection of viruses having circular genomes.

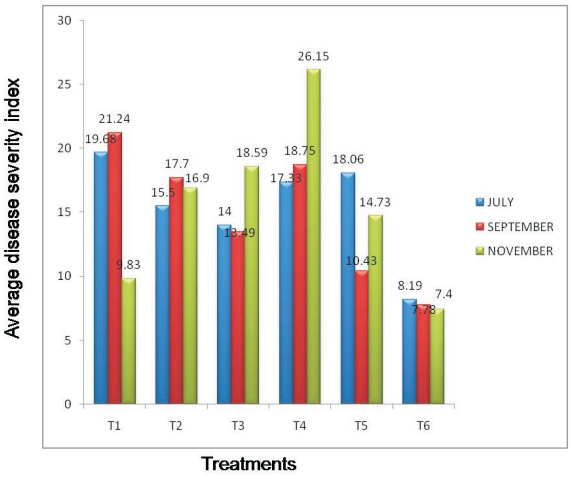
Screening germplasm against banana viruses

Banana germplasm samples (22) received from AICRP (TF) centers viz., Arabhavi (Karnataka) and Jorhat (Assam) were screened

against banana viruses. 16 accessions were positive for BSMYV and one accession was positive for BBrMV & CMV. Three hundred and eleven germplasm samples from NRCB field gene bank were tested for BBTV and CMV. Two samples were positive for BBTV and none of the samples were positive for CMV. For supply of virus free Udhayam banana, 99 clumps of Udhayam mother plants and 59 *in vitro* plants were tested against BBTV, CMV, BBrMV and BaMMV and 92 samples were found to be free of viruses.

Effect of organic fertilizers application on BBrMV and BSV infected Poovan plants

The influence of organic and inorganic fertilizer treatments on the expression of BSMYV in the second ratoon crop of cv. Poovan was recorded during November 2012 which indicated least severity index in plants applied with 125% RDF, whereas in treatment T4, the incidence was 26.15%. Three periodical observations showed that the plants applied with organic fertilizers showed higher severity index compared to treatments with inorganic fertilizer application (Fig. 48).



T1-20kg FYM+1kg VC; T2- 12kg FYM+1.5kg VC; T3-15kg FYM+1.25kg VC; T4-9kg FYM+2.kg VC; T5- 100g Urea+200g Super+100g MOP; T6-150g Urea+250g Super+150g MOP

Fig. 48. BSV symptom expression and different fertilizer treatment in cv. Poovan

4.4.5 Host-virus interaction in Banana: Molecular mechanism of resistance and susceptibility, latency, integration and episomal expression of EPRV's

Analysis of yield, expression of BSV symptoms, symptom severity in the permanent field trail was studied for cv.Poovan. Non-symptomatic Poovan plants planted during 2005-06 was continued as 7th ratoon crop in 2012-13. The expression of BSMYV symptom was observed in 7 plants in 2012-13. Out of 600 plants planted, 96 plants have expressed the symptoms of streak disease during the last 8 years so far. Analysis of disease severity index, yield, girth and plant height over the years revealed high variation between the years. It appears that the wide variation in the yield may be due to weather factors prevailed in the corresponding years.

Comparison of BSV severity in TC and sucker grown plants of cv. Poovan

The comparison of streak virus severity index and yield loss was studied from field grown BSMYV infected Poovan plants obtained through tissue culture and the plants raised through conventional suckers. Results indicated significantly higher severity in TC plants than in healthy as well as sucker grown infected plants. Height and bunch weight (14.71 kg/plant) was obtained from healthy plants while less in the streak virus infected tissue culture plants (8.7 kg per plant) and the sucker grown infected plants yielded 11.29 kg per plant (Table 28).

Latency of bunchy top disease in Grand Naine and Hill banana

BBTV infection was transferred through viruliferous aphids (*Pentalonia nigronervosa*) to virus free tissue culture plants of cv. Grand Naine. Out of 306 plants, 109 were positive in PCR and 84 plants exhibited symptoms 50-140 days after inoculation. 15 plants indicated latency with no expression of typical bunchy

Table 28. Comparison of BSV severity in TC and sucker grown plants of cv. Poovan

Treatments	Height (cm)	Girth (cm)	No. of Leaves	DS*	No. of Hands	Bunch Weight (Kg.)
T1	221.854	51.521	8.801	40.463	8.854	8.736
T2	254.521	55.424	7.804	28.016	10.951	11.29
T3	282.379	65.236	8.33	0	10.234	14.71
CD(0.05)	12.878	3.317	1.046	5.3034	0.874	1.006

T1- BSV infected TC plant; T2- BSV infected conventional suckers; T3-Healthy control *Disease severity.

top symptoms. Latent plants of hill banana collected during the survey were identified by PCR technique.

Studies on banana streak virus integration

Southern blotting analysis using probe of 1.3kb size was labeled with DIG (Digoxigen) - 11dUTP to study the integration of BSOLV genome in banana and the result revealed that the integration of BSOLV genome recorded in cv. Poovan (AAB) but not in cv. Grand Naine (AAA). Rolling Circle Amplification (RCA) was carried out to confirm the type of BSV species infecting cv.Poovan and Virupakshi. The amplification was observed only from the DNA isolated from infected but was absent in healthy. The amplified fragments were subjected to RFLP using single cutter enzymes. The RFLP pattern obtained differentiated the BSV species infecting the variety. It has been speculated there must be presence of a new BSV species in cv. Hill banana based on RCA-RFLP.

Development of RNAi construct targeting multiple viruses

Intron containing hairpin RNA construct targeting three banana viruses was prepared for developing multiple virus resistant transgenics. By adopting the protocol developed by IIHR, the RNAi construct was prepared The partial genes used were movement protein gene of BBTV and coat protein gene of CMV and BBrMV (Fig. 49).

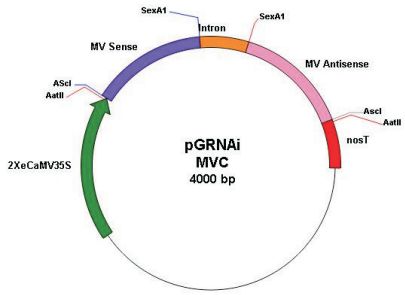


Fig. 49. RNAi construct for multiple viruses (BBTV / BBrMV / CMV)

Isolation and characterization of endophytes

Twenty endophytic bacteria were isolated from both BBTV infected and healthy plants of cvs. Grand Naine and Hill banana, and three were identified by sequence analysis of 16s rRNA gene. The bacteria identified had higher sequence similarity with an endophytic bacterium C01 and two sequences were matching with sequence of uncultured bacteria deposited in the NCBI Gen Bank. Two endophytic bacteria were isolated from *Pentalonia nigronervosa*, the vector of BBTV.

Studies on the effect of endophytic bacterial inoculation on morphological character of the tissue culture banana plants of cv. Grand Naine indicated that the microbe inoculated plants increased the plant growth parameters when compared to the control. Enumeration of microbial population against bio-primed and non-primed plants was studied. The results showed that bacterial load was higher in the bio-primed plants especially in the plants treated with *Bacillus subtilis* and *Pseudomonas fluorescens* compared to the non-

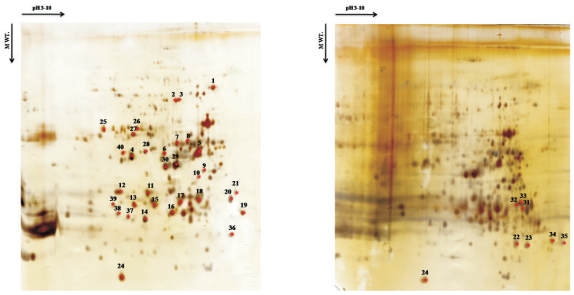
treated Grand Naine TC plants. Movement of endophytic bacteria inside the Grand Nain plants was confirmed with the strain *Pseudomonas fluorescens* by root feeding method at different time interval. The result revealed that the bacteria can penetrate from the root to the other part of the plant. To induce ISR in Grand Naine TC plants, the plants were bio-primed with three endophytic bacterial inoculants and those plants were tested for the resistance by transmitting BBTV with viruliferous aphids. BBTV symptom was expressed within 27.2 days in bio-primed TC plants compared to non treated plants (85 days).

Transmission of BBTV

Transmission efficiency of *Pentalonia nigronervosa f . typica* was studied under different temperatures for acquisition access period (AAP) and inoculation access period (IAP). The results indicated that percent transmission efficiency was higher (75%) at 28°C than 22, 24, 26 and 36°C. Transmission efficiency of banana aphids were compared under four RH viz., 35-40%; 40- 45%, 50-55% and 60-65%. The results indicated that the transmission efficiency was higher at 60-65% humidity. A single aphid could transmit the BBTV disease but with less percentage (15%) and disease incidence increased when the aphid per plant ratio increased to 5, 10 and 30 and the per cent transmission was 55, 65 and 80 respectively.

4.4.6 Proteomic analysis of host–BBTV interaction in banana

2-DE analysis of proteins isolated from healthy and BBTV infected hill banana tissue was carried out using pH 3-10, 18 cm IPG strips with silver staining. More than 600 protein spots detected by Melanie-7 software. Out of which, 220 spots were observed to occur in all gels. Differentially regulated proteins spots (40) were mass fingerprinted and 32 were annotated. Most of these proteins were involved in stress response, signal transduction, protein synthesis, metabolism, plant growth, cell division and structure, photosynthesis, energy and replication (Fig. 50 a&b).



a b

Numbers indicate spots showing significantly upregulated and downregulated proteins from healthy (a), BBTV infected hill banana (b). Astreix indicate the annotated protein spots.

Fig. 50a - b Differentially expressed hill banana leaf protein spots observed by conventional 2-DE analysis

In total, 15 upregulated and 17 downregulated protein spots were observed in the infected samples. The proteins observed with the highest induction levels were: Cinnamoyl-CoA reductase, Feruloyl CoA ortho-hydroxylase, pentatricopeptide repeat-containing protein, serine/threonine-protein phosphatase and Zinc finger CCCH domain-containing protein. Defense related and signal transduction proteins were among the highest induced proteins in BBTV infected hill banana leaves. Plant metabolism and growth related proteins were upregulated whereas protein synthesis, photosynthesis and cell division related proteins were downregulated, which can be corroborated with the symptom development due to BBTV infection. Proteomic analysis of root proteins of BBTV infected and healthy hill banana showed 600 reproducible spots out of which 60 spots indicated two- fold differential expressions (Table 29).

Phloem Proteomics

Among the four protein extraction methods evaluated for phloem protein isolation *viz.*, acetone/ ethanol, ice-cold acetone, TCA acetone method and EDTA methods, the acetone ethanol method yielded

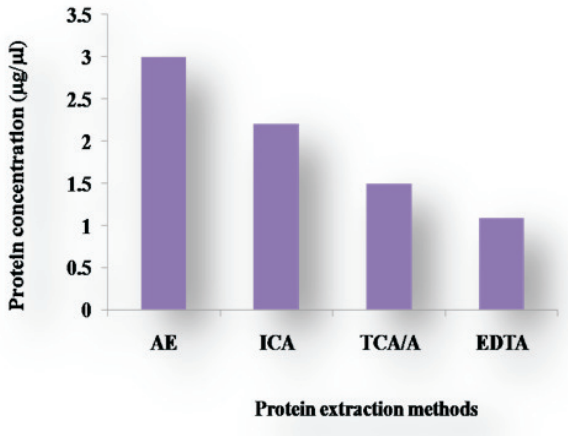
higher protein (2.2µg/µl) than the other three methods and produced 3.6 times and 4.9 times more protein spots than ice-cold acetone and TCA/acetone methods, respectively. EDTA protocol produced poor protein resolution and the other three methods detected more protein spots in the low molecular weight region and in lower pI/anionic region (Fig. 51 a -b).

Table 29. Differentially expressed proteins of healthy and BBTV infected leaf

Spot No.	Protein Information	T. pI /M Wt.	Score	PM	SC (%)
3	Plastid 30S ribosomal protein S2	9.48/27.0	40	7	18
6	Exopolygalacturonase	9.08/40.53	39	5	8
7	Peptide deformylase 1B	9.28/31.29	40	6	27
8	Ubiquinol oxidase 1	8.57/36.58	37	13	33
10	Protein BPS1	8.98/38.78	39	8	16
11	Vacuolar-processing enzyme	5.78/55.64	44	8	23
12	ATP-dependent DNA helicase 2 subunit KU70	5.15/70.70	48	10	16
13	Photosystem II 5 kDa protein	9.55/11.19	44	4	71
16	Calcium-dependent protein kinase isoform 11	5.50/61.62	39	7	11
17	Protein YABBY 7	8.09/18.53	38	6	36
18	Protein ycf2	8.91/24.56	41	15	8
19	Putative pentatricopeptide repeat-containing protein	6.27/95.72	35	7	6
20	GDSL esterase/lipase	6.71/39.51	39	6	16
21	Zinc finger CCCH domain-containing protein 13	8.50/9.84	40	4	25
22	Pentatricopeptide repeat-containing protein	9.38/55.56	43	9	30
23	Beta-D-xylosidase 1	8.79/84.44	39	9	16
24	V-type proton ATPase catalytic subunit A	5.19/69.03	38	6	16
25	Probable L-ascorbate peroxidase 6, chloroplastic	6.73/33.65	40	6	24
26	Probable calcium-binding protein CML14	4.83/18.67	38	6	29
27	Subtilisin-chymotrypsin inhibitor CI-1C	6.78/8.25	36	3	37
28	Full=Receptor-like protein kinase FERONIA	5.82/98.82	39	4	6
29	UDP-glycosyltransferase	5.74/52.03	35	5	6
30	UDP-glycosyltransferase	5.59/55.42	33	7	16
31	DNA-directed RNA polymerase subunit alpha	6.57/38.96	48	8	23
32	Cinnamoyl-CoA reductase 1	6.13/37.86	36	5	14
33	Feruloyl CoA ortho-hydroxylase 2	5.93/41.02	40	6	19
34	Serine/threonine-protein phosphatase 2A (65 kDa regulatory subunit A gamma isoform)	4.94/66.21	47	7	19

Spot No.	Protein Information	T. pI /M Wt.	Score	PM	SC (%)
35	Putative mannan endo-1,4-beta-mannosidase P	8.18/45.55	47	7	19
36	Aldehyde dehydrogenase family 3 member I1	8.74/60.64	45	11	16
37	Farnesyl pyrophosphate synthase 1	5.51/39.62	38	7	17
39	Oxygen-evolving enhancer protein 1	5.29/35.22	29	6	20
40	CASP-like protein	9.71/22.29	26	4	21

T. pI/M Wt. = theoretical pI and molecular weight, PM = number of peptides matched, SC = percentage of sequence coverage



AE=Acetone/Ethanol method, ICA=Ice-cold acetone method, TCA/A=TCA/Acetone method, EDTA method

Fig. 51a. Classification of protein concentration of four extraction method

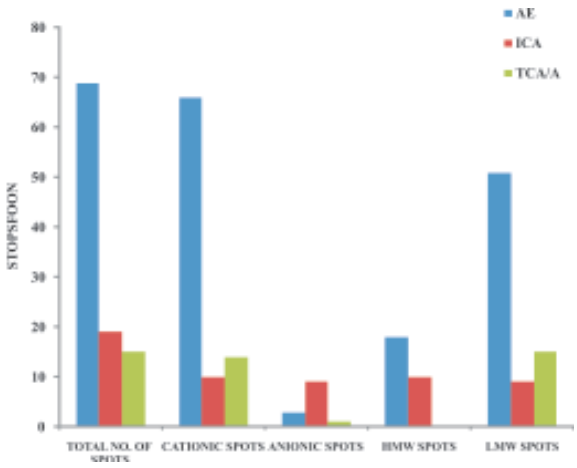


Fig. 51b. Classification of significant number of spots within different methods, different categories of anionic, cationic proteins and with different MW. AE=Acetone/Ethanol method, ICA=Ice-cold acetone method, TCA/A= TCA/Acetone method

4.5 EXTERNALLY FUNDED PROJECTS

4.5.1. DST Project: Identification of molecular strategies for the control of *Cosmopolites sordidus* Ger.)(Coleoptera: Curculionidae) a major pest of bananas. (2012-15) (PI- B.Padmanaban)

Banana corm weevil from banana growing areas of Tamil Nadu, Kerala, Maharashtra and Karnataka were collected. Part of these collected weevils was sent to National Chemical Laboratory, Pune for molecular characterization and the remaining weevils are being reared for screening at NRC for Banana.

4.5.2. DBT Project: Molecular strategies for the control of *Odoiporus longicollis* Olivier) (Coleoptera: Curculionidae) a major pest of bananas. (2013-16) PI-B.Padmanaban, Co-PI-R.Thangavelu

Banana stem weevil from Maharastra, Kerala and Tamil Nadu were collected. A part of these collected weevils was sent to NCL, Pune for molecular characterization and the remaining weevils are being reared for screening. Besides, 50 isolates of endophytic *Metarhizium anisopliae* and 3 isolates of *Beauveria bassiana* were isolated from *Musa* germplasm.

4.5.3. Coffee Board Project: Eco-friendly approaches for the management of coffee white stem borer, *Xylotrechus quadripes* Chev. (Coleoptera: Cerambycidae) (2012-14) (PI- B. Padmanaban)

Three endophytic fungi were isolated from coffee leaves and were identified as: *Penicillium oxalicum, Aspergillus niger and Colletotrichum gloesporoides,* three isolates of *Metarhizium anisopliae* and three isolates of *Beauveria bassiana* (CCRI, RCRS and NRCB). The isolates were evaluated against Coffee white stem borer under laboratory conditions. 60 % mortality was recorded in the NRCB isolate on the 3rd day of application, whereas the CCRI isolate recorded 40 % mortality on 4th day. The RCRS isolate recorded 60% mortality on 5th day.

4.5.4. Outreach Project on *Phytophthora, Fusarium a*nd *Ralstonia* diseases of Horticultural and Field Crops (PI-R. Thangavelu, Co.PI- S. Backiyarani)

i. Field evaluation of combined application of endophytic and rhizospheric fungal and bacterial antagonists for the management of Fusarium wilt disease under field condition

The combined application of fungal endophytic *Penicillium pinophilum* Bc2 + rhizospheric *T. koningii*, endophytic *Penicillium* spp. Dsr1 + rhizospheric *T. koningii*, and bacterial endophytic Tvpr1 + rhizospheric Jrb1 under field condition in cv. Grand Naine have significantly decreased the Fusarium wilt disease severity which recorded a disease score of 1.70, 1.68, and 1.76 respectively as compared to the untreated plants in cv. Grand Naine. Also, among different time of applications, treatments given at three times viz., at the time of planting + 2nd month after planting + 4th month after planting have recorded a lowest disease severity of 1.68 and the number of plants came for harvest was 94.4% whereas in the untreated control it was 52.63%.

ii. Field evaluation of combined application of endophytic and rhizospheric fungal antagonists with or without fungicide application for the management of Fusarium wilt disease under field condition

The combined application of rhizospheric and endophytic fungal antagonists along with or without fungicide application under field conditions significantly increased the bunch weight (up to 74.8%) and suppressed the Fusarium wilt disease compared to untreated plants. However, among different time of applications, the application of the effective

treatments for three times viz., at the time of planting + 2nd month after planting + 4th month after planting recorded the lowest score of Fusarium wilt disease which was ranged from 1.47 to 2.05 and were on par with each other.

iii. Evaluation of fungal antagonists along with botanicals for the suppression of Fusarium wilt disease under pot culture condition

The combined application of *Trichoderma harzianum* (Prr2) + *Hibiscus* leaf extract., *Trichoderma harzianum* (Prr2) + Zimmu leaf extract 50%, *Penicillium pinophilum* (Bc2) + *Alpinia* leaf extract. *Penicillium pinophilum* (Bc2) + *Hibiscus* leaf extract. *Penicillium pinophilum* (Bc2) + Zimmu, *Penicillium* (Dsr1) + Zimmu combination under pot culture condition in cv. Grand Naine resulted in complete control (100% reduction) of the disease. Besides, these combinations significantly increased the plant growth parameters such as height (33.60%), girth (80%), no. of leaves (42.11%), leaf area (128.15%) and no. of roots (143.04) when compared to *Foc* alone inoculated control plants.

iv. Bio priming of banana plants with the combined application of bacterial antagonists and botanicals for the suppression of Fusarium wilt disease

The biopriming of banana plants with the combined application of *Pseudomonas putida* + Alpinia leaf extract, *Pseudomonas putida* + *Hibiscus* leaf extract, *Pseudomonas putida* + Zimmu leaf extract, *Bacillus* sp.+ Zimmu combinations resulted in complete control (100% reduction) of the disease under pot culture condition. Besides, these combinations have significantly increased the plant growth parameters such as height (up to 38.3%), girth (up to 71.4%) no. of leaves (42.1%) leaf area (93.5%) and no. of roots (143.04) when compared to *Foc* alone inoculated control plants.

v. Efficacy of liquid formulation for the suppression of Fusarium wilt disease under pot culture condition

The pot culture testing of the efficacy of liquid formulation of *Trichoderma* sp. (which was stored for 13 months at 25 ± 2°C) at 5, 10 and 15% conc. in cv. Grand Naine indicated that the application of all the concentrations resulted in zero incidence of both external and internal symptoms of Fusarium wilt disease even after six months of planting.

vi. Colonization of banana tissues by the *T. harzianum* of endophytic and *T. longibrachiatum* of rhizospheric origin under pot culture condition

Colonization of root, corm and stem of banana tissues by the *T. harzianum* of endophytic origin and *T. longibrachiatum* of rhizospheric origin, which was observed for up to eight weeks, revealed that both the isolates endophytically colonized root and corm tissues and not stem tissues. This study has also

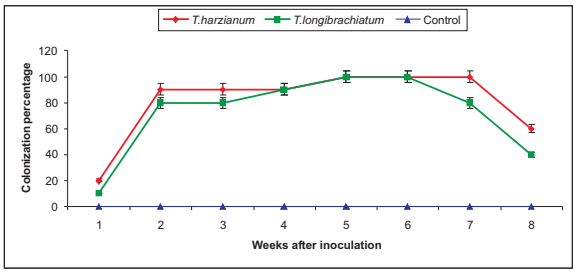


Fig. 52a. Colonization of *Trichoderma* sp. in banana

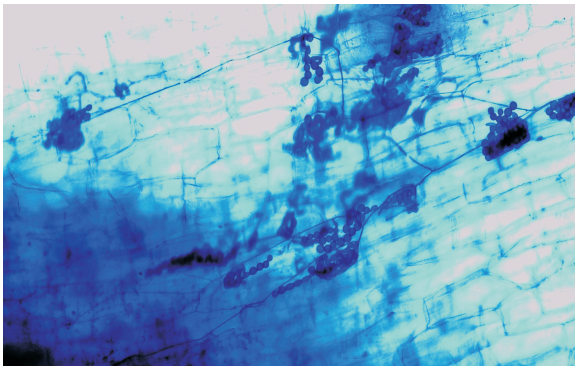


Fig. 52b. Colonization of rhizospheric *T. longibrachiatum* in root

revealed that, irrespective of origin of *Trichoderma* spp. both the isolates of *Trichoderma* colonized the root and corm tissues endophytically (Fig. 52 a&b).

vii. Quantification of *T. harzianum* of endophytic and *T. longibrachiatum* of rhizospheric origin in soil under pot culture condition

Quantification of *Trichoderma* spp. population of both endophytic and rhizhospheric origin in the rhizosphere soil indicated that both the *T. harzianum* isolated from plant tissues and *T. longibrachiatum* isolated from the soil were present in the rhizosphere soil and maintained the same population level (10^6 CFU/g of soil) till 7th week of sampling and started decreasing at 8th week of sampling.

4.5.5. Harnessing arbuscular mycorrhizae for biofertilization in horticultural crops (PI-R.Thangavelu)

i. Molecular identification of effective VAM isolates

Four different effective VAM isolates isolated from banana cultivars were identified as *Glomus etunicatum, Archaeospora leptoticha, G. trimurales* and *Pacispora scintinallans* by sequencing 18s rDNA analysis. Further, the genetic diversity analysis carried out for these isolates using the 18s rDNA sequencing indicated that *Glomus etunicatum, A. leptoticha, G. trimurales* were clustered together in group A and *P. scintinallans* in a separate group B (Fig. 53).

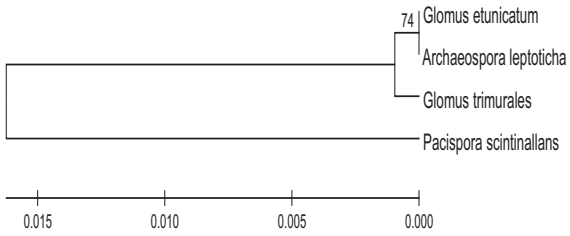


Fig. 53. Phylogenetic analysis of four different VAM isolates using 18s rDNA sequences using UPGMA method

ii. Molecular identification and characterization of Mycorrhizae helper bacterium (MHB) isolates

By sequencing the 6s-rDNA region, the nine different mycorrhizae helper bacterium (MHB) isolates isolated from different banana

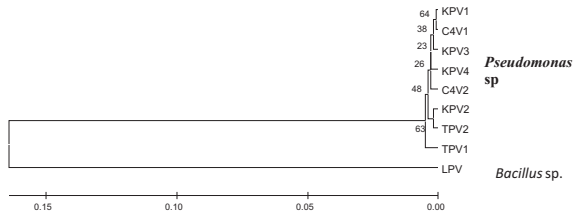


Fig. 54. Diversity analysis of helper bacterium

cultivars were identified as *Bacillus subtilis*, *Pseudomonas aeruginosa* and *Pseudomonas* spp. Further, the genetic diversity analysis carried out for these nine MHB isolates using these sequences indicated that all the *Pseudomonas* spp. were clustered together in one group A and *Bacillus subtilis* alone in separate group B (Fig. 54).

iii. Evaluation of VAM isolates along with MHB isolates for the suppression of the nematode *Meloidogyne incognita* infestation in banana under pot culture condition

The pot culture evaluation of four isolates of VAM viz., (*Glomus etunicatum, Archaeospora leptoticha, G. trimurales* and *Pacispora scintinallans*), nine MHB isolates (one strain of *Bacillus subtilis*, five strains of *Pseudomonas aeruginosa* and three strains of other *Pseudomonas* spp.) alone and also in combinations for the suppression of the nematode *Meloidogyne incognita* infestation was implemented. As there was no infestation in the control plants which were inoculated with *M. incognita,* the trial will be repeated once again.

4.5.6. DBT project : Evaluation of transgenic banana for resistance to Banana Bunchy top virus (Rep mediated) (PI-R. Selvarajan, Co.PI- C. Anuradha)

The putative transgenic lines were reconfirmed with southern blot analysis. Ten

southern positive lines obtained were maintained in the transgenic glass house. Thirty plants were obtained from shoot tip propagation from three lines. In order to generate more number of transgenic lines of Hill banana, Embryogenic Cell Suspension (ECS) was initiated. Totally 13,000 explants from 985 virus free hill banana male buds were used. So far 66 (2.4%) friable embryogenic calli were obtained from 8 months old initiated explants. Twenty lines of ECS have been established. Co-cultivation was done with three lines using hairpin construct of replicase gene of BBTV and transformed cells are kept in the selection media incorporated with Kanamycin.

4.5.7. Network Project on Transgenic in Crops – Transgenic Component (PI- R. Selvarajan)

Three southern positive plants were reconfirmed using BBTV CP gene labeled with DIG and maintained in the transgenic glass house. In order to obtain good quality ECS, callus induction from immature male flower has been initiated once again for cv. Hill banana. 50 explants were used for *in planta* transformation. Totally 230 plants were obtained and screened against BBTV CP gene. Two ECS lines were transformed with the cp gene construct.

4.5.8. DBT-ATL scheme for virus indexing (PI- R. Selvarajan)

Mother cultures of Tissue culture banana plants received from DBT recognized tissue culture production units were tested for four known banana viruses under DBT –ATL. During 2012-13, 2986 samples were tested for BBTV, BSMYV, CMV and BBrMV. Out of the 2986 samples, 69 were positive for BBTV and 27 were positive for CMV.

4.5.9. DBT-ATL scheme for Genetic fidelity testing (PI-S. Uma, Co.PI- M.S. Saraswathi)

Sixty six batches of tissue culture plants at various stages of production (varieties Grand Naine, Dwarf Cavendish and Ambamore) from 17 different tissue culture companies have been tested for their genetic fidelity using SSR and ISSR markers and test reports issued.

4.5.10. Functional genomics Component for sigatoka and drought (PI- S. Uma, Co-PI- R. Thangavelu, S. Backiyarani and M.S. Saraswathi)

Whole Transcriptome profiling of *Musa balbisiana*

Transcriptomic sequencing of *Musa balbisiana* was analysed using Ion torrent technology. About 4.5 millions Ion torrent paired-end reads were generated and assembled using the MIRA assembler. The assembly produced 82413 unique transcripts. Sequence similarity search against Swiss-prot database identified a total of 35783 unique transcripts (62.18%) with significant hits. Out of these, 193826 gene ontology terms were assigned to unique transcripts. Functional annotation against Plant CYC pathway database identified 20696 unique transcripts which were mapped to 455 pathways. There were 4780 SSRs were obtained from 82413 unigenes (Fig. 53). 2628 primers were designed for these SSR sequences. About 7818 SNPs were detected, out of which 343 were found to be heterozygous and 7475 homozygous (Table 30). Under the Molecular function ontology, proteins involved in ATP binding was dominant while in cellular component ontology, proteins for nucleus and Integral to membrane were generally encoded

Table 30. Ion torrent transcriptome sequencing details for *Musa balbisiana*

Sample	Total No. of Bases (Mbp)	No. of Reads	GC(%)	Q20 (%)
Banana	519.87	4598181	49.7	85.66

Table 31. Summary of Single Nucleotide Polymorphism (SNP) in the *Musa* transcriptome

SNP Details	Total	Heterozygous	Homozygous
SNPs	7818	343	7475
InDels (Insertions + Deletions)	2872	1179	1693
Deletions	1842	732	1110
Insertions	1030	447	583

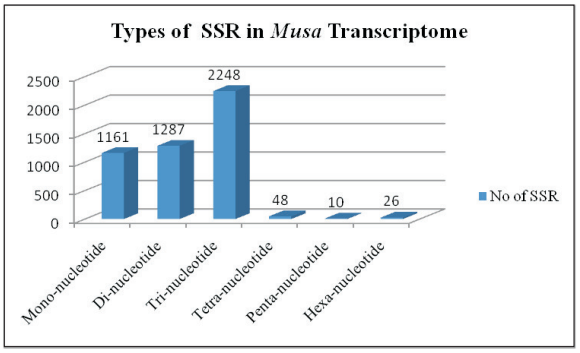


Fig. 55. Summary of simple sequence repeat (SSR) type in the *Musa* transcriptome

by the *Musa* transcripts. Biological process ontology distribution on the other hand, contains mainly proteins involved in Transcription DNA-Dependent and salt stress response (Fig. 55).Comparative genomics studies were carried out between *Musa* and other five crops (*Arabidopsis thaliana, Glycine max, Oriza sativa, Ricinus communis, Sorghum bicolor).*

Musa balbisiana transcriptome sequencing was performed in Ion torrent genome sequencing machine. 45,98,181 reads of transcriptome and total 519.87 base pairs of reads were generated. The GC percentage of reads was found to be 49.7 and quality of the base pairs (Q20) percentage is 85.66. The summary of the Ion torrent transcriptome sequencing details were shown in (Table 31).

Subtractive Hybridization Experiments

The unigene sequences (498 unigenes) obtained from SSH clones were subjected to BLAST2GO analysis and 206 Top BLAST hits were resulted and out of which, some of defense related genes like TIR-NBS-LRR resistance protein, cytochrome oxidase, lipoxygenase, ethylene response factor, serine-glyoxylate aminotransferase, flavin-containing monooxygenase, auxin response factor, ATP synthase subunit, catalase , metallothionein, retrotransposon ty1-copia etc. Gene ontology reported 337 ESTs did not have any GO terms. Other EST sequences were distributed among molecular function, cellular component and biological process with the hits of about 120, 78, 212 respectively. KEGG pathway analysis resulted in enzymes like catalase, cytochrome-c oxidase, flavin-containing monooxygenase, serine-glyoxylate transaminase, aminomethyl transferase.

Differential Display Reverse Transcriptase PCR (DDRT) experiment

About 84 differentially expressed amplicons were resulted in DDRT experiment of Sigatoka resistant and susceptible using 3 anchored and 7 arbitrary primers against cv. Manoranjtham (Sigatoka resistant) and cv. Grand Naine (susceptible).

Isolation of full- length gene using RACE

The pathogenesis related protein 1 was found to be one of the resistant gene for

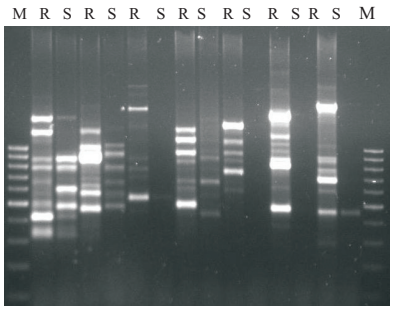


Fig. 56. Shows of differentially expressed amplicons between Resistant (R) and Susceptible (S). M – 100bp Marker

Sigatoka resistance. About 1 Kb of 3' end of PR1 was isolated using RLM RACE kit (Ambion) (Fig. 56).

Relative quantification of microRNA under soil moisture stress

Differential regulation of miRNAs (miR169,miR156 and miR2118) under normal and moisture stress were quantified using relative quantification method of real time PCR assay with miR399 and 25s rRNA. The results revealed that all three miRNAs were up regulated (Fig. 57) during soil moisture deficit stress. But the level of expression was low in control as against the stressed samples for all three miRNAs. The level of expression was maximum on 7th and 24th day for miR156,

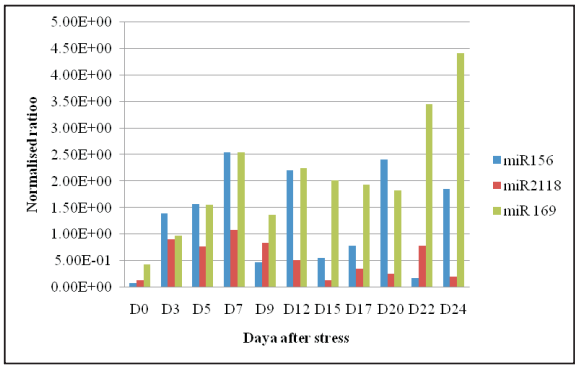


Fig. 57. MicroRNA quantities under soil moisture stress

miR2118 and miR169 respectively. The expression of miR169 was significantly up-regulated than miR156 and miR2118 as the drought progressed.

miRNA influence on moisture stress associated transcripts-Dehydrin and Aquaporin

Relative quantification of miR169, dehydrin and aquaporin simultaneously under stress revealed that all the three were up-regulated during drought soil moisture deficit stress. This might be due to the fact that expression of transcription factors like DREB under drought might have up-regulated by binding with DRE present in the promoter region of stress inducible target genes like Dehydrin and Aquaporin. The expression of miR169 in later stages of soil moisture deficit stress might have limited the expression of dehydrin and vice versa indicating that there might be inverse relationship (Fig. 58a&b) between miR169 and dehydrin. The response of miR169 on target genes or vice versa might depend on the intensity of the stress

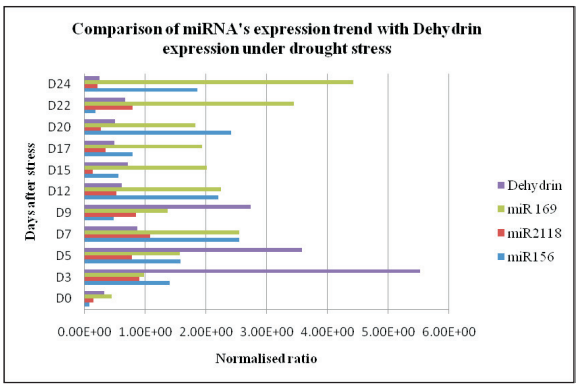


Fig. 58a. Comparison of miRNA expression with drought associated gene-Dehydrin

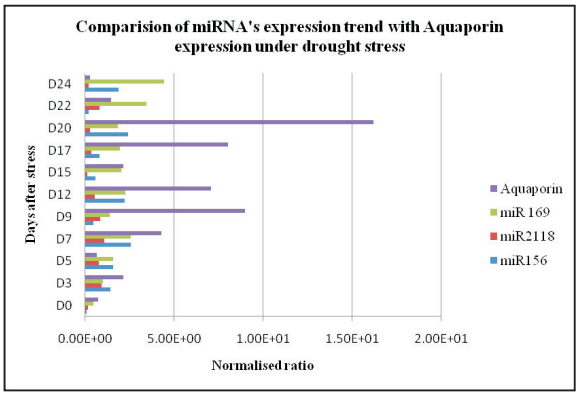


Fig. 58b. Comparison of miRNA expression with drought associated gene- Aquaporin

experienced. Over expression of dehydrin and aquaporin might have regulated the common transcription factor-DREB which in turn regulated the drought inducible genes, thereby creating a balance in their expression under stress.

Differential expression of proteins under normal and moisture stress conditions

Drought imposed leaf tissues of cv. Saba collected at different time intervals (0, 7th, 14th, 20th and 24th day after stress) were used

Table 32. Differentially expressed proteins during soil moisture deficit

S.No.	Spot No.	Proteins Identification by MALDI-TOF and PMF	Cellular location
1	2395	UDP-glucoronosyl/UDP-glucosyl transferase family protein	Cell membrane
2	3(9)	Hypothetical protein OsI_32444 (*Oryza sativa Indica* Group)	Nucleus
3	24(12)	tRNA-Ile lysidine synthase [*Oocystis solitaria*]	Chloroplast
4	20(1)	Ubiquitin-conjugating enzyme E2 8 OS=*Arabidopsis thaliana* GN=UBC8 PE=1 SV=1	Nucleus
5	2455	Nucleolin	Chloroplast
6	3(10)	Argininosuccinate synthase [*Zea mays*]	Cytoplasm
7	24(14)	Predicted protein [*Physcomitrella patens subsp. patens*]	Mitochondrion
8	7(3)	Iron-sulfer cluster scaffold protein ISA1, partial (*Eucalyptus grandis)*	Nucleus.
9	1992	60 for gi|77555275, Retrotransposon protein, putative, unclassified [*Oryza sativa Japonica* Group]	Cell membrane
10	1852	BTB/POZ domain-containing protein	Nucleus
11	24(8)	Transcription factor AS1 (*Arabidopsis thaliana*)	Chloroplast.
12	24(4)	Conserved hypothetical protein (*Ricinus communis*)	Chloroplast.
13	7(2)	Ribosomal protein S7 (*Keteleeria davidiana*)	Chloroplast
14	2430	AS-ZmSLR protein	Cytoplasm. Nucleus.
15	3(5)	Ethylene-responsive transcription factor WRI1-like [*Brachypodium distachyon*]	Nucleus
16	24(6)	Putative F-box/FBD/LRR-repeat protein At2g05300 OS=*Arabidopsis thaliana*	Cell membrane
17	24(15)	Hypothetical protein SELMODRAFT_162780 (*Selaginella moellendorffii*)	Nucleus.
18	2818	Telomere repeat-binding protein 2	Cell membrane
19	3(8)	Pseudouridine synthase-like protein	Nucleus.
20	24(7)	Calcium-dependent protein kinase isoform 11 OS= *Oryza sativa subsp. japonica*	Nucleus.
21	7(4)	Pre-mRNA-splicing factor 38B (*Arabidopsis thaliana*)	Cytoplasm.
22	3(6)	SAP7_ORYSJ, Zinc finger A20 and AN1 domain-containing stress-associated protein 7 OS=*Oryza sativa subsp. japonica* GN=SAP7 PE=2 SV=1	Cytoplasm. Nucleus.

S.No.	Spot No.	Proteins Identification by MALDI-TOF and PMF	Cellular location
23	24(1b)	gi|11863553, Stress-induced protein SAM22-like [*Glycine max*]	Endoplasmic reticulum.
24	24(1d)	68 for gi|224082502, SAUR family protein [*Populus trichocarpa*]	Mitochondrion
25	3(1)	Peptidyl-prolyl cis-trans isomerase CYP20-1-like	Chloroplast
26	3(7)	RCOM_0085470 mitochondrial uncoupling protein, putative [*Ricinus communis*]	Nucleus
27	24(2a)	gi|225454520, PREDICTED: UPF0667 protein C1orf55 homolog [*Vitis vinifera*]	Chloroplast
28	3(3)	LOC100836810 pentatricopeptide repeat-containing protein At5g48910-like [*Brachypodium distachyon*]	Nucleus
29	24(1c)	flavin-containing monooxygenase-like protein	cytoplasm
30	3(4)	EV267509.1 GLLBJ80TF JCVI-SOY1 *Glycine max* c DNA 5', mRNA sequence	

for comparative proteomics approach. 30 differentially expressed protein species were identified (Fig. 59 & Table 32) by two dimensional gel electrophoresis combined with

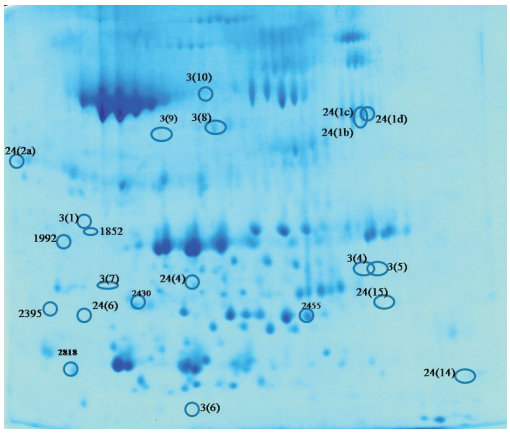


Fig. 59. 2D protein gel indicating the protein spots identified by MALDI-TOF-MS.

MALDI-TOF MS spectroscopy. The functional annotation of these proteins and comparative analysis with drought susceptible cultivars could provide important information about drought responsive /drought tolerant mechanism, which ultimately useful for improvement of banana crop against drought stress.

4.5.11. Protection of Plant Varieties (PPV) and Farmer's Right Authority (FRA) (PI- S. Uma, Co-PI- S. Backiyarani and M.S. Saraswathi)

Framing Crop Specific DUS Guidelines for Banana (*Musa* Spp.)

Morphological characterization during vegetative, pre- flowering, post-flowering and post harvest stages have been completed for main and ratoon crop of DUS accessions at both the Centers, NRCB, Tiruchirapalli and HRC, Nagicherra, Tripura.

Prepared of 20 min. documentary film on the 'Rejuvenation of Hill Banana Programme' to commemorate the Annual Day celebration and Plant Genome Saviour Award ceremony of PPV & FRA

4.5.12. DBT project: Improved Livelihoods through Conservation and Cultivation of Near Extinct Landraces of Banana of Kolli Hills (PI- S. Uma, Co-PI- M.S. Saraswathi and S. Backiyarani)

Kolli Hills in Tamilnadu is the home for fragrant banana landraces, namely

Manoranjitham. Under this project efforts are made to standardize the mass multiplication through tissue culture, large scale multiplication, distribution to the target groups and rejuvenation in their natural habitat.

Shoot tip culture of near extinct *Musa* cv.Manoranjitham

A total of 155 platlets were produced from 3 suckers with an average shoot production of 51.6 plantlets /sucker within 10 months. ~90 - 95% survival rate was observed in primary and secondary hardening.

Shoot tip culture method with apical and lateral meristem was initiated The plants were hardened by gradually increasing the light intensity and reducing relative humidity and after 45 days, the plants were ready for field planting having well developed leaves (3-5) and roots.

As an initial step, from three suckers obtained, nearly 130 plants were propagated and distributed to farmers on 19.1.2013. Along with the plant, 1kg vermicompost, 250g potash and 250g urea was also distributed.

4.5.13. DBT –QUT Project : Bio-fortification and Development of Disease resistance in Banana

The mother plants of cvs. Rasthali and Grand Naine were indexed for four major viruses like Banana bract mosaic virus, Bunchy top virus, Banana streak virus and Cucumber Mosaic Virus. 72 and 80 flower buds of virus indexed cvs. Rasthali and Grand Naine were collected and supplied to the partner institutes viz., National Agri-Food Biotechnology Institute (NABI) and Bhabha Atomic Research Centre (BARC). Similarly 30 buds of cv. Rasthali, free from all four viruses have been initiated at NRCB.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

- 250 Udhayam banana plants have been distributed to interested banana growers.
- Demonstrated bunch cover technology using polypropylene nonwoven bunch sleeves in the summer crop of banana cv. Grand Naine at Chinnamanur, Theni and in cvs. Ney Poovan and Rasthali in Thottiam, Tiruchirapalli.
- About 4550 persons belong to various groups *viz.,* Banana farmers/ entrepreneurs/ Horticultural/ Agricultural Officers /Colleges were given training on Improved Production Technology including Post Harvest Management and Value Addition in Banana.

Polypropylene nonwoven bunch sleeves in the summer crop of banana cv. Grand Naine

5.1 Radio Talks - (Through All India Radio, Tiruchirapalli)

Name of the Scientist	Topic	Date
B. Padmanaban	Integrated pest management in banana Question and answer in Tamil	07.09.2012
I. Ravi	Improvement of bunch quality in Tamil.	24.08.2012
K. J. Jeyabaskaran	Micronutrient managment in banana - Question and answer in Tamil	02.11.2012
K. N. Shiva	Post harvest management in banana in Tamil	26.12.2012

5.2 Exhibitions conducted /participated

Sl. No.	Name of the Event	Organiser(s)/ Venue	Date
1.	National Conference on Adaption to Climate Change for Sustained Production of Banana.	AIPUB, ICAR, NHB, NRCB and Jain Irrigation System Ltd. at Jalgaon, Maharashtra	7th - 10th Apr., 2012
2.	Kissan Mela - 2012	NRCB at Tiruchirappalli, Tamil Nadu	27th Aug., 2012

Sl. No.	Name of the Event	Organiser(s)/ Venue	Date
3.	National Level Banana Seminar - 2012	Dept. of Horticulture & Plantation Crops, Govt. of Tami Nadu, National Horticulture Mission and NRCB at Theni, Tamil Nadu	3rd – 4th Nov., 2012
4.	Western Ghats Banana Fest -2012	*Kadamba* marketing Ltd. and State Horticultural Department at Sirsi, North Karnataka	17th - 18th Nov., 2012
5.	Tuber Fest -2012	Central Tuber Crops Research Institute at Sreekariyam, Kerala	29th - 31st Nov., 2012
6.	Tamil Nadu Banana Festival - 2012	CII & TN State Horticulture Department at Chennai Trade Centre, Chennai	21st – 22nd Dec., 2012
7.	Agri Expo - 2013 Tamil Nadu	*Dinamalar* Daily & TNAU at Karur,	4th – 7th Jan., 2013
8.	XI Agricultural Science Congress	NASS at OUAT at Bhubaneswar	7th – 9th Feb., 2013
9.	Agri Expo - 2013	*Puthiyathalaimurai*-Media/ G' Corner at Tiruchirapalli	15th – 17th Feb., 2013

Shri S. Damodaran, Minister for Agriculture Govt. of TN, Shri. O. Panneerselvam, Minister for Finance, Govt. of TN, Shri K. S. Palanisamy IAS, District Collector, Theni visit to NRCB stall at Theni

Dr. Santhosh Babu, Commissioner Horticulture, Govt. of Tamil Nadu visits the NRCB stall at Theni

5.4. Publicity

Totally 14 Press Meets/ 13 Press Notes on NRCB activities/ functions and eight different NRCB technological information (articles) were published through different National, International and local Media including Dailies, Tamil magazines/ Journal, AIR/ TV - Farm division, *etc.*

6. EDUCATION AND TRAINING

6.1 Education (Students guided)

Name	Degree	Project title	Guide
K. Maragatham	M. Sc. (Biochem.)	Isolation and identification of volatiles of banana leaf sheath cv. Karpuravalli against weevil management	B. Padmanaban
S. Ramalakshmi	M. Sc. (Micro.)	Isolation of cultivable bacteria from banana aphid and its characterisation	--Do--
A. Parveen Banu	M. Sc. (Micro.)	Biosynthesis and efficiency of fungus mediated nano particles against banana stem weevil	--Do--
D. Dharani	B. Tech. (Biotech.)	Analysis of BB genome using SSR Markers	S. Uma
P. Naveen Prabhu	B. Tech. (Biotech.)	Histological studies of embryo development in *Musa* hybrids	--Do--
R. Sathiya	M. Sc. (Biotech.)	Microsporogenesis in banana	--Do--
R. Sivasankari	M. Sc. (Biotech.)	Histological and anatomical studies of seed production	--Do--
K. Krishna Surender	Ph. D. (Plant Physiology)	Studies on the impact of water sress on growth and productivity of banana (*Musa* spp.) cultivars and hybrids	I. Ravi
M. Pazhaniyammal	M. Sc. (Micro.)	Influence of potassium solubilizing bacteria (*Bacillus* sp) on the plant growth and rhizosphere soil nutrient status of cv. Grand Naine (*Musa* spp AAA)	V. Kumar
N. Thivya	M. Sc. (Micro.)	Studies on effect of phosphate solubilizing fungi on soil nutrients and growth of tissue cultured banana cv. Grand Naine (AAA)	--Do--
X. Jeni	M. Sc. (Biochem.)	Studies on enzymatic and protein profile changes during finger drop in Rasthali banana	M. Mayil Vaganan
A.V. Anbumani	M. Sc. (Biotech.)	Computer prediction of miRNA from ESTs and their validation	S. Backiyarani

Name	Degree	Project title	Guide
I. Jeya Priya	M. Tech. (Biotech.)	Expression of *Musa* chitinase and their activity	--Do--
R. Geethanjali	B. Tech. (Biotech.)	Identification of BB genome specific markers	--Do--
V. Midhun	B. Tech. (Biotech.)	Gene annotation of SSR containing *Musa* ESTs	--Do--
S. Praveena	M. Sc. (Biotech.)	DNA profiling of unique landraces of banana (*Musa* spp.) using ISSR markers	M.S. Saraswathi
P. Rinu	M. Sc. (Biotech.)	SSR markers as a tool for molecular profiling of unique landraces of banana (*Musa* spp.)	--Do--
M. Selvasumathi	M. Sc. (Biotech.)	Development of low cost tissue culture protocols for mass multiplication of three commercial varieties of banana (*Musa* spp.)	--Do--
K. Anitha	M. Sc. (Biotech.)	Comparison of phloem protein extraction methods for proteomic studies in banana	C. Anuradha

6.2 List of Trainings offered

Sl. No.	Title	Date	No	Course Director/ Coordinator
1.	19th NRCB Foundation Day- Farmers Day at NRCB	27.08.2012	500	M. M. Mustaffa
2.	Value-added Products from Banana to the Farmers/ Entrepreneurs/Women)	10-15.09.2012	12	K. N. Shiva
3.	ICAR short course on 'Advances in Gene identification and molecular markers development'	01-12.10.2012	20	S. Uma
4.	DBT funded 'Awareness and training programme for the regeneration of near extinct landraces of banana in Kolli Hills, Tamil Nadu	19.02.2013	150	S. Uma
5.	Production of value added products from banana (under ATMA scheme)	23.02.2013	10	K.N. Shiva
6.	Isolation, identification and characterization of banana pathogens to AICRP Scientists	21-23.03.2013	7	R. Thangavelu

7. AWARDS AND RECOGNITIONS

7.1 Awards

Best Annual Report Award for 2011-2012

National Research Centre for Banana, Tiruchirapalli received the **"Best Annual Report Award"** for 2011-2012 among the small ICAR Institutes.

Name	Name of the award	Awarded by/ Organizer/ Date
M. M. Mustaffa	Fellow of Horticulture Society of India for 2011	Horticulture Society of India (HSI) during the 5th National Horticulture Congress held at PAU, Ludhiana, Punjab on 06.11.2012
B. Padmanaban	Dr. S. Sithanantham Award for 2008-09 for contribution towards the biological control	Association for Advancement of Pest Management in Horticultural Ecosystem (AAPMHE), during the IV of insect pests of Horticultural National Symposium on Plant crops. Protection held at IIHR, Hessaraghatta, Bengaluru on 25.04.2012
	Fellow of AIPUB Award for 2011-12 towards his contribution on Banana Research & Development.	AIPUB & NRCB and JILS Ltd. during the National conference on Adoption to climate change for sustained Production of Banana held at Jain Hills, Jalgoan, Maharastra on 07.04.2012
	Distinguished Alumnus Award for 2012 for his contribution towards the Research & Development	Bharathidasan University, Tiruchirapalli during the Annual alumni meet of Jamal Mohamed College, Tiruchirapalli on 26.08.2012
S. Uma	Shri Girdhari Lal Chadha Memorial Gold Medal for 2011	Horticulture Society of India during the 5th National Horticulture Congress held at PAU, Ludhiana, Punjab on 06.11.2012
	Fellow of Horticulture Society of India for 2011	Horticulture Society of India (HSI) during the 5th National Horticulture Congress held at PAU, Ludhiana, Punjab on 06.11.2012
	Fellow of Indian Society of Plant Genetic Resources" for 2010	ISPGR during the 5th National Horticulture Congress held at PAU, Ludhiana, Punjab on 27.10.2012
I. Ravi & M. Mayil Vaganan	Best Poster Award for the paper entitled Evaluation of banana genotypes for soil moisture deficit stress tolerance	AIPUB/ NRCB during the National Conference on Climate change for sustained production of banana, 7-10 April, 2012, Jain Hills, Jalgaon, Maharashtra
R.Thangavelu	Fellow of AIPUB award for the year 2011 for outstanding	AIPUB/NRCB during the National Conference on Adaption to Climate

Name	Name of the award	Awarded by/ Organizer/ Date
	contribution towards banana research in India	Change for Sustained production of Banana which was held at Jain Hills, Jalgaon, Maharastra, on 07.04.2012.
	Best poster presentation award for the poster entitled *In vivo* evaluation of botanicals for the management of *Eumusae* leaf spot disease of banana	AIPUB/ NRCB during the National Conference on Adaption to Climate Change for Sustained production of Banana which was held at Jain Hills, Jalgaon, Maharastra, on 07.04.2012.
V. Kumar	Fellow of AIPUB for the year 2011 for outstanding contribution towards banana research	AIPUB/NRCB during the National Conference on Adaption to Climate Change for Sustained production of Banana which was held at Jain Hills, Jalgaon, Maharastra, on 07.04.2012.
K. N. Shiva	Best Oral Presentation Award for the Research paper entitled '*Valam tharum vazhayin madhiputtapatta porutgal*' (Tamil)	21st National Seminar on Scientific Tamil, organized by CIAE-R/s, Coimbatore & All India Tamil Scientific Association, Thanjavur, Tamil Nadu at Santhalinga Adigalar Arts & Science College, Perur, Coimbatore, T. N. during 9-10.02.2013.
	Best Oral Presentation Award for the Research paper entitled '*Vazhai kalyivugalyin payangal – Oru kannottam*' (Tamil)	21st National Seminar on Scientific Tamil, organized by CIAE, Coimbatore & All India Tamil Scientific Association, Thanjavur, Tamil Nadu at Santhalinga Adigalar Arts & Science College, Perur, Coimbatore, T. N. during 9-10.02.2013.

Dr. S. Uma receiving the "Fellow of Horticulture Society of India Award" at PAU, Ludhiana

The "Fellow of AIPUB Award" to Dr. R. Thangavelu, NRCB

The "Fellow of AIPUB Award" to Dr. B. Padmanaban, NRCB

The "Fellow of AIPUB Award" to Dr. V. Kumar, NRCB

7.2 Recognitions

Name	Particulars
B. Padmanaban	Secretary, QRT of NRCB for the period 2007- 2012 by the Indian Council of Agricultural Research, New Delhi
	Member Secretary- RAC of NRCB for the period up to 2014 by the Indian Council of Agricultural Research, New Delhi
	As an external examiner evaluated the Ph.D. degree thesis and as a Chairman, conducted the Ph. D. *viva-voce* of student at the University of Kerala on 12.12.2013
S. Uma	Member, Scientific committee on International Conference on Banana organized by TBRI, Taiwan organized in collaboration with BIOVERSITY and BAPNET during 19-21st November 2012 at Lees Hotel, Kaohsiung, Taiwan
	Invitee Member to guide the discussions on 'Needs of the germpalsm collection managers – diversity and knowledge' during MusaNet Diversity Working Group on setting the priorities of using wild species and wild relatives of *Musa* on July 9th and July 10th 2012 at Center for International Forestry Research (CIFOR), Bogor, Indonesia
I. Ravi	Convener for two technical sessions *i.e.*, "Climate change impact on banana production" and "Genotypes resilient to climate change" in National conference on 'Adaption of climate change for sustained production of Banana, at Jain hills, Jalgaon, Maharashtra from 7th to 10th April 2012 organized by NRCB and AIPUB
	Co - Chairman for Ms. S. Sarumathi (Biochemistry), who has enrolled for Ph. D. at Bharathidasan University, Tiruchirapalli
V. Kumar	Member, Accreditation and Assessment Committee, National Horticulture Board, Govt. of India for rating of Horticulture Nurseries in Tamil Nadu during 28-31 January 2013
	Treasurer, 'Association for the Improvement in Production and Utilization of Banana (AIPUB)'
	Member, Board of Studies/ Ad-hoc Committee, Bharathidasan University, Tiruchirapalli for the preparation of Regulations and Syllabi for the Diploma/ Certificate Courses on (i) Banana Cultivation and (ii) Banana Processing and Value Addition
R. Selvarajan	Member, Board of studies in Plant Pathology, Faculty of Agriculture, Annamalai University
	Editor 'Indian Journal of Virology' (a Springer publication) for 2012-'13
	External member of doctoral committee for Ph.D. scholar Ms. C. Janani under Plant Biotechnology, Bharathidasan University, Tiruchirapalli

Name	Particulars
	External examiner to conduct *viva-voice* exam for a Ph. D. scholar, Mr. R. Karuppiah, on 21st May 2012 for his thesis entitled on "Molecular characterization and diagnosis of four major viruses infecting sugarcane in India" at SBI, Coimbatore
	Member, Selection Committte for the selection of research fellows for the UGC-BSR research fellowships in Dept. of Plant Science, Centre of Excellence in Life Sciences, Bharathidasan University, Tiruchirapalli on 9th May, 2012
	DBT nominee, Selection Committte for the selection of research fellows for the DBT funded project entitled "Molecular diversity of cyanobacteria and their potentials as biosurfactants and flocculants" on 25th Feb, 2013 at National Facility for Marine Cyanobacteria, Bharathidasan University, Tiruchirapalli
M. Mayil Vaganan	Evaluated the Ph. D. thesis entitled 'Modification of structural and functional properties of tuber starches by complexation with fatty acids, lipids and surfactants' of G. S. Radhika of the University of Kerala, Thiruvananthapuram
	A member of doctoral committee for the candidate Mr. M. Kumaravel, Ph. D. Scholar of NRC for Banana registered with Bharathidasan University, Trichy
K.N. Shiva	Life member, All India Scientific Tamil Association, Thanjavur, Tamil Nadu.
	Executive Council Member, Indian Society for Spices, IISR, Calicut for 2012-2014
	Editor, e-Newsletter of ITMU, NRC Banana, Tiruchirappalli, Tamil Nadu for 2012-2013
S. Backiyarani	Member, Doctoral Committee for three Ph. D. scholar of the Bharathidasan University, Tiruchirappalli.
	IJSC member for 2012-15
M. S. Saraswathi	Member, Doctoral Committee for two students registered with Bharathidasan University, Tiruchirappalli
C. Anuradha	External examiner for Ph.D. degree in Department of Environmental Biotechnology, Bharathidasan University, Tiruchirappalli
	Examiner, University of Horticultural Sciences, Bagalkot, Karnataka for evaluating M. Sc. thesis
	External examinar for question papers setting for M. Sc. Eco-Biotechnology course by Department of Environmental Biotechnology, Bharathidasan University, Tiruchirappalli

8. LNKAGES AND COLLABORATIONS IN INDIA AND ABROAD

- NRCB is collaborating with BIRAC of Department of Biotechnology, GOI and Queensland University of Technology, Australia on a project on 'Biofortification and evaluation of Indian bananas with iron constructs' with M. Mayil Vaganan as PI of the project with budget of 59.19 lakhs.
- National Chemical Laboratory, Pune for genetic diversity studies of banana weevils under DST and DBT projects.
- Coffee Board, Govt.of India, Bengaluru for developing eco-friendly management for Coffee white stem borer.
- Collaboration with three Centers *viz.*, RAU, Pusa; HRS, Kovvur; BRS, Jalgoan and Gandevi for evaluation of fibre of banana varieties of regional importance under All India Coordinated Research Project on Tropical Fruits, IIHR (ICAR).
- Collaboration with Central Institute of Agricultural Engineering–Regional Station, Coimbatore in the development of Banana Central Core Stem slicer and juice extractor.

9. PUBLICATIONS

9.1 Research Papers

9.1.1 International

Backiyarani, S., Singh, J., Elanchezhian, R. and Abbott, A. G. 2012. The first genetic map and positions of major fruit trait loci of bitter melon (*Momordica charantia*). *J. Pl. Sci. Mol. Breeding* 1:1-6.

Backiyarani, S., Uma, S., Varatharaj, P. and Saraswathi, M.S. 2012. Mining of EST-SSR markers of *Musa* and their transferability studies among the members of order the Zingiberales. *App. Biochem. and Biotech*. DOI 10.1007/s12010-012-9975-2.

Elayabalan, S., Kalaiponmani, K., M. Pillay, Chandrasekar, A., Selvarajan, R., Kumar, K. K. and Balasubramanian, P. 2013. Efficient regeneration of the endangered banana cultivar 'Virupakshi' (AAB) via embryogenic cell suspension from immature male flowers. *African J. Biotech.* 12:563-569.

Elayabalan, S., Kalaiponmani, K., Subramaniam, S., Selvarajan, R., Panchanathan, R., Muthuvelayutham, R., Kumar, K.K. and Balasubramanian, P. 2013. Development of agrobacterium-mediated transformation of highly valued hill banana cultivar Virupakshi (AAB) for resistance to BBTV disease. *World J. Microbiol. Biotech*. 29:589-96.

Krishna Surendar, K., Durga Devi, D., Ravi, I., Jeyakumar, P. and Velayudham, K. 2013. Effect of water deficit on relationship between yield and physiological attributes of banana cultivars and hybrids. *Inter. J. Hort.* 3:61-69.

Krishna Surendar, K., Durga Devi, D., Ravi, I., Jeyakumar, P., Ramesh Kumar, S. and Velayudham, K. 2013 Studies on the impact of water deficit on plant height, relative water content, total chlorophyll, osmotic potential and yield of banana (*Musa* spp.,) cultivars and hybrids. *Inter. J. Hort.* 3:52-60.

Ravi, I., Uma, S., Mayil Vaganan, M. and Mustaffa, M. M. 2012. Phenotyping bananas for drought resistance. *Front. Physiol*. 4:1-15. DOI: 10.3389/fphys. 2013.00009.

Sangeetha, G., Thangavelu, R., Usha Rani, S. and Muthukumar, A. 2013. Antimicrobial activity of medicinal plants and induction of defense related compounds in banana fruits cv. Robusta against crown rot pathogens. *Biol. Control* 64:16–25.

Thangavelu, R., Ganga Devi, P., Gopi, M. and Mustaffa, M.M. 2013. Management of Eumusae leaf spot disease of banana caused by *Mycosphaerella eumusae* with Zimmu leaf extract, *Crop Protect.* 46:100-105.

9.1.2 National

Anuradha, C., Gupta, G. P. Sasikumar, K. and Ananda Kumar, P. 2012. Antagonistic effect of *Bacillus thuringiensis* toxins Cry1Ac and Cry1Jb on the cotton boll worm, *Helicoverpa armigera. Ind. J. Ag. Sci.* 82: 900–2.

Ravi, I. and Mustaffa, M. M. 2013 Starch and amylose variability in banana cultivars. *Ind. J. Pl. Physiol.* DOI 10.1007/s40502-013-0014-2.

Selvarajan, R., Balasubramanian, V., Jeyabaskaran, K.J., Pandey, S.D. and Mustaffa, M.M. 2012. Mitigating the effect of banana bract mosaic disease through application of increased doses of fertilizer in banana cultivar Robusta (AAA). *J. Pl. Dis. Sci.* 7:158-161.

Selvarajan, R. and Balasubramanian. V. 2013. Natural Occurrence of Banana bunchy top virus in *Ensete superbum*; *Ind. J. Virol*. DOI1007/s13337-012-0123-y.

Uma, S., Lakshmi, S., Saraswathi, M. S., Akbar, A. and Mustaffa. M. M. 2012. Plant regeneration through somatic embryogenesis from immature and mature zygotic embryos of *Musa acuminata* ssp. *Burmannica. In Vitro Cell. Dev. Biol*. 48:539–545, DOI 10.1007/s11627-012-9462-z.

9.2 Books/ Chapters in books

Anuradha, C. and Ananda Kumar, P. 2012. Protein engineering of delta-endotoxin by domain shuffling. ISBN (978-3-659-17113-0). LAMBERT academic publishing, Germany. P. 370.

Anuradha, C. and Mahal, G. S. 2013. Introgression of Genes from Wild Progenitors in Durum. ISBN (978-3-659-30839-0). LAMBERT academic publishing, Germany. P. 99.

Krishna Surender, K., Durga Devi, D. and Ravi, I. 2013. Effect of water stress on banana cultivars and hybrids. LAP LAMBERT Academic Publications, Germany. Pp.109.

Ravi, I. and Mustaffa, M. M. 2013. Impact, adaptation and mitigation strategies for climate resilient banana production. In: *Climate-Resilient Horticulture: Adaptation and Mitigation Strategies.* (Eds.) Singh, H. C. P., Rao, N. K. S. and Shivashankar, K. S. Publisher: Springer Verlag. Pp. 302.

Selvarajan, R. and V. Balasubramanian. 2012. Diseases of Banana. In: *Diseases of fruit crops* (Eds. A.K. Misra, P. Chowdappa, Pratibha Sharma and R.K. Khetarpal), pp. 225-275. *Indian Phytopathological Society*. (ISBN: 81-7019-474-1).

Selvarajan, R., V. Balasubramanian and Mary Sheeba, M. 2012. Banana bunchy top virus: Symptomatology, Molecular characterization, Genetic Diversity, Diagnosis and Management Strategies, In*: Recent Trends in Plant Virology.* Eds. Govind P. Rao, VK Baranwal, Bikash Mandal and Narayan Rishi. Studium Press LLC, Texas, U.S.A. pp. 367-387.(ISBN:1-933699-72-8).

Sheela, M. S. and Sundararaju, P. 2012. Nematode infection in banana In: *Nematode Infestations, Part III: Horticultural Crops* (Eds.M.R.Khan and Shamim Jairajpuri,M.) Published by The National Academy of Sciences, India. Pp. 42-44.

Sundararaju, P. 2012. Nematode infestation in palms In: *Nematode Infestations, Part III: Horticultural Crops* (Eds. M. R. Khan and Shamim Jairajpuri, M.) Published by The

National Academy of Sciences, India. Pp. 484-506.

9.3 Popular Article

Anuradha, C. and Parameswari, B. 2012. Computational identification of micro RNA in plants. *Research News for U (RNFU)* ISSN: Vol. 9, 97-101.

Anuradha, C. 2012. Conservation Strategies for *MUSA. Research News for U (RNFU)* ISSN: Vol. 7: 70-74.

Jeyabaskaran, K. J. and Mustaffa, M. M. 2012. Vermicompost from banana residues (*Vaazhai kazhivilirunthu manpuzhu compost* – Tamil) in *Vivasaya Kalam* section of *Dinakaran*, 18.09.2012, Pp. 16.

Jeyabaskaran, K. J. and Kumar, V. 2012. Fertiliser tailoring for Grand Naine banana under different edapho-climatic conditions. In: *Souvenir and Abstracts of National Conference on Adaption to Climate change for Sustained Production of Banana*, Jalgaon, Maharashtra, 7-10 April, 2012, 112.

Jeyabaskaran, K. J. and V. Kumar. 2012. Nutritional deficiencies in banana induced by climate change. In: *Souvenir and Abstracts of National Conference on Adaption to Climate change for Sustained Production of Banana,* Jalgaon, Maharashtra, 7-10 April, 2012, pp. 40-45.

Jeyabaskaran, K. J. and Kumar, V. 2012. Resilience of micronutrient management with sulphur for Ney Poovan banana under tropical conditions of Tiruchirapalli. In: *Souvenir and Abstracts of National Conference on Adaption to Climate change for Sustained Production of Banana* held at Jalgaon, Maharashtra, 7-10 April, 2012, Pp. 111.

Kumar, V. 2012. High Density Planting in Banana- New techniques (Tamil) in '*Valarum Vivasaya Tamilagam*, April 12. Pp. 36-38.

Kumar, V. 2013. *Vaazhai Saagupadiyil Asathalam* (Tamil) in *Dinamalar*- Tamil Daily, March, 2012. Pp. 19.

Kumar, V. and Mustaffa, M. M. 2012. Banana Bunch Sleeves: A handy tool to thwart the challenges of biotic and abiotic stresses to ensure blemish less fruits in bananas and plantain. In: *The Souvenir of National Conference on Climate Change*, Jalgaon, 7-10 April, 2012. Pp. 46-50.

Kumar, V. and Mustaffa, M. M. 2012. Overall Status of Banana Industry in India In: *Technical Bulletin of the State Level Workshop on Precision farming Technologies for Banana,* MPKV, Rahuri, Maharashtra, 23 November, 2012. Pp. 72-84.

Kumar, V., Soundararajan, R. and Jeyabaskaran, K. J. 2012. Use of plant growth regulators for mitigating the high temperature in banana cv. Robusta. In: *Souvenir and Abstracts of National Conference on Adaption to Climate change for Sustained Production of Banana,* Jalgaon, Maharashtra, 7-10 April, 2012, Pp. 113.

Kumar, V. 2012. *Vaazhaiyil Adarnadavu Sagupadi* (Tamil). In: *Velaan Vaniga Uzhagam,* Nov., 6 pp. 34-39.

Kumar, V. 2013. *Vaazhai Vaithal Vaazhalam* (Tamil) In: *Puthiya Thalaimurai*, March 12. Pp. 34-39.

Kumar, V. 2013. *Vaazhaiyil Adarnadavu Sagupadi* (Tamil). In: *Naam Uzhavar*, January, 2013, Pp.16-18.

Mustaffa, M. M. and Ravi, I. 2012. Climate change a boon for banana growers: An overview. In: *Souvenir of National Conference on Climate change for sustained production of banana*, 7-10 April, 2012, Jalgaon, Maharashtra. Pp. 20-28.

Mustaffa, M. M. and Shiva K. N. 2012. Banana and Processed Products as Food, Nutrient and Livelihood. In: *Shodh Chintan* (Souvenir): *4th Swadesh Prem Jagriti Sangosthi - Global Conference on Horticulture for food, nutrition and livelihood options,*

OUAT, Bhubaneswar, Odisha, 28-31 May, 2012, Pp. 78-82.

Mustaffa, M. M. and Shiva, K. N. 2012. Indian Banana Industry: Challenges and Way Forward. In: *Agriculture Today – Year Book* 2012, pp. 54-57.

Padmanaban, B. 2012. *Kizhangu koon vandu thakkuthal –Orunginaintha Kattuppadttu muraikalal ippirachanaikku theervu* (Tamil), *Valarum Vivasaya Thamizhakam*, June, 2012, pp. 40-41.

Padmanaban, B. 2012. *Vazhayil kizhangu koon vandu thakkuthal- orunginaintha kattuppadu muraikal* (Tamil), *Velan vanika Ulagam*, June, pp. 2012. 64-66.

Padmanaban, B. 2012. *Vazhayil thandu thulaippan: Thakkuthalum athanaikkattu-paduthum muraikalum* (Tamil). *Valarum Vivasaya Thamizhakam*, July, 2012. pp. 42-43.

Padmanaban, B. 2012. *Koon vandai kattupaduthum murai* (Tamil), *Daily Thanthi,* 7th May, 2012. pp. 5.

Padmanaban, B. 2012. *Vazhai koon vandukku inakavartchi pori* (Tamil), *Pasumai Vikatan* dated 25th May, 2012.pp. 46.

Padmanaban, B. 2012. *Vazhaikizhangu koon vandu–Orunginaintha kattuppadu muraikal* (Tamil), *Indraya Velanmai*, May, 2012. pp. 36-38.

Padmanaban, B. 2012. *Vazhzyil thandu thulaippan thakkuthalum athaikattu paduthum muraikalum* (Tamil), *Dhinamalar-Vivasayamalar,* 4th July, 2012. pp. 6.

Ravi, I. and Mayil Vaganan, M. 2012. Climate change and technological adaptations for banana production. In: *Souvenir of National Conference on Adaption to Climate change for Sustained Production of Banana*. 7-10 April, 2012. Jalgoan, Maharashtra, pp. 35-39.

Selvarajan, R., C. Anuradha, I. Ravi, V. Kumar and Jeyabaskaran, K.J. 2012. Influence of climatic factors on the expression of viral diseases of banana and plantain. In: *Souvenir and Abstracts of National Conference on Adaption to Climate change for Sustained Production of Banana* Jalgaon, Maharashtra 7-10 April, 2012. pp 123.

Shiva, K. N. and Mustaffa, M. M. 2012. *Suvaiyana porul thayarikkalam vazhayil* (Tasty products can be prepared from banana) (Tamil). *Vivasaya Malar of Dinamalar* 1st August, 2012. pp. 7.

Shiva, K. N., Mustaffa, M. M. and Kamaraju, K. 2013. *Valam tharum vazhayin madhiputtapatta porutgal* (Tamil). In: *Food Technology 21st National Seminar on Scientific Tamil,* Tamil University, Thanjavur, Tamil Nadu at Santhalinga Adigalar Arts & Science College, Perur, Coimbatore, T.N. 9-10 February, 2013. pp. 43-45.

Sundararaju, P. 2012. Nematode attacks on banana and their management (Tamil). *Dinakaran* 3rd July, 2012. pp. 4.

Sundararaju, P. 2012. Emerging nematode problems in banana due to climate change. In : *Souvenir of National Conference on Adaption to Climate Change for sustained Production of banana*, Jalgaon, Maharashtra, 7-10, April, pp. 67-71.

Sundararaju, P. and Mustaffa, M. M. 2012. Nematode management in banana (Tamil), *Daily Thanthi,* 11th October, 2012. pp.

Sundararaju, P. and Mustaffa, M. M. 2012. Nematode attacks in banana and their integrated management practices. *Velan Vanika Uzhagam,* 6: pp. 44-46.

Thangavelu, R. and Ganga Devi, P. 2012. Influence of climate change on Sigatoka leaf spot disease of banana and its Management. In*: Souvenir on National conference on Adaptation to Climatic Change for Sustained production of Banana,* Jalgaon, Maharashtra 7-10th April, 2012. pp. 76-79.

9.4. Technical bulletins

Uma, S., Saraswathi, M.S. and Durai, P. 2012. *'Khela Vruddhi – Vazhai Kanru Utpathiyil*

Oru Pudhiya Thozhil Nutpam' 2012. Tech. Doc. No. 19. (in Tamil) National Research Centre for Banana, Tiruchirapalli, Tamil Nadu. P. 16.

Uma, S., Saraswathi, M.S., Durai, P. and Mustaffa, M.M. *Vazham Tharum Vazhai Ragangal*. 2012. Tech. doc. No. 20. (in Tamil). National Research Centre for Banana, Tiruchirapalli, Tamil Nadu. P. 20.

9.5 Extension folders/ Reports/ Scientific/Teaching reviews

Mustaffa, M. M and Kumar, V. 2012. Banana production and productivity enhancement through spatial, water and nutrient management" *Journal of Horticultural Sciences*, June 2012 7(1):1-28.

Padmanaban, B. 2012. Background information paper for the Quinquennial Review Team (1.4.2007 to 31.3.2012) of National Research Centre for Banana, Tiruchirapalli. pp. 23.

Padmanaban, B. Third Quinquennial Review Report for the period 1.4.2007 to 31.3.2012, National Research Centre for Banana, Tiruchirapalli. pp 57.

Shiva, K. N., Mustaffa, M. M. and Kamaraju, K. 2013. *Vazhai kalyivugalyin payanpadugal* (Tamil), National Research Centre for Banana, Trichy, Tamil Nadu. pp. 4.

Uma, S., Saraswathi, M. S., Backiyarani, S., Durai, P. and Mustaffa, M.M., 2013. *Karuvazhai – Sagupadi Kurippugal* (Tamil), Extension Folder No. 22, NRCB, Trichy pp. 12.

9.6 Training Manual Chapter

Mayil Vaganan, M. and Mustaffa, M. M. 2012. Metabolomic analysis in crops as functional genomics and for biomarker metabolite identification. In: *Theory and Practices on Advances in Gene Identification and Marker Development*. Crop Improvement Division, National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, pp. 134-140.

Padmanaban, B and Mustaffa, M. M. 2013 Chemical Ecology of Banana weevil borers, Tamil Nadu Agricultural University, Coimbatore. Manuscript submitted on 'Infochemicals for eco-friendly Insect Pest Management' Tamil Nadu Agricultural University, Coimbatore from February 6-26, 2013. pp. 60-22.

Saraswathi, M. S., Uma, S., Backiyarani, S. and Udhayanjali, K. 2012. Molecular Markers and their applications. In: *Theory and Practice on Advances in Gene identification and Marker development.* Crop Improvement Division, National Research Centre for Banana, Tiruchirapalli. pp 1-110.

Saraswathi, M. S., Uma, S., Backiyarani, S. and Valarmathi. G. 2012. Fluorescence In Situ Hybridization (FISH). *Ibit* pp. 111-115.

Backiyarani, S., Uma, S., Saraswathi, M. S. and Tharani, G. 2012. Molecular Cloning in Crop Improvement. In: *Theory and Practice on Advances in Gene identification and Marker development.* Crop Improvement, National Research Centre for Banana, Tiruchirapalli. pp. 35-52.

Chandrasekar, A., Backiyarani, S., Uma, S. and Saraswathi, M.S. 2012. Genomics and Bioinformatics Resources for Crop Improvement. *Ibit* pp. 53-77.

Shiva, K. N., Mustaffa, M. M. and Kamaraju, K. 2012. Training Manual on *Value-added Products from Banana,* 10–15 Sept., National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, P. 104.

Shiva, K. N. and Mustaffa, M. M. (Eds.) 2012. *e-Newsletter of ITMU,* 1: (1). National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, P. 4.

Shiva, K. N. and Mustaffa, M. M. (Eds.) 2012. *e-Newsletter of ITMU*, 1: (2). National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, P. 4.

Shiva, K. N., Mustaffa, M. M. and Ravichamy, P. (Eds). 2012. *Souvenir & Abstracts for the National Conference on Adaption of Climate*

Change on Sustained Production of Banana, 7-10 April, Jalgaon, Maharashtra, P. 176.

Uma, S., Backiyarani, S. and Saraswathi, M. S. (Eds). 2012. *Advances in gene identification and marker development*. National Research Center for Banana, Tiruchirapalli, Tamil Nadu. Pp. 240.

Uma, S., Backiyarani, S., Saraswathi, M. S., Saravana kumar, A.S. and Muthuswamy, M. 2012. Gene Identification –Genomic and Transcriptomic Approaches. In: *Theory and Practice on Advances in Gene identification and Marker development*. Crop Improvement Division, National Research Centre for Banana, Tiruchirapalli Pp. 11-34.

9.7 Research papers/ Abstracts presentations in Conferences/ Symposia/ Seminars/ Workshops/ Other fora

9.7.1 International

Anuradha, C., Selvarajan, R., Mayil Vaganan, M., Sarumathi, S. and Mustaffa, M. M. 2013. Proteomic analysis of host-virus interactions towards understanding the pathogenesis of banana bunchy top virus. *International Conference on Advances in Biotechnology and Patenting,* 18-21, February. Bharathidasan University, Tiruchirapalli, Tamil Nadu, India. pp.26.

Backiyarani, S., Uma, S., Saraswathi, M. S. and Mustaffa, M.M. 2012. Potential of Musa EST-SSR markers on improving members of the order Zingiberals. In: *International Banana Symposium on Banana improvement, health management, use diversification and adaptation to climate change*, 19-22, November, Kaohsiung City, Taiwan, Republic of China. pp. 37.

Mayil Vaganan, M., Fiehn, O. and Mustaffa, M. M. 2013. Qualitative analysis of pectin metabolites during banana ripening by GC-MS: A metabolomics approach. In: *International Conference on Advances in Biotechnology and Patenting*, 18-21, February, 2013. Bharathidasan University, Tiruchirapalli, Tamil Nadu, India. pp. 56.

Mayil Vaganan, M., Kind, T., Fiehn, O. and Mustaffa, M. M. 2013. Mining metabolites: extracting the banana metabolome from the literatures. *Ibit* pp. 159.

Mayil Vaganan, M., Sarumathi, S., Anuradha, C., Nandakumar, A., Ravi, I. and Mustaffa, M. M. 2013. Evaluation of different protein extraction methods for banana (*Musa* spp.) root proteome analysis by two-dimensional electrophoresis. *Ibit* pp. 158.

Mayil Vaganan, M., Sarumathi, S., Ravi, I., Sundararaju, P. and Mustaffa, M. M. 2013. Proteomic analysis of banana roots and identification of differentially regulated proteins in response to *Pratylenchus coffeae* infection. *Ibit* pp. 11.

Muthusamy, M., Backiyarani, S., Saraswathi, M. S. and Uma, S. 2012. Computational prediction, identification and expression profiling of micro RNA against drought stress in banana. In: *International Banana Symposium on Banana improvement, health management, use diversification and adaptation to climate change,* 19-22, November. Kaohsiung city, Taiwan, Republic of China. pp. 17.

Padmanaban, B., Uma, S. and Mustaffa, M. M. 2012. Screening of *Musa* germplasm against banana thrips. 2012. *Ibit* pp. 36.

Saraswathi, M. S., Uma, S., Brindha, K., Udhayanjali, K., Suresh Babu., K. Punniyakotti, E., Durai, P. and Backiyarani, S. 2012. DNA fingerprinting of popular Indian banana varieties using SSR and ISSR markers. *Ibit* pp. 28.

Thangavelu, R., Ganga Devi, P. and Mustaffa, M.M. 2012. Identification and Development of Molecular markers specific to eumusae leaf spot disease. *Ibit* pp. 31.

Thangavelu, R. 2012. The status of Fusarium wilt research in India. *Ibit* pp. 8.

Uma, S., Backiyarani, S., Thangavelu, R., Saravanakumar, A.S., Saraswathi, M. S. and Sudhakar, B. 2012. Differential gene expression in response to *Mycosphaerella eumusae. Ibit* pp. 22.

Uma. S. 2012. Banana and Plantain breeding – A review on problems, prospects and new initiatives. 2012. *Ibit* pp. 32.

9.7.2 National

Akbar, A., Uma, S., Saraswathi, M.S., Backiyarani, S. and Durai, P. 2012. Ensuring the potential of somatic embryogenesis as a mass multiplication tool in banana through comparative field evaluation of ECS derived plants. In: *Fifth Indian Horticulture Congress on Horticulture for Food and Environment,* 6-9, November. Punjab Agricultural University, Ludhiana. pp. 259.

Arun, K., Uma, S., Saraswathi, M.S., Backiyarani, S. and Durai. P., 2012. New protocol for efficient multiple shoot induction and plant regeneration from immature hybrid embryos of banana. *Ibit* pp. 259.

Backiyarani, S., Uma, S., Saraswathi, M. S. and Sundararaju, P. 2012. Development of EST-SSR marker linked to root-lesion nematode, *Pratylenchus coffeae* resistance in banana. In: *National Conference on Adaption to Climate Change for sustained Production of banana,* 7-10, April, Jalgaon, Maharashtra. pp. 128.

Backiyarani, S., Uma, S., Tharani, G., Saraswathi, M. S. and Sundararaju, P. Isolation and characterization of full length nematode resistant genes from *P. coffeae* resistant *Musa* cultivar. In: *Fifth Indian Horticulture Congress on Horticulture for Food and Environment,* 6-9, November, Punjab Agricultural University, Ludhiana. pp. 27.

Durai, P., Saraswathi, M.S., Jeyabalan, N., Mustaffa, M. M. and Uma, S. 2012. Assessment of intersectional relationship between *Eumusa* and Rhodochlamys of the genus *Musa* through morphotaxonomy and microsatellite markers for use in banana improvement. *Ibit* Pp. 29.

Kumar, V., Mustaffa, M. M. and K. J. Jeyabaskaran. 2012. Effect of INM including foliar fertilization with soluble fertilizers on growth, yield and fruit quality of Robusta (AAA) and Ney Poovan (AB) bananas In: *Global Conference on Horticulture for Food, Nutrition and Livelyhood options*, 28-31 May. OUAT, Bhubaneswar, Odisha. pp. 42.

Kumar, V., Sundararajan, P. and Jeyabaskaran, K. J. 2012. Use of plant growth regulators for mitigating the high temperature in banana cv. Robusta. In: *National Conference on Climate Change,* 7-10 April, 2012. Jalgaon, Maharshtra. pp. 113.

Muthusamy, M., Backiyarani, S., Saraswathi, M. S. and Uma. S. 2012. Proteomic approach for the identification of drought responsive genes in banana, a non-model crop. In: *Fifth Indian Horticulture Congress on Horticulture for Food and Environment,* 6-9, November. Punjab Agricultural University, Ludhiana. pp. 28.

Muthusamy, M., Uma., S., Backiyarani S. and Saraswathi, M. S. 2012. Identification of differentially expressed glycoproteins in drought tolerant *Musa* species (*M. laterita*). In: *Souvenir and Abstracts of the National conference on adaption to Climate change for sustained production of banana,* 7 -10, April. Jalgaon Maharashtra. pp. 105.

Nandakumar, S. and Ravichamy, P. 2012. Influences of Media for Environment and Banana farmers protection. In: *12th Conference on Tamizhaga Ariviyal Perava*i. 23-25 August. Periyar University, Salem, Tamil Nadu. pp. 879.

Nandakumar, S. and Ravichamy, P. 2012. Influence of Globalization: Information

dissemination of Local Media for the Indian farmers. In: *National Conference on Globalization, Local Media & Social Issues*, 14-15 December. Manonmaniam Sundaranar University, Tirunelveli. pp. 27.

Padmanaban, B. Goswami, A. and Karthikeyan, C. 2012. Screening of Nanoparticles against insect pests of banana under laboratory conditions. *Global Conference on Horticulture for Food and Nutrition*, 28-31 May. Orissa University of Agriculture and Technology, Bhubaneswar. pp.

Padmanaban, B. and Palanichamy, S. 2013. Screening of fractions of host plant extract of cv. Nendran to study the enhancement of attractiveness of semiochemical to banana stem weevil, *Odoiporus longicollis* (Oliver). *International Conference on Insect Science*, 14-16 February. UAS, Bangalore. pp.

Padmanaban, B., Karthikeyan. C. and Uma, S. 2012. Screening of *Musa* germplasm against banana aphid, *Pentalonia nigronervosa*, In: *National Conference on Banana on climate change for Sustainable production*, 7-10 April, Jalgoan, Maharashtra. pp.

Padmanaban, B., Siva Priya, R., Thangavelu, R. 2012. Evaluation of endophytic *Metarhizium anizopilae* (Metschinihof) against banana Aphid, *Pentalonia nigronervosa. Ibit* pp. 127.

Padmanaban, B., Siva Priya, R. and Kohila, S. 2012. Evaluation of rhizospheric and endophytic fungi, *Metarhizium anisopliae* against Banana aphid, *Pentalonia nigronervosa*. *IV National Symposium on Plant Protection in Horticultural Crops: Emerging Challenges and sustainable management*, 25-28 April. Indian Institute of Horticultural Research, Bangalore. pp. 103.

Padmanaban, B., Karthikeyan, C. and S. Palanichamy. 2012. Screening of semiochemicals against banana corm weevil, *Cosmopolites sordidus. Ibit* pp. 40.

Padmanaban.B., Siva Priya, R., Thangavelu, R. and.Mustaffa, M .M. 2012. Evaluation of endophytic fungi, *Metarhizium anisopliae* against Banana aphid, *Pentalonia nigronervosa* (Coq.). In: *National Conference on Banana on climate change for Sustainable production*, 7-10 April, Jalgoan, Maharashtra.

Ravi, I., Krishna, S. S., Uma, S. and Mayil Vaganan, M. 2012. Evaluation of banana genotypes for soil moisture deficit stress tolerance. *Ibit*

Saraswathi, M. S., Thangavelu, R., Uma, S., Kannan, G., and Sumathi, S., 2012. Role of native VAM and its helper bacteria on the acclimatization of tissue cultured banana variety Grand Naine. In: *Fifth Indian Horticulture Congress on Horticulture for Food and Environment,* 6-9, November. Punjab Agricultural University, Ludhiana. pp.

Saraswathi, M.S., Uma, S., Kannan, G., Yogachandru, R., Saranya, M., Punniyakotti, E., Backiyarani, S. and Mustaffa, M. M. 2012. Climate change not an inhibition for the production of quality planting material of banana variety Udhayam (Pisang Awak – ABB). In: *Nat. Conf. on Adaption to Climate Change for Sustained Production of Banana,* 7-10 April. Jalgoan, Maharashtra. pp. 114.

Selvarajan, R. 2012. Loop mediated isothermal amplification (LAMP) for rapid and sensitive detection of BBTV. In. *National symposium on "Heading towards molecular horizon in plant pathology: Host resistance, pathogen dynamics, diagnostics and management"* organized at SBI, Coimbatore by the South Zone, IPS 16&17 November. pp 43.

Selvarajan, R., Anuradha, C., Ravi, I., Kumar, V., Jeyabaskaran, K. J. and Mustaffa, M. M. 2012. Influence of climatic factors on the expression of viral diseases of banana

and plantain. In: *Nat. Conf. on Adaption to Climate Change for Sustained Production of Banana,* 7-10 April. Jalgoan, Maharashtra. pp 123-124.

Sundararaju, P., Rajeshwari, J.P., Anitha Sree,T. and Paulin Reneeta, N. 2012. Efficacy of endophytic bacteria and their biocontrol potential against root-lesion nematode, *Pratylenchus coffeae* in banana. pp. 120.

Sundararaju, P., Sangeetha, S., Anitha Sree, T. and Paulin Reneeta, N. 2012. Isolation, identification and evaluation of endophytic fungi against root-lesion nematode, *Pratylenchus coffeae* in banana. *Ibit* pp. 119.

Sundararaju, P., Uma, S. and Anitha Sree, T. 2012. Screening of banana hybrids for dual resistance to *Pratylenchus coffeae* and *Meloidogyne incognita Ibit* pp. 130.

Suresh Pardeshi, R., Thangavelu, R. Shaik, N. B. and Chaure, J. 2012. Management of leaf spot disease with combined application of mineral oil and fungicide. *Ibit* pp. 124.

Thangavelu, R. and Sumathi, S. 2012. Interaction effect of *Glomus* spp. and its Mycorrhizae helper bacterium isolates for the suppression of Fusarium wilt disease in banana. *Ibit* pp. 129.

Thangavelu, R. and Ganga Devi. P. 2012. *In vivo* evaluation of botanicals for the management of Eumusae leaf spot disease of banana. *Ibit* pp. 122.

Thangavelu, R. and Ganga Devi, P. 2012. Genetic Diversity of *Mycosphaerella eumusae* pathogen causing leaf spot disease of Banana and its management by native microbes. *Ibit* pp. 122.

Thangavelu, R. and Gopi, M. 2012. Suppression of Fusarium wilt disease (*Foc*) by biocontrol agents having multiple functions in cv. Cavendish. *Ibit* pp. 121.

Thangavelu, R., Gopi, M. and Mustaffa, M. M.. 2012. Field evaluation of Antagonistic microbes for the suppression of Fusarium wilt disease in India In: *International Banana Symposium on Banana Improvement, Health Management, Use Diversification and Adaptation to Climate Change*,Taiwan,19-22 November. pp. 69.

Uma, S., Arun, K., Saraswathi, M.S., Backiyarani, S. and Durai, P. 2012. Seed priming studies for improved germination and regeneration of hybrid seeds in banana. In: *Nat. Conf. on Adaption to Climate Change for Sustained Production of Banana,* 7-10 April. Jalgoan, Maharashtra. pp. 114.

Uma, S., Backiyarani, S., Thangavelu, R., Selvarajan, R., Saravanakumar, A.S., Saraswathi, M.S. and Sudhakar, B. 2012. Transcriptional Response of banana Sigatoka leafspot disease revealed by cDNA SSH analysis In: *Fifth Indian Horticulture Congress on Horticulture for Food and Environment,* 6-9, November. Punjab Agricultural University, Ludhiana. pp. 32.

Uma, S., Sajith, K.P., Saraswathi, M.S., Backiyarani, S. and Durai P. 2012. Need for rejuvenation of near extinct fragrant banana land race in India and role of NRCB. In: *Nat. Conf. on Adaption to Climate Change for Sustained Production of Banana,* 7-10 April. Jalgoan, Maharashtra. Pp. 108.

10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

- A total of 15,317 mother culture samples of TC banana were tested for the presence of virus and approximately a gross amount of 28,37,382/- has been generated under contract service for virus indexing.
- Polyclonal antiserum produced for CMV, BBrMV and BBTV has been sold to tissue culture companies and also to the State Agricultural Universities *viz*., KAU, APHU and Department of Horticulture, Kerala and from this, an amount of 88,000/- has been realized from the sale of antisera.
- Conducted a Contract Research on Performance of 'Repol', a polypropylene based nonwoven fabric as bunch sleeves on bunch characteristics and fruit quality in certain commercial cultivars of banana funded by Reliance Industries Ltd., Chennai.
- Production technology of Banana flower *thokku* (pickle) was transferred to Mr. K. G. Balaji, Bogar Herbals (P) Ltd., Kulithalai, Karur, Tamil Nadu under Licensing of Technical Know-how on October 2012.
- Banana flour to Mr. A. Sadhik Ali, Manapparai, Tiruchirappalli, Tamil Nadu under Licensing of Technical Know-how on October, 2012.
- Postharvest handling, pre-treatments, packing and storage of Banana Central Core Stem to Mr. M. Moorthi, Krishnarayapuram, Karur Dt., Tamil Nadu under Licensing of Technical Know-how on 18th December 2012.
- Mother culture of cv. Ney Poovan has been sold to a commercial firm at M/s. Dhanam Agro Biotech, Kaveripattinam, Dharmapuri.
- Around 250 proliferating cultures of Udhayam have been supplied to a private tissue culture company for mass multiplication purpose.
- Five hundred shoot tips of Udhayam have been initiated, 1000 cultures are in various stages of multiplication, 200 plants in rooting, 600 in primary hardening and 250 plants have been distributed to the interested growers.

11. QRT / RAC / IMC/ IRC MEETINGS

QRT Visits

QRT members visit to NRCB Research farm

The QRT of NRC for Banana under the Chairmanship of Dr. S. D. Shikhamany, Former VC, APHU, Hyderabad along with Members of QRT *viz.*, Dr. S. Sambandamurthy, Former Dean, TNAU, Coimbatore; Dr. P. K. Ray, Head, Dept. of Horticulture, Rajendra Agricultural University, Pusa, Bihar; Dr. E. I. Jonathan, Director, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore and Dr. Sosamma Jacob, Professor & Head, Dept. of Entomology, College of Horticulture, Kerala Agricultural University, Thrissur and Dr. B. Padmanaban, Principal Scientist, NRCB reviewed the ongoing and other research programmes of the Centre on 18 & 19 June, 2012 (first time) and 16 & 17 July, 2012 (second time). Dr. M. M. Mustaffa, Director, NRCB along with all the scientists of the Centre participated in the deliberations and discussions during the team meeting. The final QRT report was submitted to ICAR on 16.10.2012 along with the recommendations.

QRT members visit to NRCB Research farm

Salient Recommendations of III QRT of NRCB for the period 2007 - '12

- Priority has to be given for building up a germplasm bank and identifying sources of resistance to biotic and abiotic stresses.
- In addition to the approved genomic classification, a horticultural classification of grouping all varieties with similar horticultural traits under each genomic group is needed.
- Research on resistance breeding, particularly tolerant to major viral and fungal diseases, insect pests, nematodes, salt, drought and flood should continue with added impetus. It should be made a long-term programme of the centre as visible benefit may not be available within 5 years.
- The three mutants of Rasthali variety identified for resistance to *Fusarium* wilt may be tested under field conditions, simultaneously in multilocations and in hot spot areas for their yield potential and other economic characters.
- The identification of heterozygous parents in diploid AA and BB groups may be used in developing linkage maps. The work on developing genetic linkage maps and identifying specific markers for high yield has to be intensified in future.
- Hybrid 2/5-05 which was found to be resistant to Sigatoka leaf spot may be multiplied and tested simultaneously in multilocations for yield and resistance.
- Long term manurial experiment with recommended high doses of fertilizers in intensive cropping system may be taken up and the effect of fertilizers in soil may be studied.
- Crop logging with reference to the optimal values of plant growth parameters at different stages of growth based on their correlations with bunch

weight are to be established and means to improve them to be evolved to maintain the required growth in the early vegetative phase that has potential for final growth and fruiting of the plant.

- More stress has to be given for biological control involving the identification and use of predators, parasitoids and pathogens for pest management in the field.
- As there is an increasing awareness and demand for pesticide residue free fruits, identification and evaluation of eco-friendly novel molecules/ approaches for pest management has to be emphasized.
- The use petroleum oil for control of Sigatoka leaf spot may be popularised. Residue studies may also be taken up to assess the presence of petroleum product in the fruit.
- Pre-harvest practices should be standardized including handling and modified atmospheric storage to delay the ripening of banana.
- Wind is the largest single source of loss to banana production. Due to the climate change, unusual and unexpected squally winds occur often causing loss to the growers. Studies may be taken up to evolve economic ways of mitigating the wind force in banana tract for minimizing the loss to the farmers.
- The development of technological options rather than a single package of practice are recommended as this would help farmers of different socio-economic groups.
- Publication of success stories can be an effective link among the farmers and traders for sharing the experiences derived from successful implementation of the research findings.
- An optimized system of production considering economical and ecological point of view should be promoted through farmers training and mass-media communication.
- A full-fledged banana museum, of national standard, depicting all the recent technologies developed has to be established for the benefit of the farmers and other visitors.
- A field demonstration banana orchard with all the released banana varieties has to be maintained all through the year at the centre.RAC Meeting

RAC Meeting

Research Advisory Committee (RAC) meeting of the Centre was conducted on 30th November and 1st December, 2012, wherein all the members of RAC including the Chairman Dr. G. L. Kaul, Former VC, AAU attended the meeting. Recommendations generated from the meeting were approved by the Council and communicated the same to all the members.

RAC members visit to NRCB Research farm

Recommendations of XII RAC Meeting

- The survey for germplasm has to completed at the earliest so that the valuable germplasm material present in remote areas can be utilized.
- Besides the biotic and abiotic stress parameters, observations on phenotypic characters / indicators for water logging also have to be studied.

- In order to achieve the task of B-genome sequencing work, Indian partners may be identified for initiation of B-genome sequencing works.
- To utilize the banana germplasm effectively, NRCB should register all the banana accessions with NBPGR in Access Platform.
- The micronutrients play a major role in the banana production, in order to identify the symptoms by the banana growers the deficiency symptoms of banana and their amelioration may be prepared in the form of bulletin and sent to all SAU's / Research organizations and this will be useful for the farming community.
- The tailoring equations developed by the NRCB for banana is found to be very useful in the resource management and banana production. These equations developed for micro-nutrients, macro nutrients for major varieties has to be prepared in the form of extension bulletins and supplied to Krishi Vigyan Kendras' for the benefit of farming community.
- Several products are developed by NRCB but production is restricted with Self-help groups and small and medium entrepreneurs. In order to commercialize the products at national level Post harvest technology Scientist needs training therefore the Scientist may be deputed to CFTRI, Mysore to know how the products are being commercialized and accordingly facilities may be created at NRCB and develop products.
- Many products are developed at NRCB and it appears that these are not tested at pilot scale level. Unless these products are tested at pilot scale level. The problems

RAC Members

Sl. No.	Name and Address	Position
1.	Dr. G. L. Kaul, Former VC, AAU, Ghaziabad – 201 012. U.P.	Chairman
2.	Dr. V. Rajagopal, Former Director, CPCRI, Tirupathi.	Member
3.	Dr. R. T. Patil, Director, Technocrats Institute of Technology, Bhopal	Member
4.	Dr. R. K. Tyagi, Head, Division of Germplasm, NBPGR, Pusa, New Delhi.	Member
5.	Dr. S. K. Apte, Associate Director, BMG, Bhabha Atomic Research Centre, Trombay, Mumbai.	Member
6.	Dr. G. Chandrasekar, Head, Dept. of Plant Pathology, Tamil Nadu Agril. University, Coimbatore	Member
7.	The Asst. Director General (Hort.I) Indian Council of Agril. Research, KAB-II, Pusa, New Delhi	Member
8.	Dr. M. M. Mustaffa, The Director, NRC for Banana, Thogamalai Road, Thayanur Post, Tiruchirappalli	Member
9.	Shri Shaker Nagarajan, President, Tamil Nadu Hill Banana Growers Federation, Pattiveeranpatti, Tamil Nadu	Member (IMC Rep.)
10.	Shri Bopanna Venkata Rao, Banana Growers, Kovvur, West Godavari, AP	Member(IMC Rep.)
11.	Dr. B. Padmanaban, Principal Scientist, NRC for Banana, Thogamalai Road, Thayanur Post, Tiruchirappalli	Member Secretary

and feasibility at commercial level may not be known, therefore banana by-products developed at the Centre may be tested at pilot scale level.

- Since banana scarring beetle is problem in 40% of the banana growing areas in India (Assam, West Bengal, Bihar, Eastern Uttar Pradesh and NEH Region) and it affects cosmetic value of the fruit and reduces the appeal of the fruit and fetches only 50% the actual cost. Being a national institute studies on banana scarring beetle may be initiated West Bengal in collaboration with BCKV, Mohanpur.
- The Fusarium wilt and leaf spot disease are a major problem in all banana growing areas of India, major emphasis should be given on bio-control aspect; accordingly technical programme may be prepared.
- Management practices for soft rot (*Erwinia*) in Banana should developed since the varieties like Thella chakkerakeli, Mortaman and culinary varieties like Kovvur Bontha are more susceptible and in future the above cultivar may become extinct like Amrutpani.

IMC Meeting

The Sixteenth meeting of the Institute Management Committee (IMC) was held on 16.07.2012 under the chairmanship of Dr. M. M. Mustaffa, Director, NRC for banana along with members of IMC. In the meeting, various policy decisions were discussed and recommended for approval by the Council.

IRC Meeting

The Sixteenth Institute Research Council meeting was held on 14.4.2012, 15.5.2012 and 22.5.2012 under the Chairmanship of Dr. M. M. Mustaffa, Director, NRCB. The salient research achievements of previous year and technical programmes for the next year were presented by the respective project leaders of the institute as well as externally funded projects. The Chairman has reviewed the research achievements made under each project and gave critical inputs for refinement of the research programmes.

Dr. M. M. Mustaffa, Director NRCB, Chairing the IMC meeting

Dr. M. M. Mustaffa, Director, NRCB Chairing the IRC meeting

Members present in the IMC meeting were

Sl. No.	Name and Address	Capacity
01.	Dr. M. M. Mustaffa Director, NRC for Banana, Tiruchirappalli	Chairman
02.	Dr. P. L. Saroj Assistant Director General (Hort.), ICAR, New Delhi	Member

Sl. No.	Name and Address	Capacity
03.	Dr. N. Kumar Dean (Horticulture), Tamil Nadu Agricultural University, Coimbatore.	Member
04.	Shri. T. Chandra Sekaran Deputy Director of Horticulture, Directorate of Horticulture & Plantation Crops Govt. of Tamil Nadu, Chepauk, Chennai	Member
05.	Dr. C. K. Narayana Principal Scientist, IIHR, Hesseraghatta, Bangalore	Member
06.	Dr. Sukhada Mohandoss Principal Scientist, IIHR, Hesseraghatta, Bangalore	Member
07.	Dr. S. Uma Principal Scientist, NRC for Banana, Tiruchirappalli	Member
08.	Shri. Shaker Nagarajan President, Tamil Nadu Hill Banana Growers Federation Pattiveeranpatti, Dindigul District, Tamil Nadu.	Member (Non-Official)
09.	Shri. Bopanna Venkata Rao Banana Grower, Nalamvari, Kovvur West Godavari District, Andhra Pradesh.	Member (Non-Official)
10.	Shri. S. A. Hamza Finance & Accounts Officer Sugarcane Breeding Institute, Coimbatore.	Member
11.	Dr. P. Sundararaju Principal Scientist, NRC for Banana, Tiruchirappalli	Special Invitee
12.	Shri M. Krishnan Administrative Officer, NRC for Banana, Tiruchirapalli	Member Secretary

12. TRAININGS/ REFERESHER COURSES/ SUMMER/ WINTER INSTITUTES/ MEETINGS/ SEMINARS/ CONFERENCES/ SYMPOSIA/ WORKSHOPS ATTENDED BY THE SCIENTISTS

13.1 Trainings/ Refresher Courses attended by the scientists

Name of the Scientist	Name of the training programme /Venue	Period
R. Thangavelu	Genomic Data Analysis (under NAIP), Indian Agricultural Statistics Research Institute (ICAR), Pusa, New Delhi	7 -19 Jan., 2013
R. Selvarajan	IPR and Biotechnology, NAARM, Hyderabad	2 –25 Sept., 2012
K. N. Shiva	Analysis of Experimental Data using SAS (under NAIP), NAARM, Hyderabad, A.P.	2–8 Nov., 2012
	Management Development Programme on Harnessing Intellectual Property for Strategic Competitive and Collaborative Advantage, IIM, Ahmedabad	14-16, Feb., 2013
	MDP Workshop on Technology Management for Researchers (under NAIP), NAARM, Hyderabad	28 Feb.-6 March, 2013
S. Backiyarani	Statistical Approaches for Genomic Data Analysis (under NAIP), IASRI, New Delhi	7-19 Jan., 2013
C. Anuradha	2DE Electrophoresis, CPMB, TNAU, Coimbatore	13-15 July, 2012
	Gene Identification and marker development ICAR sponsored Short term training, NRCB Trichy	9-19 Oct., 2012
	In vitro culture, embryogenesis and genetic transformation of banana Queensland University of Technology, Brisbane, Australia	9-15 Dec., 2012
	Next generation sequencing data analysis and annotation DBT sponsored training programme at IISR, Calicut	12 -16 March, 2013

12.2. Meetings/ Seminars/ Conference/ Symposia/ Workshop attended by the scientists

Name	Name of the Progamme/ Venue	Date(s)
M. M. Mustaffa	National Conference on Climate Change in Banana Jalgaon, Maharashtra	8-10 Apr., 2012
	ICAR Institute Horticulture Division Meeting ICAR, New Delhi	6 May, 2012
	NRCB-QRT Preliminary Meeting, ICAR, New Delhi	18 May, 2012
	Global Conference on Horticulture, OUAT, Bhubaneshwar	30-31 May, 2012
	ICAR Regional Committee Meeting, SBI, Coimbatore	15-17 June, 2012
	ICAR Institute Horticulture Division Meeting ICAR, New Delhi	23 July, 2012
	NICRA Project – Technical Programme finalization Meeting, IIHR, Bangalore	29-30 Aug., 2012
	Knowledge Meet at ICAR, New Delhi	20-21 Aug., 2012
	Hort. Division Meeting, ICAR, N.Delhi	23rd Aug.., 2012
	Biofortification Project finalization meeting at BIRAC, New Delhi	24th Aug., 2012
	Plan Expenditure Review Meeting at the O/o of DDG (Hort.) and DG-ICAR	6-7 Sept., 2012
	Banana Seminar, Theni organized by the Theni Banana Growers Association	3 Nov., 2012
	BAPNET Steering Committee Meeting / International Banana Symposium at Kaohsiung, Taiwan	18-22 Nov., 2012
	National Consultation on "Management of Genetic Resources of Horticultural Crops" at NBPGR, New Delhi	18-19 Dec., 2012
	TN Banana Summit – organized by CII, Chennai	21 Dec., 2012
	Consortium Advisory Committee Meeting of NAIP Project on Natural Fibires / National Seminar on Tropical and Sub-tropical Horticultural Crops NAU, Navsri, Gujarat	7-11 Jan., 2013
	Scientific Workers Conference, TNAU, Coimbatore	1-2 Feb., 2013
	18th Group Discussion of AICRP on Tropical Fruits YSRHU, Venkataramanagudem, West Godavari Distt. A.P.	7-11 Feb., 2013

Name	Name of the Progamme/ Venue	Date(s)
	Global Consultation on Use and Management of Agro-biodiver-sity for sustainable Food Security, NASC Complex, New Delhi	12-14th Feb., 2013
	HoDs/Directors Meeting with Secretary-DARE and DG-ICARICAR, New Delhi	11-14 Mar., 2013
	ICAR Institute Directors' Conference, ICAR, New Delhi	18-21 Mar., 2013
P. Sundararaju	National Conference on Adaption to climate change for sustained production of banana, Jain Hills, Jalgaon, Maharashtra	7-10 Apr., 2012
	Institute Management Committee meeting of the Directorate of Oil Palm Research (DOPR), Pedavegi, Eluru, Andhra Pradesh	28 July, 2012
	Nodal officers meeting of Horticultural Institutes designated for RFD, KAB-II, New Delhi	23 Nov., 2012
	Sensitization meeting of PME cell of ICAR" (Nodal Officer) at NDRI, Karnal	8th Dec., 2012
	19th Institute Foundation Day coinciding with Farmers Field Day held at NRCB Farm	27 Aug., 2012
	XVIII Group Discussion Meeting of AICRP (Tropical Fruits), YSR Horticultural University, Venkataramannagudem, Andhra Pradesh	8-11 Feb., 2013
B. Padmanaban	National Conference on Adaption to climate change for sustained production of banana, Jain Hills, Jalgaon, Maharashtra	7-10 Apr., 2012
	Farmers meeting, Tamil Nadu Hill Banana Growers Federation, Thandikudi	24 July, 2012
	As a Director's nominee involved in the selection Posts SMS Programme, Hansrover KVK, Perambalur Dt. and CREED KVK, Cholamadevi, Ariyalur Dt.	3 - 5 Oct., 2012
	Tamil Nadu Banana Festival- 2012 organized by the Confederation of Indian Industry (CII), Chennai	21 Dec., 2012
	Launching of DBT Funded project on improvement of livelihoods through conservation of near extinct banana land races of Kolli hills, Namakkal	19 Feb., 2013
S. Uma	GCDT funded projects on the Regeneration and safety duplication of the priority Musa accessions, FAO HQ, Rome	17-19 Apr., 2012
	International Taxonomic Advisory Group on Bananas, *Musa* Net Diversity Working Group,	9-10 July, 2012

Name	Name of the Progamme/ Venue	Date(s)
	Center for International Forestry Research (CIFOR), Bogor, Indonesia	
	Consultation Meeting on Musa wild species and wild relatives for use in banana and plantain improvement, Center for International Forestry Research (CIFOR), Bogor, Indonesia	11-13 July, 2012
	Indian Horticultural Congres, Horticulture Society of India, PAU, Ludhiana	6-9 Nov., 2012
	Half yearly review meeting of the PPV & FRA funded projects on developing DUS guidelines for crops and Plant Genome annual award ceremony of the Authority, New Delhi	21-22 May, 2012
	17th AICRP on Tropical fruits Group meeting at YSRHU, Tadepalligudem, Andhra Pradesh	6-10 Feb., 2013
	Doctoral and Synopsis meeting Satyabhama University, Chennai	14 Feb., 2013
I. Ravi	National conference on Adaption of climate change for sustained production of Banana, Jalgaon, Maharashtra	7-10 Apr., 2012
	SAS software installation training cum workshop for nodal officers of SSCNARS, NAARM, Hyderabad	27 July, 2012
R. Thangavelu	National conference on Adaptation to Climatic Change for Sustained Production of Banana, Jalgaon, Maharashtra	7-10 Apr., 2012
	Farmers meeting, Tamil Nadu Hill Banana Growers Federation at Thandikudi	24 July, 2012
	National Symposia on "Heading Towards Molecular Horizons in Plant Pathology: Host Resistance, Pathogen Dynamics, Diagnostics and Management, Sugarcane Breeding Institute, Coimbatore, Tamil Nadu	16-18 Nov., 2012
	International Banana Symposium on "Banana Improvement, Health Management, Use Diversification and Adaptation to Climate Change" held at Taiwan, Republic of China	19-22 Nov., 2012
	XVIII Group discussion of AICRP on Tropical Fruits organized by AICRP on Tropical fruits (ICAR), Horticultural Research Station, Kovvur. A.P.	8-11 Feb., 2013

Name	Name of the Progamme/ Venue	Date(s)
	Launching Programme of DBT funded project on improvement of livelihoods through conservation of near extinct banana land races of Kolli hills, Namakkal District	19 Feb., 2013
V. Kumar	National conference on Adaptation to Climatic Change for Sustained Production of Banana, Jalgaon, Maharastra	7-10 Apr., 2012
	VII Scientific Advisory Council Meeting, TNAU KVK, Vamban, Pudukottai	18 Apr., 2012
	Global Conference on Horticulture for Food, Nutrition and Livelihood held at OUAT, Bhubaneswar, Orissa	28-31 May, 2012
	Training on Advanced Production technologies for enhancing the production of quality bananas by Sri Avinashilingam KVK, Mettupalayam, Coimbatore	2-3 Sept., 2012
	State Level Workshop on Precision farming Technologies for Banana	23 Nov., 2012
	RFD Nodal Officers Meeting to finalize the RFD 2013-14, NASC, New Delhi	16 Jan., 2013
R. Selvarajan	National conference Adaption to climate change for sustained production of Banana, Jain Hills, Jalgaon, Maharashtra	7-10 Apr., 2012
	Global conference on Horticulture for Food, Nutrition and livelihood options, OUAT, Bhubaneswar	28-31 May, 12
	"Plant Genome Saviour Award" for saving the Virupakshi banana from extinction. felicitation function, Tamil Nadu Hill banana Growers Federation, Thandikudi	24 July, 2012
	XVIII foundation day celebrations as Banana field day (Kissan Mela), NRC for Banana, Trichy	27 Aug., 2012
	National symposium on Heading towards molecular horizon in plant pathology, SBI, Coimbatore	16-17 Nov., 2012
	National symposium on Blending conventional and modern plant pathology for sustainable agriculture, IIHR, Bangalore	4-6 Dec., 2012
	Brain storming session on Coconut root wilt disease at Kayangulam	8 Dec., 2012

Name	Name of the Progamme/ Venue	Date(s)
	A review meeting on the Network Project on Transgenic in Crops -TC at NRCPB, New Delhi	15-16 Jan., 2013
	TN Banana festival 2012, CII, Chennai	21 Dec., 2012
	International conference on sustainable utilization management and conservation of bioresources ST. Joseph's College, Tiruchirapalli	11 Jan., 2013
	National workshop on Foresight and future pathways of agricultural research through youth in India, NASC, New Delhi	1-2 Mar.,2013
M.Mayil Vaganan	International Conference on Advances in Biotechnology and Patenting; School of Biotechnology and Genetic Engineering, Bharathidasan University, Tiruchirapalli	18 -21 Feb., 2013
	Review meeting Biofortification and evaluation of Indian banana with iron constructs; BIRAC-Department of Biotechnology, New Delhi	21 Mar., 2013
K.J. Jeyabaskaran	National Conference on Adaption to Climate Change for Sustained Production of Banana, Jain Hills, Jalgaon, Maharashtra	10 Apr., 2012
K.N. Shiva	Agri Expo - 2012, Dinamalar Newspaper at Fort ground, Near old bus stand, Vellore Dt.,	29 July, 2012
	NRCB 19th Foundation Day, NRC Banana, Tiruchirappalli, Tamil Nadu	27 Aug., 2012
	Awareness cum discussion programme on Food Safety and Standards Act, organized by Dhinamalar Newspaper, Femina Hotel, Tiruchirappalli, Tamil Nadu	30 Sept., 2012
	National Seminar on Banana, Dept. of Hort., TN Govt. Theni	3-4 Nov., 2012
	Awareness programme on Harvesting, postharvest handling, Dept. of Agrl. Marketing, Dept. of Agriculture, ATMA and KVK-VC & RI, Mohanur Namakkal Dt.	8 Dec., 2012
	3rd International Conference on Food Technology (INFOTECH 2013), Indian Institute of Crop Processing Technology, Thanjavur, India	4 & 5 Jan., 2013
	Agri Expo - 2013, Dinamalar Daily (Tamil) Newspaper Karur, T.N.	6 Jan., 2013
	Farmer's Grievance Day meeting, Namakkal Collectorate premise, Namakkal, Tamil Nadu	30 Jan., 2013

Name	Name of the Progamme/ Venue	Date(s)
	21st National Seminar on Scientific Tamil, CIAE-R/s, Santhalinga Adigalar Arts & Science College, Perur, Coimbatore, Tamil Nadu	9-10 Feb., 2013
	Annual Review Meeting of ITMU for the year: 2012-13, ZTM-BPD South Zone, DOR, Hyderabad, A.P.	7 Mar. 2013
S. Backiyarani	Plant breeders Meet at NBPGR to discuss about the plan proposal on Pre breeding for Banana	3-4, May, 2012
	Review meeting on Foreign Aided projects at ICAR, New Delhi	6 July, 2012
	Musa whole genome sequencing meeting to prepare a project proposal on BB genome sequencing at NRCPB, ICAR, New Delhi	6. Sept., 2012
	Annual review meeting of the NPTC- functional Genomics project held at NRCPB, ICAR, New Delhi	15-16 Jan., 2013
	18th Group Discussion on All India Co-ordinated Research Project on Tropical Fruits, Dr. YSR Horticultural University, Venkataramannagudem, West Godavari Dist., Andhra Pradesh	8-11 Feb., 2013
M. S. Saraswathi	Annual review meeting of the foreign funded projects, KAB II, New Delhi	4 Feb., 2013
	19th Foundation day celebrations at NRCB, Tiruchirappali	27 Aug., 2012
C. Anuradha	International Conference on Advances in Biotechnology and Patenting at Bharathidasan University, Tiruchirappali	18-21 Feb., 2013

Dr. M.M.Mustaffa, Director speaking in the Banana Festival at Chennai

M.M.Mustaffa, Director speaking in the National Banana seminar at Theni

13. WORKSHOPS, SEMINARS, SUMMER INSTITUTES, FARMERS DAY, TRAINING PROGRAMMES, ETC. ORGANIZED AT THE CENTRE

National Conference

A National Conference on 'Adaption to Climate Change for Sustained Production of Banana' was organized by the Association for the Improvement in Production and Utilization of Banana (AIPUB) and National Research Centre for Banana (NRCB), Tiruchirapalli in collaboration with Jain Irrigation Systems Ltd. (JISL), Jalgaon and Confederation of Horticulture Association of India (CHAI) during 7-10 April, 2012 at Jalgaon, Maharashtra. The conference was organized with a theme on 'To alleviate climate change for sustained production of banana'. During this conference, many emerging issues were discussed to mitigate the climate change. The conference was attended by more than 500 delegates consisting of scientists, technocrats, and developmental officials, progressive growers from nine different banana growing states and representatives from industries involved in banana production.

The chief guest of the conference Shri Radhakrishna Vikhe Patil, Hon'ble Minister of Agriculture and Marketing, Govt. of Maharashtra released the 'Souvenir-cum-Abstract' of the conference brought out by the AIPUB. He also released a book in Marathi on 'Improved Production Technologies of Banana'. The chief guest also gave away the 'Jain Awards' to 10 farmers hailing from different banana growing areas like Gujarat, Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Tamil Nadu.

Banana Show/ Exhibition

To show the strength in banana production and quality fruits, a banana show was organized on 7th April, 2012 at 10.30 AM. Farmers from Jalgaon, Yawal, Raver and Chinawal districts in Maharashtra and Burhanpur district in Madhya Pradesh have participated in the show. Prizes were awarded to the best three banana bunches by Shri Gulab Rao Devkar, Hon'ble Minister of State for Agriculture and Transport, Govt. of Maharashtra.

An exhibition was also organized to show the technologies available and inputs for the

better production of banana. In the exhibition, apart from NRCB and JISL, four service-providers have also participated.

Kissan Mela

The National Research Centre for Banana, Tiruchirapalli celebrated its 19th Foundation Day on 27. 08. 2012 by organizing a 'Banana Field Day' with a theme on 'Generation of Wealth from Banana Waste'.

The Field Day was organized mainly to highlight and disseminate the use of various technologies developed by the Centre including banana waste recycling, vermicomposting technology and banana waste utilization procsses. In the technical sessions, scientists of NRCB delivered lectures on postharvest technology, soil management, high density planting and management of pest and diseases, *etc.* In addition, there was a Scientist – Farmers interactive session in which many aspects of improved production, protection and postharvest technologies were discussed. In the field day, banana researchers, agriculture & horticulture officers, progressive farmers and entrepreneurs from different banana cultivating areas of Tamil Nadu had participated and discussed about various constraints to maximise the production and productivity of banana in India.

Inauguration of DBT funded project on Conservation and rejuvenation of near extinct traditional bananas of Kolli Hills

The National Research Centre for Banana, Tiruchirpalli organized farmers' awareness training programme on the Conservation and rejuvenation of near extinct traditional bananas of Kolli Hills on 19th February 2013 in collaboration with State Department of Horticulture, Namakkal at Semmedu, Kollihills, Namakkal District. Dr. D. Jagannathan, IAS, District Collector, was the Chief Guest of the function. This project was funded by the Department of Biotechnology (DBT), Government of India, New Delhi.

The function was presided over by Dr. M. M. Mustaffa, Director, NRC Banana, Tiruchirappali and Dr. S. Uma, Principal Scientist briefed about the project significance. Dr. B. Padmanaban, Principal Scientist, Dr. R. Thangavelu, Principal Scientist, Dr. S. Backiyarani and Dr. M. S. Sarawathi also spoke on the occasion.

This project envisages collection, conservation and rejuvenation of two near

extinct traditional banana varieties *viz*., *Karuvazhai* and *Numaran*. The existence of the plants is under threat due to the rampant incidence of Bunchy Top virus, Fusarium wilt, nematodes and stem weevil, which has completely devastated these two niche varieties which are grown in homestead garden for the livelihood and sustenance of the tribals of Kolli hills. This project aims at to develop tissue culture protocol, to multiply on large scale for distribution to the tribal beneficiaries in the Kolli Hills and to ensure re-establishment of these two endangered varieties in their natural habitat.

The beneficiaries under the project were handed over with a kit containing tissue culture plants, fertilizers, bio-fertilizers and plant

protection chemicals and a booklet on improved production and protection technologies. The scientists will guide the beneficiaries over the next three years for the successful rejuvenation of these native banana varieties in their natural habitat for the economical, food and nutritional security of the tribals and farmers of the Kolli Hills of Namakkal district.

14. DISTINGUISHED VISITORS

Sl. No.	Name & Address of visitors	Date of visit
1.	Dr. S. D. Shikhamany, Former VC, APHU, Hyderabad	18.6.2012
2.	Dr. S. Sambandamurthy, Former Dean, TNAU, Coimbatore	18.6.2012
3.	Dr. P. K. Ray, Head, Dept. of Horticulture, Rajendra Agricultural University, Pusa, Bihar	18.6.2012
4.	Dr. E. I. Jonathan, Director, Centre for Plant Protection Studies, Tamil Nadu Agricultural University, Coimbatore	18.6.2012
5.	Dr. Sosamma Jacob, Professor & Head, Dept. of Entomology, College of Horticulture, Kerala Agricultural University, Thrissur	18.6.2012
6.	Dr. H.P.Singh, DDG (Hort.), ICAR, New Delhi	12.7.2012
7.	Dr. N. Kumar, Dean (Horticulture) Tamil Nadu Agricultural University, Coimbatore	16.7.2012
8.	Shri T. Chandra Sekaran, Deputy Director of Horticulture, Govt. of Tamil Nadu, Chepauk, Chennai	16.7.2012
9.	Dr. C. K. Narayana, Principal Scientist and Head, Post Harvest Technology, IIHR, Hesseraghatta, Lake post, Bangalore	16.7.2012
10.	Dr. Sukhada Mohandos, Principal Scientist, IIHR, Hesseraghatta Lake post, Bangalore	16.7.2012
11.	Dr. G. L. Kaul, Former VC, AAU, Ghaziabad, U. P.	30.8.2012
12.	Dr. R. K. Tyagi, Head, Division of Germplasm, NBPGR, Pusa, New Delhi.	30.8.2012

Sl. No.	Name & Address of visitors	Date of visit
13.	Dr. G. Chandra Sekar, Head, Dept. of Plant Pathology, Tamil Nadu Agril. University, Coimbatore	30.8.2012
14.	Dr. N.K. Krishna Kumar, DDG (Hort.), ICAR, New Delhi	24.12.2012

Visitors

More than 4500 farmers including agricultural & horticultural officers, self help groups, students and VIPs visited the Centre

Dr. H.P. Singh, DDG (Hort.), ICAR, New Delhi visits NRCB research farm on 12.7.2012

Dr. N.K. Krishna Kumar, DDG (Hort.), ICAR, New Delhi, opens the new Net House at NRCB on his visit on 24.12.2012

QRT members visit to NRCB Reaearch farm

Tirunelveli Farmers visiting the NRCB

15. EMPOWERMENT OF WOMEN

About 1450 women including students, SHG and other women entrepreneurs from different parts of country visited NRCB and learnt various technologies available at NRCB on Crop Improvement, Crop Production, Crop protection and Post Harvest Technologies.

Dr. S. Uma delivered a lecture on 'Research frontiers in horticulture for women' on the eve of Womens' day celebrations at Horticulture College and Research Institute (Women), TNAU, Tiruchirapalli on 08.03.2013.

TNAU - Horticultural Research Students Visits at NRCB

16. PERSONNEL

New Appointment

Sl. No.	Name	Designation	Date of Joining
1.	Mr. P. Murugan	Assistant	27.08.2012
2.	Ms. Richa Sood	Assistant	19.11.2012

Promotion

Sl. No.	Name	Designation	w .e. f
1.	Dr. R. Thangavelu	Senior Scientist to Principal Scientist	01.01.2009
2.	Dr. R. Selvarajan	Senior Scientist to Principal Scientist	25.07.2009
3.	Dr. M. S. Saraswathi	Scientist (SS) to Senior Scientist	02.03.2008
4.	Dr. P. Durai	T5, Technical Officer to T6	10.05.2010
5.	Mr. T. Sekar	T-3, Technical Assistant to T-4	10.03.2012
6.	Mr. V. Selvaraj	T-3, Technical Assistant to T-4	05.03.2012
7.	Mr. A. Subramanian	T-2, Driver to T-3	29.06.2011
8.	Mr. P. Mohan	T-2 Driver to T-3	08.07.2011
9.	Mr. V. Manoharan	T-2 Driver to T-3	18.06.2012

Probation

Mr. M. Bathrinath, T-3, Technical Assistant have completed probation period on recommendation of the departmental promotion committee w.e.f. 27.12.2012.

Upgradation

Smt. K. Mariyammal, Skilled Supporting Staff was granted first financial upgradation under MACP on completion of 10 years regular service w. e. f. 17.10.2011.

Institute Joint Staff Council

The newly elected Institute Joint staff council (IJSC) of NRC for Banana for the period 13.09.2012 to 12.09.2015 is as follows:

Dr. I. Ravi, Senior Scientist

Dr. S. Backiyarani, Senior Scientist

Mr. M. Krishnan, Administrative Officer

Mrs. C.Gomathi, Asst. Finance & Accounts Officer

Mr. M. Devarajan, Lower Division Clerk

Mr. A. Subramanian, T-2, Driver

Mr. P. Kamaraj, Mali SSG-II

Mr. V. Ganesan, Mali SSG-I

Mr. R. Pitchaimuthu, T-3, Field Technician has been elected as Secretary Staff Side and

Mr. R. Sridhar, Perssonal Assistant has been selected as CJSC Member.

Scientific Staff

Sl. No.	Name	Designation
1.	Dr. M. M.Mustaffa	Director
2.	Dr. P. Sundararaju	Principal Scientist
3.	Dr. B. Padmanaban	Principal Scientist
4.	Dr. S. Uma	Principal Scientist
5.	Dr. R. Thangavelu	Principal Scientist
6.	Dr. R. Selvarajan	Principal Scientist
7.	Dr. I. Ravi	Senior Scientist
8.	Dr. V. Kumar	Senior Scientist
9.	Dr. M. Mayil Vaganan	Senior Scientist
10.	Dr. K. J. Jeyabaskaran	Senior Scientist
11.	Dr. K.N.Shiva	Senior Scientist
12.	Dr. S. Backiyarani	Senior Scientist
13.	Dr. M. S. Saraswathi	Senior Scientist
14.	Mr. R. Natarajan	Scientist
15.	Dr. C. Anuradha	Scientist

Technical Staff

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

Administrative, Audits & Accounts and Supporting Staff

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

17. OTHER INFORMATIONS

Hindi Week Celebrations

National Research Centre for Banana celebrated 'Hindi Week' from 3rd to 8th October 2012. On this occasion, Writing, Noting and Drafting, Song, Recitation & Extempore speach, Quiz (Official language & Gen Knowledge) and Memory Test in Hindi were conducted for promoting Hindi as official language in Central Govt. offices under the auspices of the Indian Council of Agricultural Research (ICAR), New Delhi . The Concluding Ceremony and Prize Distribution were held on 12th October 2012 at the Centre. Colonel S. Ved Nayagam, NCC Commander, Tiruchirappalli graced the occasion as Chief Guest and distributed prizes to the winners of various competitions. In his address, he emphasized the importance of promoting Hindi as official language and the necessity of learning Hindi as '*Rajbhasha*' by every citizen. In his address, he also stressed the importance of Hindi which would ensure survival of any individual elsewhere in the country and also in the professional carrier working in All India Transfer Services. The Colonel also imparted many easy methods which could be adapted by the individuals for learning Hindi such as listening to Hindi music, movies, reading simple comics and by applying Roman Hindi method also. At the beginning, Dr. K. J. Jeyabhaskaran, Senior Scientist welcomed the gathering. Dr. M. M. Mustaffa, Director, NRC Banana delivered the Presidential address and spoke on Hindi week celebrations. The programme came to an end with the vote of thanks by Dr. K.N. Shiva, Senior Scientist and Member-Secretary, Official Language Implementation Committee of the Centre.

Colonel S. Ved Nayagam delivers Chief Guest address

ANNEXURE I

List of On-going Institute Projects

1. Crop Improvement

2000711002 : Crop improvement of banana through conventional breeding
M. M. Mustaffa, S. Uma, S. Backiyarani and R. Natarajan

2000711004 : Improvement and management of banana genetic resources in Indian subcontinent
S. Uma, M.S. Saraswathi and R. Natarajan

2000711005 : Identification and characterisation of nematode resistance gene(s) in banana
S. Backiyarani, S. Uma and M. S. Saraswathi, P. Sundararaju and M. Mayil Vaganan

2000711006 : Improvement of Rasthali through induced mutagenesis
M. S. Saraswathi, S. Uma, S. Backiyarani and R. Thangavelu

2. Crop Production

2000713001 : Standardization of agro-techniques for banana production and productivity
V. Kumar, M. M. Mustaffa and K. J. Jeyabaskaran

2000713006 : Fertilizer tailoring for targeted banana yield and sustainable soil health
K. J. Jeyabaskaran and V. Kumar

2000716001 : Studies on physiology of flowering and fruit development in banana
I. Ravi and K. J. Jeyabaskaran

2000716002 : Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance
I. Ravi, M. Mayil Vaganan and K. J. Jeyabaskaran

2000716003 : Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance
I. Ravi, M. Mayil Vaganan and S. Uma

2000716004 : Physiological and biochemical mechanism of nematodes and pseudostem weevil resistance and identification of 'biomarker metabolites' in banana
M. Mayil Vaganan, I. Ravi, P. Sundararaju and B. Padmanaban

2000717003 : Development of pre and post harvest techniques for leaf production in banana
K. N. Shiva and K. J. Jeyabaskaran

2000717004 : Development of modified atmosphere packaging techniques in banana and plantain for domestic and export markets
K. N. Shiva, I. Ravi and V. Kumar

2000717005 : Development and refinement of value added products in banana and plantain
K. N. Shiva, M. M. Mustaffa and M. Mayil Vaganan

3. Crop Protection

2000715006 : Management of Banana weevils
B. Padmanaban and R. Thangavelu

2000715002 : Studies on banana nematodes and their management
P. Sundararaju, M. Mayil Vaganan and S. Backiyarani

2000715003 : Investigation on fungal and bacterial diseases of banana and their management
R. Thangavelu

2000715005 : Studies on viral diseases of banana and their management
R. Selvarajan and C. Anuradha

2000715007 : Host-virus interactions in Banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's
R. Selvarajan and I. Ravi

2000715008 : Proteomic analysis of host-BBTV interaction in banana
C. Anuradha, R. Selvarajan and M. Mayil Vaganan

4. External funded projects

A. ICAR Funded Projects

1. Network Project on Transgenic in crops – Banana functional genomics

   Sigatoka component
   S. Uma, R. Thangavelu, S. Backiyarani and M. S. Saraswathi

   Drought component
   I. Ravi, S. Backiyarani and M. S. Saraswathi

2. Outreach Project on Phytophthora, Fusarium & Ralstonia diseases of horticultural and field crops
   R. Thangavelu and S. Backiyarani

3. Network Project on Harnessing arbuscular mycorrhizae in horticultural crops
   R. Thangavelu

4 Network Project on Transgenic in Crops - Transgenic Component: Development of transgenic banana resistant to Banana Streak Virus (BSV) and Banana Bunchy Top Virus (BBTV)
R. Selvarajan and C. Anuradha

5. Intellectual Property Management and Transfer/ Commercialization of Agricultural Technology-IPR
C. Anuradha

B. Projects Funded by other Agencies

1. DBT- Improved livelihoods through conservation and rejuvenation of near extinct banana land races of Kolli hills of Tamil Nadu
S. Uma, M. S. Saraswathi and S. Backiyarani

2. PPV&FRA - Framing Crop Specific DUS Guidelines for Banana
S. Uma, S. Backiyarani and M. S. Saraswathi

3. DBT - Accredited Test Laboratory and National Certification System for Tissue Culture raised Plants (NCS-TCP) Genetic Fidelity Testing component Virus Indexing component
S. Uma, R. Selvarajan and M. S. Saraswathi

4. DBT - Evaluation of transgenic banana for resistance to Banana Bunchy top virus (Replicase mediated)
R. Selvarajan and C. Anuradha

5. DST - Identification of molecular strategies for the control of *Cosmopolites sordidus* Ger.) (Coleoptera: Curculionidae) (a major pest of bananas
Lalitha Sunil Kumar, NCL, Pune and B. Padmanaban

6. DBT - Molecular approaches for the control of *Odoiporus longicollis* (Oliver) (Coleoptera: Curculionidae) (a major pest of banana)
B. Padmanaban, Lalitha Sunil Kumar, NCL, Pune and R. Thangavelu

7. Coffee Board - Eco-friendly approaches for the management of coffee white stem borer, *Xylotrechus quadripes* Chev. (Coleoptera: Cerambycidae)
Abraham Vargheese and B. Padmanaban

8. DBT - Biofortification and development of disease resistance in bananaComponent-I : Transfer and evaluation of Indian banana with pro Vitamin-A (PVA) constructs
S. Backiyarani and S. Uma

9. DBT - Component-II:Transfer and evaluation of Indian banana with Iron constructs constructs
M. Mayil Vaganan and C. Anuradha

10. DBT - Component-III: Development of efficient ECS for Rasthali and providing authentic virus free IMFC to Indian Partners constructs
S. Uma and S. Backiyarani

ANNEXURE-II

Meteorological Data

Month	Min. Temp (°C)	Max. Temp (°C)	Relative Humidity (%)	Rain fall (mm)
April 2012	26.13	38.80	83.63	10.54
May 2012	27.10	38.61	73.10	3.54
June 2012	26.80	37.60	72.03	29.90
July 2012	25.71	36.93	72.51	12.00
August 2012	25.64	36.16	76.35	65.50
September 2012	25.50	36.70	76.50	109.9
October 2012	24.26	32.58	84.74	280.40
November 2012	22.93	32.66	90.93	-
December 2012	22.51	31.96	89.12	2.10
January 2013	21.06	32.67	88.74	-
February 2013	22.25	33.92	89.39	-
March 2013	23.90	36.51	88.48	-
Total				**513.88**

भाकृअनुप
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तायनूर पोस्ठ तोगमलै रोड तिरूच्चिरापक्कि ६२० १०२, तमिल नाडु

National Research Centre for Banana

(Indian Council of Agricultural Research)
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