# NRC BANANA

## ANNUAL REPORT 2011 - 2012

## वार्षिक प्रतिवेदन २०११ - '१२

भाकृअनुप
ICAR

**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**

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# PREFACE

I am glad to present the Annual Report 2011-12 of NRC Banana, Trichy in which the progress of NRCB for the period from April, 2011 to March, 2012 are presented. Research activities in the areas of Improvement, Production, Protection, Post harvest Technology and Transfer of Technology are included in this Annual Report. The research programmes and their findings are covered in this report.

During the period, two wild and four accessions were collected from Tripura and Odisha and are included in the field gene bank. Eighty eight exotic accessions are introduced from ITC, Belgium and 62 accessions were characterized based on the morphotaxonomic parameters. Mass multiplication techniques have been standardized for *Australimusa, Callimusa* such as *Musa textilis, M.boman* and *M.jackeyii*. Also standardized the protocols for direct regeneration from immature flower buds of cv. Robusta. Hydropriming with GA-3 enhanced the germination percentage of seeds upto 82%. *Fusarium* wilt resistant three putatitive mutants of Rasthali have been identified and mass multiplication by *in-vitro* is in progress. Expression profiling of resistant gene analogus indicated C1, C5 and C6 transcripts involvement in root lesion nematode resistance.

Application of 300g N in 7:2:1 ratio and 400g K in 4:3:3 ratio at vegetative, flowering and bunch development stages recorded highest bunch weight and yield at 2.4 x 2.4 spacing in Udhayam banana. Application of Ferrous sulphate with sulphur at three months after planting along with foliar spray of zinc sulphate and borox recorded highest bunch weight with highest TSS, lowest acidity and highest pulp-peel ratio in Ney Poovan. A new compound was observed in root lesion nematode inoculated plants which was absent in un-inoculated plant. Ethrel sprayed Poovan fruits in LDPE bags with 0.5% ventilation has greater consumer acceptance in the retail market.

Soil application of *P.lilacinus* and *Pseudomonas fluorescens* + neem cake and growing marigold as intercrop significantly reduced the root lesion nematode population in both soil and roots and produced maximum bunch weight in Udhayam banana. Host extracts with semio-chemical in the ratio of 3:2 was found effective in attracting the banana stem weevil. Bio-priming of banana plants with either *Trichoderma harzianum* or *Penicillium pinophilum* with botanical Zimmu or *Hibiscus* sp. resulted in complete control of Fusarium wilt disease incidence and also increased the growth parameters. Soil moisture stress on tissue culture Poovan banana expressed typical symptoms of banana streak Mysore virus. More than 90% incidence of Banana Bunch Top Virus was observed during the survey in Tamil Nadu.

In the area of HRD, Scientists were deputed to four international and three national trainings to upgrade their skills and knowledge. More than 57 lectures on different aspects of banana production were given through mass media like AIR, Doordharsan, Makkal TV. NRCB has participated in 7 exhibitions at regional and national levels and organized 14 on-campus training

on production and post harvest technology on banana. Technologies of Value Added Products of banana like Thokku, Fig, Flower pickle protocols were transferred to entrepreneurs and Self Help Groups.

I would like to express my sincere gratitude to Dr.S.Ayyappan, Secretary – DARE and Director General, ICAR for his valuable guidance and Dr.H.P.Singh, Dy. Director General (Hort.), ICAR for his constant inspiration and encouragement. I also compliment the Chairman and members of the publication committee of the NRC Banana for their input in bringing out this document in time.

**(M.M.Mustaffa)**
Director

# 2. कार्यकारी सरांश

तिरुचिरापल्ली के राष्ट्रीय केला अनुसंधान केन्द्र के क्षेत्र जीन बैंक त्रिपुरा और ओडिशा द्वारा प्राप्त दो जंगली और चार खेती की प्रकार से मजबूत किया गया है. अस्सी आठ विदेशी परिग्रहण आईटीसी बेल्जियम से शुरू किया गया है जिनमें से बासठ रूपात्मक वर्गीकरण लक्षण वर्णन और मूल्यांकन के उद्देश से क्षेत्र लगाए है. 14 प्रमुख व्यावसायिक किस्मों पर डीएनए उंगली मुद्रण प्रोफ़ाइल विकसित किया गया है जिससे किस्म पंजीकरण और ब्रीडर अधिकार के उल्लंघन का पता लगाना और बइओ- पैरसी में सहायता होगा.

विविधता उद्यम में मकरो प्रचार परीक्षण साबित किया है कि बिसथार विधि पोत विधि से अधिक लाभप्रद है क्यूंकि बिसथार विधि में गुणन कि दर अधिक है. निकट विलुप्त विविधता मनोरंजिथं और औस्त्रेलिमुसा, काल्लिमुसा के अड़ियल सदस्यों जैसे मूसा तेक्सतिलिस, एम. बोमन और एम् .जच्केयी में जन गुणन और टिशू कल्चर तकनीक विकसित किया गया है. इसके अलावा, अपरिपक्व पुरुष फूल कलियों से प्रत्यक्ष संयंत्र उत्थान प्रोटोकॉल cv. रोबस्टा में भी मानकीकृत किया गया है.

युग्मनज भ्रूण संस्कृति ज़ाय्गोटिक भ्रूण संस्कृति के अध्ययन संकेत दिया कि तीन दिन ह्यदरो प्रिमिंग में ४०.८% तक अधिक बड़ाया अंकुरण मिला है जबकि गैर भिगो बीज में केवल २०.८०% है. तीन वृद्धि परीक्षण नियामकों के बीच में तीन दिन प्रिमिंग $GA_3$ 10 प्पम करने पर दोगुनी अंकुरण प्रतिशत (82.40) तीन दिनों की न्यूनतम समय में प्राप्त हुआ है. इसके अलावा शूट और जड़ लंबाई, रूट संख्या जैसे अन्य विकास विशेषताओं बढ़ाया भी है. रस्थाली की तीन ख्यात म्यूटेंट फुसेरियम विल्ट के प्रतिरोध के साथ पॉट संस्कृति के अध्ययन में पहचान की गई है और वे इन विट्रो द्वारा आगे गुणन के लिए आरंभ किया गया है और बीमार भूखंडों और गर्म स्थान क्षेत्रों में स्क्रीनिंग भी शुरू कि गयी है

*प्रत्यलेंकस काफ्फिए* संक्रमित जड़ नमूने में प्रतिरोधी जीन समधर्मा (RGAs) के अभिव्यक्ति रूपरेखा संकेत दिया कि C1: C5 और C6 के टेप, ख़र्थोबिउम्थम में जड़ घाव निमेटोड प्रतिरोध से संबंधित हो सकता है. एटीपी सिंथेस के पूर्ण लंबाई जीन के अलगाव और अनुक्रमण ने एम. अक्युमिनाठा एटीपी सिंथेस बीटा उप इकाई को 98% अनुरूपता दिखाया और 97% मक्का और चावल एटीपी सिंथेस को अनुरूपता दिखाता है. पार प्रजातियों, पार पीढ़ी और पार परिवार बदले जाने की योग्यता के उच्च प्रतिशत का सुझाव दिया है कि *मूसा* ईएसटी SSR तुलनात्मक मानचित्रण के लिए एक मूल्यवान स्रोत हो जाएगा cos के मार्करों को विकसित करके *ज़िन्गिबीरेसीए* और *मुसेसीए* पर विकासवादी अध्ययन में इस्तेमाल किया जा सकता है

उद्यम 2.4 x 2.4 मीटर की एक व्यापक दूरी पर साथ लागू का 07:02:01 में 300g एन और 4:03:03 अनुपात में 400 ग्राम K के क्रमशः वनस्पति, फूल, और गुच्छा के विकास के चरणों पर उच्चतम 38.5 किलो / संयंत्र का गुच्छा वजन दर्ज की गई है. 20 किलो FYM + 0.9 किलो नीम केक + 2.0 किलो वर्मीकम्पोस्ट + 0.9 किलो मूंगफली केक के आवेदन से BSV और BBrMV पीड़ित पूवन को दर्ज अधिकतम उपज, उच्च TSS और कम अम्लता मिली अकार्बनिक उर्वरकों के तुलना में.

पांच ग्राम के फैरस सल्फेट + 20 ग्राम सल्फर के आवेदन संयंत्र प्रति तीन महीने पर बोने के बाद (एमएपी) और इसके साथ साथ 0.5% के प्रत्येक जिंक सल्फेट और बोरेक्रस पत्ते का स्प्रे जो 3, 5 और 7 एमएपी के आवेदन पर नेय पूवन में उच्चतम गुच्छा वजन (16.6 किलो) उच्चतम टीएसएस ($29.8^0$ ब्रिक्स), सबसे कम अम्लता (0.39%) और 7.79 के अनुपात छील उच्चतम लुगदी के साथ दर्ज की गई. उर्वरक समायोजन समीकरण विविधता ग्रांडे नैन के लिए विकसित किया गया है और यह विभिन्न किस्मों के लिए भारत भर में विभिन्न AICRP केन्द्रों में पुष्टि की गई है. जड़ घाव निमेटोड की टीका यांगाम्बी के.एम.-5 30 दिनों के बाद उसकी फेनोलिक चयापचयों का विश्लेषण की उपस्थिति से पता चला निमेटोड टीका पौधों में एक नया परिसर और वही गैर टीका नियंत्रण में अनुपस्थित था.

केला - आधारित अचार पर भंडारण पढ़ाई संकेत दिया कि छील और मध्य कोर स्टेम अचार छह महीने तक गुणवत्ता और स्वाद में बिना कोई गिरावट स्थिति में संग्रहित किया जा सकता. ओस्मोटिकल्ली निर्जलित केले के सुखाने समय 50% कम गया था पोटेशियम मेटा-द्वि-सल्फ़ाईट के साथ इलाज की तुलना में. अधिकतम टीएसएस, अम्लता कुल शर्करा और उपभोक्ता स्वीकृति एथरेल इलाज पूवन फल LDPE बैग में संग्रहित तीन दिनों के लिए 0.5% वेंटीलेशन के साथ दर्ज की है. 15 दिनों के लिए 0°C में संग्रहित संघनित दूध के साथ तैयार किये हुए सिप अप सबसे अच्छा और 6.93 का एक सुखात्मक स्कोर के साथ स्वीकार किया गया था. फाइबर निकासी के विभिन्न तरीकों की कोशिश में यह साबित है की मशीन निकाले फाइबर क्षार इलाज फाइबर सभी किस्मों में और सभी AICRP केंद्रों पर नेत्रहीन से बेहतर है.

*पेसिलोम्य्सस लिलासिनस* + *स्यूडोमोनास फ्लुओरेसेंस* @ 30g प्रत्येक संयंत्र / + नीम केक @ 250g/ संयंत्र के मिट्टी आवेदन और बढ़ती मेरीगोल्ड अंतर फसलों के रूप में लगाने पर जड़ घाव निमेटोड की जनसंख्या दोनों मिट्टी (मिट्टी <15 / नेमाटोड छ) और जड़ों (रूट <20 नेमाटोड / छ) में महत्वपूर्ण कमी के परिणामस्वरूप दिखाई दी और अधिकतम गुच्छा वजन 34.5 किलोग्राम / संयंत्र उत्पादित हुई. तीस संकर जांच के बीच, 15 और 4 संकर *प्रत्य्लेंकस काफ्फिए* और मेलोइदोगय्न इन्कोग्निटा क्रमशः के लिए प्रतिरोधी पाए गए. इन संकर प्रतिरोधी जीन की पहचान के लिए और आणविक मार्करों के विकास के लिए प्रभावी ढंग से इस्तेमाल किया जा सकता है.

मेटार्हैज़ियम -66 अनिसोप्लिए स्टेम घुन के खिलाफ प्रभावी पाया गया था जबकि *बी. बस्सिआना* - 32 कार्म घुन के खिलाफ प्रभावी पाया गया था. निकालने के मेजबान और सेमिओकेमिकल अनुपात 3:02 एक कम समय में केले स्टेम घुन को आकर्षित करने के लिए प्रभावी पाया गया था. मेटार्हैज़ियम अनिसोप्लिए की दो आइसोलेट्स और *लेकानिसिल्लियम लेकाणी* के पांच आइसोलेट्स, एफिड जनसंख्या में काफी नियंत्रण है.

ग्रैंड नैन केले के पौधों के जैव - भड़काना या तो ट्राइकोडर्मा हर्ज़िअनम या *पेनिसिलियम पिनोफिलम* (30g चावल खरब अनाज कि तैयारी में 109 spores/ml/ संयंत्र से युक्त) के

साथ साथ वनस्पति ज़िम्मु, अल्पिनिया प्रजातियों या हैबिस्कस प्रजातियों के साथ (250ml/plant) परिणामस्वरूप में फुसेरियम विल्ट रोग के पूर्ण नियंत्रण संयंत्र विकास पैरामीटर जैसे ऊंचाई (33.60%), परिधि (80%), पत्तियों की संख्या (42.11%), पत्ती क्षेत्र (128.15%) और जड़ों की संख्या (143.04%) अकेले टीका एफओसी(FOC) पौधों की तुलना में उल्लेखनीय वृद्धि दिखाई दी.

कवकनाशी प्रतिरोधी कवक जैव नियंत्रण एजेंट या तो एन्ड्रोफैटिक *ट्राइकोडर्मा हर्ज़िअनम* + Prr2 + हिंज़ोस्फेरिक *टी. हर्ज़िअनम* या एन्ड्रोफैटिक *पेनिसिलियम पिनोफिलम* BC2 + हिंज़ोस्फेरिक *टी. कोनिंगी* का क्षेत्र आवेदन 30g चावल खरब अनाज या तालक पाउडर फार्मूलों संयंत्र प्रति तीन बार अर्थात 0, 2 और 4 महीने में लागू करना है. ऐसे करने में रोपण के बाद फुसेरियम विल्ट रोग की गंभीरता (1.47 के रोग स्कोर) में महत्वपूर्ण कमी और उपज में वृद्धि (74.8%) के रूप में अनुपचारित नियंत्रण पौधों (4.1 का रोग स्कोर) की तुलना में दर्ज दिखाई दी.

cv. रोबस्टा केले के पौधों में दोनों एन्ड्रोफैटिक (6M2) और अध्युद्विदीय (1E2) जीवाणु जैव एजेंट @ 109 सेल्स /ml का पर्ण पर फुहाव 5 महीने बाद, 20 दिनों के अंतराल में चार बार रोपण में महत्वपूर्ण दबा पत्ता स्थान बीमारी की गंभीरता (47.9%) और YLS 0 (41.03%) के मूल्य में वृद्धि हुई अनुपचारित नियंत्रण पौधों की तुलना में.

तमिलनाडु में किए गए सर्वेक्षण में संवर्धित ऊतक और पारंपरिक चूसने वाला बड़े पौधों CVS. ग्रांड नैन, लाल केला, हिल केले और पूवन केलों में BBTV का 90% घटना का पता चला. ऊतक सुसंस्कृत पूवन केले स्ट्रीक मैसूर (BSMyV) वायरस के विशिष्ट लक्षणों का प्रदर्शन पौधों पर मिट्टी नमी तनाव रोग की गंभीरता और वायरस अनुमापांक (दास एलिसा परीक्षण पर आधारित) में महत्वपूर्ण वृद्धि का संकेत है. उदयम केले के वायरस अनुक्रमण NRCB क्षेत्र से एकत्र ने संकेत दिया की उपस्थिति केले हल्के मोज़ेक वायरस और 250 आधार जोड़ी का टुकड़ा का अनुक्रमण 87% अनुरूपता प्रकाशित दृश्यों के साथ संकेत किया गया था. BBrMV की कोट प्रोटीन जीन की समान क्लोनिंग और अनुक्रम विश्लेषण तमिलनाडु और केरल के विभिन्न स्थानों से एकत्र ने 97-99% समानता न्युक्लियोटाइड स्तर में और > 97% समानता एमिनो एसिड के स्तर पर प्रकाशित दृश्यों के साथ प्रदर्शन है.

## प्रौद्योगिकी के हस्तांतरण

2011-12 के दौरान, वैज्ञानिकों ने आल इंडिया रेडियो, तिरुचिरापल्ली में छह रेडियो वार्ता, दूर्धर्शन और मक्कल टीवी, चेन्नई में तीन टीवी वार्ता और 57 व्याख्यान केले के विभिन्न पहलुओं में दिया गया है. NRCB ने भाग लिया/आयोजित किया सात प्रदर्शनियों राष्ट्रीय स्तर पर और केले का उत्पादन और पोस्थार्वेस्ट प्रौद्योगिकी पर चौदह पर-परिसर में प्रशिक्षण का आयोजन किया. उन्नीस शोध पत्र, आठ पुस्तक अध्याय, सात लोकप्रिय लेख, आठ तकनीकी बुलेटिन / विस्तार फ़ोल्डर्स, एक फिल्म दस्तावेज़ और 16 शोध पत्र राष्ट्रीय और अंतरराष्ट्रीय सम्मेलनों / संगोष्ठियों सेमिनार / कार्यशाला / बैठक में भी प्रस्तुत किए गए. 27 अति विशिष्ट व्यक्तियों और 3950 केले किसानों, कृषि एवं बागवानी अधिकारियों, स्वयं सहायता समूहों

और छात्रों का दौरा किया और केंद्र की गतिविधियों पर उनका आकलन किया गया. टेक्नोलॉजी के मूल्य पर केले के थोक्कू, फिग, मैदा और फूल अचार की तैयारी भी कई ग्राहकों को स्थानांतरित कर दिया गया.

## मानव संसाधन विकास और शिक्षा

वैज्ञानिकों ने चार अंतरराष्ट्रीय प्रशिक्षण और तीन राष्ट्रीय प्रशिक्षण के लिए प्रतिनियुक्त किया गया है और कृषि विज्ञान के नवीनतम घटनाओं में कौशल और ज्ञान को अद्यतन किया है. शिक्षा और प्रशिक्षण कार्यक्रम के तहत, 13 - M.Sc, M.Tec, B.Tec, एम. फिल, विभिन्न विश्वविद्यालयों के छात्रों को पीएचडी केले के विभिन्न पहलुओं में अपने काम / शोध प्रबंध परियोजना के लिए निर्देशित किया है. पूरी तरह से 85 सेमिनार / सम्मेलन / संगोष्ठियों / कार्यशाला बैठकों , क्षेत्रीय / राष्ट्रीय / अंतरराष्ट्रीय स्तर पर वैज्ञानिकों ने भाग लिए.

## राजस्व पीढ़ी

₹ 25.55 लाख को राजस्व के रूप में केन्द्र द्वारा एहसास किया गया है.

## 3. EXECUTIVE SUMMARY

Field gene bank of National Research Centre for Banana, Tiruchirappalli was strengthened by addition of two wild and four cultivated types from Tripura and Odisha. Eighty eight exotic accessions have been introduced from ITC Belgium and 62 were field planted for morpho-taxonomic characterization and evaluation. DNA finger printing profile has been developed for 14 major commercial varieties. This would aid in varietal registration and detecting infringement of breeder's rights and bio-piracy.

Macro propagation in Udhayam variety indicated bed method was more advantageous due to higher rate of multiplication over pot method. Tissue culture techniques have been developed for near extinct landrace Manoranjitham and for recalcitrant members of *Australimusa* and *Callimusa* such as *Musa textilis, M. boman* and *M.jackeyii*. Besides, protocol for the direct plant regeneration from immature male flower buds of cv. Robusta has also been standardized.

Studies on zygotic embryo culture indicated hydropriming for three days enhanced germination up to 40.80% as against 20.80% in unsoaked seeds. Among the three growth regulators tested, priming in 10 ppm $GA_3$ for three days doubled the germination (82.40%) in three days and also enhanced other growth characteristics like shoot and root length, root number etc. Three putative mutants of Rasthali with Fusarium wilt resistance have been identified and initiated for further multiplication as *in -vitro* and screening in sick plots and hot spot areas.

Expression profiling of Resistant Gene Analogus (RGAs) in *Pratylenchus coffeae* infected root samples indicated that C1, C5 and C6 transcripts might be related to root lesion nematode resistance in Karthobiumtham. Isolation and sequencing of full length genes of ATP synthase showed 98% homology to *M. acuminata* ATP synthase beta sub unit and 97% homology to the Maize and Rice ATP synthase. The high percentage of cross species, cross genera and cross family transferability suggested that *Musa* EST-SSR will be a valuable source for the comparative mapping by developing cos markers which could be used in the evolutionary studies on *Zingiberaceae* and *Musaceae.*

Udhayam at a wider spacing of 2.4 X 2.4 m and applied with 300g N in 7:2:1 and 400 g K in 4:3:3 ratios at vegetative, flowering and bunch development stages respectively recorded the highest bunch weight of 38.5 kg/plant. Application of 20 kg FYM + 0.9 kg Neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake to the BSV and BBrMV infested Poovan recorded the maximum yield, high TSS and low acidity as compared to inorganic fertilizers.

Application of five g of ferrous sulphate + 20 g sulphur per plant at three months after planting (MAP) along with foliar spray of 0.5% each of zinc sulphate and borax at 3, 5 & 7 MAP recorded the highest bunch weight in Ney Poovan (16.6 kg) with highest TSS (29.8 °Brix), lowest acidity (0.39%) and highest pulp peel ratio of 7.79. Fertilizer adjustment equation has been developed for variety Grande Naine and was validated for different varieties at different AICRP Centres across India. Analysis of phenolic metabolites in Yangambi KM-5 after 30 days of root lesion nematode inoculation showed the presence of a new compound in nematode inoculated plants and the same was absent in un-inoculated control.

Storage studies on banana based pickles indicated that peel and central core stem pickles could be stored up to six months without any deterioration in quality and taste. The drying time was reduced by 50% in osmotically dehydrated bananas than potassium meta-bi-sulphite treated ones. Ethrel treated Poovan fruits stored in LDPE bags with 0.5% ventilation for three days has recorded the maximum TSS, acidity, total sugars and consumer's acceptance. The Sip-up prepared with condensed milk and stored at 0°C for 15 days was accepted as the best with a Hedonic score of 6.93. Among the various methods of fibre extraction tried, machine extracted fibre was visually better than

the alkali treated fibre in all varieties and at all AICRP centres studied.

Soil application of *Pecilomyces lilacinus* + *Pseudomonas fluorescens* @ 30g each/plant + Neem cake @ 250g/plant and growing Marigold as intercrop resulted in significant reduction in root lesion nematode population of both soil (<15 nematodes/g soil) and roots (<20 nematodes/g root) and produced the maximum bunch weight of 34.5 kg/plant. Among the thirty hybrids screened, 15 and 4 hybrid was found resistant to *Pratylenchus coffeae* and *Meloidogyne incognita* respectively. These hybrids could be effectively used for the identification of resistant gene and also for the development of molecular markers.

*Metarrhizium anisopliae* –66 was found effective against stem weevil while *B. bassiana*-32 was found effective against corm weevil. Host extract and semio-chemical in the ratio 3:2 was found effective for attracting banana stem weevil in a short time. Two isolates of *Metarrhizium anisopliae* and five isolates of *Lecanicillium lecanii*, were found to control the aphid population significantly.

Bio-priming of banana plants cv. Grand Naine with either *Trichoderma harzianum* or *Penicillium pinophilum* (30g of rice chaffy grain formulation containing $10^9$spores/ml/plant) along with botanicals Zimmu, *Alpinia* sp or *Hisbiscus* sp. (250ml/plant) resulted in complete control of Fusarium wilt disease and significant increase in plant growth parameters such as height (33.60%), girth (80%), no. of leaves (42.11%), leaf area (128.15%) and number of roots (143.04%) when compared to *Foc* alone inoculated plants.

Field application of fungicide resistant fungal bio-control agents either endophytic *Trichderma harzianum* Prr2 + rhizospheric *T. harzianum,* or endophytic *Penicillium pinophilum* Bc2 + rhizospheric *T. koningii*, applied 30g of either rice chaffy grain/talc cum powder formulations per plant for three times ($0^{th}$, $2^{nd}$ and $4^{th}$ month after planting) recorded significant decrease in Fusarium wilt disease severity (disease score of 1.47) and increase in yield (74.8%) as compared to untreated control plants (disease score of 4.1),

The foliar spray of banana plants cv. Robusta with both endophytic (6M2) and epiphytic (1E2) bacterial bio-agents ($10^9$cells/ml) for four times at 20 days interval after 5 months of planting significantly suppressed the leaf spot disease severity (47.9%) and increased the value of YLS-0 (41.03%) when compared to untreated control plants.

Surveys undertaken in Tamil Nadu revealed 90% incidence of BBTV in tissue cultured and conventional sucker grown plants of cvs. Grande Nain, Red banana, Hill banana and Poovan banana. Soil moisture stress on tissue cultured Poovan plants exhibiting typical symptoms of Banana Streak Mysore Virus (BSMyV) indicated significant increase in the severity of the disease and the virus titre (based on DAS ELISA test). Virus indexing of Udhayam banana collected from NRCB field has indicated the presence of banana mild mosaic virus and sequencing of the 250 bp fragment indicated 87% homology with published sequences. Similar cloning and sequence analysis of coat protein gene of BBrMV collected from different places of Tamil Nadu and Kerala exhibited 97-99% similarity at the nucleotide level and >97% similarity at amino acid level with published sequences.

## Transfer of Technology

During 2011-12, Scientists gave six radio talks in All India Radio, Tiruchirapalli, three television talks in Doordharshan & Makkal TV, Chennai and 57 lectures in different aspects of banana. NRCB had participated/ organized seven exhibitions at regional/ national levels and organized fourteen on –campus trainings on production and post harvest technology of banana. Nineteen research papers, eight book chapters, seven popular article, eight technical bulletins/ extension folders, One document film and 16 research papers were also presented in National and International Conferences/ Symposia/ Seminars/ Workshop/ Meetings. As many as 27 VIPs and about 3950 banana farmers, Agricultural & Horticultural officers,

self help groups and students visited and were appraised on the activities of the Centre. Technologies on value added products of banana such as Thokku, Fig, Flour and Flower Pickle preparations were also transferred to several clients.

## HRD and Education

Scientists have been deputed to four international trainings and three national trainings to update their skill and knowledge in the latest developments of agricultural sciences. Under education and training programme, 13 M.Sc, M.Tec, B.Tec, M.Phil, Ph.D students from different Universities have been guided for their project/ thesis work in various aspects of banana. Totally 85 seminars/ conference/ symposia/ workshop/ meetings were attended by the Scientists at Regional/ National/ International levels.

## Revenue Generation

A total of Rs. 25.55 lakhs was realized as revenue by the Centre.

# 4. 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 min and max 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., Crop Improvement, Crop Production, Post harvest Management and Crop Protection. It has well-equipped laboratories for tissue culture, biotechnology, soil science, nutrient management, physiology, biochemistry, entomology, nematology, fungal, bacterial, viral pathology and post harvest technology research.

In late nineties, 10 collection surveys through explorations were made. 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 were introduced. The Centre has completed seven in-house research projects and 11 are in progress in the 11th five year plan. In addition to Centre's in-house projects, 26 externally funded projects by AP Cess fund of ICAR, NATP, DBT, NHB and INIBAP were completed. The Perspective Plan and Vision 2030 documents on the research priorities and also inputs from QRT and RAC were published. The Centre conducts two meetings of Institute Research Council to review the on-going research projects and also to incorporate the RAC recommendations. The vision of the centre is to increase the production and productivity of bananas and plantains to meet the growing need in India.

## Mandate

- 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 total of 360 core accessions have been collected from both indigenous and exotic sources, which are maintained in the Centre's gene bank at Tiruchirapalli and the satellite gene bank at Agali. Among the collections, 92 accessions are highly resistant and 25 are resistant to Sigatoka leaf spot disease. A NRCB selection Udhayam, which belongs to *Pisang Awak* sub group, is a high yielder was released in 2008. Embryogenic cell suspensions (ECS) for five different commercial varieties viz., Rasthali, Nendran, Ney Poovan, Robusta and Grand Nain have been developed and regeneration protocol from ECS for Nendran and Rasthali has been standardized. Picloram based medium was found more efficient in the formation of somatic embryos in cvs. Rasthali and Nendran. Field evaluation of ECS regenerated plants are performing well than the conventional derived plants such as suckers and

shoot tip derived tissue cultured plants. 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. Besides, tissue culture techniques have been developed for near extinct landrace Manoranjitham and for recalcitrant members of *Australimusa* and *Callimusa* such as *Musa textilis, M. boman* and *M.jackeyii*. Protocol for the direct plant regeneration from immature male flower buds of cv. Robusta has also been standardized. Three putative mutants of Rasthali with Fusarium wilt resistance have been identified and initiated for further multiplication. The NRCB has developed a 'DNA Bank for *Musa* germplasm with 225 accessions. A farmer's friendly method of mass production of banana planting material called 'Macro propagation' has been developed to meet the need of small and marginal farmers. Evaluation of commercial cultivars based on their nutritional parameters has indicated that Pachanadan and Nendran are highly nutritious with respect to all minerals and carotenoids followed by Udhayam banana. Database has been created to understand the best season for hybrid seed production and their regeneration.

## Crop Production

Poovan plants supplied with 20 l water/ day/plant and 75% N (150 g N/plant) as fertigation increased the yield by 20% with maximum net profit and 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. Application of 15 kg rice husk ash + 25 g V AM + 80% recommended NPK gave an additional profit of Rs. 32,500/ha. Udhayam at a wider spacing of 2.4 X 2.4 m and applied with 300g N in 7:2:1 and 400 g K in 4:3:3 ratios at vegetative, flowering and bunch development stages respectively recorded the highest bunch weight of 38.5 kg/plant. 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. It was also found that application of five g of ferrous sulphate + 20 g sulphur per plant at three months after planting (MAP) along with foliar spray of 0.5% each of zinc sulphate and borax at 3, 5 & 7 MAP recorded the highest bunch weight in Ney Poovan (16.6 kg) with highest TSS (29.8 °Brix), lowest acidity (0.39%) and highest pulp peel ratio of 7.79.The study on the effect of organics on the BSV and BBMV infected Poovan showed that the 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. Application of 20 kg FYM + 0.9 kg Neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake to the BSV and BBrMV infested Poovan

recorded the maximum yield, high TSS and low acidity as compared to inorganic fertilizers. Eight drought tolerant accessions were identified based on leaf water retention capacity. The leaf longevity was more in Robusta than Nendran, Rasthali and Ney Poovan bananas. Saba, Karpuravalli and Ney Poovan have been identified as tolerant cultivars to salt stress. Drought tolerant Saba and Karpuravalli cultivars maintained higher (>200) K/Na ratio in leaf (lamina and midrib) when compared with susceptible Ney Poovan, Nendran and Robusta cultivars (4.52 to 17.56) at shooting and fruit maturity. A study on biochemical resistance mechanism of banana to *Pratylenchus coffeae* generally indicated that the activity of phenol oxidizing enzymes, stress related enzymes and the level of total phenols, lignin and tannins were higher even at 180 days in resistant than in susceptible cultivars. The induction of these above said enzymes were more in the nematode challenge inoculated plants than in the unchallenged plants.

## Post Harvest Technology

Pre-packaging in 400 gauge LDPE bags, low temperature storage, use of ethylene absorbents and pre-storage treatments have resulted in extension of shelf life up to 3 months in Robusta, Grand Nain, Rasthali and Ney Poovan bananas. Several value added products like flower thokku, peel thokku, fruit pickle, fig, biscuits, jam, ready to serve beverages and functional foods like chapathi, bread and health drink have been developed. Banana and Jamun juice blend was the best among 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°. Storage studies on banana-based pickles indicated that peel and central core stem pickles could be stored up to six months without any deterioration in quality and taste. The drying time was reduced by 50% in osmotically dehydrated bananas than potassium meta-bi-sulphite treated ones. Among the various methods of fibre extraction tried, machine extracted fibre was visually better than the alkali treated fibre in all varieties and at all AICRP centres studied.

## 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* 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. Soil application of *Pecilomyces lilacinus* + *Pseudomonas fluorescens* @ 30g each/ plant + Neem cake@250g/plant and growing Marigold as intercrop resulted in significant reduction in root lesion nematode population of both soil (<15 nematodes/g soil) and roots (<20 nematodes/g root) and produced the maximum bunch weight of 34.5 kg/plant. Swabbing 0.06% Chlorpyrifos 20 EC on the pseudo stem of 1.2 m height during 5th and 8th 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 7$^{th}$ months 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. Field evaluation conducted using funnel trap in a weevil (*O. longicollis)* endemic areas of Theni and Dindigul districts of Tamil Nadu showed that the weevil attraction was maximum (80 % ) in the treatment of Semiochemical No.1 + host plant volatile extract obtained from cv. Nendran. Two

isolates of *Metarrhizium anisopliae* and five isolates of *Lecanicillium lecanii*, were found to control the aphid population significantly.

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. Field application of fungicide resistant fungal bio-control agents either endophytic *Trichderma harzianum* Prr2 + rhizospheric *T. harzianum,* or endophytic *Penicillium pinophilum* Bc2 + rhizospheric *T. koningii*, applied 30g of either rice chaffy grain/ talc cum powder formulations per plant for three times ($0^{th}$, $2^{nd}$ and $4^{th}$ month after planting) recorded significant decrease in Fusarium wilt disease severity (disease score of 1.47) and increase in yield (74.8%) as compared to untreated control plants (disease score of 4.1).

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.* Soil application of increased dose of fertilizer (150% of RDF) in cv. Poovan has compensated the yield loss due to BBrMV. Poly clonal 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 BSMys V in Poovan and BBTV in Hill banana. Primers and probe have been designed for rep gene of BBTV and assessed the quantity of its transcripts in latent and severely infected plant susing real time PCR. Virus indexing of Udhayam banana collected from NRCB field has indicated the presence of banana mild mosaic virus and sequencing of the 250 bp fragment indicated 87% homology with published sequences. Similar cloning and sequence analysis of coat protein gene of BBrMV collected from different places of Tamil Nadu and Kerala exhibited 97-99% similarity at the nucleotide level and >97% similarity at amino acid level with published sequences.

## Transfer of Technology

During 2011-2012, scientists gave six radio talks in All India Radio, Tiruchirapalli, three television talks in Doordharshan & Makkal TV, Chennai and participated/ organized seven exhibitions at regional/ national levels. Fourteen on –campus trainings on production and post harvest technology of banana were organized. Nineteen research papers, eight book chapters, seven popular article, eight technical bulletins/ extension folders, One film document and 16 research papers were presented in National and International Conferences/ Symposia/ Seminars/ Workshop/ Meetings. Fifty seven lectures were delivered in different aspects of banana by NRCB Scientists. Under education and training programme, about 13 M.Sc, M.Tec, B.Tec, M.Phil, Ph.D students from different Universities have been guided for their project/ thesis work in various aspects of banana. Totally 85 seminars/ conference/ symposia/

workshop/ meetings were attended by the Scientists at Regional/ National/ International As many as 27 VIPs and about 3950 banana farmers, Agricultural & Horticultural officers, self help groups and students visited and were appraised the activities of the Centre. Technologies on value added products of banana (Thokku, Fig, Flour and Flower Pickle) were transferred to several clients.

## Linkages and Collaboration

The Centre has developed good linkages with international institutes viz., Bioversity International, France and QDPI, Australia. It collaborates with different national research institutions for different activities viz., NBPGR, New Delhi; BARC and CIRCOT, Mumbai; IIHR, Bangalore; NHB and DBT New Delhi 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) Centers 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

During the period of 2011-12, a total of Rs. 25.55 lakhs was generated through the sale of farm produces, virus indexing etc.

## BUDGET DETAILS (REVISED ESTIMATE) FOR THE YEAR 2011 - 2012

| Sl. No. | Head of Account | PLAN Amount (Rs. in lakhs) | NON-PLAN Amount (Rs. in lakhs) |
|---|---|---|---|
| 1. | Esst. Charges | 0 | 270.00 |
| 2. | OTA | 0 | 0.10 |
| 3. | Travelling Allowances | 2.00 | 2.50 |
| 4. | Other Charges | 125.70 | 69.50 |
| 5. | Human Resource Development | 2.00 | 1.00 |
| 6. | Equipments | 100.00 | 15.00 |
| 7. | Works | 169.00 | 9.00 |
| 8. | Furniture & Fixtures | 23.00 | 0 |
| 9. | Library books | 2.00 | 0 |
| 10. | Information Technology | 2.00 | 0 |
| | **TOTAL Rs.** | **425.70** | **367.10** |

# 5. RESEARCH ACHIEVEMENTS

## 5. 1 CROP IMPROVEMENT

### 5.1.1 Genetic Resource Management

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

#### Collection

Five accessions namely Aittakola, Mizo Cavendish, Sabri, Behula (cooking type) and *M. acuminata* wild have been collected from HRC, Nagicherra and Baramurah forest range, Tripura and were added to the field genebank of NRCB, Trichy. Promising Cavendish clone with improved traits like short duration were collected from the secondary source in Odisha, as tissue cultured plantlets and field planted. *M.acuminata* ssp *burmannica* was collected as open pollinated seedling and seeds between 10° 13' and 10° 31' N. latitude and between 76° 52' and 77° 23' E. longitude respectively in Anamalai Hills, Tamil Nadu.

Besides, 88 exotic accessions were received from ITC, Belgium and were multiplied *in vitro*. Out of these, 62 accessions have been field planted for characterization and evaluation studies.

#### Characterization

During the reporting period, the plant crop of 200 priority accessions and ratoon crop of 110 accessions have been characterized using *Musa* descriptor. A rationalized photo descriptor has been compiled for 110 accessions.

#### DNA fingerprinting

#### ISSR markers

Ten primers were tested for DNA fingerprinting of 14 commercial varieties of *Musa* representing AAA, AAB, ABB and AB genomes. Nine primers ave amplified products resulting in discrete, repeatable amplicons and were considered for the genetic diversity analysis. From these amplicons, 105 alleles were identified with a mean of 11.7 alleles per primer based on the presence (1) and absence (0) of alleles. Maximum 20 alleles were observed in primer pair UBC 811 and minimum 7 alleles in primer pair UBC 836. ISSR primers produced unique bands for five major commercial varieties (Table 1). Primer UBC 834 produced three bands which were unique to Red banana (Fig.1) While primer UBC 811 produced common bands (876 BP) shared by the varieties

Table 1. Unique bands produced by different microsatellite markers

| Accession Name | Primer pair | Allele size in bp |
|---|---|---|
| Red banana (AAA) | UBC 834 | 867, 1258, 1366 |
| | UBC 842 | 801 |
| Poovan (AAB) | UBC 836 | 967 |
| | UBC 840 | 529 |
| Rasthali (AAB) | UBC 841 | 1497 |
| Nendran (AAB) | UBC 840 | 2118 |
| | UBC 841 | 1649 |
| Neypoovan (AB) | UBC 808 | 2017, 2117 |
| | UBC 840 | 608, 1637 |

Table 2. Common bands produced by varieties in the same genomic group by different microsatellite markers

| Genome | Varieties | Primer | Allele size in bp |
|---|---|---|---|
| AAA | 1. Grand Naine<br>2. Robusta<br>3. Dwarf Cavendish | UBC 841 | 527 |

| | | | |
|---|---|---|---|
| | 4. Red banana | | |
| AAB | 1.Poovan<br>2.Rasthali<br>3.Nendran<br>4.Pachanadan | UBC 811 | 876 |
| ABB | 1.Monthan<br>2.Kothia<br>3.Karpuravalli<br>4.Udhayam<br>5.Peyan | UBC 811 | 414 |

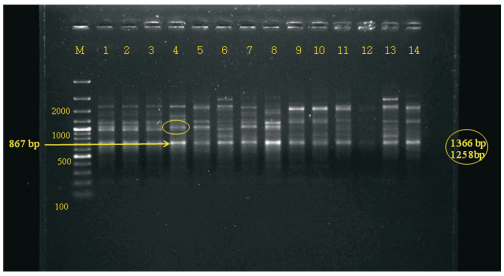



Fig. 1. Profile of commercial varieties using ISSR marker UBC 834

1.Grand Naine 2.Robusta 3.Dwarf Cavendish 4.Red banana 5.Poovan 6.Rasthali 7.Nendran 8.Pachanadan 9.Monthan 10.Kothia 11.Karpuravalli 12.Udhayam 13.Neypoovan 14.Peyan

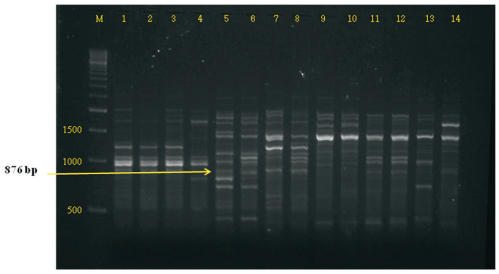



Fig. 2. Profile of commercial varieties using ISSR marker UBC 811

1.Grand Naine 2.Robusta 3.Dwarf Cavendish 4.Red banana 5.Poovan 6.Rasthali 7.Nendran 8.Pachanadan 9.Monthan 10.Kothia 11.Karpuravalli 12.Udhayam 13.Neypoovan 14.Peyan

in the same genomic group (AAB) (Table 2 & Fig. 2).

## SSR markers

Out of 20 primer pairs tested, 16 primer pairs generated unique alleles in different varieties of the same or different genomic groups (AAA, AAB, ABB and AB) (Table 3 & Fig. 3) and 14 primers produced alleles that are commonly shared by different varieties in the same genomic group (AAA, AAB and ABB).

Table. 3. Unique bands produced by different microsatellites markers

| Accession Name | Primer pair | Allele size in bp |
|---|---|---|
| Grand Naine (AAA) | AGMI 67/68 | 127, 146 |
| | AGMI 95/96 | 272, 278 |
| | AGMI 103/104 | 207 |
| | AGMI 113/114 | 214 |
| | AGMI 123/124 | 322 |
| | AGMI 197/198 | 94 |
| | Ma 8a/8b | 241 |
| | Ma 24a/24b | 111 |
| Robusta (AAA) | AGMI 103/104 | 199 |

| | | |
|---|---|---|
| | AGMI 105/106 | 307 |
| | AGMI 133/134 | 408 |
| Red banana (AAA) | Ma SSR 24a/24b | 115 |
| Poovan (AAB) | AGMI 24/25 | 223 |
| | Ma SSR 2-10 | 153 |
| Rasthali (AAB) | AGMI 35/36 | 110 |
| | AGMI 123/124 | 315 |
| Pachanadan (AAB) | AGMI 67/68 | 131 |
| | AGMI 105/106 | 245 |
| Nendran (AAB) | AGMI 113/114 | 231 |
| | Ma SSR 1-19 | 218 |
| Monthan (ABB) | AGMI 103/104 | 193 |
| Kothia (ABB) | AGMI 67/68 | 108 |
| | AGMI 95/96 | 164 |
| | AGMI 103/104 | 191 |
| | AGMI 105/106 | 242 |
| | AGMI 123/124 | 292 |
| | AGMI 129/130 | 240 |
| Karpuravalli (ABB) | AGMI 197/198 | 111 |
| | Mb SSR 1-149 | 196 |
| Udhayam (ABB) | AGMI 24/25 | 238 |
| Peyan (ABB) | AGMI 197/198 | 120 |
| Neypoovan (AB) | AGMI 197,198 | 142 |

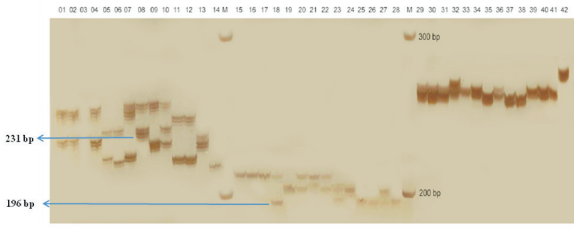



Fig 3 - Profile of commercial varieties using SSR markers AGMI 113/114, Mb SSR 1-149 and AGMI 95/96

Lane Nos. 1, 15, 29 – Peyan; 2, 16, 30 - Ney poovan, 3, 17, 31 – Udhayam, 4, 18, 32 – Karpuravalli, 5, 19, 33 – Kothia, 6, 20, 34 - Monthan 7, 21, 35 – Pachanadan, 8, 22, 36 – Nendran, 9, 23, 37 – Rasthali 10, 24, 38 – Poovan, 11, 25, 39 - Red banana, 12, 26, 40 - Dwarf Cavendish 13, 27, 41 – Robusta, 14, 28, 42 - Grand Naine

## Field evaluation of Reference *Musa* collections

24 reference *Musa* accessions were received, regenerated and evaluated in the field. Morpho-taxonomic characterization was carried out and documented in the database for 15 accessions, which have come for harvest. Results of characterization have led to the identification of Indian equivalent or synonymous of respective groups and subgroups (Table 4).

An exotic introduction *Musa textilis* accession, which has the potential for fibre industry, was multiplied and first batch of 18 plantlets are being hardened. Similarly *M.jackyii*, an ornamental and recalcitrant members of

Table 4. Reference *Musa* accessions and their Indian equivalents

| ITC No. | ITC name | genome | Indian equivalent |
|---|---|---|---|
| 0654 | Petite Naine | AAA | Dwarf Cavendish |
| 0825 | Uzhakan | AAB | French Plantain |
| 0123 | Simili Rajah | ABB | Kothia |
| 0277 | Leite | AAA | Thella Chakkarakeli |
| 0361 | Blue java | ABB | Vennutu Mannan |
| 0649 | Foconah | AAB | Hill Banana |
| 0659 | Namwa Khom | ABB | Karpuravalli- Dwarf |
| 0769 | Figue Pomme Geante | AAB | Rasthali |
| 1441 | Pisang Ceylan | AAB | Mysore Poovan |
| 1483 | Monthan | ABB | Monthan |
| 0069 | Type 2x | AA | Unique |

Callimusa has been regenerated successfully and taken for hardening.

## Evaluation

Evaluation of NRCB Selection- 08 (ABB) under multi location trials at TNAU, Coimbatore revealed its superiority in terms of high yield (average bunch yield of 29kgs) against the local Monthan (25kgs).

## Screening of core collection of banana against root -knot and root-lesion nematodes

Screening of 30 banana hybrids with different parental combinations against root lesion nematode, *P. coffeae* and root-knot nematode, *M. incognita* under pot culture condition indicated that none of the hybrids was found resistant to both root-lesion and root-knot nematodes. However, individual hybrid performance revealed that H 15 and H 4 were found resistant to *P.coffeae* and *M.incognita* respectively (Table 5 & 6).

## Screening of *Musa* germplasm for their reaction to banana aphid, *Pentalonia nigronervosa*

*Musa* germplasm (313) belongs to eight different genomic groups (BB-24, AB-23, AA-26, AAA-27, ABB-69, AAB-134, ABBB-9 and Rhodochlayms-1) were screened for their reaction to banana aphid, *Pentalonia nigronervosa* using midrib as a feeding material. The observation on the development of aphid population was recorded for a period of ten days. The results of the study indicated that none of the accessions were found resistant to aphid.

## Supply of planting material and fidelity testing services

Standardized the macropropagation technique for NRCB released variety Udhayam to develop large number of planting material and supply to the farmers. Two planting methods *viz.*, pot and bed methods with four biofertilizers were tried. The results indicated that bed method was found advantageous over

a b

Fig. 4. Evaluation of macropropagation in (a) Bed and (b) Pot methods for cv.Udhayam

pot method which produced average one bud / sucker, while pot method produced 0.6 bud / sucker. In cv. Udhayam, primary bud formation after primary decapitation was delayed and took 33 days compared to cv. Rasthali and cv. Grand Naine which took 18 days and 21 days respectively for primary bud formation in pot method (Fig. 4).

Table 5. Reaction of banana hybrids to root- knot nematode *Meloidogyne incognita*

| Hybrid Nos | Parents | % of infection | Root wt(g) | RKI* | Nematodes / 10g roots | Host reaction** |
|---|---|---|---|---|---|---|
| 57 | Lairawk X Namarai | - | 265 | - | - | R |
| 144 | K.Valli X P. jajee | 0.6 | 490 | 3 | 1470 | HS |
| 47 | P.jajee X Imbogo | 4.8 | 125 | 2 | 750 | HS |
| 109 | K.valli X P.jajee | 3.18 | 220 | 3 | 1540 | HS |
| 14 | Anaikomban X P.jajee | 3.33 | 90 | 2 | 217 | S |
| 11 | Matti X Cv. Rose | 1.28 | 390 | 3 | 1950 | HS |
| 36 | Anaikomban X Namarai | 3.85 | 130 | 3 | 650 | HS |
| 55 | Namarai X P. lilin | 20 | 230 | 4 | 10580 | HS |
| 1 | P.jajee X Matti | 10.53 | 190 | 4 | 3800 | HS |
| 38 | Anaikomban X Cv. Rose | 1.71 | 175 | 2 | 525 | HS |
| 59 | P.jajee X Cv.Rose | 3.04 | 395 | 3 | 4740 | HS |
| 26 | Anaikomban X P.lilin | 0.41 | 485 | 2 | 970 | HS |
| 29 | Manoranjitham X A.komban | 54.5 | 55 | 4 | 1650 | HS |
| 118 | K.Valli X P. jajee | 1.64 | 610 | 3 | 6100 | HS |
| 49 | P.jajee X Matti | 21.33 | 375 | 4 | 30000 | HS |
| 48 | P.jajee X Matti | 9.52 | 315 | 4 | 9450 | HS |
| 12 | Sannachenkadali X Lairawk | 400 | 20 | 4 | 1600 | HS |
| 13 | Anaikomban X P.jajee | 4.67 | 535 | 3 | 13375 | HS |
| 16 | Anaikomban X Lairawk | 1.14 | 1140 | 3 | 14820 | HS |
| 113 | K.Valli X P. jajee | 2.45 | 245 | 2 | 1470 | HS |
| 121 | P.jajee X Lairawk | 35.3 | 85 | 4 | 2550 | HS |
| 110 | K.Valli X P. jajee | - | 890 | - | - | R |
| 15 | Sannachenkadali X Lairawk | - | 115 | - | - | R |
| 119 | P.jajee X Lairawk | - | 125 | - | - | R |
| 17 | Burrocemsa X H-3 | 21.14 | 175 | 4 | 6475 | HS |
| 4 | K.Valli X P. jajee | 150 | 60 | 4 | 5400 | HS |
| 3 | K.Valli X P. jajee | 15.62 | 730 | 3 | 83220 | HS |
| 8 | Matti X A.komban | 2.08 | 480 | 3 | 4800 | HS |
| 6 | K.Valli X P. jajee | 11.56 | 1125 | 4 | 146250 | HS |
| 5 | K.Valli X P. jajee | 25 | 1800 | 5 | 81000 | HS |
| SED | | 18.88 | | | 0.39 | |
| CD (P=0.05) | | 37.81 | | | 0.79 | |
| CV% | | 6.90 | | | 17.50 | |

Table 6. Reaction of banana hybrids to root- lesion nematode, *Pratylenchus coffeae*

| Hybrid Nos | Parents | Infected (%) | Root wt(g) | RLI* | Nematodes / 10g roots | Host reaction** |
|---|---|---|---|---|---|---|
| 57 | Lairawk X Namarai | 0.41 | 265 | 3 | 1590 | HS |
| 144 | K.Valli X P. jajee | - | 490 | 2 | 980 | HS |
| 47 | P.jajee X Imbogo | - | 125 | - | 0 | R |
| 109 | K.valli X P.jajee | - | 220 | - | 0 | R |
| 14 | Anaikomban X P.jajee | - | 90 | - | 0 | R |
| 11 | Matti X Cv. | - | 390 | - | 0 | R |
| 36 | Rose Anaikomban X Namarai | - | 130 | - | 0 | R |
| 55 | Namarai X P. lilin | - | 230 | - | 0 | R |
| 1 | P.jajee X Matti | - | 190 | - | 0 | R |
| 38 | Anaikomban X Cv. Rose | 3.3 | 175 | - | 0 | R |
| 59 | P.jajee X Cv.Rose | - | 395 | 3 | 5135 | HS |
| 26 | Anaikomban X P.lilin | - | 480 | - | 0 | R |
| 29 | Manoranjitham X Anaikomban | - | 55 | - | 0 | R |
| 118 | K.Valli X P. jajee | 0.53 | 610 | - | 0 | R |
| 49 | P.jajee X Matti | - | 375 | 2 | 750 | HS |
| 48 | P.jajee X Matti | 25 | 315 | - | 0 | R |
| 12 | Sannachenkadali X Lairawk | - | 20 | 3 | 100 | S |
| 13 | Anaikomban X P.jajee | 0.53 | 535 | - | 0 | R |
| 16 | Anaikomban X Lairawk | 2.45 | 1140 | 3 | 6840 | HS |
| 113 | K.Valli X P. jajee | 2.35 | 245 | 3 | 1470 | HS |
| 121 | P.jajee X Lairawk | 5.6 | 85 | 1 | 170 | S |
| 110 | K.Valli X P. jajee | 11.3 | 89 | 3 | 445 | S |
| 15 | Sannachenkadali X Lairawk | 8 | 115 | 3 | 1495 | HS |
| 119 | P.jajee X Lairawk | 1.71 | 125 | 3 | 1250 | HS |
| 17 | Burrocemsa X H-3 | - | 175 | 2 | 525 | HS |
| 4 | K.Valli X P. jajee | 2.88 | 60 | - | 0 | R |
| 3 | K.Valli X P. jajee | 4.2 | 730 | 4 | 15330 | HS |
| 8 | Matti X Anaikomban | 2.67 | 480 | 4 | 9600 | HS |
| 6 | K.Valli X P. jajee | - | 1125 | 4 | 33750 | HS |
| 5 | K.Valli X P. jajee | 2.26 | 1800 | - | 0 | R |
| SED | | 18.88 | | | 0.39 | |
| CD (P=0.05) | | 37.81 | | | 0.71 | |
| CV% | | 6.09 | | | 17.50 | |

RLI- Root Lesion Index

1 = no infection; 2 = 1-10 lesions; 3 =11-15 lesions; 4 = 16-20 lesions; 5 = above 20 lesions

** Host reaction R- Resistant; S - Susceptible; HS - Highly susceptible

### Effect of bio-inoculants on the secondary hardening of cv. Grand Naine

The experiment was conducted with four treatments viz., KP VAM + *Rhizobium*, KP VAM + *Azatobacter*, KP VAM + *Pseudomonas* - PC2 and KP VAM alone with 10 replications in a completely randomized design. The control was Grand Naine plants without bio-inoculants. The treatments were imposed twice i.e., during the primary and secondary hardening stages respectively. Data on growth parameters recorded both during the primary and secondary hardening stages. Results indicated that non-significant differences existed in primary stage among the various treatments for all growth parameters except for longest root length and it was maximum in KPVAM + *Rhizobium* (4.9 cm). Results of secondary hardening indicated that highly significant differences existed among the treatments and treatment KPVAM + *Rhizobium* was found better in terms of root length, plant girth and leaf area followed by KPVAM + *Azatobacter* (Fig. 5).

Control | Kp VAM + *Rhizobium* | Kp VAM + *Azatobacter* | Kp VAM + PC2 | VAM

Fig. 5. Effect of bio-inoculants on the secondary hardening of cv. Grand Naine

## 5.1.2 Improvement of banana through conventional breeding

### Diploid breeding and development of synthetic diploids

A total of 55 (AA x AA) crosses were made and got 96 seeds which were initiated for regeneration under *in-vitro*. Four cross combinations (cv. Rose x Pisang Lilin; cv. Rose x Calcutta -4; Pisang Lilin x Pisang Lilin; Pisang Lilin x Calcutta -4) have germinated and regenerated into plantlets.

For the first time, seed set was observed in crosses involving AB genotypes. In AB x AA combination 5 crosses were made and seed set was observed in only two cross combinations *viz.,* Adukka Kunnan x Pisang Jajee and Adukka Kunnan x Narmine resulting in 135 seeds. Seed from one combination (Adukka Kunnan x Pisang Jajee) germinated under *in-vitro* through embryo culture and 10 plants are being hardened.

### Improvement of Pisang Awak for resistance to Fusarium wilt and dwarfness

For improving Pisang Awak cultivars, 25 bunches from 14 different accessions belonging to Pisang Awak subgroup were crossed which resulted in 2678 hybrid seeds and were initiated *in-vitro.* Enna Benian was the best female parent exhibiting an average of 438 seeds per bunch while Bhurkel produced only three seeds per bunch. Out of 14 fertile bunches, only three combinations with Pisang Jajee exhibited *in-vitro* germination. At Agali, 55 bunches belonging to Pisang Awak sub group were crossed with potential male parents and harvesting of crossed bunches is in progress (Table 7).

To improve NRCB developed variety Udhayam for Fusarium wilt resistance and dwarfness, a cross was made with resistant AA diploids resulting in 220 hybrid seeds and all these seeds are in embryo culture.

### Improvement of cooking bananas

For the improvement of superior cooking clones to Fusarium wilt resistance and other biotic stresses, Pisang Jajee, Pisang Lilin, Calcutta-4, Anaikomban, Sanna Chenkadali, cv. Rose and Calcuttta-4 were used as male parents (Table 7). A total of 159 bunches of Monthan, Saba, Kothia, and Bangrier were crossed and out of these, seed set was observed in only 19 crosses resulting in 619 hybrid seeds. Among the parents, Kothia was found to be the best female parent (>190 seeds/bunch) (Fig. 6). All these seeds were initiated *in-vitro*, of which

Table 7. Evaluation of Pisang Awak members for best female parents and production of hybrid progenies

| Female Parent | Total bunches crossed | No of fruits | % female fertility | Total no of seeds | % seed set / bunch | seeds/ fruit (average) | No of good seeds | % germination *in-vitro* | % germination *in-vivo* |
|---|---|---|---|---|---|---|---|---|---|
| Agni Malbhog (ABB) | 4 | 663 | 11.1 | 114 | 75.0 | 0.1 | 57 | 0.0 | 7.0 |
| Ankur-II (ABB) | 64 | 1890 | 66.6 | 1407 | 23.4 | 0.7 | 1095 | 0.4 | 0.0 |
| Bankela (ABB) | 21 | 2142 | 77.7 | 3300 | 80.9 | 1.5 | 2599 | 0.0 | 0.0 |
| Boddida Bukkisa (ABB) | 2 | 224 | 11.1 | 5 | 50.0 | 0.02 | 3 | 0.0 | 0.0 |
| Boothibale (ABB) | 6 | 720 | 22.2 | 221 | 83.3 | 0.3 | 172 | 0.0 | 1.2 |
| Chinia (ABB) | 10 | 1872 | 33.3 | 956 | 90.0 | 0.5 | 822 | 0.0 | 0.4 |
| Dakssin Sagar (ABB) | 4 | 576 | 11.1 | 114 | 75.0 | 0.1 | 57 | 0.0 | 0.0 |
| Desshikadali (ABB) | 7 | 384 | 22.2 | 91 | 28.5 | 0.23 | 61 | 0.0 | 0.0 |
| Enikomban (ABB) | 1 | 112 | 11.1 | 121 | 100.0 | 1 | 64 | 0.0 | 0.0 |
| Ennabenian (ABB) | 11 | 1020 | 33.3 | 1355 | 45.4 | 1.3 | 1214 | 0.0 | 0.0 |
| Gauria (ABB) | 3 | 126 | 11.1 | 114 | 33.3 | 0.9 | 66 | 0.0 | 0.0 |
| Karpuravalli (ABB) | 16 | 640 | 33.3 | 366 | 25.0 | 0.5 | 257 | 0.0 | 3.5 |
| Nepalivannan (ABB) | 7 | 900 | 33.3 | 142 | 85.7 | 0.1 | 101 | 0.0 | 0.0 |
| Udhayam (ABB) | 151 | 4913 | 66.6 | 1808 | 11.2 | 0.3 | 1336 | 4.1 | 0.0 |
| Poombidiyan (ABB) | 4 | 182 | 11.1 | 18 | 50.0 | 0.07 | 14 | 0 | 27.7 |

Fig. 6. Seed set in Kothia (ABB)

<8.0% of seeds have shown signs of regeneration.

## Field evaluation of F1 progenies

Phenotyping of F1 progenies 37 progenies have been phenotyped for 121 morphotaxonomic characters. Study on nutritional contents of parthenocarpic progenies has been completed for 4 progenies.

## Evaluation of NRCB selection -003

Evaluation of NRCB Sel- 003 for the second consecutive year has proved its superiority over local check (Monthan) with respect to all fruit traits. Improved selection exhibited 17.53% increase in yield over local Monthan (Table 8).

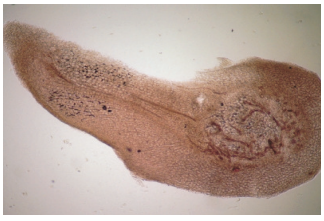
## Histological studies on somatic embryo development.

Histological sections of differentiated somatic embryos (Fig. 7) showed a bipolar structure with the shoot and root apices with trifid vascularization, and entirely surrounded by an epidermis. Sections also revealed distinct cell types, a parenchyma in the outer cells layer and several vascular tissues in the central zone. The parenchyma cells were larger in size and the vascular tissues were small cells, which exhibited a marked contrast between the tissues. The section reveals further development of vascular traces.

Table 8. Performance evaluation of NRCB Selection -003 with local check Monthan

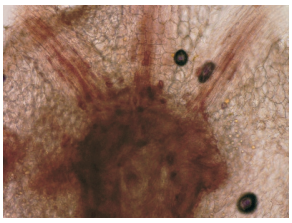
| Varieties | Height (in cm) | Days taken for shooting | Days taken for bunch maturation | Duration | Bunch weight (Kg) | No. of hands | Total no. of fruits |
|---|---|---|---|---|---|---|---|
| Bangrier (NRCB Selection) | 370.30b | 287.00b | 95.80b | 382.80b | 28.15a | 9.40a | 116.40a |
| Kanchikela | 396.60a | 293.20a | 106.30a | 399.50a | 22.55b | 8.50b | 107.80b |
| SEd | 6.34 | 1.98 | 1.79 | 2.13 | 0.74 | 0.31 | 1.77 |
| CD (p=0.05) | 14.35 | 4.48 | 4.06 | 4.84 | 1.69 | 0.71 | 4.00 |
| CV% | 3.70 | 1.53 | 3.98 | 1.22 | 6.60 | 7.86 | 3.53 |
| Level of significance | ** | ** | ** | ** | ** | * | ** |

** Highly significant, * Significant

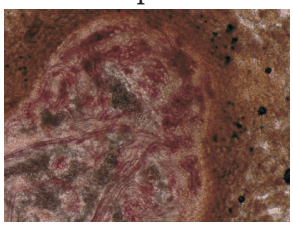


a. Germinating embryo

b. Embryos showing shoot primordia



c. Scattered Vascular bundle



d. Embryos showing root primordial

Fig. 7. Histological sections of differentiated somatic embryos at various developmental stages

For the first time, F1 seeds of triploid x diploid crosses namely Chakkarakeli X Pisang Jajee, Bankela X Pisang Jajee, Dakshin sagar x Pisang Jajee and Monthan x Pisang Jajee have germinated under *in vitro* conditions.

For the first time, seed set in cv. Ladies Finger was observed when crossed with Pisang Jajee (AA). Only two seeds germinated and were planted in field.

Hybrid seeds derived from four cross combinations namely Marabale x Pisang Jajee, Sakkai x Pisang Jajee (3X x 2X) and synthetic diploids of cv.Rose x Pisang Lilin and Pisang Lilin x Pisang Lilin, have germinated out of 24 crosses.

### 5.1.3 Improvement of banana through non-conventional approaches

#### *Mass multiplication protocol for near extinct landrace Manoranjitham*

*In-vitro* mass multiplication of cv. Manoranjitham exhibited rapid multiplication rate with 19.86 buds from a single clump in shoot multiplication media. From three shoot tips, 120 plantlets have been regenerated and transferred to rooting medium and 53 cultures are in the proliferation stage (Fig 8 & 9).

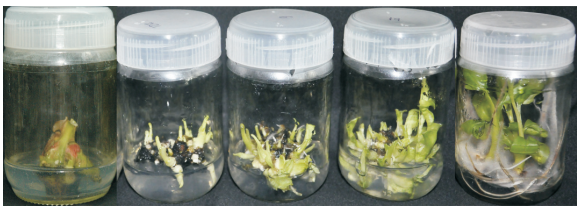


Fig. 8. Different stages of multiplication of cv. Manoranjitham

Fig. 9. Shoot multiplication

## Multiplication protocol for *M.boman*, of Australimusa section

Different modified media were tried for multiplication of *M.bomban*, among them medium with 50% growth promoters T2 (MS half strength + BAP – 1.5mg & IAA .5mg) was found successful for better shoot proliferation followed by T4 media without any growth promoters (Fig. 10).

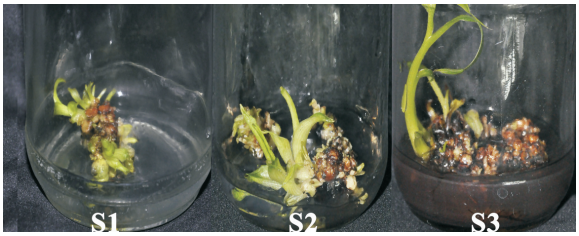
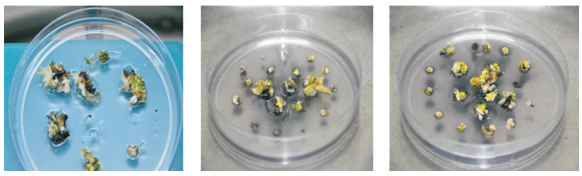



Fig. 10. Different Stages of shoot proliferation in *M. boman*

## Direct plant regeneration from immature flower buds

Direct plant regeneration from immature male flower buds of cv. Robusta ( Fig. 11) showed good response for regeneration of leafy clusters within 60 days of initiation in all the treatments tried except M1 medium ( Table 9) The proliferating clusters were transferred to six different media combinations. Among these, MS medium supplemented with BAP and IAA showed better response for rapid proliferation. However, the bud proliferation was maximum in M5 derived shoots on subculturing in T6 medium (Table 10). The cv. Rasthali also showed good response for leafy cluster



Grand Naine Rasthali Robusta

Fig. 11. Direct plant regeneration from immature flower buds

Table. 10. Standardization of best media for shooting

| Treatments | Basal medium | BAP | TDZ |
|---|---|---|---|
| **M1** | MS | 8mg/1 | - |
| **M2** | MS | 10mg/1 | - |
| **M3** | MS | - | 0.4mg/1 |
| **M4** | MS | - | 0.5mg/1 |
| **M5** | MS | 8mg/1 | 0.4mg/1 |

formation in the medium such as M2, M3 and M4 with an earliest of 49 days in M2 and maximum of 56 days in M3.

Initiated leafy clumps from M2, M3, M4 and M5 were then transferred to other six media combinations for proliferation and shoot regeneration. Among the six media combinations tried, T6 showed good response to proliferation of initiated leafy clumps.

## Regeneration of ECS and plantlet development in cv. Udhayam

For the first time, somatic embryogenesis has been reported in cv. Udhayam. Immature male flower buds were initiated in MA1

Table 9. Standardization of media for proliferation

| Treatments | Nature of Response | |
|---|---|---|
| | % of Proliferation (cv.Robusta) | % of Proliferation (cv.Rasthali) |
| **T1 (**MS+ 3mg/l BAP +1mg/lGA3**)** | **12%** | **10%** |
| **T2 (**1/2MS**)** | **0** | **0** |
| **T3 (**MS+3mg/l BAP+0.5mg/l GA3+1mg/l Kin **)** | **25%** | **29%** |
| **T4 (**MS+2mg/l BAP+ 0.5mg/l TDZ **)** | **53%** | **50%** |
| **T5 (**1/2MS+3mg/l BAP+1mg/l IAA**)** | **15%** | **20%** |
| **T6 (**MS+3mg/l BAP+1mg/l IAA**)** | **90%** | **86%** |

medium and it took 6-7 months for embryogenic callus formation. When proembryos were transferred to MA2 medium, it had exhibited good proliferation (Fig. 12).

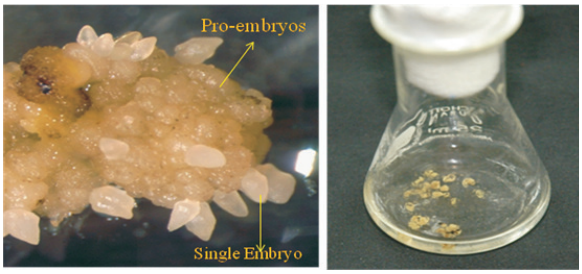



Fig. 12. Development of pro embryos and development of ECS in cv. Udhayam

## Proteomic studies of embryo development

Besides shoot tip cultures, somatic embryogenesis could also be exploited as a mass multiplication technique. But the response is highly genotype dependant and is not successful in all the commercial varieties due to recalcitrance of varieties to become embryogenic. The problem was approached through proteomic analysis during the process of callus formation across contrasting (embryogenic and non - embryogenic cultivars) genotypes. The protein extraction from the non - embryogenic calli (two types of calli, white calli -WC and brown calli - BC) was standardized in cv. Rasthali. Among three different extraction methods namely TCA/ acetone, phenol and phenol+TCA, phenol alone followed by Phenol + TCA combination gave better results in terms of quantity and quality of protein (Fig. 13) . The protein of 34KDa was found to be highly expressed in white non embryogenic calli compared to brown calli. Also the Protein of 16KDa was found to be expressed only in brown non embryogenic calli. Colloidal CBB and silver staining resulted in improved identification and visibility of low abundant proteins in both fresh and stored samples of non-embryogenic calli (Fig. 13).

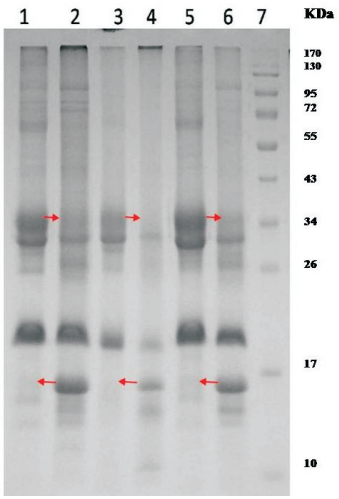
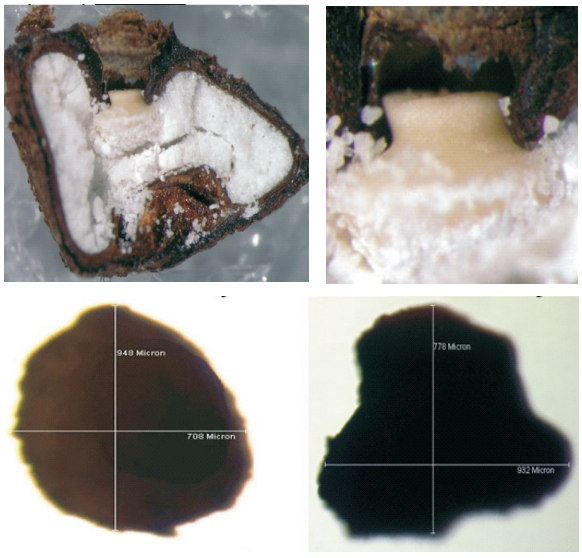



Fig. 13. SDS - PAGE gel picture of Non embryogenic calli protein of Rasthali

Lane 1-Protein from WC by Phenol method, Lane 2 - Protein from BC by Phenol method, Lane 3-Protein from WC by TCA method, Lane 4-Protein from BC by TCA method, Lane 5-Protein from WC by Phenol+TCA method, Lane 6-Protein from BC by Phenol+TCA method, Lane 7-Phage marker (10-170 KDa)

## 5.1.4 Embryo culture studies in Banana

Hybrid seeds of the cross Pisang Jajee x *M.acuminata* ssp. *burmannicoides* were extracted after full maturity. The intact seeds were hydroprimed for 1, 2, 3, 4 and 5 days. Results indicated that hydropriming for three days induced germination upto 40.80%. The




T. S of embryo L. S of embryo

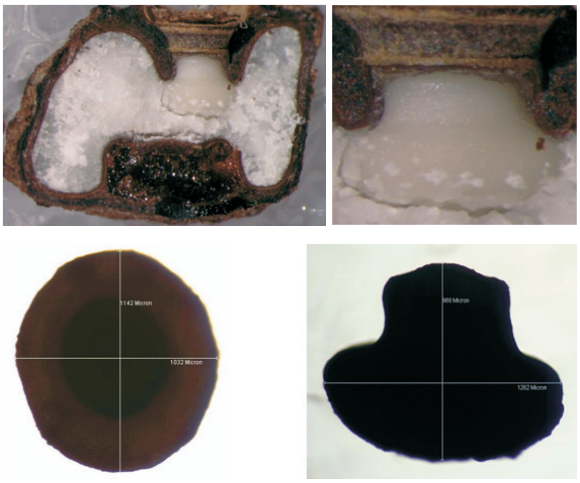
Fig. 14. physical features of seed and embryo (cross section) before hydropriming

Table 11. Effect of soaking duration on physical parameters of hybrid banana seeds

| S.No. | Soaking hours | Initial weight (g) | Final weight (g) | Difference (mg) | % weight gain |
|---|---|---|---|---|---|
| 1 | 24 hrs | 510.8 | 590.7 | 79.9 | 15.64 |
| 2 | 48 hrs | 468.4 | 561.6 | 93.2 | 19.90 |
| 3 | 72 hrs | 497.0 | 606.6 | 109.6 | 22.00 |
| 4 | 96 hrs | 461.5 | 563.3 | 101.8 | 22.06 |
| 5 | 120 hrs | 509.7 | 610.4 | 100.7 | 19.76 |

difference in weight was found to increase upto 3 days and after which it started declining as depicted in the table 11.

There was a significant enlargement of the embryo after hydropriming for five days as depicted in the figure. The difference in embryo size before and after hydropriming was 364µm and 288µm in the transverse and longitudinal sections respectively (Fig. 14 & 15).



T. S of embryo L. S of embryo

Fig. 15. Physical features of seed and embryo (cross section) after hydropriming

## Embryo rescue in hybrid embryos

Embryo rescue was attempted in *M. ornata* hybrids at 60, 80 and 100% maturity (Fig. 16). The immature embryos were initiated in eight different media containing BAP and Kinetin at different levels for direct and indirect organogenesis in immature zygotic embryos. Results indicated that both 60 & 80 % matured embryos are suitable for callus formation (Fig. 17).

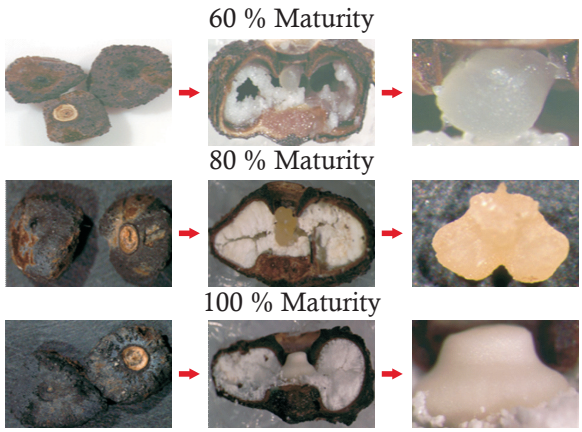
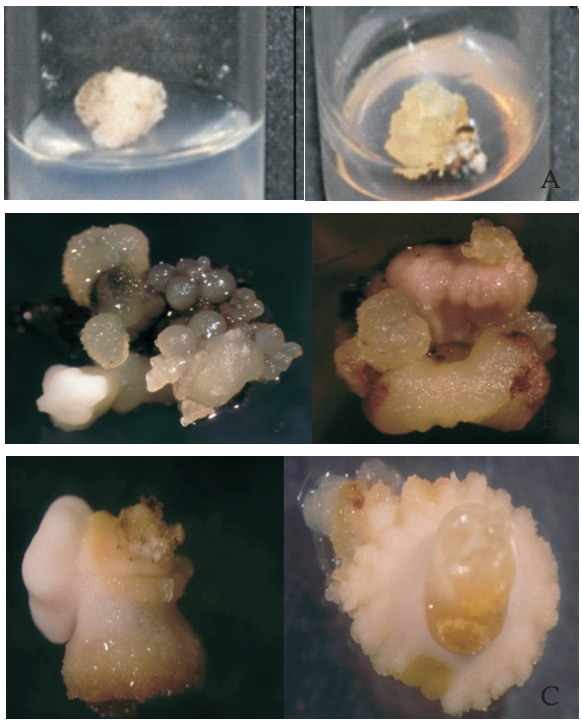



Fig. 16. Cross section of seed at various stages of embryo development




Calli from A. 60 % , B. 80 % and C. 100 % matured hybrid embryos

Fig. 17. Different types of calli derived from hybrids embryos

### Multiple shoot induction studies in hybrid embryos

Mature embryos of the cross, Manoranjitham x Pisang Lilin, were initiated in different media with different growth regulator combinations. Media supplemented with BAP + IAA (1.0mg/l & 0.5mg/l) and NAA + IBA (2.0mg/l & 1.0mg/l) resulted in multiple shoots (6-8) (Fig. 18).

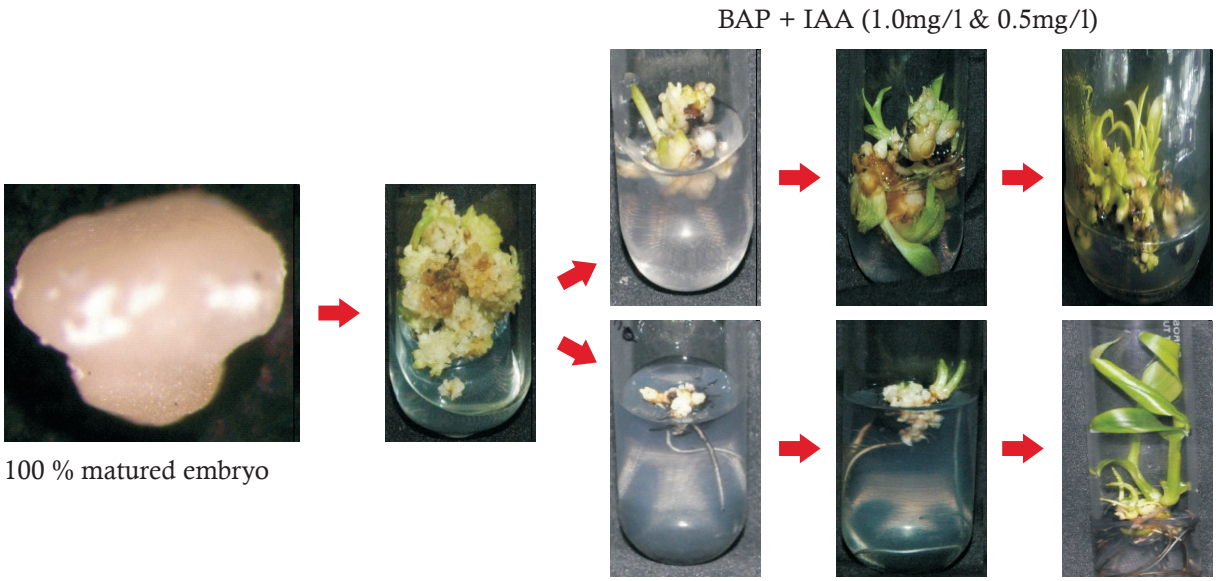



Fig. 18. Multiple shoots from single hybrid embryo of Manoranjitham x Pisang Lilin cross

### Somatic embryogenesis and ECS development of hybrid embryos

For the first time, somatic embryogenesis in hybrid embryos of Marabale x Pisang Jajee (AAB x AA) was established in MA1 medium. A part of the proembryos have been initiated in liquid culture (MA 2 medium) for the establishment of ECS and the rest was regenerated directly using MS medium supplemented with BAP + Kinetin + NAA (Fig. 19).

### 5.1.5 Development of di-haploids in banana through anther culture

Standardization of techniques to develop di-haploids was initiated using a large number of diploids (AA and BB) and the results indicated that flower buds with a size of 12-16cm, flowers of 3-5cm length and 1-3 cm width anthers having uni-nucleate pollen was best to use under *in vitro* culture. Eight diploids were tried with four basal media having 25 different growth regulator combinations. Direct regeneration was obtained with cv. Sasrabale (BB) in NN medium, while callus formation was observed in B5 medium. Both media had the same hormonal combinations of BAP (1.0 mg/lit) and IAA (0.4mg/lit). Callus formation was also observed in cvs. Hatidat, Pisang Jajee and Attikol with MS and NN media. Studies across various diploid (AA and BB) cultivars have revealed that callus development generally takes about 3-6 months after initiation (Fig. 20 & 21).

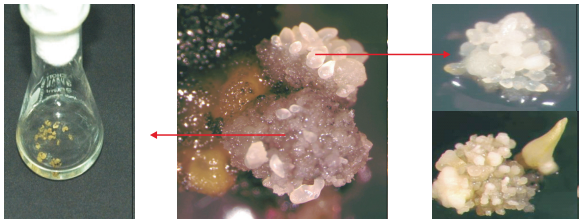



Fig. 19. Direct and indirect regeneration of somatic embryos of hybrid Marabale x Pisang Jajee

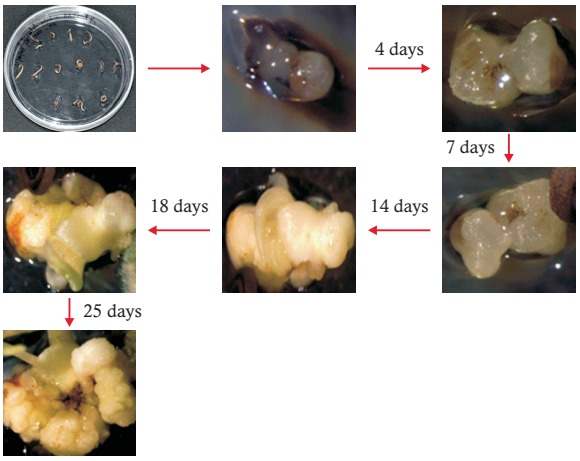



Fig. 20. Developmental stages of direct regeneration observed with anther culture of cv. Sasrable (BB)

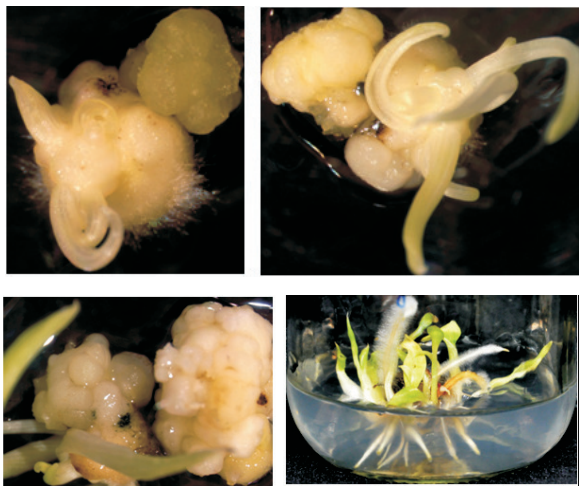


Fig. 21. Different stages of shoot multiplication

### Development of linkage maps

Parental polymorphism survey of the parents Phirima wild and Calcutta 4 using 45 markers led to the identification of 27 polymorphic SSRs, which will be used in the segregating population, which in turn useful for the development of linkage maps.

## 5.1.6 Improvement of Rasthali through induced mutagenesis

### Screening of mutants for Fusarium wilt resistance

The ethyl methane sulphonate derived plantlets of Rasthali were screened under pot conditions using *Foc* @ 30g/pot (VCG 0124) and scored for the incidence of Fusarium wilt after eight months of inoculation. Results indicated that three plants exhibited no symptoms and six plants scored two on the disease scale of 1-6 (Fig. 22).

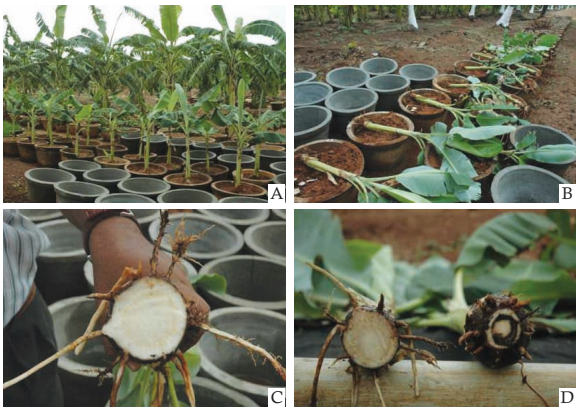



Fig. 22. Screening for Fusarium wilt resistance in EMS derived Rasthali plants

A. Challenging with spores of *Foc* race 1 @ 30g/pot
B. Disease scoring after 8 months of *Foc* inoculation
C. Putative Rasthali mutant with Fusarium wilt resistance
D. Healthy and diseased Rasthali mutants

The putative mutants identified through pot screening were initiated *in vitro* for mass multiplication and further screening. The stringency of screening was increased by using higher concentrations of Fusaric acid (0.0375 and 0.05 mM) and culture filtrate (5, 6, 7 and 8%). It was observed that 50% of the shoots survived at 0.05 mM and 7% fusaric acid and culture filtrate respectively. The plantlets derived after multiplication will be subjected for pot as well as field screening.

Sodium azide derived plantlets of Rasthali were screened with 30g/pot of *Foc* (VCG 0124) twice (3$^{rd}$ and 5$^{th}$) and scored for wilt incidence after seven months of spore re-inoculation. Results indicated that ten plants recorded five score and only one plant scored two on the disease scale of 1-6. The same plant has been initiated *in vitro* for further multiplication and screening (Fig. 23)

Fig. 23. Screening for Fusarium wilt resistance in $NaN_3$ derived plants

1. Challenging with spores of *Foc* race1 @ 30g/pot
2. Disease scoring after 7 months of reinoculation
3. Rasthali mutant with disease score 2
4. Healthy and susceptible Rasthali mutants

### Field evaluation of Rasthali mutants for desirable agronomic traits

Rasthali mutants were planted in the field for the evaluation of desirable agronomic traits other than Fusarium wilt resistance. Regular package of practices were adopted and regular observations on growth and yield parameters were recorded. Observations revealed no significant variations among the mutated and non- mutated control (Table 12).

## 5.1.7 Identification and characterization of nematode resistant gene (s) in banana

Representative RGA specific primers were designed from each RGA family to study the expression profile of *Musa* RGAs. The time course expression studies on nematode inoculated root tissues showed that C6 RGA was expressed only in resistant cultivar and not in susceptible one. It was also observed that transcript level of C1 and C5 RGAs were upregulated only in resistant cultivar Karthobiumtham, while the transcript level of C2 and C3 RGAs was static in both resistant and susceptible (Nendran) cultivars (Fig ). This suggested that C1, C5 and C6 RGAs transcripts might be related to resistance of Karthobiumtham against root lesion nematode (*P.coffeae*) (Fig. 24).

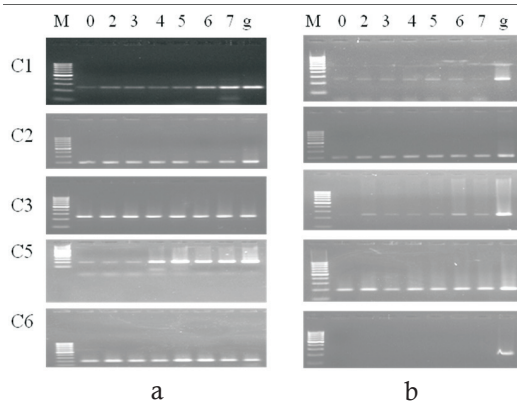



Fig. 24. Expression profiles of Musa RGAs C1, C2, C3, C4, C5 and C6 at 0, 2, 3, 4, 5, 6, 7 days after inoculation with *P.coffeae* in a) resistant cultivar Karthobiumtham b) susceptible cultivar (Nendran) g-genomic DNA

### Full-length isolation of ATP synthase

Based on the expression studies, it was found that mRNA levels were upregulated in

Table 12. Yield and quality traits recorded in Mutated Rasthali

| Explant | Treatments | No. of days taken for flowering | No. of days taken for harvesting | Bunch weight (Kg) | No.of hands | No. of fingers | TSS Brix | Acidity (%) |
|---|---|---|---|---|---|---|---|---|
| P.B | EMS 0.6% for 1/2hr | 331 | 123 | 5.5 | 5 | 60 | 21.4 | 0.25 |
| P.B | EMS 0.6% for 1/2hr | 353 | 123 | 6.0 | 6 | 75 | 20.9 | 0.24 |
| P.B | EMS 0.6% for 1/2hr | 340 | 126 | 6.0 | 5 | 60 | 21.9 | 0.20 |
| S.T | $NaN_3$ 0.02% for 5 hrs | 334 | 126 | 6.0 | 5 | 61 | 22.0 | 0.21 |
| Control | Non-mutated Rasthali | 344 | 121 | 6.5 | 5 | 64 | 22.0 | 0.22 |

P.B.- Proliferating buds and S.T. – Shoot tips

the *P.coffeae* infected root samples for the genes such as ATP synthase, isoprenoid biosynthesis like protein, peroxidase, NADH-plastoquinone oxidoreductase, protease inhibitor, chitinase, metalothionine, C5 and C6 RGAs. Hence, efforts were made to isolate the full length of some of the selected genes like ATP synthase, which is involved in the production of inception elicitor that activates plant defense responses and RGAs that are involved in signal transduction pathway. By using RACE-PCR, ATP synthase (1447bp) and C6 RGA (2028bp) genes were isolated from cv. Karthobiumtham and sequenced. The result of sequence analysis showed 98% homology to the *M.acuminata* ATP synthase beta sub unit and 97% homology to the Maize and Rice ATP synthase.

## Development of functional EST-SSR markers for *P. coffeae* nematode resistance

From the *Musa* EST-SSR database developed at NRCB, class I SSRs (>20 nucleotide) alone were screened for di, tri, tetra and penta repeats, which resulted in 240 ESTs. All the ESTs were annotated to know the putative function and found that 128 ESTs are having some specific functions. Of which, 86 ESTs were hit with resistance related genes or genes involved in defence pathway/signal transduction. From these ESTs, 14 ESTs were chosen based on high query coverage and identity percentage. The primers designed to all these ESTs were tested against the nematode resistant and susceptible cultivars, of which four primers namely SSR22 (Ethylene response transcription factor (GA 12), STR4 (longin like protein (T16), STR17 (RAS related protein (AGGG) 5 and STR8 (dehydrin gene (GGA7) showed clear polymorphism (Fig. 25)

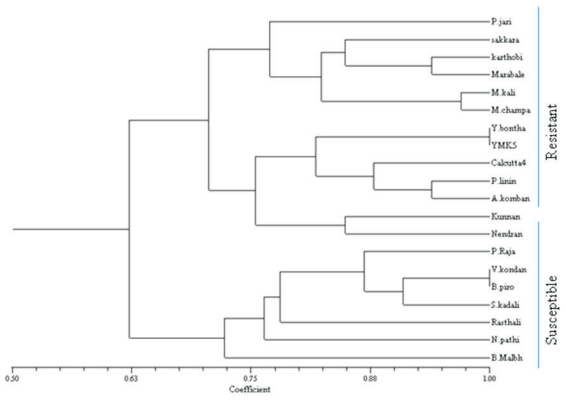



Fig. 25. The dendrogram showing the genetic variation between the resistant and susceptible *Musa* accessions by using UPGMA cluster analysis by using STR4, STR8, STR17 and STR22 EST-SSR primers.

## Study on transferability of EST-SSRs derived from cultivated banana accessions.

To know the transferability of banana's EST-SSRs, 24 randomly selected EST-SSRs representing di, tri, tetra, penta and hexa repeat (each two) primers were used for testing against different species of *Musa* such as *M.acuminata, M. balbisiana, M. ornata, M. laterita, M. nagensium, M. itinerans, M. sikkinensis* and related genus Ensete. (*Ensete superbum* and *E.glaucum)* (Fig. 26). The amplification results showed that all the 21 functional EST-SSR primers produced amplicons in all *Musa* and *Ensete* species of *Musa*ceae. Similarly, transferability in related family of order Zingiberale revealed that out of twenty-one polymorphic EST-SSR markers, transferability was observed for *Zingiber officinale* (12)*; Curcuma longa* (10) and *Elettaria cardmomum* (12) of family Zingiberaceae. This high percentage of cross species, cross genera and cross family transferability suggested that these *Musa* EST-SSR markers will be a valuable resource for the comparative mapping by developing COS markers, in evolutionary studies and in improvement of the members of Zingiberaceae and Musaceae.

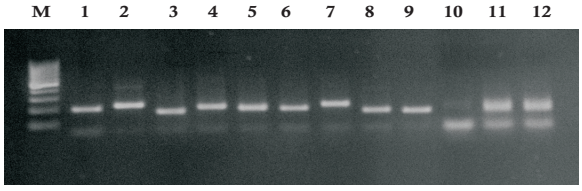



Fig. 26. Amplification patterns obtained with primer MESSR17 in 3% agarose gel electrophoresis of various genera of order Zingiberales.

Lane 1. *Musa acuminata;* 2. *M. balbisiana;* 3. *M. ornate;* 4. *M. laterita;* 5. *M. negensium;* 6. *M. itinerans;* 7. *M. sikkimennis;* 8. *Ensete superbum ;* 9. *E. glacum;* 10. *Zingiber officinale;* 11. *Elettaria cardamomum;* 12. *Curcuma longa, M-Marker*

## 5.2 CROP PRODUCTION

### 5.2.1 Standardization of agro techniques for banana production and productivity

#### Standardization of spacing and nutrient requirements for banana cv. Udhayam (ABB)

In first ratoon crop, plants at wider spacing 2.1X2.4m (1984 plants/ha) recorded significantly the highest bunch weight (30.3 kg) plant$^{-1}$, number of hands (16.1) and fingers (273.4) followed by 2.1X2.1m spacing (2267 plants/ha). Whereas, plants at 1.8 X 1.8m spacing (3086 plants./ha) recorded the lowest bunch weight (24.6 kg), hands (14.4) and fingers (254.6) per bunch (Fig. 27).

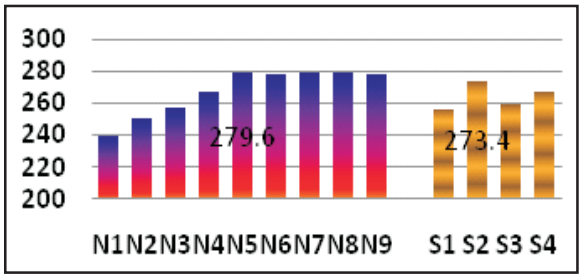



Fig. 27. Effect of spacing and N&K nutrition on number of fingers / bunch

Among nine different combinations of N&K fertilizers, application of 300g N and 400g K plant$^{-1}$ was found optimum and recorded the highest bunch weight of 30 kg with more number of hands (15.65) and fingers (279.6) per bunch, the highest TSS (29.6° B), pulp peel ratio

Fig. 28. Udhayam bunch at 2.1X2.4m spacing with 300:400 N&K plant$^{-1}$

(6.82) and the lowest fruit acidity of 0.53% (Fig. 28). The treatment also recorded the highest benefit cost ratio of 2.97. Whereas, the least bunch weight (18.6 kg), hands (14.1) and fingers (230.9) per bunch were recorded with the lowest fertilizer dose of 200:300g N&K plant$^{-1}$.

#### Standardization of stage wise nutrient requirement for Udhayam banana

In a trial on stage wise nutrient requirement for cv. Udhayam, among the three different split doses of fertilizers tried, application of Recommended Dose Fertilizers (RDF) i.e., 300 g N and 400 g K/plant in the ratio of 7:2:1 N and 4:3:3 $K_2O$ during the vegetative, flowering and bunch development stages (N1) recorded the highest bunch weight (34.2 kg) as well as total yield (72.67 t/ha). Whereas, the plants applied with fertilizers in the ratio of 7:3:0 N (i.e., no N during fruit development stage) and 6:2.5:1.5 $K_2O$ (N3) recorded the least bunch weight (27.1 kg) and total yield of 58.27 t/ha (Fig. 29).

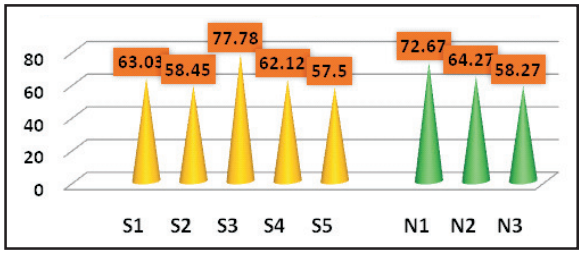



Fig. 29. Effect of stage wise nutrition on total yield (t/ha) in cv. Udhayam

Among all the treatment combinations, the plants at the wider spacing (2.4 X 2.4m) and applied with RDF fertilizers in the ratio of 7:2:1 N and 4:3:3 $K_2O$ during the vegetative, flowering and bunch development stages (S2N1) recorded the highest bunch weight of 38.5 kg/ha with the highest number of hands and fingers (Table 13).

#### Studies on the effect of organics on the BSV and BBrMV infested Poovan banana

The field evaluation on the effect of organics on growth and yield performance of BSV and BBrMV infected Poovan banana revealed that the time taken for fruit maturity

Table 13. Effect of stage wise nutrition on bunch weight in plant crop of cv. Udhayam

| Treatments | N1 | N2 | N3 | Mean |
|---|---|---|---|---|
| S1 | 35.6 | 32.1 | 27.6 | 31.77 [b] |
| S2 | 38.5 | 33.2 | 29.3 | 33.67 [a] |
| S3 | 31.7 | 27.7 | 24.6 | 28.0 [c] |
| S4 | 33.8 | 29.1 | 27.8 | 30.2 [b] |
| S5 | 29.5 | 27.3 | 26.0 | 24.6 [c] |
| Mean | 34.2[a] | 30.38[b] | 27.06[c] | |
| | **S. Ed.** | **C.D. (1%)** | **Significance** | **C.V. %** |
| Spacing (S) | 0.813 | 2.248 | ** | 6.15 |
| Nutrition (N) | 0.630 | 1.741 | ** | |
| S X N | 1.409 | - | NS | |

varied significantly among the organic manures or inorganic fertilizers applied.

Application of 125% RDF inorganic fertilizers significantly advanced the fruit maturity in 123.7 days that was on par with application of 100% RDF inorganic fertilizers (125.9 days). The fruit maturity was delayed in plants applied with different combinations of organic manures and the maturity was delayed significantly in both BSV (131.1 days) and BBrMV (136.5 days) infested plants while the healthy plants took just 118.4 days for fruit maturity (Fig. 30). With regard to the bunch weight and fruit characteristics, among the organics tried, application of 20 kg FYM + 0.9 kg Neem cake + 2.0 kg Vermicompost + 0.9 kg groundnut cake recorded the highest bunch weight (18.6 kg) with more number of hands (12.3) and fingers/ bunch (192.5) (Fig. 31). The same treatment also recorded the highest finger weight, length and girth. Besides, the fruit TSS (23.4° B) was more with low acidity (0.56 %) as compared to other treatments.

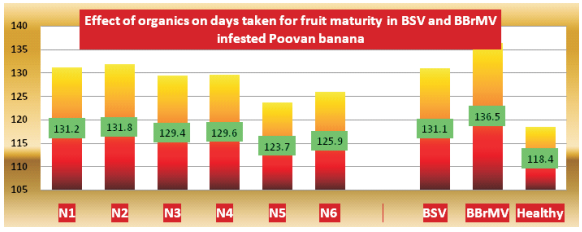



Fig. 30. Effect of organics on days taken for fruit maturity in BSV and BBrMV infested poovan banana

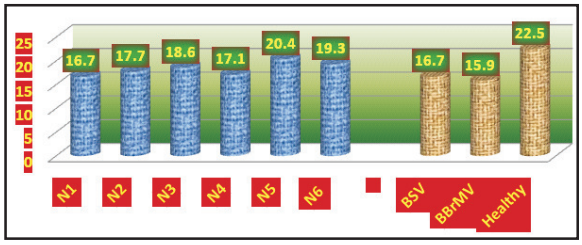



Fig. 31. Effect of organics on bunch weight (kg plant $^{-1}$) in BSV and BBrMV infested poovan banana

### 5.2.2 Studies on micronutrients in banana

Application of five g ferrous sulphate + 20g sulphur per plant at three months after planting (MAP) along with foliar spray of 0.5% each of zinc sulphate and borax at 3, 5 & 7 MAP recorded the highest bunch weight of 16.6 kg (40% more than control) and generated a net additional profit of Rs.53750/- per hectare, in Ney Poovan (ratoon-I). Sulphur application increased the plant growth and yield parameters like plant height (11.9%), girth (5.96%), number of leaves (4.41%), total leaf area (4.09%), number of fingers (2.23%) and bunch weight (14%) than without sulphur. Sulphur application also increased the leaf nutrient concentrations like N, P, K, Ca, Mg and S significantly than without sulphur application by 1.53, 0.12, 7.34, 43.48, 23.81 and 72.73% respectively. The highest B: C ratio of 3.18 was observed without S application and 3.00 with S application along with foliar spray of micronutrients. Soil application of Fe & foliar application of Zn and

B with S application recorded the highest TSS, lowest acidity and highest pulp:peel ratio of 31.2°Brix, 0.39% and 7.79 respectively while without S, they were 29.8°Brix, 0.41% and 7.46, respectively.

It was observed that the bunch weight was highly correlated with leaf K (r= 0.591**) and S (r=0.44*) in the sulphur applied plants. In the sulphur applied plants, leaf K recorded the highest 'r' values with plant height (0.522**), pseudostem girth (0.49**), total number of leaves (0.569**) and total leaf area (0.493**) indicating increased K use efficiency in banana, in the presence of sulphur (Table 14).

## Fertilizer tailoring for targeted banana yield and sustainable soil health

Under fertilizer tailoring experiment with Grand Naine banana at Erasai (Chinnamanur, Theni Dt., Tamil Nadu), the following fertilizer adjustment equations were developed.

**FN = (8.80*T) – (0.73*SN) – (0.32* ON)**

**FP = (0.84*T) – (0.77*SP) – (0.37*OP)**

**FK = (11.21*T) – (0.44*SK) – (0.39*OK)**

Where, T is yield target (t/ha), FN, FP & FK are NPK requirement through fertilizer (kg/ha), SN, SP & SK are NPK available in the soil (kg/ha) and ON, OP & OK are NPK requirement through organic manure (kg/ha). The average bunch weight obtained at different levels of N, P and K are depicted in the fig. 32 & 33.

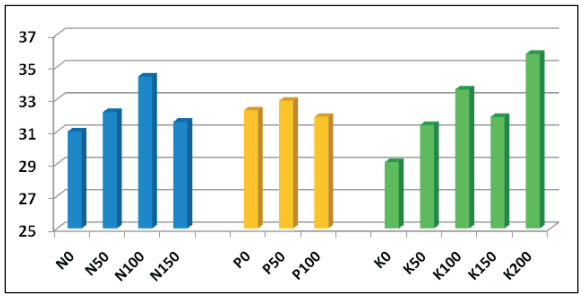



Fig. 32. Effect of graded levels of NPK on bunch weight (kg) in Grand Naine

Fig. 33. Grand Naine bunch under $N_{100\%}$ $P_{50\%}K_{200\%}$ treatment

Table 14. Corrleation between growth and yield parameters with leaf nutrient concentration

| Para - meters | Leaf N% | | Leaf P% | | Leaf K% | | Leaf Ca% | | Leaf Mg% | | Leaf S% | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | -S | +S | -S | +S | -S | +S | -S | +S | -S | +S | -S | +S |
| Plant height | -0.042 | 0.572** | -0.167 | 0.343* | -0.033 | 0.522** | -0.185 | 0.320* | 0.078 | 0.324* | -0.034 | 0.516** |
| Stem girth | 0.232 | 0.420* | 0.152 | 0.304 | 0.196 | 0.490** | -0.177 | 0.254 | 0.016 | 0.265 | 0.155 | 0.371* |
| Total number of leaves | 0.383* | 0.419* | 0.160 | 0.120 | 0.433* | 0.569** | 0.100 | 0.069 | 0.362* | -0.012 | 0.169 | 0.459* |
| Total leaf area | 0.148 | 0.302 | 0.047 | 0.252 | 0.204 | 0.493** | 0.218 | 0.241 | 0.105 | 0.175 | 0.018 | 0.330* |
| Number of fingers | 0.341* | 0.271 | 0.195 | 0.266 | 0.288 | 0.486* | 0.185 | 0.295 | 0.296 | -0.130 | 0.378 | 0.537** |
| Bunch weight | 0.204 | 0.307 | 0.202 | 0.243 | 0.354* | 0.591** | 0.169 | 0.176 | 0.141 | 0.356* | -0.032 | 0.440* |

Correlations coefficients (r) between bunch weight at harvest and leaf NPK concentrations at 4th, 5th, 6th, 7th & 8th months were worked out in Grand Naine banana. The highest 'r' values for leaf N,P,K (0.967**, 0.956** & 0.976**, respectively) were observed between 5th and 7th months. Thus, it indicated that the growth period between 5th and 7th months is very critical with respect to NPK management, in Grand Naine.

## Validation of fertilizer adjustment equations at different ACIRP Centres

A computer software for fertilizer tailoring in different banana varieties was validated at various AICRP Centers *viz.,* Arabhavi (Karnataka), Coimbatore (Tamil Nadu), Kannara (Kerala), Kovvur (Andhra Pradesh) and Mohanpur (West Bengal) to test the fertilizer adjustment equations developed by NRCB. The following outcomes were obtained.

### Coimbatore

1. Application of 228 g N, 20 g $P_2O_5$, 372 g $K_2O$ per plant recorded the highest estimated bunch yield (35 t/ha), which was 79.54% of the targeted yield (44 t/ha). The yield obtained was however higher (24.4%) than the control.

2. The actual yield obtained was higher than the predicted yield at lower targets. The targeted yield and expected yield was the same at 33 t/ha. Above this target, the actual yield was lower than the targeted yield.

## 5.3 CROP PHYSIOLOGY, BIOCHEMISTRY AND POST HARVEST TECHNOLOGY

### 5.3.1 Crop Physiology

#### Studies on physiology of flowering and fruit development in banana

Growth analyses were studied in popular banana cultivars *viz;* Poovan (AAB), Ney Poovan (AB) and Karpuravalli (ABB). Average maximum (34.95°C) and minimum temperature (24.19°C) and rainfall (1089.97mm) was recorded during growth period. The study indicated that from third month to sixth month, the average leaf production was 4.32 leaves/ month and leaf emergence rate was 1.02 leaves/ week. The leaf area index increased from 0.36 at third month to 1.42 at sixth month. The number of days taken for flowering was 285, 297 and 308 days in Ney Poovan, Poovan and Karpuravalli respectively. The number of hands varied from 9 -13. The relative growth rate (RGR) of plant height and girth varied in the range of 1.2 to 1.7 $cm^{-1}$ $m^{-1}$ $d^{-1}$and 0.3 to 0.7 $cm^{-1}$ $m^{-1}$ $d^{-1}$ respectively during fifth to seventh months. The specific leaf weight (SLW) of Poovan, Ney Poovan, Karpuravalli and Grand Nain was in the range from 0.84 to 1.4 from top fully emerged leaf to down the profile upto 9$^{th}$ leaf (Fig. 34). The increasing trend of SLW was found upto 3-4$^{th}$ leaf and among all cultivars, Karpuravalli recorded higher SLW. The total chlorophyll contents also varied with age of leaves (Fig. 35).

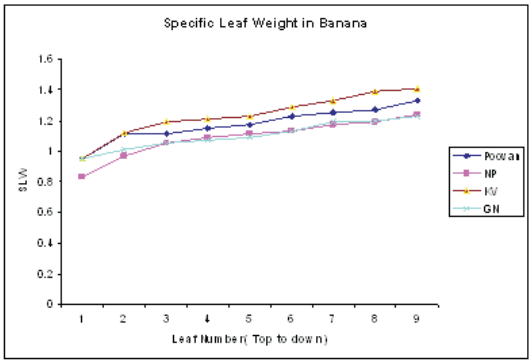



Fig. 34. Specific Leaf Weight (SLW) of banana plant down the profile

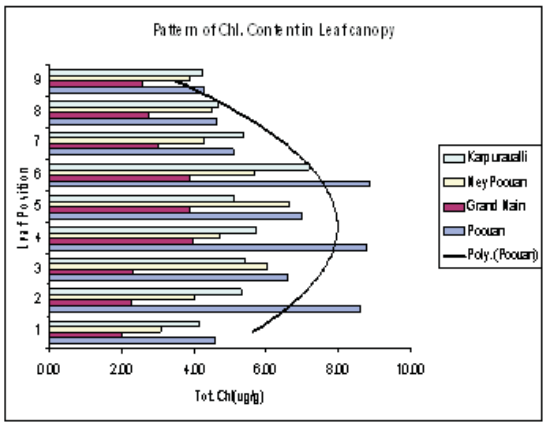



Fig. 35. Pattern of chlorophyll content variation in the leaf canopy

The chlorophyll content was lower in the first to third leaf and gradually increased up to sixth leaf and then decreased gradually to down the canopy. Dry matter partitioning of banana cultivars studied at flowering in Poovan, Karpuravalli and Ney Poovan showed that dry matter was allocated more to foliage (32-46%) followed by corm (29 -36%), pseudostem ( 26 - 32%) and flower (2 %). At 90 % fingers maturity, L/B ratio of 0.94 to 1 and total sugar content of 0.35 mg/g of pulp was recorded. Among the banana cultivars studied, Poovan recorded higher harvest index (HI) of 0.44 followed by Grand Naine, Ney Poovan and Karpuravalli, which recorded lower HI of 0.26, 0.24 and 0.23 respectively.

#### Drought stress tolerance in banana

In a pot experiment, drought tolerant indicators were evaluated in different banana cultivars. The results indicated that epicuticular wax, relative water content (RWC), osmotic potential, proline, sugar and ascorbate peroxidase were higher in Poovan, Saba, Ney Poovan, *M.balbisiana* and Monthan banana cultivars as compared to Nendran and Grand Nain plants. The study on diurnal behaviour of *in situ* water potential (WP) of Poovan banana plant indicated that the water potential was around -0.23 to – 0.25 Mpa in the morning and then decreased further and maintained around -0.6MPa from morning (10 AM to 7 PM) to evening. However during night hours the WP decreased due to rehydration (Fig. 36).

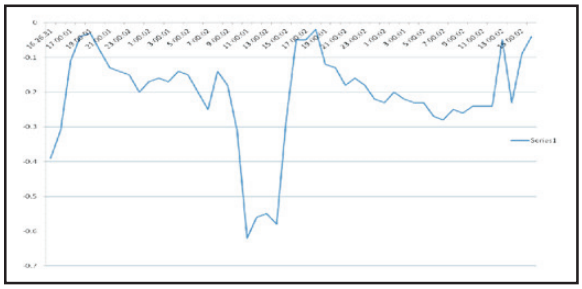


Fig. 36. Diurnal fluctuation on Water Potential

### Salt stress tolerance in banana

Saba (tolerant) and Nendran (susceptible) banana cultivars were subjected to salt stress with NaCl at 150mM concentration. After two weeks of salt treatment, new leaf production was ceased and lower leaves became scorched and senescenced. The dry matter of salt stressed leaf was decreased by 45% in cv. Nendran, where as it was 18% in cv. Saba compared to control. Similarly, chlorophyll pigments was also reduced by 29.14% in Nendran and 12.72% in Saba. The sodium and potassium contents were in the range of 2.60 % to 2.93% and 4.0 to 4.97% respectively. The $Na^+/K^+$ ratio was higher in Saba (0.73) than Nendran (0.58) plants.

## 5.3.2 Biochemistry

### Biochemical mechanism of resistance of bananas to *Pratylenchus coffeae*

Protein extraction from leaf and root tissues of banana cv. Anaikomban for identification of differentially regulated proteins on infection by root lesion nematode was carried out. Quantification of proteins by Bradford method showed that phenol-ammonium acetate and TCA-acetone methods yielded higher quantity of proteins from the leaf and root tissues (Table 15).

Table 15. Protein yield by different methods tested for banana leaf and root tissues (mg/g)

| Method | Leaf tissue | Root tissue |
|---|---|---|
| Phenol-Ammonium acetate | 6.80 | 0.89 |
| Trichloroacetic acid-Acetone | 7.10 | 0.85 |
| Tris Buffer | 0.68 | 0.56 |
| Bio-Rad Kit | 0.91 | 0.44 |

Assessment of quality of the proteins extracted from the phenol-ammonium acetate and TCA-acetone methods by SDS-PAGE showed more intensively stained proteins from the Anaikomban banana leaf (Fig. 37).

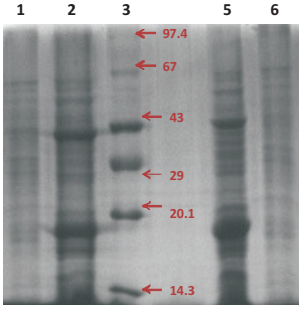



Fig. 37. TCA/ Acetone & phenol ammonium acetate method of leaf and root proteins

Lane 1 : Anai komban root proteins by TCA/ Acetone Method (50 µg)
Lane 2 : Anai komban leaf proteins by TCA/ Acetone Method (50 µg)
Lane 3 : Protein Molecular weight marker
Lane 5 : Anai komban leaf proteins by Phenol/ Ammonium acetate method (50 µg)
Lane 6 : Anai komban root proteins by Phenol/ Ammonium acetate method (50 µg)a

Total phenolic compounds extracted from roots of nematode-resistant banana variety, Yangambi Km5 and susceptible cultivar, Nendran at seven and 30 days after inoculation of the root lesion nematode, *Pratylenchus coffeae,* were analyzed by Reverse Phase HPLC using $C_{18}$ universal column and the eluents were monitored at 280 nm using PDA detector. Out of four mobile systems tried for separation of phenolic compounds, the trifluoroacetic acid-methanol and formic acid-methanol produced clear separation of phenolic compounds with distinctive peaks. Analysis of phenolic compounds indicated the presence of six phenolic compounds in roots of nematode-inoculated Yangambi Km5 and Nendran whereas, only five compounds were eluted in the roots of uninoculated control plants. Other phenolic compounds showed high accumulation in roots of Yangambi Km5 inoculated with root lesion nematode. Analysis of phenolic metabolites in roots at 30 days after inoculation showed similar results of higher accumulation as well as appearance of a new

compound in nematode inoculated Yangambi Km5 than uninoculated control.

### 5.3.3 Post-Harvest Technology

#### Comparative evaluation of banana flower, fruit, stem and peel pickles

In a study on comparative evaluation of four banana-based pickles (fruit, flower, central core stem and peel) stored up to six months, it was observed that peel and central core stem pickles have recorded a Hedonic score of 7.46 and 7.38, respectively. However, flower pickle was highly accepted (with a Hedonic score of 8.07) with total chlorides of 7.93% and crude fiber of 2.51% after six months of storage (Fig. 38).

#### Drying of osmotic dehydrated banana as influenced by different shapes

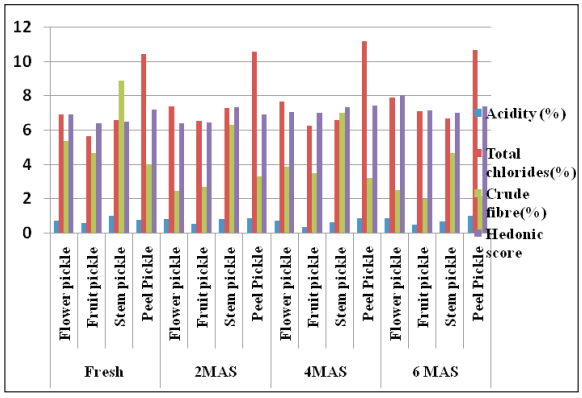



Fig. 38. Comparative evaluation of banana – Flower, fruit, stem and peel pickles

In this study, a reduction of 23-25 hours in drying time was achieved by treating in sugar syrup for different shapes (slices/dice/cubes) of banana, when compared to whole fruits, which took 46.30 hrs for drying. It was also observed that osmotic dehydrated bananas took lesser drying time (23-25 hrs) as compared to potassium metabisulphite (29-32 hrs) treated ones.

#### Analysis of biochemical constituents in banana peel

Six commercial varieties were analyzed for biochemical constituents in the banana ripe fruit peels. Maximum crude fiber (4.40%) and starch (1.12%) were observed in 'Udhayam' and total sugar (6.40%) in 'Saba, on fresh weight basis, while in the unripe peels, maximum crude fiber (16.89%) was observed in 'Neypoovan', total sugar (2.16%) in 'Grand Naine' and starch (36.13%) and protein (4.24%) in 'Poovan' on dry weight basis (Fig. 39). In the case of unripe peels, maximum crude fiber (2.46%) and total sugar (0.27%) was observed in 'Neypoovan', starch (5.86%) in 'Grand Naine' on fresh weight basis; while in ripe peels, maximum crude fiber (18.90%) was recorded in 'Karpuravalli', total sugar (17.33%) in 'Saba, and starch (15.06%) in 'Grand Naine' on dry weight basis (Fig. 40)

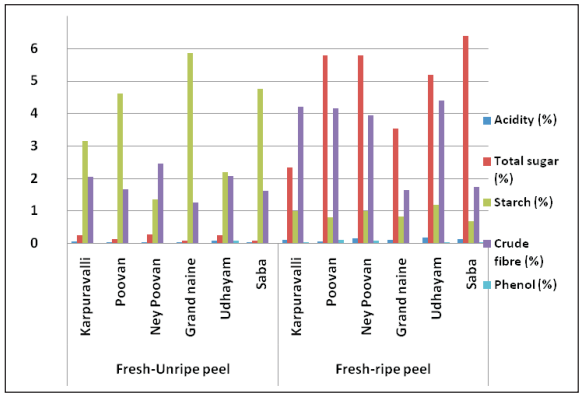



Fig. 39. Chemical parameters of fresh banana peel

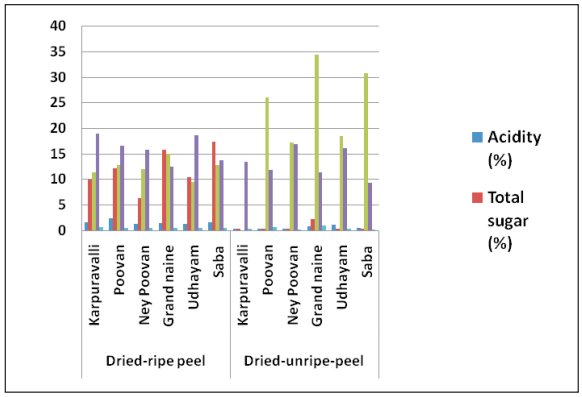



Fig. 40. Chemical parameters in dried banana peel

#### Development of retail packaging in banana

A trail was conducted to find out a suitable consumer unit package using Poovan banana. For this purpose, polybags with 0.25 to 1.0% vent, ethylene absorbent KMnO4 were used. Of the various treatments, packing of ethrel treated

fruits in 0.50% ventilated low-density polyethylene (LDPE) bags resulted in maximum TSS (22°Brix), acidity (0.39%), total sugars (21.20%) and starch (1.28%) after three days of storage at room temperature, which has recorded Hedonic scale of 6.5 (Fig. 41).

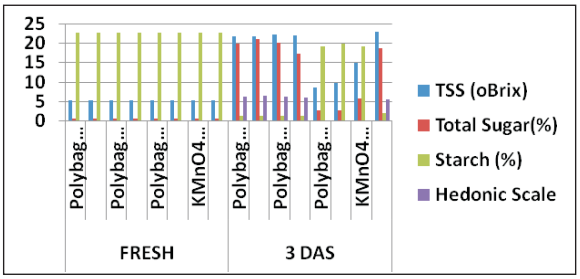



Fig. 41. Effect of packing materials on quality of ripened banana

## Improvement of Sip-up'

Of the various flavours tried for improving Sip-up' and its consistency, the product prepared with condensed milk and stored up to 15 days at 0°C was accepted as the best with a Hedonic score of 6.93, followed by rose milk (Hedonic score of 6.82) (Fig. 42)

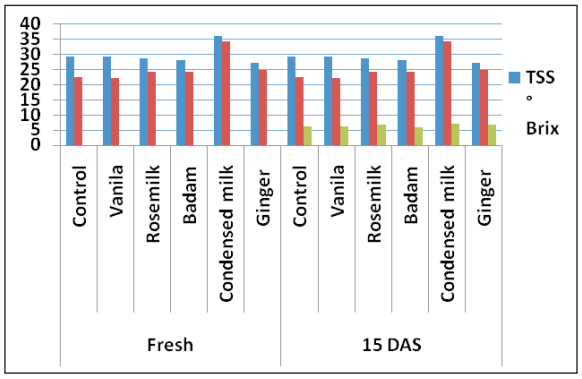



Fig. 42. Evaluation of Sip-up with different flavours & stored at O°C

## Evaluation of commercial banana varieties for fibre extraction

Among five banana varieties evaluated for fibre extraction using fibre extractor (developed by CTRI, Rajahmundry, A.P.), Rasthali gave maximum dry recovery of fiber (0.72%), followed by Udhayam (0.59%) and Saba (0.58%). With regard to biochemical parameters of fibre, 'Saba' registered with maximum cellulose (67%) and lignin (11.45%) contents, while 'Red banana' recorded minimum pectin (2.10%) content.

## Comparative evaluation of methods for fibre extraction and its quality

An experiment was conducted to find out banana varieties of regional importance suitable for fibre extraction in different AICRP centers *viz*., NRCB, Trichy (Lead Center); TNAU, Coimbatore; BRS, Kannara; RAU, Pusa; BCKV, Mohanpur; HRS, Kovvur; BRS, Jalgoan and KRC College Hort. (UHS) and Arabhavi. Among the various methods employed for banana fiber extraction and tensile properties, it is concluded that the machine extraction was found to be commercially feasible, followed by 0.1% NaOH (Table 16). Alkali treatment gave the smooth fiber with dull appearance. However, machine extracted fiber was visually looking better than alkali one (Fig. 43).

Fig. 43. Comparative evaluation of banana fiber extracted by various methods

Table 16. Best treatments of fibre extraction identified based on chemical and tensile properties

| Centre | Variety | Method |
|---|---|---|
| NRCB, Trichy | Poovan | Machine extraction & 0.1% NaOH |
| UHS, Arabhavi | Rajapuri | 1.0% NaOH & Manual extraction |
| TNAU, Coimbatore | Neypoovan | 1.0% & 0.1% NaOH |
| BCKV, Kalyani | Grand Naine | 0.1% NaOH |
| BRS, Kannara | Nendran | 0.5% NaOH |

## 5.4. CROP PROTECTION

### 5.4.1 Nematode Management

#### Management of root-knot nematode in cv. Udhayam banana by non-chemical methods

Application of different biocontrol agents along with Neem cake under the field condition significantly reduced the root-knot indices and nematode populations besides increasing plant growth and yield over untreated control in Udhayam banana.starch (1.12%). However, application of *P. lilacinus* + *P. flourescens* + Neem cake + Marigold as intercrop was found to be the best recording the maximum number of hands (19), number of fruits (325) and bunch weight (34.5Kg/plant) with significant reduction in nematode populations from soil (<15 nematodes/g soil) and roots (<20 nematodes/g root) compared to untreated control plants (>100 nematodes/g root and soil) (Table 17).

#### Isolation of nematicidal fractions from botanicals

Silver nanoparticles synthesized from *Cephalandra indica* extract were characterized by

Table 17. Management of root-knot nematode in Udhayam banana under field condition

| Treatment | Details | No. of hands | No. of fingers | Bunch wt(kg) | Nematodes/ g root |
|---|---|---|---|---|---|
| T1 | Sucker dip in Nimbicidine @ 15ml/1 water for 30 min | 9.0 | 136.0 | 12.3 | 22.3 |
| T2 | T1+Marigold as intercrop | 12.0 | 186.3 | 17.6 | 21.0 |
| T3 | T1+Neem cake @ 250g/Plant | 12.7 | 211.0 | 20.5 | 19.0 |
| T4 | T3+ Marigold as intercrop | 12.7 | 241.0 | 19.0 | 16.7 |
| T5 | NRCB Nemacinus (*P.lilacinus* @ 30g +Neem cake @ 250g/plant) | 13.3 | 223.7 | 20.0 | 19.0 |
| T6 | T5+ Marigold as intercrop | 15.0 | 225.0 | 29.5 | 18.0 |
| T7 | NRCB Nemacens(*P.fluorescens* @ 30g+Neem cake @ 250g/plant) | 12.6 | 220.3 | 29.0 | 16.3 |
| T8 | T7+Marigold as intercrop | 14.6 | 263.0 | 28.0 | 19.7 |
| T9 | *P.linacinus* @15g/plant+*P.flourescens*@15g/ plant +Neem cake @ 250g/plant | 12.3 | 221.0 | 27.5 | 16.0 |
| T10 | T9+Marigold as intercrop | 18.5 | 325.0 | 34.5 | 14.3 |
| T11 | VAM(*Glomus fasciculatum* + *G.mosseae*) @ 15g/plant | 13.0 | 219.0 | 23.5 | 21.0 |
| T12 | T11+ Marigold as intercrop | 12.0 | 226.0 | 18.0 | 26.3 |
| T13 | Carbofuran @ 30g/plant | 11.3 | 158.0 | 14.8 | 23.0 |
| T14 | Caldan @ 10g/plant | 9.6 | 144.0 | 13.0 | 22.0 |
| T15 | Control | 9.3 | 146.0 | 10.2 | 43.0 |
| | SED | 036 | 1.42 | 0.27 | 2.50 |
| | CD (P=0.05) | 0.75 | 2.92 | 0.57 | 5.12 |
| | CV% | 3.80 | 0.84 | 0.77 | 13.74 |

using UV-visible spectroscopy, SEM and FTIR. These synthesized silver nanoparticles were tested against root- lesion nematodes at 0.1M of 10, 20, 30, 40, 50% concentrations under laboratory conditions. The results of the study indicated that all the concentrations showed antagonistic effect against root-lesion nematodes, *P. coffeae.*

## 5.4.2. Management of Banana weevils

### Isolation and evaluation of endophytic fungi against banana weevils

A total of 148 endophytic entomopathogenic fungal isolates were isolated from 122 *Musa* accessions belonging to eight different genomic groups (BB- 24, AB –23, AA-26, AAA -27, ABB-69, AAB-134, ABBB-9, Rhodochlayms-1). These endophytes were identified as *Beauveria bassiana*, *Metarhizium anisopliae* and *Lecanicillium lecanii* based on cultural and morphological characters. The endophytic *M. anisopliae* and *B. bassiana* isolates were evaluated against stem and corm weevil respectively under *in vitro* condition. The results of the study showed that among the *Metarhizium anisopliae* isolates, maximum stem weevil mortality of 76% was recorded by the strain Endo *M. anisopliae* –66 and maximum corm weevil mortality of 54% was recorded by the strain endo *B. bassiana* –32.

### Improving the efficacy of semiochemical lure for banana stem weevil

In order to improve the efficiency of attractiveness of stem weevil to semiochemical lure, six different ratios of host extract and semiochemical (1:2, 1:3, 2:1, 2:3, 3:1 and 3:2) were tested by electro antenna gram (EAG). The results indicated that the ratio of 3:2 had registered higher EAG values (0.163 mV). For further confirmation of this 3:2 ratio, wind tunnel bioassay method was studied which indicated that time taken to reach the sample by male and female stem weevil was very short ie 8.14 and 13.2 minutes respectively (Fig. 44) as compared to other ratios indicating that 3:2

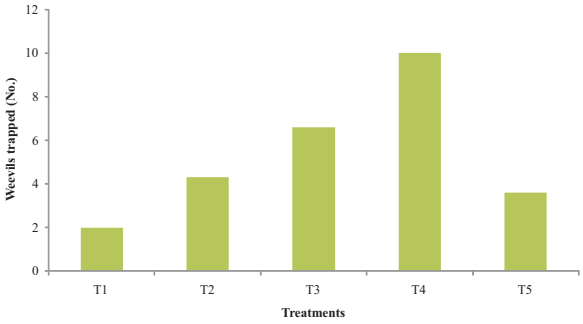



Fig. 44 Corm weevil attracted to different traps

T1-HPE (Host plant extract), T2-Sc.No.1 (Semiochemical), T3-Sc.No.1+HPE, T4-Cosmolure (pheromone), T5-Longitudinal split banana stem trap.

ratio of host extract and semiochemical is the best ratio to attract weevils in a short time.

### Identification of banana leaf sheath and corm volatiles

Banana leaf sheath and corm volatiles of cvs Poovan and Nendran were collected by four different methods viz., headspace, air-entrainment, solvent extraction and soxhlet methods. The analysis of these volatiles by GC-MS indicated a wide variations in the Retention Time (RT) values and several compounds in the leaf sheath and corm volatiles of cvs Poovan and Nendran were recorded.

### Field evaluation of improved semiochemical trap for banana weevils.

A field experiment was conducted at NRCB farm to evaluate the effectiveness of

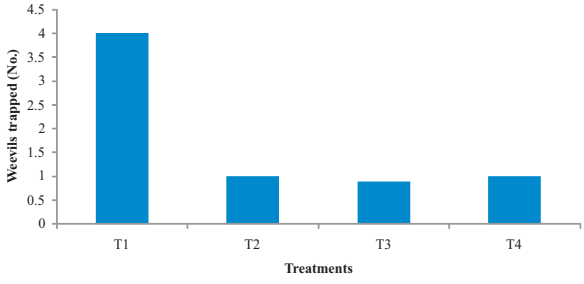



Fig. 45 Stem weevil attracted to different traps.

T1-Sc.No.2+HPE, T2-Sc.No.2 (Semiochemical), T3-Host plant extract, T4- Longitudinal split banana stem trap.

semiochemical trap with HPE to attract banana corm weevil, *Cosmopolites sordidus* by Pitfall method. The analysis of data indicated that a maximum of 10.1 weevil/trap was recorded in the Cosmolure pheromone trap, followed by 6.6 weevils/ trap in the treatment Sc.No.1 +HPE and 3.6 weevils/ trap in the stem trap (Fig. 45).

### *In vitro* evaluation of native endophytes against banana aphid

Seventy five isolates of *Metarhizium anisopliae* and 52 isolates of *Lecanicillium lecanii*, which were isolated from the stem of different *Musa* germplasm accessions were screened against banana aphid under laboratory conditions by detatched mid rib bioassay method. The fungal conidiospores of 1 x $10^9$ cfu/ ml, was swabbed on the banana leaf sheath and the aphids were allowed to feed and aphid mortality was recorded for 10 days. The results of the study showed that among the *Metarhizium anisopliae* isolates, the strain NRCB-145 *Ma* (Endo) & 162 *Ma* (Endo) had recorded a maximum aphid mortality of 80% compared to other isolates. In the case of *Lecanicillium lecanii*, a maximum aphid mortality of 91% was recorded by the strains NRCB-Endo-*Ll* -124, 153, 190, 256 and 296 and a minimum mortality of 20% by the strain NRCB-Endo-*Ll*- 254. The standard control (imidacloprid) recorded 100% aphid mortality as against zero percent in the untreated control (Fig. 46 ).

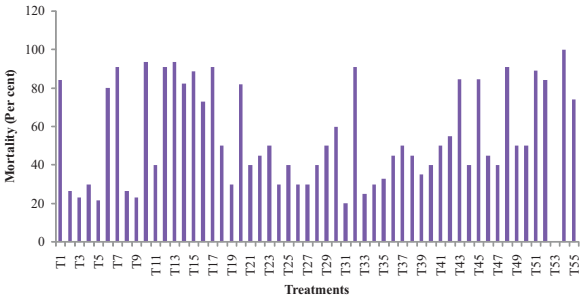



Fig. 46. Evaluation of endophytic *V.lecanni* against banana aphid

T1-T52- endo-Ll(1)-endo-Ll(52), T53-Control, T54-Imidacloprid, T55-Commerical formulation.

## 5.4.3 Investigation on Fungal and bacterial diseases of banana and their management

### Characterization of the *Foc* isolates of West Bengal and Odisha

The characterization of *Foc* isolates obtained from West Bengal and Odisha recorded the presence of VCGs 0124 in cv. Kanthali (ABB) and 0125 in cv. Mortaman (AAB) in West Bengal and VCG 01220 in cv. Monthan (ABB) in Odisha (Fig. 47)

Fig. 47. *In vitro* hetero karyon formation between *nit* - M testers and unknown *Foc*

### Genetic diversity of Indian *Foc* isolates by Mitochondrial small subunit region (Mtssu)

Genetic diversity analysis for 25 representative isolates of *Foc* collected from different parts of India, 7 isolates of VCG obtained from Australia (for comparison) and two isolates of non- pathogenic *Fusarium oxysporum*, was carried out by RFLP analysis of Mitochondrial small subunit region by using 4 different restriction enzymes viz., *Hinf* I, *Rsa* I, *Alu* I and *Hae* III. The results of the analysis indicated that the RFLP analysis could not differentiate the *Foc* isolates of India based on race or VCG or the geographic origin. Besides, the analysis failed to distinguish pathogenic *Foc* from the non -pathogenic *Fusarium* spp.

## Bio-priming of banana plants with mixers of endophytic fungi and botanical leaf extract for the suppression of fusarium wilt

Combined application of three effective endopyhtic fungi viz., *Trichoderma harzianum* (Prr2), *Penicillium pinophilum* (Bc2), *Penicillium* spp. (Dsr1) and three effective botanicals viz., *Alpinia* sp., *Hibiscus* sp. and Zimmu were evaluated against Fusarium wilt pathogen (*Foc*-VCG 0124) under pot culture condition in cv. Grand Naine. Ten days after planting of banana plants in the pots, the bio-agents were given as biopriming (@ 30g of rice chaffy grain formulation containing $10^9$spores/ml per pot) and leaf extracts (@250ml/plant) were applied individually around the plants in soil. Observations on plant growth parameters, number of roots and disease score of internal symptoms taken at 6 months after planting showed that the combined application of both endophytic fungi and botanicals significantly increased the plant growth parameters such as height (33.60%), girth (80%), no. of leaves (42.11%), leaf area (128.15%) and roots (143.04%) when compared to *Foc* alone inoculated control plants.

With regard to effect on Fusarium wilt disease, complete control (100% reduction) of the disease was observed in *Trichoderma harzianum* (Prr2)+ *Hibiscus* sp., *Trichoderma harzianum* (Prr2) + Zimmu, *Penicillium pinophilum* (Bc2) + *Alpinia* sp. *Penicillium pinophilum* (Bc2) + *Hibiscus* sp. *Penicillium pinophilum* (Bc2) +Zimmu, *Penicillium* (Dsr1) + Zimmu combinations (Fig. 48).

Fig. 48. Effect of biopriming of endophyti fungi *Penicillium pinophilum* (Bc2) + botanical Zimmu application in cv. Grand Naine under pot culture condition

## Evaluation of endophytic and rhizospheric bacterial and fungal isolates for the suppression of Fusarium wilt disease in cv. Grand Naine under field condition

A field trial was conducted in a wilt hot spot area at Muthalapuram in Chinnamanur taluk of Theni district to evaluate the efficacy of different endophytic and rhizospheric fungal and bacterial isolates for the suppression of Fusarium wilt disease in cv. Grand Naine. The results indicated that combined application of fungal endophytic *Penicillium pinophilum* Bc2 + rhizospheric *T.koningii*, endophytic *Penicillium* spp. Dsr1 + rhizospheric *T. koningii*, and bacterial endophyticTvpr1 + rhizospheric Jrb1 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. Also, among time of applications, treatments given at three times viz., at the time of planting + 2nd after planting + 4th month after planting have recorded a lowest disease severity of 1.68. The treatments also increased the bunch weight (26.24%) and number of hands (12.88%) significantly as compared to untreated control plants. Besides, the number of plants came for harvest was 94.4% whereas in the untreated control it was 52.63% (Fig. 49).

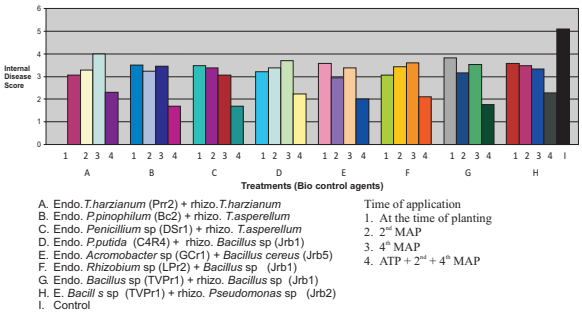



Fig. 49. Field evaluation of endophytic and rhizospheric Fungal and Bacterial isolates against *Foc* VCG-0124 in cv.Grand Naine

## Evaluation of fungicide resistant mutant of *Trichoderma* isolates under field condition

This field trial was also conducted in a wilt hot spot area at Muthalapuram in Chinnamanur

taluk of Theni district, Tamil Nadu to evaluate the effectiveness of fungicide resistant mutant of *Trichoderma* spp. isolates viz. endophytic *T.harzianum* Prr2, *Penicillium pinophylum* Bc2 and *Penicillium* sp. isolates and rhizospheric *T. harzianum* and *T. koningii* isolates along with chemical fungicide Difenaconazole (0.1%) @ 250ml/ plant for the suppression of Fusarium wilt disease in cv. Grand Naine. The observations on number of plants infected, Fusarium wilt disease severity, plants came for harvest and yield parameters such as no. of hands and bunch weight were recorded at the time of harvest. The result of the study indicated that the combined application of rhizospheric and endophytic fungal antagonists along with or without fungicide application significantly increased the bunch weight (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 which were on par with each other. The percent increase in bunch yield was ranged from 48.3 to 74.8 when compared to untreated control plants and the maximum increase in yield was observed in *Penicillium* sp. Dsr1 + *T. koningii* applied plants (Fig. 50).

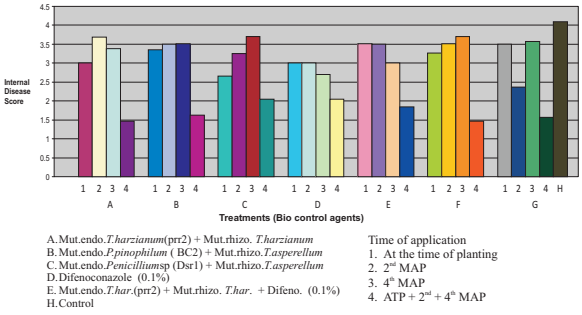



Fig. 50. Field evaluation of Mutant endophytic and Mutant rhizospheric *Trichoderma* isolates against *Foc* VCG-0124 in cv.Grand Naine

### Evaluation of effective biocontrol agent against different VCGs of *Foc*

The *in vitro* evaluation of different effective *Trichoderma* spp. (which have been identified as effective against the virulent strain of *Foc* VCG 0124) against other VCGs such as 01220, 0125, 0124/5, 01211, 01212, 01217 and 01214 for the inhibition of mycelial growth and spore germination indicated that there was no significant difference of inhibition of mycelial growth and spore germination among the VCGs indicating that the *Trichoderma* spp. identified against virulent strain of *Foc* VCG 0124 is also effective against other VCGs.

Effect of Zimmu leaf extract on *Foc* under *in vitro* condition.

The *Foc* propagules present in the field condition was simulated in the micro pots and the Zimmu leaf extract was added at 50% conc for once. Complete inhibition of spore germination of *Foc* was achieved in 10 days after application of Zimmu extract.

### Development of liquid formulation for the effective *Trichoderma* isolates

Evaluation of shelf life of *Trichoderma* spp. in liquid formulation indicated that population of *Trichoderma* spp. was $3x10^{10}$ in molasses medium at 12 months after inoculation.

### Evaluation of transgenic plants of IIHR for their reaction to Fusarium wilt disease

The transgenic plants (40 nos) of cv. Nanjangode Rasabale received from IIHR, Bangalore, were evaluated for their reaction to Fusarium wilt disease *Foc* race1 of VCG 0125 under pot culture condition. The observation indicated that none of the plants showed resistance to wilt disease.

## Eumusae leaf spot disease

## Characterization

### Development of specific SCAR marker for *Mycosphaerella eumusae*

RAPD-PCR was carried out for five representative of *M. eumusae* isolates and identified two unique bands with a size of 1000bp and 1300bp specific to *M. eumusae.*

These two specific bands were cloned and sequenced. Based on the results, six different sets of primers were designed and synthesized. The primers designed were validated using DNA obtained from *M. eumusae, M. fijiensis, M. musicola* and 27 other leaf spot pathogens. The results showed that only two primers (3F &3R and 5F & 5R) produced expected size of 200bp amplicon, which is unique to *M. eumusae*. Also, these primers produced band of 450bp size for *Corynespora* spp. and *Alternaria* spp., and further work is in progress.

### Evaluation of talcum powder based formulation of endophytic bacterial isolates against leaf spot disease

A field evaluation with nine endophytic and two epiphytic bacterial isolates at Vayalur area in Trichy district was carried out for the control of eumusae leaf spot disease in banana cvs. Robusta (Cavendish -AAA) and Nendran (AAB). The bacterial bio-agents were sprayed ($10^9$cells/ml) for four times at 20 days interval after 5 months of planting. Necessary control (fungicide Propiconazole 0.05% + oil 1%) was also maintained. The results in cv. Robusta indicated that both endophytic (6M2) and epiphytic(1E2) bacterial bio-agents spray significantly suppressed the leaf spot disease severity (47.9%) and increased the value of YLS-0 (41.03%) when compared to untreated control plants. However, the maximum reduction of disease (60.9%) and increase in value of YLS-0 (89.7%) was observed in Propiconazole 0.1% + mineral Oil 1% treated plants when compared to untreated control plants (Table 18).

In the case of Nendran, although the trend of suppression of leaf spot disease severity and increase in value of YLS-0 was the same, the degree of suppression of disease severity (up to 63.5%) and increase in value of YLS-0 (89.3%) was more due to the application of bio-agents (6M2) compared to untreated control plants. In general, the endophytic bacterial isolates particularly the strain 8L4 performed better in reducing the leaf spot disease severity compared to other bacterial isolates.

Table 18. Field evaluation of talcum powder based formulation of endophytic bacterial isolates against leaf spot disease in cv. Robusta

| Treatments | Vegetative stage | | Flowering stage | | Harvesting stage | |
|---|---|---|---|---|---|---|
| | Disease severity | % reduction over control | Disease severity | % reduction over control | Disease severity | % reduction over control |
| *Bacillus* sp. 6M2 | 23.84 c | 47.98 | 32.90 c | 43.56 | 50.60 bc | 29.12 |
| *Citrobacter* sp. 8L4 | 35.53 a | 22.47 | 39.19 ab | 32.77 | 52.10 abc | 27.02 |
| *Klebsiella* sp. 5R | 35.10 ab | 23.41 | 35.01 ab | 39.94 | 50.30c b | 29.54 |
| *Serratia* sp. 11C2 | 34.54 ab | 24.63 | 41.60 a | 28.64 | 59.20 a | 17.07 |
| *Lactobacillus* sp.14M2 | 32.69 ab | 28.67 | 39.90 ab | 31.56 | 47.60 c | 33.32 |
| *Serratia* sp. 2M | 35.16 ab | 23.28 | 38.70 ab | 33.61 | 53.40 abc | 25.19 |
| *Citrobacter* sp. 16C2 | 31.75 b | 30.72 | 36.80 bc | 36.87 | 57.16 ab | 19.93 |
| *Pseudomonas* sp. 12R2 | 35.79 a | 21.90 | 41.80 a | 28.30 | 54.70 abc | 23.37 |
| *Pseudomonas* sp. 13.a | 35.05 ab | 23.52 | 40.40 ab | 30.70 | 56.50 ab | 20.85 |
| Propiconazole 0.1% | 24.67 c | 46.17 | 23.80 d | 59.17 | 27.90 d | 60.91 |
| Control | 45.83 d | 0 | 58.30 e | 0 | 71.39 e | 0 |
| CD (P=0.05) | 3.47** | — | 3.17** | — | 8.81** | — |

### Evaluation of fungicide Nativo (Bayer company) for the control of leaf spot disease

A field experiment under contract research was conducted at Erasainayakkanur in Theni district to evaluate the effect of a fungicide Nativo (Tebuconazole 50% + Trifloxystrobin 25% WG) in cv. Grand Naine. The result of the study showed that among different concentrations, Nativo 1.4 g/litre recorded maximum reduction of leaf spot severity (32.80%) and increase the value of YLS-0 (43%) as compared to control. The effect of this chemical was on par with the control treatment Propiconazole 0.05%+ oil 1% in reducing the leaf spot disease severity (38.09%) and increase in value of YLS-0 (437.48%) as compared to unsprayed control plants.

### Characterization of principle compound of Zimmu leaf extract

The GC-MS analysis of two lipid compounds LP-B1 and LP-B2 isolated from the botanical Zimmu indicated the presence of six and five different compounds respectively. The compounds identified were Tetradecane, 2,6,10-trimethyl dodecane, Hexadecane, 2,6,10,15-tetramethyl-heptadecane, 9-hexyl- heptadecane and 1-chloro- heptacosane in lipid B1 and Tetradecane, 2,6,10-trimethyl dodecane, Hexadecane, 2,6,10,15-tetramethyl-heptadecane, 9-hexyl- heptadecane in lipid –B2 (Table 19).

Table 19. Characterization of principle compound extracted from Zimmu leaf extract by GC-MS analysis – Lipid 1

| S.No. | Retention time | Name of the compound | Molecular formula | Molecular Weight | Peak Area % |
|---|---|---|---|---|---|
| 1 | 2.65 | Tetradecane | C14H30 | 198 | 22.53 |
| 2 | 3.02 | Dodecane, 2,6,10-trimethyl- | C15H32 | 212 | 26.37 |
| 3 | 4.95 | Hexadecane | C16H34 | 226 | 17.03 |
| 4 | 5.54 | Heptadecane, 2,6,10,15-tetramethyl- | C21H44 | 296 | 18.68 |
| 5 | 7.63 | Heptadecane, 9-hexyl- | C23H48 | 324 | 8.79 |
| 6 | 8.18 | Heptacosane, 1-chloro- | C27H55Cl | 414 | 6.59 |

## Post-harvest disease

### Isolation and evaluation of native fungal and bacterial epiphytic isolates for the management of anthracnose disease

Totally 20 bacterial and 10 fungal epiphytic isolates obtained from 10 different banana accessions were screened for the inhibition of mycelial growth and spore germination of *Colletotrichum musae* pathogen under *in vitro* condition. The results indicated that the isolates S23b, S17, 140d RT1, S18C IS13F, IS11F have recorded the maximum inhibition of mycelial growth (75%) of the pathogen and the isolates RT1, 140b, 140d, S18c, S23b, S17, 132f, 6f and IS13F have recorded 100% inhibition of spore germination of *Colletotrichum musae* pathogen. The epiphytic bacterial isolates, IS19B, E33B have recorded the maximum of 60% inhibition of mycelial growth of the pathogen and isolates IS1B, IS2B, IS4B, IS5B, IS6B, IS7B, IS8B, IS16B, IS19B, E33B recorded 100% inhibition of spore germination of *Colletotrichum musae*. All the isolates significantly reduced the disease severity, which ranged from 52-77%. It was also observed that days taken to attain the maximum disease severity were high in the above-mentioned effective isolates (7-14 days) when compared to pathogen alone-inoculated control.

## 5.4.4 Studies on viral diseases and their management

### Survey for viral diseases

Survey undertaken in Theni, Dindugal and Pudukottai districts of Tamil Nadu revealed that

up to 90% incidence of BBTV in tissue cultured and conventional sucker grown plants of cvs. Grande Nain, Red banana, Hill banana and Poovan banana was recorded.

## Molecular Characterization of banana viruses

### BBTV

The coat protein and replicase genes of BBTV from naturally infected *Ensete* samples in Coimbatore were cloned and sequenced. The nucleotide sequence was 99 % similar to BBTV. The DNA isolated from aphids feeding on the infected *Ensete* were also positive for BBTV and both cp and rep gene of BBTV could be amplified (Fig. 51). Therefore, it was concluded that BBTV would have been transmitted to *Ensete* by banana black aphids *Pentalonia nigronervosa.*

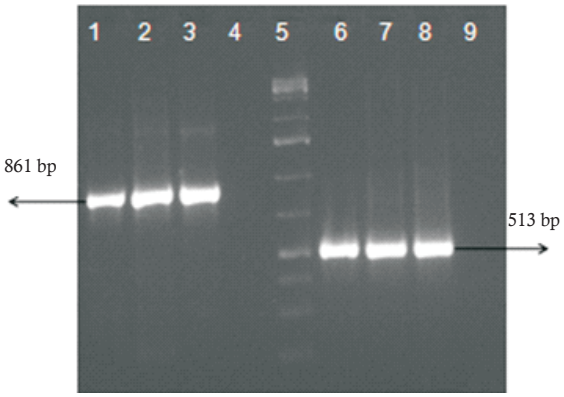



Fig. 51. PCR amplification of BBTV replicase and coat protein gene in Ensete.Lane 1-3: BBTV Rep gene; Lane 4: Healthy control; Lane 5: 1 kb ladder; Lane 6-8: BBTV CP gene; Lane 9: Healthy control

### BBrMV

Coat protein gene of BBrMV infected Neypoovan and H201 from Trichy, Nendran from Karur, Poovan from Seruvaviduthi (Pudukottai district), Grand Naine and Red banana from Theni, Ney Poovan from Kerala was cloned and sequenced. The results revealed 97-99% similarity at the nucleotide level and more than 97% at amino acid level with published sequences.

### BaMMV

Udhyam and Karpuravalli banana exhibiting mild to moderate mosaic symptoms has been recorded in the NRCB research fields. To identify the virus, primers specific to CMV, BBrMV and BaMMV were used to amplify the suspected virus. The results showed that among the primers tried, the banana mild mosaic virus specific primer had generated the expected amplicon from the samples of Udhayam banana having mild mosaic symptoms. The amplified fragment of 250 bp was cloned and sequenced. The sequence had 86-87% homology with a published BaMMV coat protein sequence.

### BSV

Tissue cultured Grand Naine banana expressing symptoms of streak and mosaic were collected in Theni district. Among different primers specific to different viruses tried to identify the viruses, the BADNA degenerate primers targeting the partial RT-RNase region, had generated expected amplicon of banana streak virus. The cloning and sequencing of this amplified band revealed 96-97 % sequence similarity with banana streak Uganda G and C viruses.

### Expression of recombinant coat proteins of BBTV and BBrMV in *E.coli*

The expressed coat protein of BBTV with 20kDa size obtained in insoluble form as inclusion body was purified and polyclonal antiserum was raised. The ELISA carried out revealed that the antiserum raised was not specific to BBTV.

The expressed coat protein of BBrMV was purified and polyclonal antiserum was raised. DAC-ELISA and western blot assays have been standardized using this antiserum (Fig. 52). Imunno-sorbent electron microscopy done using this antiserum decorated the BBrMV particles. DAC-ELISA with a modified antigen extraction buffer gave very good results while detecting the virus from different plant parts. IgG was purified from the polyclonal antiserum and conjugate was prepared.

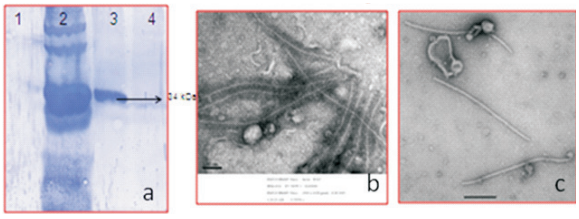



Fig. 52. Western blot and ISEM assay of BBrMV recombinant polyclonal antiserum. a. Lane 1: Non induced; Lane 2: Induced; Lane 3: BBrMV infected sample; Lane 4: Healthy control. b. Decorated; c. Non- decorated

## Diagnostic techniques for banana viruses

Lateral flow immune assay (LFIA) based dipstick is a user's friendly detection technique. An attempt was made to develop LFIA for cucumber mosaic virus infecting banana. Using IgG purified from polyclonal antiserum raised against CMV recombinant coat protein, lateral flow strips (dipstick) were prepared and the resulting dipsticks could able to detect the virus in positive samples but not from healthy negative samples (Fig. 53). However, CMV infected *Nicotiana* samples did not give reactions in strips. For the detection of BBrMV using real time

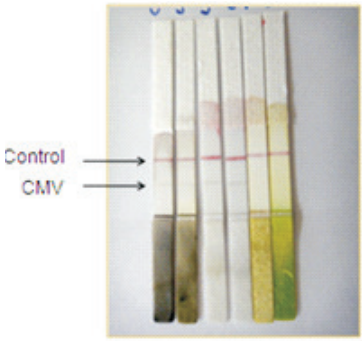



Fig.53. Standardization of lateral flow immune assay/Dip stick assay for detection of CMV

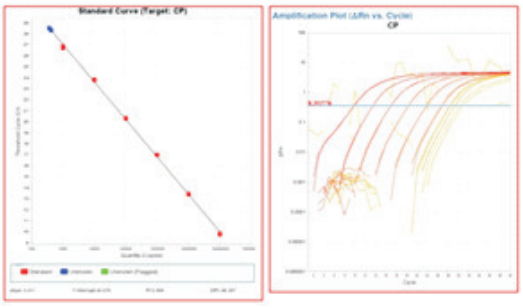


Fig.54. Detection of BBrMV in realtime PC R assay

PCR approach, primers and TaqMan probe were designed and the real time PCR carried out showed that the amplification was observed only from positive samples and the Ct value was 28.29 (Fig. 54).

## Supply of virus indexed hill banana mother plants

Virus free healthy suckers of Hill banana are being maintained in the field and about 100 BBTV free suckers of Hill banana were supplied to the banana farmers.

## Screening germplasm against banana viruses

The screening of germplasm for four banana viruses viz., BBTV, BSMYV, CMV and BBrMV showed that among 99 germplasm samples received from NBPGR, New Delhi 57 accessions were tested positive for BSMYV and one for BBrMV. Similarly, among 311 germplasm of NRCB screened against BBrMV, 25 were tested positive and out of 70 clumps of Udhayam screened, 27 were found free of BBTV, BSMYV, CMV, BanMMV and BBrMV.

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

## Expression of BSV symptoms and its severity

Non-symptomatic Poovan plants planted during the year 2005-06 was continued and evaluated the 6th ratoon crop. The observation on the expression of BSV symptom indicated that out of 700 plants planted, so far 89 plants have expressed the symptoms of streak disease and this year alone, nine plants have showed the symptoms of BSV. Analysis of disease severity index, yield, girth and plant height over the years revealed that higher variation between the years and the weather factors prevailed in the corresponding year was observed.

## Studies on banana streak virus integration

Partial Banana Streak Obino 1' Elwai Virus (BSOLV) genomic sequences have integrated

into the host genome of cultivars Udhayam, *Musa balbisiana*, Rasthali, Nendran, Poovan and Ney Poovan. Two BSOLV based primers designed have distinguished the cv. Poovan from the rest of the 'B' genome containing varieties such as Rasthali, Ney Poovan, Udhyam and Nendran. Besides, a BSOLV specific primer did not yield any product from Poovan, Grand Nain (AAA) and Matti (AA) (Fig. 55) and the same was confirmed by real time PCR assay. Based on the quantitative PCR, it is concluded that a single copy of BSOLV is believed to be integrated in the varieties tested for integration.

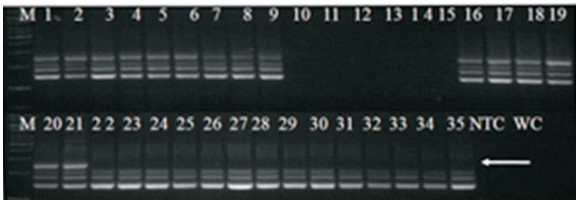



Fig.55. Distinguishing cv. Poovan from the rest of the B genome containing varieties based on PCR with specific primer designed from BSOLV. Lane M:1 kb ladder plus; Lane 1-3:Udhayam(ABB); lane 4-6: Nendran( AAB);Lane 7-9 : Ney Poovan (AB); Lane 10-12: Grand Naine ( AAA); Lane 13-15:Matti (AA); Lane 15-18:Rasthali (AAB); Lane 19-21: *Musa balbisiana* (BB); Lane 22-35 : Poovan (AAB); Lane 36-Non template control (NTC): Lane 36: Water Control (WC).

## Real time PCR assay for assessing the virus responsive micro RNA's with respect to BSV in Poovan

MicroRNAs (miRNAs) are a class of small, non-coding RNAs that regulate post-transcriptional expression in plants and animals. Computational prediction of miRNAs from banana EST and BAC sequences was performed, which resulted in 18 banana miRNAs belonging to 16 miRNA families. For the 18 miRNAs, 25 banana ESTs were found as their potential targets. Most of these targets encode transcriptional factors, which play some role in banana development. Out of 18 miRNA representatives, only virus responsive microRNA's such as miR156, 159, 166 were cloned and sequenced. Using real time PCR, three miRNA's were quantified and all of them found to be up regulated in BSV infected plants compared to control (Fig. 56). Additionally, real time PCR assays were performed to profile the expression levels of miR166 after the infection of *Banana streak Mysore virus* (BSMysV). The results showed that symptom severity was correlated to the expression level of miRNAs.

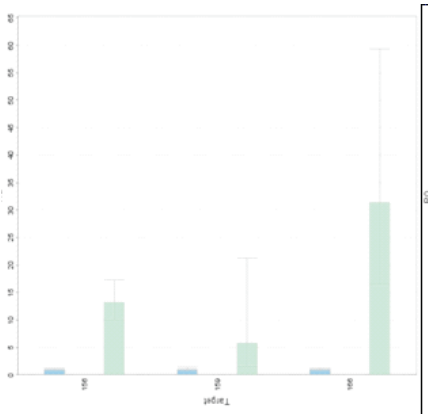


Fig.56. Expression levels of selected miRNAs modulated by BSMysV infection in banana plants using quantitative real-time (qRT-PCR).

## Isolation and characterization of endophytes associated with BBTV infected and healthy Grand Naine banana and study on the latency of bunchy top disease in Grand Naine

A total of five endophytic bacteria were isolated from healthy Grand Naine banana and the molecular characterization by sequencing 16s rRNA showed that the sequences of four bacteria were matching with the sequences of *Bacillus pumilus, Bacillus cereus, Bacillus subtilis,* and *Pseudomonas* spp and sequence of one bacterium was matching with sequence of uncultured bacteria deposited in the NCBI Gen Bank. Besides, endophytic bacteria were isolated from BBTV latent plants and aphids as well.

BBTV was transferred to the virus free Grand Naine tissue cultured plants through viruliferous aphids *Pentalonia nigronervosa*. Out of 24 plants subjected for the transfer of BBTV, 15 were positive in PCR and only six plants exhibited symptoms. The remaining nine plants did not express any symptoms of BBTV for more than 360 days and remained latent. These nine plants were repeatedly tested for the

presence of BBTV by PCR and were found positive for coat protein gene.

### Green house study on the effect of soil moisture stress on BSMYV in cv. Poovan

The tissue cultured Poovan plants exhibiting typical symptoms of BSMYV were subjected to water stress by withdrawing water for 15 days. The observations on this viral disease indicated that the severity of the disease and the virus titre (based on DAS ELISA test) were significantly more in the water stressed plants compared to non-stressed control plants.

### Standardization of SAAT transformation with CMV cp gene construct in Grand Naine.

Sonication-assisted Agrobacterium-mediated genetic Transformation (SAAT) method (Subramanyam et al., 2011) was used to transfer CMVcp genes into cv. Grand Naine. Cefotaxime (500 mg/l) was used to eliminate *Agrobacterium* and Kanamycin 250 mg/ml was used for the selection of transformants. The explants were then transferred into *Agrobacterium* suspension and sonicated for 4 min. A total of 180 shoot tips have been transformed through SAAT method for the development of putative transgenics with CMV *cp* gene. Due to over growth of *Agrobacterium,* shoot buds got initiated only in two out of 180 shoot tips. Further standardization of SAAT method will be carried out for the development of CMVcp transgenics.

## 5.5 EXTERNALLY FUNDED PROJECTS

### 5.5.1 Functional Genomics (Sigatoka and Drought) S.Uma S. Backiyarani, M.S.Saraswathi, R. Thangavelu and I. Ravi

#### Isolation of Resistant Gene Analogus (RGAs) from Sigatoka resistant accession

RGAs were isolated and sequenced from Sigatoka resistant cultivar Manoranjitham. Annotated results revealed that, all positive clones were related to RGAs of NBS-LRR family with 90-100% homology. (Fig. 57)

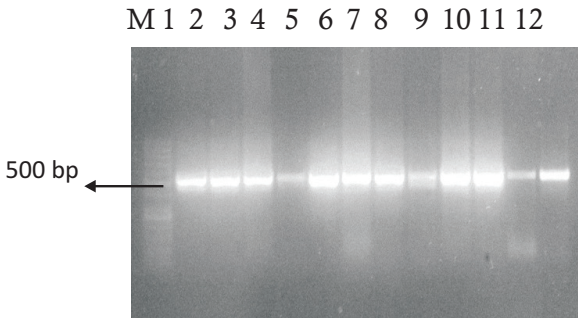



Fig. 57. Gel showing bands of Resistant Gene Analogues (RGAs) form Sigatoka resistant accession

Lane M - 100bp marker
Lane 1-12 - RGA positive clones

#### Isolation of antifungal genes from Sigatoka resistant cultivar

Primers were designed from five antifungal genes namely *Oryza sativa* Beta-glucanase (OSBG), *Zea mays* Ribosome inactivating protein (ZMRIP), *Zea mays* Pathogenesis-related proteins (ZMPR), *Arabidopsis thaliana* antifungal protein (ATAF) and *Zea Mays* antifungal protein (ZMAF) and used to amplify the cDNA of Sigatoka resistant cultivar Manoranjitham. Only three primers namely ZMRIP (550bp), OSBG (450bp), ZMPR (470 bp) gave the expected product size (Fig. 58). All these amplicons were sequenced and BLAST analysis revealed that only pathogenesis-related

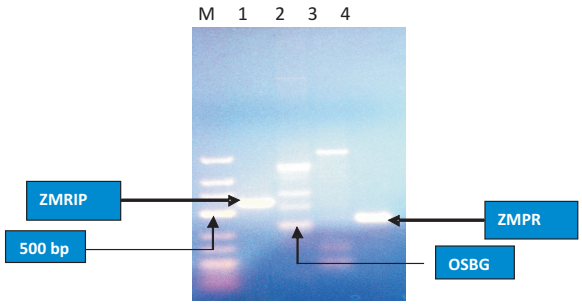



Fig. 58. Amplicons of defense related genes

Lane M - 100bp marker, Lane 1 - ZMRIP, Lane 2 - OSBG, Lane 3 - ATAF, Lane 4 - ZMPR

(PR) proteins had 80% homology with PR-1 protein. Efforts are being taken for isolating full-length gene of PR-1 protein.

#### Selection of suitable ESTs of cDNA – SSH library for expression profiling study

A total of nine primers were designed from the differentially expressed ESTs, which are obtained from cDNA –SSH library of Sigatoka challenged plants and validated through real time PCR. Based on the melting curve analysis (Fig. 59), eight EST derived primers namely USK17 (*Photobacterium damselae*, trpB gene for putative transposase), USK21 (*Photobacterium damselae,* partial coi genes for putative cytochrome C oxidase proteins), USK28 (*Musa AAAB Group,* catalase 2 gene), USK 39 (*Avena sativa*, Fructose 1,6-bisphosphate aldolase precursor), USK 41(*Zantedeschia aethiopica*, rubisco activase (rca2)), USK 119 (*Lanaria lanata,* PsaB-like (psaB) gene), USK 120 (*Musa acuminata,* photosystem I P700 apoprotein A2 (psaB) gene) and USK 227 (*Bos Taurus,* collectin precursor (CL-46) gene, complete cds) were

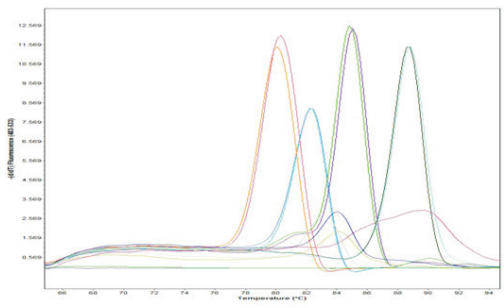


Fig. 59. Melting curve analysis of ESTs from Sigatoka challenged SSH-cDNA library

found to be effective for expression profiling study during Sigatoka infestation in resistant and susceptible cultivar through real time PCR.

### 5.5.2 Identification of suitable housekeeping gene for expression studies through real time PCR

Primers of seven house keeping genes namely RPS2, Ubiquitin, Elongation factor, Ribulose 1,5, bis-phosphate carboxylase and Beta tubulin were used for identifying suitable reference control for real time PCR analysis. All the primers were tested against various tissues (leaf, root, pulp, sheath, and stem) and tissues from various stress conditions (Sigatoka and drought) at different time intervals. The results revealed that RPS2 and Ubiquitin were found to express constantly in all the samples across various tissues and stresses (Sigatoka and drought) and hence can be used as internal control in expression studies.

### Expression profiling of drought associated coding and non-coding miRNA

Influence of drought on transcripts like dehydrin and aquaporin were profiled during progressive drought (DAS 0-24) in drought tolerant cultivar Saba and moderately tolerant Monthan. Saba had relatively high expression of these transcripts under drought stress (Fig. 60&61). In Saba, the expression of aquaporin started from 3rd day itself and increased over time with its peak on 20th day. Maximum expression of dehydrin was observed on 3rd day itself which declined further slowly. While cv. Monthan had poor expression of aquaporin and dehydrin and were uniform in the intial period of stress and attained maximum on 22nd day.

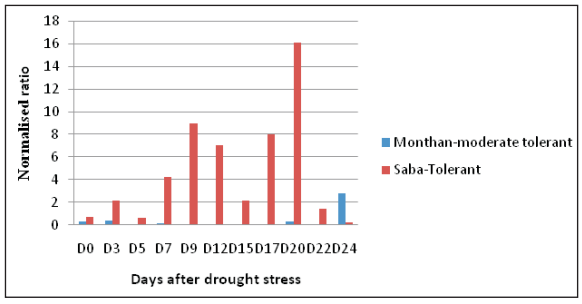



Fig. 60. Aquaporin expression in drought stressed leaf samples of tolerant and moderately tolerant cultivars.

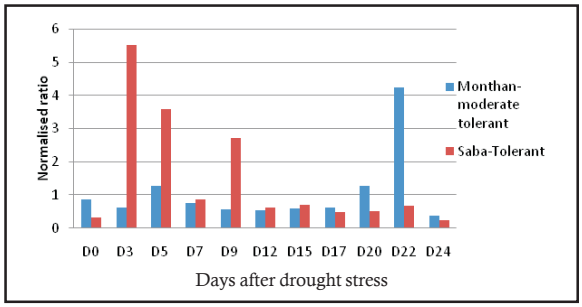



Fig. 61. Dehydrin expression in drought stressed leaf samples of tolerant and moderately tolerant cultivars.

Drought related miRNAs (microRNA) were predicted from drought stressed *Musa* ESTs namely miR156, 169, 2118,399 and 396. Expression profiling of these miRNAs across different tissues (sheath, corm, leaf, bract and flower bud), suggested that miRNA396c had least variation suggesting its suitability for reference miRNA (Fig. 62). Its confirmation is in progress.

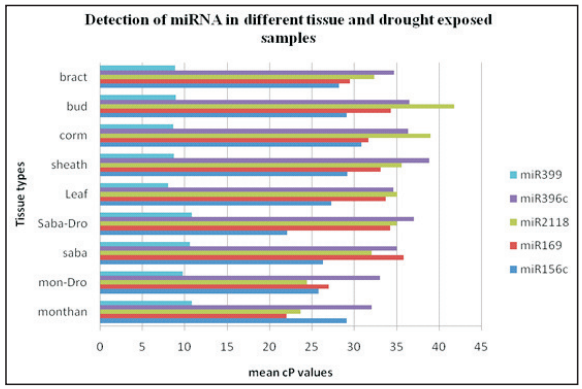



Fig. 62.Detection of miRNA in different tissue and drought exposed samples

### 5.5.3 Screening of banana germplasm for drought for the benefit of resource poor farmers

### Screening for banana germplasm for drought for the benefit of resource poor farmers.

Screening against drought tolerance was studied in 18 banana genotypes *viz.*, Paglapahad

wild, Attikol, Karpuravalli, Peyan, Kothia, Vennutu Mannan, Saba, Monthan, Nendran, Poovan, Chinali, Rasthali, Jwari bale, Ney Poovan, Robusta, Red banana, Pisang Jaribuaya and Calcutta 4 in the field under irrigated control and soil moisture deficit stress. The treatments were : T1 = Irrigated control and T2 = Soil moisture deficit stress. Three beds (each bed had five plants/genotype) were maintained per treatment and each treatment was maintained separately. Six months after planting, soil moisture stress was imposed by withholding irrigation in the treatment plot for 4 weeks. Irrigated control plot was given normal irrigation at 7-10 days interval, when the available soil moisture was between 27- 31%. At the end of soil moisture stress treatment, the soil matric potential was - 0.6 MPa. At the end of fourth week, irrigated and drought stressed plants produced 11.94 and 8.44 leaves respectively. The number of green leaves in irrigated plants was significantly higher (11.94) than water stressed plants (8.44). There was no significant variation with first week of stress imposition and the genotypic variation was recorded in number of green leaves throughout the experimental period. In water stress imposed plants, the total number of senescent leaves was significantly higher (4.17) than irrigated control (2.22) and was 89.86% more than irrigated control. With regard to bunch weight of different genotypes, cultivars Saba, Monthan and Vennutu Mannan recorded higher yield under stress condition and same genotypes also recorded higher bunch yield under irrigated environment. The interaction plots for yield analyses revealed that genotypes which produced higher bunch weight under irrigated control also performed well under stress environment (Fig. 63). Correlation analysis revealed that bunch weight and RWC and osmotic potential and finger number were significantly and positively correlated. Generally bunch yield of all genotypes decreased under soil moisture deficit stress. Results of this study indicated that Saba, Monthan and Vennutu Mannan are potential banana genotypes under water limited environment compared to other commercial banana cultivars.

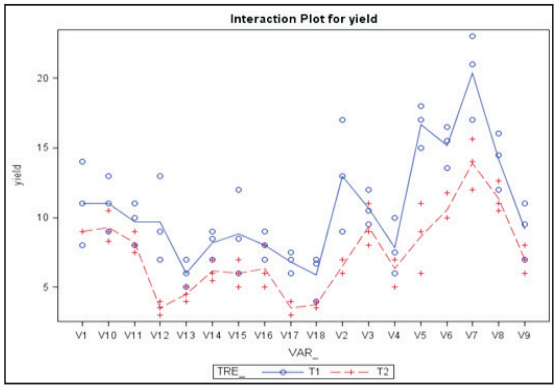



Fig. 63. Interaction plot for yield analyses under irrigated and drought stress conditions.

## Molecular understanding of drought tolerance mechanism of selected cultivars under simulated drought environment

Two dimensional gel electrophoresis protocols were standardized for differential expression of banana leaf proteins across drought tolerant and moderately tolerant *Musa* cultivars. Rubisco is one of the major leaf proteins contributing by >50% of total proteins and poses a major problem in the detection of low abundant proteins during sample preparation for proteomics. This problem to overcome and identification of low abundant proteins in leaves could be achieved through PEG-4000 (16%) fractionation during protein extraction (Fig. 64).

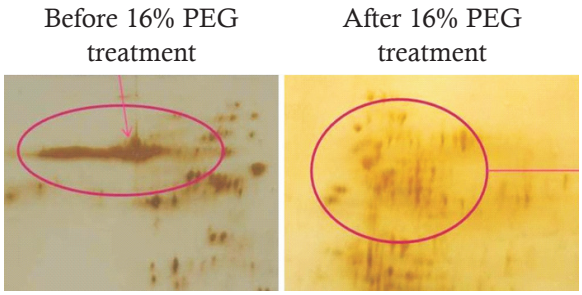



Fig.64. PEG-4000 (polyethylene glycol) fractionation for removal of leaf major abundant protein-Rubisco.

Comparative protein analysis between drought stressed and non-stressed leaf samples of *M. laterita* exhibited differential expression in protein profiles. In drought stressed samples, protein of 24 KDa was expressed, where as in

the non-stressed plants, proteins with a molecular weight of 30, 75 and 80 KDa were expressed.

## Analysis of differentially expressed glycoproteins under drought stress

The analysis of differentially expressed glycoproteins in the drought stressed plants indicated significant variations in protein expression and changes in post-translational modifications of proteins between drought stressed and non-stressed plants (Fig. 65) . The characterization of four differentially expressed glycoproteins (signalling proteins) of *Musa laterita*, a supposedly tolerant species, is in progress. One of the membrane protein identified as Alpha NSF protein was expressed only in drought stressed samples. The expression of three proteins with a size of 30, 55, and 56 kDa were masked under stress condition.

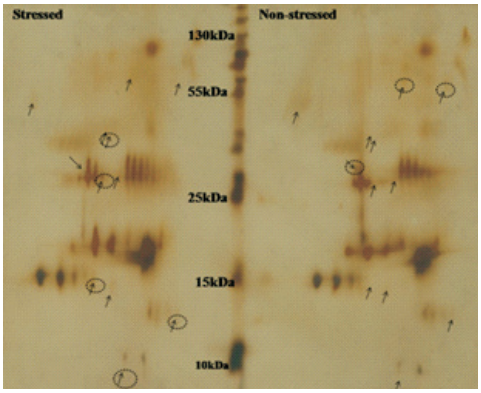



Fig. 65. differential expression of glycoproteins under drought stress

## Comparative proteome analysis of normal and drought imposed leaf samples of drought tolerant cv. Saba

Preliminary studies on the time course differential protein expression during progressive drought in drought tolerant cv. Saba revealed significant variation between control and drought imposed samples on 3rd and 24th day after drought imposition (Fig. 66) . Samples collected at weekly intervals to determine the exact stage of expression of drought induced (progressive drought) protein by 2D analysis showed the differential expression of 45 protein species and the same has been sent for Peptide Mass fingerprinting analysis.

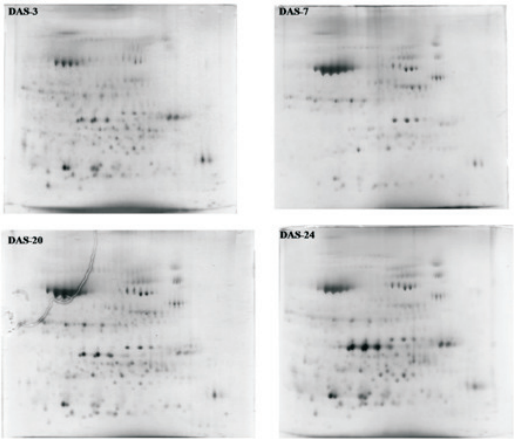



Fig.66. Comparative proteome analysis of normal and drought imposed leaf samples of drought tolerant cv. Saba

## Framing Crop Specific DUS guidelines for Banana

A total of 360 nos of banana suckers have been multiplied from 30 varieties and supplied to Birsa University of Agriculture, Ranchi, Jharkhand and Konkan Krishi Vidyapeeth , Dapoli, Maharashtra for DUS characterization.

Morphological characterization during vegetative, pre-flowering, post-flowering and post harvesting stages has been completed for all the 30 accessions grown under insect proof roofless net for the development of DUS guidelines (Fig 67&68).

Fig. 67. DUS field NRCB, Trichy during the visit of Registrar, PPV & FRA

Fig. 68. View of DUS field at HRC, Nagicherra, Tripura

### 5.5.4 Net work project on Fusarium wilt

#### Pot culture evaluation of individual effect of mutant endophytic *Trichoderma* spp. against Fusarium wilt pathogen *Foc* - VCG-0124

The individual application of three effective endopyhtic *Trichoderma* spp. viz., *Trichoderma harzianum* (Prr2), *Penicillium pinophilum* (Bc2) and *Penicillium* spp. (Dsr1) was evaluated against Fusarium wilt pathogen (*Foc*-VCG 0124) under pot culture condition in cv. Grand Naine. The bio-agents were given as biopriming by applying 30g of rice chaffy grain formulation per plant 10 days after planting of banana plants. The observation on plant growth parameters, number of roots and disease score of internal symptoms was taken at 6 months after planting. The results of the experiment showed that the individual application of three effective endopyhtic *Trichoderma* spp. significantly increased the plant growth parameters such as height (93.60%), girth (68.8%), no. of leaves (56.5%), leaf area (183.2%) and roots (156.7%) when compared to *Foc* alone inoculated control plants. With regard to effect on Fusarium wilt disease, the individual application of all the three *Trichoderma* spp. have recorded complete control (100% reduction) of the disease and the *Foc* alone inoculated plants showed the disease score of 5.2.

#### Pot culture evaluation of individual effect of mutant rhizospheric *Trichoderma* spp. against Fusarium wilt pathogen *Foc* - VCG-0124

The individual effect of six effective isolates of rhizospheric *Trichoderma* spp. viz., *Trichoderma harzianum*, *Trichoderma pseudokoningii*, *Trichoderma asperellum, Trichoderma koningii* (140C), *Trichoderma viride* (K2T5) and *T. viride* (poo) was evaluated against Fusarium wilt pathogen (*Foc*-VCG 0124) under pot culture condition in cv. Grand Naine. The rhizospheric *Trichoderma* spp. isolates were applied in soil around the plants 10 days after planting @30g/plant as rice chaffy grain formulation.

The observation on plant growth parameters, number of roots and disease score of internal symptoms was taken at 6 months after planting. The results of the experiment showed that the individual application of six effective rhizospheric *Trichoderma* spp. significantly increased the plant growth parameters such as height (up to 108.5%), girth (77%), no. of leaves (68.7%), leaf area (193.6%) and roots (152.1%) when compared to *Foc* alone inoculated plants. With regard to effect on Fusarium wilt disease, the individual application *Trichoderma harzianum*, *Trichoderma asperellum* and *Trichoderma koningii* (140C) have recorded complete control (100% reduction) of the disease and the *Foc* alone-inoculated plants showed the disease score of 5.2.

#### Evaluation of combined application of mutant endophytic *Trichoderma* spp. and mutant rhizospheric *Trichoderma* spp.

The combined application of three fungicide resistant endophytic mutant *Trichoderma* spp. viz., *Trichoderma harzianum* (Prr2), *Penicillium pinophilum* (Bc2), *Penicillium* spp. (Dsr1) and six effective mutant rhizospheric *Trichoderma* spp. viz., *Trichoderma harzianum*, *Trichoderma pseudokoningii*, *Trichoderma asperellum, Trichoderma koningii* (140C), *Trichoderma viride* (K2T5) and *T. viride* (poo) was evaluated against Fusarium wilt pathogen (*Foc*-

VCG 0124) under pot culture condition in cv. Grand Naine. The endophytic mutant *Trichoderma* spp. isolates were given to plants as biopriming and rhizospheric mutant *Trichoderma* spp. isolates were applied in soil around the plants @50g/plant as rice chaffy grain formulation.

The observation on plant growth parameters, number of roots and disease score of internal symptoms was taken at 6 months after planting. The results of the experiment showed that the individual application of three effective endopyhtic *Trichoderma* spp. significantly increased the plant growth parameters such as height (up to 113.7%), girth (77%), no. of leaves (75%), leaf area (215.8%) and roots (125.6%) when compared to *Foc* alone inoculated control plants. With regard to effect on Fusarium wilt disease, the combined application of the following combinations viz., *Trichoderma harzianum* (Prr2) + *T. harzianum*, *T. harzianum* (Prr2) + *T.asperellum*, *T. harzianum* (Prr2) + *Trichoderma koningii* (140C), *Penicillium pinophilum* (Bc2) + *T. harzianum*, *P. pinophilum* (Bc2)+ *T. pseudokoningii*, *P. pinophilum* (Bc2) + *T. asperellum*, *P. pinophilum* (Bc2) + T. koningii 140C, *P. pinophilum* (Bc2) + *T. viride* (K2T5), *P. pinophilum* (Bc2) + *T. viride* (poo), *Penicillium* spp. (Dsr1) + *Trichoderma pseudokoningii*, *Penicillium* spp. (Dsr1) + *Trichoderma asperellum*, *Trichoderma asperellum* + *T. viride* (poo) have recorded 100% reduction of Fusarium wilt disease and the *Foc* alone inoculated plants showed the disease score of 5.2.

## Evaluation of combined effect of biopriming of endophytic bacterial isolates

The biopriming of banana plants (@30 g of talc cum powder formulation of individual bacteria) with different combinations of five different endophytic bacteria viz., *Lysinibacillus* spp. Dsr1, Enbr1, *Burkheldoria* spp. Gctcr1, *Ochromobacter* Pjr1 and Gctcc2 was evaluated against Fusarium wilt pathogen (*Foc*-VCG 0124) under pot culture condition in cv. Grand Naine. The observation on plant growth parameters, number of roots and disease score of internal symptoms was taken at 6 months after planting. The results of the experiment showed that generally the biopriming of all the combinations of different endophytic bacterial isolates significantly increased the plant growth parameters such as height (88.8%), girth (91.8%), no. of leaves (87.5%), leaf area (161.8%) and roots (139.19%) when compared to *Foc* alone inoculated control plants. With regard to effect on Fusarium wilt disease, the biopriming of seven different combinations of endophytic bacterial isolates viz., *Lysinibacillus* spp. Dsr1+ Enbr1, *Lysinibacillus* spp. Dsr1+ *Ochromobacter* Pjr1, Enbr1 + *Burkheldoria* spp. Gctcr1, Enbr1+ *Ochromobacter* Pjr1, Enbr1+ Gctcc2, *Burkheldoria* spp. Gctcr 1+ *Ochromobacter* Pjr1 and *Ochromobacter* Pjr1 + Gctcc2 have recorded 100% reduction of Fusarium wilt disease and the *Foc* alone inoculated plants showed the disease score of 5.2.

## Evaluation of combined application of Difenaconazole and fungicide resistant mutant strains of *Trichoderma* spp. of rhizospheric and endophytic nature

The effect of soil application of fungicide Difenaconazole 0.1% along with fungicide resistant mutant of rhizospheric and endophytic *Trichoderma* spp. was evaluated for the suppression of Fusarium wilt disease under pot culture condition in cv. Grand Naine. The observation on plant growth parameters, number of roots and disease score of internal symptoms was taken at 6 months after planting. The result of the study showed that the soil application of Difenaconazole (0.1%) + rhizospheric *T. harzianum*, Difenaconazole (0.1%) + rhizospheric *Trichoderma viride* K2T5, Difenaconazole (0.1%) + rhizospheric *T. asperellum*, Difenaconazole (0.1%) + rhizospheric *T. pseudokoningii,* Difenaconazole (0.1%) + rhizospheric *T. koningii* 140c, Difenaconazole (0.1%)+ *Penicillium* sp. Dsr1, Difenaconazole (0.1%) + endophytic *T. harzianum* Prr2, Difenaconazole (0.1%) + endophytic *P. pinophilum* Bc2 recorded complete suppression of the disease with an internal score of 1.0 (healthy) as against pathogen alone

inoculated control plants which recorded *Foc* score of 4.8 (maximum score is 6.00).

### Evaluation of combined application of endophytic bacteria (biopriming) and botanical leaf extracts

The combined application of three effective endopyhtic bacteria viz., *Pseudomonas putida* (C4r4), *Acromobacter* (Gcr1) and *Bacillus* sp. (Tvpr1) and three effective botanicals viz., *Alpinia* sp., *Hibiscus* sp. and Zimmu was evaluated against Fusarium wilt pathogen (*Foc*-VCG 0124) under pot culture condition in cv. Grand Naine. The bio-agents were given as biopriming and leaf extracts were applied individually around the plants in soil (@250ml/ plant). The observation on plant growth parameters, number of roots and disease score of internal symptoms was taken at 6 months after planting. The results of the experiment showed that the combined application of both endophytic bacteria and botanicals significantly increased the plant growth parameters such as height (up to 38.32%), girth (71.43%), no. of leaves (41.11%), leaf area (93.56%) and roots (141.115) when compared to *Foc* alone inoculated plants.

However maximum increase of plant growth parameters was observed in *Bacillus* sp. + Zimmu treated plants and number of roots in *P. putida* +Zimmu treated banana plants. With regard to effect on Fusarium wilt disease, complete control (100% reduction) of the disease was observed in *P. putida* (C4r4) + *Alpinia* sp., *P. putida* (C4r4) + *Hibiscus* sp., *P. putida* (C4r4) + Zimmu, *Acromobacter* (Gcr1) +Zimmu, *Bacillus* sp. (Tvpr1) + Zimmu (Fig. 69).

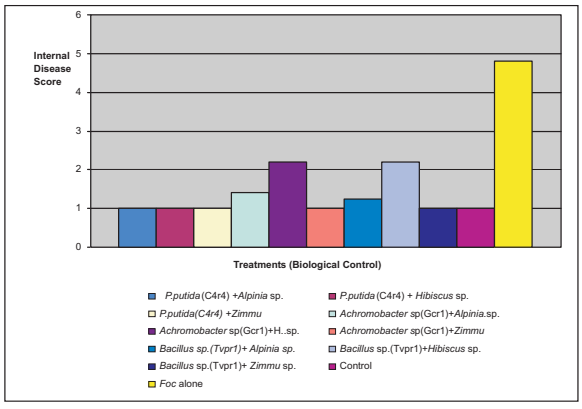



Fig. 69. Pot culture evaluation of endophytic bacteria (biopriming) + botanical leaf extract against Fusarium wilt disease (*Foc* VCG-0124)

## 5.5.5 Externally funded project-AMAAS

### Interaction effect of *Glomus* spp. and its Mycorrhizae Helper Bacterium (MHB) isolates for the suppression of Fusarium wilt disease in banana

Totally four isolates of VAM and nine isolates of MHB were evaluated individually as well as in combinations for the suppression of Fusarium wilt disease (*Foc* -VCG 0124) in cv. Grand Naine under pot culture condition. Besides, VAM isolate obtained from the market and necessary positive and negative controls were also maintained for comparison. The VAM and MHB were applied @ 50g each per plant at 10 days after planting. After 6 months of planting, observation on plant growth parameters, root characters and Fusarium wilt disease severity were recorded and analyzed statistically. The results indicated that all the VAM isolates individually as well as in combination with respective MHB isolates reduced the Fusarium wilt disease and also increased the plant growth and root characters significantly compared to *Foc* alone inoculated plants. However, complete control of Fusarium wilt disease (100% reduction) was recorded only in the plants treated with VAM+ MHB isolates viz., KPV+ *Enterobacter* sp. + *Azotobacter* sp. and TPV+ *Pseudomonas* sp. (Fig. 70).

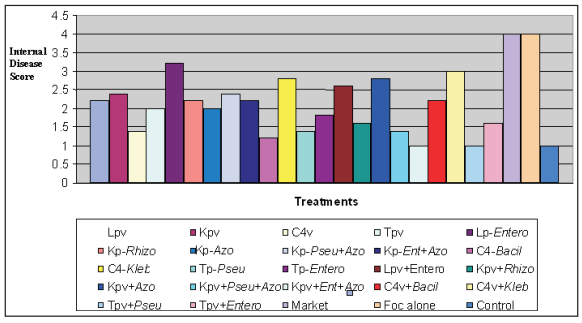



Fig. 70. Pot culture evaluation of VAM and VAM + MHB against Fusarium wilt disease (*Foc*) in cv. Grand Naine

### Network Project on Transgenic in Crops – Transgenic Component Development of transgenic banana with resistance to streak virus and bunchy top viruses. ( R.Selvarajan)

Southern analysis using radio labeled coat protein gene probes was carried out for PCR positive plants. Among 59 PCR positives, 3 plants were found positive in southern analysis.

### DBT-ATL scheme for virus indexing

Tissue culture samples were tested for banana viruses under contract service/ DBT – ATL scheme. Totally 11,216 samples had been tested for the presence of virus, out of which 2764 is for BBTV, 2775 for BSMYV, 2715 for BBrMV and 2926 for CMV. The number of positives for BBTV, BBrMV and CMV were 35, 9 and 7 respectively.

# 6. TECHNOLOGY ASSESSED AND TRANSFERRED

## 6.1 Training

### Partnership Development, Including Licensing of ICAR Technologies

Under Licensing of Technical Know-How, training on production of Banana Flower Pickle (Thokku) was licensed to Mr. P. Ravichandran, Trichy and three Banana based value added products namely Banana Fig, Flour and Banana Flower Pickle were commercialized to Mr. M Prakash, Proprietor, Plantation Foods (P) Ltd. Pirattiyur, Trichy.

## 6.2 Radio talks

| Name of the Scientist | Topic | Date of Broadcast |
|---|---|---|
| Jeyabaskaran, K. J. | Vaazaiyil Nunnutta Saththu Melanmai (Micronutrient management in banana) Question and Answers (in Tamil) | 21.04.2011. AIR, Trichy |
| | Vaazaiyil Uttachathu Melanmai (Nutrient management in banana) – Question and Answers (in Tamil) | 10.10.2011 AIR, Trichy |
| Kumar, V. | Weed management in banana cultivation- Vaazhai Sagupadiyil Kalai Nirvaagam Question and Answers (in Tamil) | 06.01.2012 AIR, Trichy |
| | Improved production technologies for cultivation of tissue culture bananas Question and Answers (in Tamil) | 27.05. 2011 AIR, Trichy |
| Sarashwathi, M.S. | Thisu valarppu vazhai Question and Answers (in Tamil) | 22.02.2012 AIR, Trichy |
| Selvarajan, R. | Vazhaiyil virus noi mazhanmai | 14.02.2012 AIR, Trichy |
| Shiva, K. N. | Vazhayil aruvadai pinsar thozhil nutppangal (in Tamil) | 26.11.2011 AIR, Trichy |
| Sundararaju, P. | Vazhaiyil Iyarka Murayil Nurpuzhu Melanmai Question and Answers (in Tamil) | 19.07.2011 AIR, Trichy |

## 6.3 Television Talks

| Name of the Scientist | Topic | Date of telecast |
|---|---|---|
| Shiva, K.N. | Production of value added products from Banana(Vazhayiliruinthu athiputtapattaporukkal thayarithyal) | 25.11.2011 & 26.11.2011/ Makkal TV, Chennai |
| Uma, S. | Udhayam uruvana varalaru' | 12.07.2011/ Makkal TV, Chennai |

## 6.4 Exhibitions conducted/ participated

| Sl. No. | Name of the Events | Organiser/ venue | Date(s) |
|---|---|---|---|
| 1. | Agri Expo- 2011 | Dinakaran Daily, Tiruchirapalli, Tamil Nadu | 15 - 17 July, 2011 |
| 2. | Kissan Mela - 2011 Tamil Nadu | NRCB, Tiruchirapalli, | 21 August 2011 |
| 3. | National Agri-Horti Expo - 2011 | Dept. of Agri-Horticultur, Kerala and Dept. of Consumers affairs & food, Govt. of India, Cochin, Kerala | 3 - 7 September, 2011 |
| 4. | Kissan Mela - 2012 | IISR Kozhikode, Kerala | 16- 18 Februar 2012 |
| 5. | Agricultural Education Day | NRCB, Tiruchirapalli, Tamil Nadu | 28 Feb. 2012 |
| 6. | Grievance Committee Meet | NRCB and State Depts., Govt. of TN, Tiruchirapalli, Tamil Nadu | 21 March, 2012 |
| 7. | Agri Expo - 2012 | Dinamalar Daily & IICPT Tiruchirapalli, Tamil Nadu | 23 - 26 March, 2012 |

Vice Chancellor, TNAU visiting the NRCB stall at Dinamalar Agri Expo-2011, Trichy

Farmers visiting the NRCB stall during Kissan Mela-2011 at NRCB, Trichy

# 7. EDUCATION AND TRAININGS

## 7.1 Educations (Students guided)

| Student Name | Degree | Project Title | Guide |
|---|---|---|---|
| J.P. Rajeshwari | M.Sc. | Efficacy of endophytic bacterial isolates from rhizosphere of banana and their bio control potential against root-lesion nematode, *Pratylenchus coffeae* | P. Sundarajau |
| K. Sangeetha | M.Sc. | Isolation and identification of endophytic fungi from rhizosphere of banana and their bio control potential against root-lesion nematode, *Pratylenchus coffeae* | |
| P. Jackulin | M.Sc. | Isolation, identification and laboratory bioassay of endophytic white-halo fungus, *Lecanicillium Lecanni* to control banana aphid, *Pentalonia nigronervosa* | B. Padamanaban |
| S. Kohila | M.Sc. | Isolation, identification and evaluation of endophytic Green muscardine fungi, *Metarhizium anisopliae* against banana aphid, *Pentalonia nigronervosa* | |
| R. Ramya | M.Sc. | Molecular characterization of anthracnose pathogen (*Colletotrichum musae)* and its management by native epiphytic microbes | R. Thangavelu |
| A. Malarvizhi | M.Sc. | Screening of banana germplasm against Banana Bract Mosaic Virus (BBrMV) through ELISA and PCR techniques | R. Selvarajan |
| P. Kiran Chaudhari | M.Sc. | Preliminary studies on the transmission of banana bunchy top virus (BBTV) by *Aphis gossypii* (cotton aphid) and *Pentalonia nigronervosa f.sp caladii* (cardamom aphid) | |
| Priya Antonent Roshan | M.Phil. | Mining of EST-SSR primers from *Musa acuminata* EST database and validation in *Musa* accessions | S. Backiyarani |
| B. Elesabath Rani | M.Sc. | Development of functional EST-SSR markers linked with root- lesion nematode (*Pratylenchus coffeae*) resistance in *Musa* | |
| K. BrindhaMadha | M.Sc. | Development of functional EST-SSR markers linked with root- lesion nematode (*Pratylenchus coffeae*) resistance in *Musa* | M. S. Sareswathi |
| S. Padma Narayani | M.Sc. | Embryo rescue and multiple shoot production in *Musa ornata* hybrids | S. Uma |
| S. Aishwarya | M.Sc. | Standardization of protocol for mass multiplication of *Musa.ornata* | |
| N. Mohana Devi | B.Tech. | Standardization of protocol for mass multiplication and regeneration of plantlets of *Musa boman* | |

## 7.2 List of Trainings offered

| Sl. No. | Title of the training | Date | No of Participants |
|---|---|---|---|
| 1. | Extraction of banana fibre and production of handicrafts | 5-7 April, 2011 | 04 |
| 2. | Production of value added products from banana | 11-16 July, 2011 | 11 |
| 3. | Extraction of banana fiber and production of handicrafts | 26-28 July, 2011 | 09 |
| 4. | NRCB field day | 21 August, 2011 | 350 |
| 5. | Postharvest handling, packing, storage and ripening in banana for domestic and export markets | 12 -15 December, 2011 | 09 |
| 6. | Improved production and post harvest technology in banana | 15 December, 2011 | 17 |
| 7. | Production of value added products from Banana to M/s Gramalaya, Trichy, Tamil Nadu | 23-28 January, 2012 | 05 |
| 8. | Extraction of banana fiber and production of handicrafts | 21 – 23 February, 2012 | 30 |
| 9. | Production of value added products from banana | 27 – 29 February, 2012 | 30 |
| 10. | Production of value added products from banana | 5 – 7 March, 2012 | 30 |
| 11. | Post harvest handling, packing, storage and ripening in banana for domestic and export markets to the block technology manger | 12-15 March, 2012 | 10 |
| 12. | On- site training for the State Govt. officials of Horticultural Research Complex, Nagicherra, Agartala on developing DUS Guidelines for banana under DUS project | 4 November, 2011 | 118 |
| 13. | SAS software statistical programme training to all NRCB scientists on about SAS 9.2 software programme operation and data analyses | 16-17 December, | 8 |
| 14. | Institute Biosafety Committee (IBSC) meeting | 14 June – 21 December, 2011 | 06 |

Trainees from SHG, Trichy District attending the training on production of value added products from banana during 27 – 29 February, 2012

# 8. AWARDS AND RECOGNITIONS

## 8.1 Awards

| Name of the Scientist | Name of the Award | Given by the organizer/ Place |
|---|---|---|
| Padmanaban, B. | **"Fellow of Society for Biocontrol Advancement"** award for the year 2007-09 | National Bureau of Agriculturally Important Insects (NBAII), Bangalore, on May, 2011 |
| Selvarajan, R. | **"Hari Om Ashram Trust"** award for the biennium 2008-09 for the outstanding contribution in the field of 'Crop and Horticulture Sciences' | Shri Harish Rawat, Hon'ble MOS (A) during ICAR foundation day, held at NASC, New Delhi on 16.7.2011 |
| | **"Agrani award"** for presenting the concept of development of nanotechnology based dipstick technique for indexing and on-site detection of banana viruses | The Lt. Amit Singh Memorial Foundation at NASC, New Delhi |

**Dr. R. Selvarajan,** Sr. Scietist receiving "Hari Om Ashram Trust award for the biennium 2008-09" for the outstanding contribution in the field of 'Crop and Horticulture Sciences' from Shri Harish Rawat, Hon'ble MOS (A) during ICAR foundation day, on 16/7/2011 held at NASC, New Delhi.

**Best stall Award :** Received "Best stall award" at the Agri Expo –2012 organized by Dinamalar Tamil Daily, Trichirappali & IICPT, Thanjavure held at National College Ground, Karumandabum, Trichirapalli, Tamil Nadu

## 8.2 Recognitions

| Name of the Scientist | Particulars |
|---|---|
| Sundaraju, P. | Institute Management Committee Member- Directorate of Oil Palm Research (DOPR), Pedavegi, Eluru, Andhra Pradesh.<br>Nodal Officer for RFD, HYPM and PIMS of the Centre<br>Acted as a Chairman in one of the Sessions on Award of Prof. Raski Gold Medal Presentation in the National Symposium on "Nematodes: A Challenge under changing climate and Agricultural practices" held at KAU, Vellayani, Kovalam, Kerala during 16-18, November, 2011 |

| Name of the Scientist | Particulars |
|---|---|
| Padmanaban, B. | External examiner for the evaluation of Ph.D.,thesis entitled "Studies on Neoseilus longispinosus Evans (Acari:Phytoseiidae) a major predator of Red spider mite infesting tea with emphasis on its genetic improvement by induced pesticide resistance" submitted by Mr.V.K.Jasin Rahman to Bharathiar University, Coimbatore. |
| | Co-chaired the session –other components for eco-friendly pest management in the 3rd Biopesticide International Conference (BIOCICON 2011) held at St.Xavier's College (Autonomous), Palayamkottai-627 002, Tamil Nadu, on 29 th November, 2011. |
| Uma, S. | Selected for 'Shri. Girdhari Lal Chadha memorial Gold Medal in Fruit Science' for the year 2011 by the Horticulture Society of India |
| | Recognized as a resource person for the committee on 'Utilization of wild *Musa* species in crop improvement' by the *MusaNet*, France and FAO, Rome |
| | Identified as University nominee for the "Institute Biosafety Committee (IBSC)" of the Bharathidasan University, Trichy, Tamilnadu |
| | Recognised as the External Examiner for Ph.D. students (2 nos.) in Horticulture by TNAU, Coimbatore |
| | Acted as co- chair of the two sessions of AICRP (TF) meeting on Genetic Resource Management and Varietal Development |
| | Invited as DBT nominee for the selection of SRF under the DBT funded project operative at Bharathidasan University, Trichy |
| Thangavelu, R. | Acted as external examiner and conducted Ph. D public viva-voce of M. Poongothai, Dept. of Plant Pathology, Sugarcane Breeding Institute, Coimbatore on 23-5-2011 |
| Kumar, V. | Member, 'Assessment Committee Team' for Rating of Horticultural Nurseries under NHB Scheme for "Accreditation and Relating of Horticulture Nursery" |
| | Member of Doctoral Committee, Ph.D., Scholar Doctoral Committee Meeting, Gandhigram Rural Institute- Deemed University, Gandhigram, Dindigul, Tamil Nadu |
| | External Examiner, Evaluation of answer scripts of Ph.D. Qualifying Examination, The Gandhigram Rural Institute- Deemed University, Gandhigram, Dindigul, Tamil Nadu |
| | External Examiner, Qualifying Viva Voce for PG (M. Sc. (Hort.) students, AC&RI (TNAU), Madurai on 01.07.2011 |
| | Life member of the society for promotion of horticulture, IIHR, Bengaluru |
| Selvarajan, R. | Editor of Indian Journal of Virology (a Springer publication) for the year 2011 |
| | Acted as selection committee member for selection of research fellows for the DBT (GOI) project "Repository Marine Cyanobacteria as Bio-diesel feed stock" in National Facility for Marine Cyanobacteria, Bharathidasan University, on 27th July, 2011 |

| Name of the Scientist | Particulars |
|---|---|
| | Acted as selection committee member for selection of research fellows for the DBT (GOI) project "Abiotic stress tolerance transgenic plant production in cotton by over expression of SiNAC transcription factor gene from fox-tail millet *Agrobacterium tumefaciens* mediated transformation in School of Life Sciences, Bharathidasan University, on 6th February, 2012 |
| | Acted as external examiner to conduct viva-voice exam for Mr P.R.Rahul, on 2nd September, 2011 for his thesis entitled on "Trasncriptomic analysis of defense related gene expression in Sugarcane *Colletotrichum falcatum* interaction" (Bharathiyar University, Coimbatore) |
| | Acted as external examiner for evaluation Ph.D thesis entitled "Molecular characterization and diagnosis of four major viruses infecting sugarcane in India' submitted by Mr. R.Karuppaih (Bharathiyar University, Coimbatore) |
| | Acted as external examiner for evaluation of a Ph.D thesis entitled "Detection, identification and characterization of the viruss/es causing mosaic in elephant foot yam (*Amorphophallus paeoniifolius*)" submitted by Mr. Binoy Babu |
| | Acted as external examiner and conducted dissertation viva voice examinations for five year integrated M.Sc life sciences programme in School of life sciences, Bharathidasan University, Tiruchirappalli, on 29th April, 2011 |
| | Acted as external examiner for evaluation of M.Sc (Agri) theses, TNAU, Coimbatore |
| | Recognized as external member of doctoral committee for PhD scholar, Ms.Raksha Ramakrishna Bawankar, School of Biosciences and Technology, Vellore Institute of Technology, Vellore |
| | Recognized as a reviewer for an international journal "Virus genes" and an "Indian Journal of Virology" |
| Jeyabaskaran, K.J. | Acted as external examiner for the three M.Sc.(Ag.) –students in the Department of Soil Science and Agricultural Chemistry, Agricultural College and Research Institute, Madurai, Tamil Nadu Agricultural University, during 2011-12 |
| Backiyarani, S. | Recognized as Research Adviser for guiding research work of candidates in Plant Biotechnology leading to the degree of Doctor of Philosophy in the Bharathidasan University, Trichy |
| | Recognized as external examiner for evaluation of thesis of M.Sc (Ag) Plant Breeding and Genetics of AC&RI, Madurai |
| | Nominated as member of the Doctoral committee for the candidate Mr. R. Manohar Jebakumar and K.Arun, Ph.D scholars of Bharathidasan University, Trichy |
| | Reviewed the research article entitled on "Molecular analysis of micropropagated banana varieties (*Musa* spp. 'AAA') using RAPD markers" for the Horticultural Society of India, New Delhi |

| Name of the Scientist | Particulars |
|---|---|
| | Reviewed the research article entitled "An assessment of genetic variability, heritability and genetic advance for economically important traits in Coriander (*Coriandrum sativum* Linn.)"for Indian Society of Spices, Calicut |
| | Reviewed the research article entitled "Stable male sterile lines and identification of fertility restorer and maintainer lines in chilli (*Capsicum annuum* L.)" for Indian Society of spices, Calicut |
| Shiva, K.N. | As subject matter expert, participated in the technical discussion on "Technology and Entrepreneurship in Banana Value Chain" in the International Training Programme on Agribusiness Incubation Consortia at ICRISAT, Hyderabad, A.P. on 22nd November, 2011 |
| | Chief Guest in the Seminar on Banana Ripening – Challenges and Solutions", organized by RINAC Engineering Evolution, Chennai at Breeze Residency, Tiruchirappalli, Tamil Nadu on 18th February, 2012 |
| Sarashwathi, M.S | Member of Doctoral Research Committee for guiding Ms. Gangadevi doing Ph.D research at the Pathology lab of NRCB, Trichy |

# 9. LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

- NRC Banana has collaborated with eight coordinating centers under All India Coordinated Research Project on Tropical Fruits, IIHR (ICAR), Bengaluru for 'Evaluation of different varieties of bananas for fibre extraction', as a lead centre (2011-2013).
- A MoU was signed between NRCB and S-KVK, R.T. Malai, Kulithalai Tk., Karur Dt. for Contract Research on 'Assessment of Banana Fibre Quality of Technology Up gradation & Designing/Branding/ Labeling of Fibre Products with Specific Standards' (under MAHIMA project) for Rs. 35,000/- on 4th May 2011.

# 10. PUBLICATIONS

## 10.1 Research Papers

### 10.1.1 International


Backiyarani, S., Uma, S., Sundararaju, P., Mayilvaganan, M., Saraswathi, M. S. and Jeeva, S. 2011. Studies on time-course expression of defence genes in banana against *Pratylenchus coffeae* for the creation of a subtractive cDNA library. *Acta Hort.* 897: 281-283.

Balasubramanian. V. and Selvarajan, R. 2012. Complete genome sequence of a banana bract mosaic virus isolate infecting the French plantain cv. Nendran in India. *Archives of Virology*, 157: 397-400.

Durai, P., Uma, S., Saraswathi, M. S., Jayabalan, N. and Mustaffa, M. M. 2011. Intersectional relationship between *Eumusa* and *Rhodochlamys* of the genus *Musa* using morphotaxonamy and microsatellite markers. *Acta Hort.* 897: 267-270.

Mustaffa, M. M. and Thangavelu, R. 2011. Status of Fusarium wilt in India. *Acta Hort.* 897: 323-329.

Nwauzoma, A. B, Uma, S., Saraswathi, M. S. and Mustaffa, M. M. 2011. Developing markers for Sigatoka leaf spot disease (*Mycosphaerella musicola* Leach) resistance in banana (*Musa spp.*) *African Journal of Biotechnology*. 10(33): 6213-6219.

Saraswathi, M. S., Uma, S., Vadivel, E., Durai, P., Siva, S. A., Rajagopal, G. and Sathiamoorthy, S. 2011. Diversity analysis in Indian cooking bananas (*Musa*, ABB) through morphotaxonomic and molecular characterisation. *Acta Hort.* 897: 123-131.

Selvarajan, R., Balasubramanian, V., Sheeba, M. M., Raj Mohan, R. and Mustaffa. M. M. 2011. Virus-Indexing Technology for Production of Quality Banana Planting Material: a Boon to the Tissue-Culture Industry and Banana Growers in India. *Acta Hort. 897*: 463-469.

Srinivasan, R., Kulothungan, S., Sundararaju, P. and Govindasamy, C. 2011. Biodiversity of plant parasitic nematodes associated with banana in Thanjavur district of Tamil Nadu. *International Journal of Plant, Animal and Environmental Sciences* I: 63-69.

Thangavelu, R. Suganya Devi, P. Chrismala, P. M, and Mustaffa, M. M. 2011. Cross infection and genetic diversity of *Fusarium oxysporum* f. sp. *cubense*, the casual agent of Fusarium wilt in banana. *Acta Hort.* 897: 353- 362.

Thangavelu, R., Muthukumar, K., Ganga Devi, P. Mustaffa, M. M. 2011. Genetic Diversity of *Fusarium oxysporum* f.sp. *cubense* isolates (*Foc*) of India by inter simple sequence repeats (ISSR) analysis. *Molecular Biotechnology*. 5: 203-211.

Uma, S., Mustaffa, M. M., Saraswathi, M. S. and Durai, P. 2011. Exploitation of diploids in Indian banana breeding programmes. *Acta Hort.* 897: 215-223.

Uma, S., Saraswathi, M. S. and Anto, D. 2011. Seed as an alternative source of DNA for

molecular research of inaccessible wild *Musa* species. *Acta Hort.* 897: 285-287.

### 10.1.2 National

Anuradha, C., Gorakh, P. G., Sasikumar, K. and Polumetla, A. K. 2011. Chimeric ä-Endotoxins of *Bacillus thuringiensis* with increased activity against *Helicoverpa armigera. International Journal for Tropical Insect Science*. 31(1–2): 59–68.

Jebasingh, T., Backiyarani, S., Manohari, C. and Usha, R. 2011. Detection of cardamom mosaic virus-related sequences in plant genomes. *Indian Journal of Biotechnology*. 10: 369-371.

Jebasingh, T., Jose, M., Kasin Yadunandam, Backiyarani, S., Srividhya, S., Krishnaswamy, S. and Usha, R. 2011. Molecular moddling and conformational analysis of native and refolded/viral genome-linked protein of cardamom mosaic virus. *Indian Journal of Biochemistry and Biophysics.* 48 : 336-340.

Palanichamy. S., Padmanaban, B., Fazal Mohamed, M. I. and Mustaffa, M. M. 2011. A simple and low cost semiochemical based trapping method for the management of banana pseudostem weevil, *Odoiporus longicollis* Olivier (Coleoptera:Curculionidae). *Advances in Applied Science Research.* 2: 69-73.

Palanichamy. S, Padmanaban, B., Fazal Mohamed, M. I. and Mustaffa, M. M. 2011 Microwave Oven Assisted Extraction of Banana pseudostem kairomones as attractant of *Odoiporus longicollis* Electroantennogram investigations. *Archives of Applied Science Research.*. 3: 213-16.

Sundararaju, P., Padmanaban, B., Jaffar, S. and Hemalatha, S. 2011. Effect of *Tithonia diversifolia*, leaf extracts on the mortality of root-lesion nematode infesting banana. *Indian Journal of Nematology.* 41: 63-67.

Uma, S., Saraswathi, M. S. and Durai, P. 2011. Evidence of new species in India -Musa warnaphalya and confirmation through morpho-molecular characterization. *Indian Journal of Horticulture*. 68 (6): 145-151.

## 10.2 Book Chapter

Padmanaban, B and Mustaffa, M. M. 2011. Insect Pests of Banana; Present management strategies and future thrusts. In Recent trends in integrated Pest Mangement Invited paper of the 3rd Congress on Insect science , pest Management for food security and Environment Health (eds.) Dhawan *et.al;* April 18-20 , 2011 ,INSAIA, PAU, Ludhiana , India. pp. 195-204.

Padmanaban, B and Subaharan, K. 2012 .Nano-Insecticide; Advances in Horticulture Biotechnology. Vol.6. Westwiley publication, New Delhi. pp. 207-214.

Ravi, I. and Mustaffa, M. M. 2012. Climate change impact, adaptation and mitigation strategies for resilient banana production. *In:* Adaptation and mitigation strategies for climate resilient horticulture. (Eds: K.S.Shivashankara, Prakash Patil, G.Selvakumar and V.Sridhar). Published by IIHR, Bangalore. pp. 95-109.

Ravi, I. and Uma, S. 2011 Phenotyping bananas and plantains for adaptation to drought. *In*: P Monneveux, J-M Ribaut, eds, Drought Phenotyping in Crops: From Theory to Practice. CIMMYT/Generation Challenge Programme, Mexico City. pp. 417-436.

Selvarajan, R. 2011. Nano technological approaches for early detection of plant pathogens. *In* Principles and Practices of Nano Applications. (Eds. K.S. Subramanian, A. Lakshmann, N. Natarajan, K. Gunasekaran, C.R. Chinnamuthu, P. Latha and C. Sharmila Rahale). pp. 282-289.

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## 10.3 Popular Article

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Anuradha, C. and Sasikumar, K. 2011. DNA barcoding as a tool for algal species identification and diversity studies. *In*: "National Conference on Perspectives on Biodiversity Conservation" held on 10.12.2011 at H. H. The Rajah's Govt. College, Pudukottai. Pp.38-39.

Kumar, V. and Mustaffa, M. M. 2011. Improved production technologies for banana cultivation. In SPIC Farm News Bulletin 7.

Kumar, V. and Mustaffa, M. M. 2011. Udhayam- A new variety of banana. In SPIC Farm News Bulletin 7.

Sasi Kumar, K., Anuradha, C., Govindan, T. and Balamurugan, G. 2011. Significance of seaweed liquid fertilizers for minimizing chemical fertilizers and improving yield enhancement of *Sesamum indicum*. *In*: "National level seminar on Recent Advances in Life Sciences" during 28th and 29th December 2011 held at Department of Zoology, H. H.The Rajah's Govt. College, Pudukottai. pp. 124.

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## 10.4 Technical bulletins

Anuradha, C. and Mispah, M. 2011. ITMU-broucher. 2011 for technology commercialization and dissemination to the scientist, farmers and entrepreneurs. NRCB Technical folder. Pp. 1-10.

## 10.5 Extension folders/ reports/ Scientific/ Teaching reviews

Kumar, V. and Mustaffa, M. M. 2011. High Density Planting in banana. NRCB Extension folder No. 21.

Shiva, K. N., Ravi, I., Mustaffa, M. M., and Mail Vaganan, M. 2011. Ethylene – Pazhukka vaikum oru bathukappana hormone (Tamil). NRCB Extension folder No. 19.

Thangavelu, R. and Mustaffa, M .M. 2011. Banana leaf spot disease and Management. NRCB Extension folder No. 20.

Uma, S., Saraswathi, M. S., Durai, P. and Mustaffa, M. M. 2011. Vazhai kandru

urpathiyil oru puthiya thozhil nutpam. NRCB Extension folder No. 18.

## 10.6 Training Manual

Shiva, K. N., Mustaffa, M. M. and Kamaraju, K. 2011. Extraction of Banana Fibre and Production of Handicrafts. National Research Centre for Banana, Trichy, Tamil Nadu, P. 27.

Shiva, K. N., Mustaffa, M. M. and Kamaraju, K. 2011. Value-added Products from Banana. Published by the Director, National Research Centre for Banana, Trichy, Tamil Nadu, P. 104.

Shiva, K. N., Mustaffa, M. M. and Kamaraju, K. 2011. Post Harvest Handling, Packing, Storage and Ripening in Banana for Domestic and Export Markets to the Farmers/ Entrepreneurs. National Research Centre for Banana, Trichy, Tamil Nadu, P. 61.

## 10.7 Research papers/ Abstracts presentations in Conferences / Symposia / Seminars / workshop / other fora:

### 10.7.1 International

Backiyarani, S., Uma, S., Arunkumar, G., Saraswathi, M. S. and Sundararaju, P. 2011. Expression Profiling of Root-Lesion Nematode Responsive Genes in Banana Cultivars. *In*: Program and Abstracts of the ISHS/ProMusa symposium on *Bananas and plantains: Towards sustainable global production and improved uses* held at Bahia Othon Palace Hotel, Salvador, Bahia, Brazil, 10-14 October, 2011. pp.120.

Backiyarani, S., Uma, S., Varatharaju, P. S., Saraswathi, M. S. and Sundararaju, P. 2011. Mining of *Musa* ECT Databases for the Development, Validation and Characterization of EST-SSRS. *In:* Program and Abstracts of the ISHS/ ProMusa symposium on *Bananas and plantains: Towards sustainable global production and improved uses* held at Bahia Othon Palace Hotel, Salvador, Bahia, Brazil, 10-14 October, 2011 pp.118.

Padmanaban, B., Siva Priya, R., Thangavelu, R., Uma, S. and Mustaffa, M. M. 2012. Distribution of endophytic fungi in *Musa* germplasm and their evaluation against Banana corm weevil and Banana Aphids. *In vitro* and *In vivo* screening for the identification of Fusarium wilt resistant mutants of cv.Rasthali (Silk-AAB). International symposium on banana held during 23-26th January at Chiang Mai, Thailand (Abs.). pp.12.

Padmanaban.B., Siva Priya, R., Thangavelu, R., Uma, S. and Mustaffa, M. M. 2012. Distribution of endophytic fungi in *Musa* germplasm and their evaluation against banana corm weevil, and banana aphid. International Symposium on Banana held at Chiang Mai, Thailand during 23-26 January, 2012. pp. 12.

Padmanaban, B., Siva Priya, R. and Mustaffa, M. M. 2011. Isolation and evaluation of White Halo fungus , *Lecanicillium lecanii* (Zimmerman) Zare & Gams. (Hypocreales: Ascomycota) against banana aphid, *Pentalonia nigronervosa* (Coq.) (Homoptera; Aphididae), 3rd Biopesticide International Conference, held at St.Xavier's College, Palayamkottai, 28-30 November 2011. (Abs). pp. 4.

Padmanaban, B., Palanichamy., S. and Karthikeyan, C. 2011. Electrophysiological and olfactory responses of banana aphid, *Pentalonia nigronervosa* (Coq.) to host plant extracts and semiochemicals. 3rd Biopesticide International Conference, held at St.Xavier's College, Palayamkottai, 28-30 November, 2011. (Abs). pp. 97.

Saraswathi, M. S., Thangavelu, R., Uma, S., Backiyarani, S., Kannan, G. and Mustaffa, M. M. 2012. *In vitro* and *In vivo* screening for the identification of Fusarium wilt resistant mutants of cv.Rasthali(Silk-AAB). International symposium on banana held during 23-26th January at Chiang Mai, Thailand (Abs.). pp.21.

Saraswathi, M. S., Uma, S., Backiyarani, S., Thangavelu, R., Kannan, G. and Punniyakodi, E. 2011. Determination of the $LD_{50}$ of Mutagens and Evaluation of the Mutants against Fusarium Wilt (Race 1). *In*: Program and Abstracts of the ISHS/ProMusa symposium on *Bananas and plantains: Towards sustainable global production and improved uses* held at Bahia Othon Palace Hotel, Salvador, Bahia, Brazil, 10-14 October, 2011. pp.158.

Saraswathi, M. S., Thangavelu, R., Uma, S., Backiyarani, S., Kannan, G .and Mustaffa, M. M. 2011. *In vitro* and *in vivo* screening for the identification of Fusarium wilt resistant mutants of cv. Rasthali (Silk – AAB). *In:* Program and Abstracts of the Royal Flora International symposium on Bananas held between 23-26, January, 2012 at Chiang Mai, Thailand. pp. 21.

Sundararaju, P., Anitha shree, T. and Mustaffa, M. M. 2011. Integrated Approach for Management of Major Nematodes in Banana. International Symposium on Banana held at Chiang Mai, Thailand during 23-26 January, 2012. pp.11.

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Uma ,S., Sudhakar, B., Backiyarani, S., Thangavelu, R., Saraswathi, M. S. and Manikandan, M. 2011. Validation of EST Data Obtained for Banana Cultivar 'Manoranjitham' Challenged by the Eumusae Leaf Spot Pathogen (*Mycosphaerella eumusae*). *In:* Program and Abstracts of the ISHS/ProMusa symposium on *Bananas and plantains: Towards sustainable global production and improved uses* held at Bahia Othon Palace Hotel, Salvador, Bahia, Brazil, 10-14 October, 2011. pp.155.

Uma, S., Mustaffa, M .M., Arun, K., Saraswathi, M. S., Backiyarani, S. and Durai, P. 2011. Breeding Pisang Awak - Screening of Best Female Parents, Donor Parents and compatibility Studies. *In*: Program and Abstracts of the ISHS/ ProMusa symposium on *Bananas and plantains: Towards sustainable global production and improved uses* held at Bahia Othon Palace Hotel, Salvador, Bahia, Brazil, 10-14 October, 2011. pp.112.

### 10.7.2 National

Sundararaju, P., Uma, S. and Mustaffa, M. M. 2011. Screening of banana cultivars for dual resistance to *Pratylenchus coffeae* and *Meloidogyne incognita.* National Symposium on "Nematodes: A Challenge under changing climate and Agricultural practices" held at KAU, Vellayani, Kovalam, Kerala during 16-18, November, 2011. (Abs). pp.95-96.

## 10.8 Delivered lectures as resource person/ Invited talk/ Guest lecture, etc.

| Name | Topic/ Place | Date |
|---|---|---|
| Dr.P. Sundararaju | Nematode problems on banana and their Management for Theni Banana Growers Association, Erasainaikanur, K.K.Patti and Kudaloor, Tamil Nadu | 8 July, 2011 |
| | Biodiversity and Biosystematics of Plant Parasitic Nematodes associated with banana in India at KAU, Vellayani, Kovalam, Kerala | 16-18, November, 2011 |
| | Awareness of insect pests and nematodes damage in banana and their integrated management at Department of Horticulture, Thalavadi, Tamil Nadu | 13 December, 2011 |
| | Improved Production Technology including Post Harvest Management and Value Addition in Banana toThe banana farmers/ entrepreneurs/ Horticultural/ Agricultural Officers/college students at NRCB, Tiruchirapalli, Tamil Nadu | 1 April, 2011 – 1 March, 2012 |
| Dr. B. Padmanaban | Management of Banana weevil borers and on eco-friendly pest management at Wayanad, Kerala | 10 February, 2012 |
| | Insect Pest Mangement on Precision farming and drip irrigation at Centre for Advanced Faculty Training (CAFT) at Dept.of Entomolgy, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu | 17 February, 2012 |
| | Eco-friendly Management of Insect Pests at Department of Zoology (PG), Jamal Mohamed College, Tiruchirapalli, Tamil Nadu | 17 March, 2012 |
| Dr. S. Uma | Biotechnological approaches to improve crop plants- an overview' at St. Joseph's College, Tiruchirapalli, Tamil Nadu | 22 August, 2011 |
| Dr. I. Ravi | Allele mining at NASC complex, New Delhi | 7 September, 2011 |
| | Frontiers in allele mining in plants at Division of Crop physiology, TNAU, Coimbatore | 10 November 2011 |
| Dr. R. Thangavelu | Status of leaf spot diseases in India and their management in the National conference on "Adaption to Climatic Change for Sustained production of Banana" at Jalgaon, Maharastra | 7-10 April 2012 |
| | Integrated management of diseases in banana at ADH, Department of Horticulture, Thalavadi, Erdode , TN. | 13 December, 2011 |

| Name | Topic/ Place | Date |
|---|---|---|
| | Banana diseases and their management in one-day programme on Improved production and post harvest technology in banana at NRCB, Tiruchirapalli, TN. | 15 December, 2011 |
| | Various diseases of banana and their management during Agricultural education day organized by NRCB, Tiruchirapalli, Tamil Nadu | 28 February, 2012 |
| | The management of diseases in banana during Farmers Grievance day meeting organized jointly by Collectorate, Trichy and NRC for Banana, Tiruchirapalli, Tamil Nadu | 21 March, 2012 |
| Dr. V. Kumar | Interaction Seminar on High Density Planting in banana" during the 18th Foundation Day of NRCB | 21 August, 2011 |
| | Banana Cultivation for the Horticulture Growers from Chamrajanagara Dist. Karnataka at NRCB, Tiruchirapalli, Tamil Nadu | 30 November, 2011 |
| | Banana Cultivation for the farmers from Sankarapuram & Rishivanthium Blocks of Villupuram Dt. TN, at NRCB, Tiruchirapalli, Tamil Nadu | 30 November, 2011 |
| | Improved Cultivation Practices in for enhancing Production and Productivity on Banan in the one day Seminar organized by the '*Thamizhaga Vivasaayigal Pathukappu Sangam'* at NRCB, Tiruchirapalli, Tamil Nadu | 16 October, 2011 |
| | Improved Production Technologies for Banana and Integrated Management of Pest and Diseases of Banana in the Training organized at the TNAU-KVK, Vriddhachalam for the farmers of Cuddalore Dist, Tamil Nadu | 8 December, 2011 |
| | Demonstration of banana bunch cover technology using polythene sleeves with 6% ventilation in Rasthali and Ney Poovan bananas at Srinivasanallur, Thottiam, Tamil Nadu | 14 February, 2012 |
| | Banana Production Technology in the Agriculture Education Day at NRCB, Tiruchirapalli, Tamil Nadu | 28 February, 2012 |
| | About NRCB for MBA students from RVS-KVK Institute of Management at NRCB, Tiruchirapalli | 3 March, 2012 |
| | Recent advances in banana cultivation, for the banana growers from Kanthili Block, Vellore Dist. at NRCB, Tiruchirapalli, Tamil Nadu | 8 March, 2012 |

| Name | Topic/ Place | Date |
|---|---|---|
| | Improved Cultivation Practices for Successful banana cultivation for farmers and staff of KVK, Kamatchipuram, Theni at NRCB, Tiruchirapalli, Tamil Nadu | 30 March, 2012 |
| | Advanced production technologies including HDP and Drip & Fertigation techniques for cultivation of Tissue culture Banana' for the benefit of Thanjavur farmers at NRCB, Tiruchirapalli | 27 March, 2012 |
| Dr. R. Selvarajan | Nano technological approaches for early detection of plant pathogens in ICAR-NAIP sponsored National training on Application of nano Science and technology in agriculture during, held at TNAU, Coimbatore, Tamil Nadu | 15 - 28 December, 2011 |
| | Next generation sequencing organized by National Facility for Marine Cyanobacteria, Bharathidasan University, Tiruchirappalli, Tamil Nadu | 29 Febuary, 2012 |
| | Exploitation of genomes of viruses infecting XIX banana in biotechnology in a UGC-NRCBS Winter School on Plant viruses as tools in Biotechnology held at School of Biological sciences, Madurai Kamaraj University, Madurai, Tamil Nadu | 1 - 15 November, 2011 |
| | Viral diseases of banana and their molecular aspects at a two day workshop organized by Indian National Science Academy – Indian Agricultural Research Institute for reviewing the progress of plant virology in India to develop Vision 2030 held at INSA New Delhi | 7 - 8 December, 2011 |
| | Viral diseases and their management for farmers from Namakkal district, at NRCB, Tiruchirapalli, Tamil Nadu | 15 December, 2011 |
| | Advances in biotechnological approaches for the management of plant viruses in the National Conference on Recent Advances in Plant Biotechnology' Dept. of Plant Science, Bharathidasan University, Tiruchirappalli, Tamil Nadu | 9 - 10 February, 2012 |
| | Evaluation of transgenic hill banana against banana bunchy top virus in the DBT task force meeting on Agricultural Biotechnology at TNAU, Coimbatore | 23 August, 2011 |
| | Use of nanotechnology for developing diagnostic kits for banana viruses in the National Dialogue for application of | 8 - 9 October, 2011 |

| Name | Topic/ Place | Date |
|---|---|---|
| | nanotechnology in Agriculture held at Central Institute of fisheries education, Mumbai | |
| | Nanotechnology based detection of plant viruses and phytoplasmas in National Consultation Meet on Nano Agriculture Mission held during at NASC,Pusa, New Delhi | 11 - 12 March, 2012 |
| | Interaction Meet with Scientists trained abroad in frontier areas of Agricultural Sciences organized by NASC at New Delhi. | 28 - 30 November, 2011 |
| | Disease Forecasting Decision Support System and Establishing Plant Clinics for Managing Virus Diseases in Banana and Plantains, Maharana Pratap University of Agriculture and technology, Udaipur | 10 - 13 January, 2012 |
| Dr.K.J. Jeyabaskaran | Socio-economic research platform – formulation of network project on Socio-economic research in Horticulture, held at IIHR, Bangalore | 1 November, 2011 |
| | Advanced technologies in banana cultivation for improvement in their research programme pertaining to banana crop at KVK Centre for Development and Communication Trust, Kamatchipuram, Tamil Nadu | 24 August, 2011 |
| | Deficiency of major and minor nutrient and its remedy in banana, organized by the Saraswathi KVK and NABARD at Karur District of Tamil Nadu, | 19 April, 2011 |
| | Soil fertility and nutrient management in banana for ATMA-farmers' organized by Saraswathi KVK at Analai village, Karur, Tamil Nadu | 26 May, 2011 |
| | Deficiency of macro and micronutrients and their correcting measures in banana to banana farmers of Namakkal District at NRCB, Tiruchirapalli | 15 December, 2011 |
| | Management of problem soils and nutrient management in banana for Maharashtra farmers at NRCB, Tiruchirapalli, Tamil Nadu | 06 November, 2011 |
| | Integrated nutrient and soil management in banana cultivation to a group of farmers from Navin Seed Growers Society, Raipur at NRCB, Tiruchirapalli | 10 August, 2011 |
| | Soil fertility and nutrient management in banana in a training programme to Andhra Pradesh farmers from Srikakulam at NRCB, Tiruchirapalli, Tamil Nadu | 12 March, 2012 |

| Name | Topic/ Place | Date |
|---|---|---|
| Dr. S. Backiyarani | Commercial varieties of banana and selection of tissue culture plants for the trainees of Agricultural/Marketing/Territory Managers of Bayer Crop Sciences at Mumbai | 28 May, 2011 |
| | Genome initiatives in *Musa* in the Brain storming session on Genomics and Bioinformatics in Horticulture at IISR, Calicut | 25 June, 2011 |
| | Application of Tissue Culture in *Musa* Improvement programme at Department of Genetics, School of Biological Sciences, Madurai Kamaraj University, Madurai, Tamil Nadu | 7 August, 2011 |
| Dr. K. N. Shiva | Business Opportunities in Banana" in the *CII meeting of Trichy Zone,* organized by CII – Trichy Zone at Hotel Sangam, Tiruchirapalli, Tamil Nadu | 9 September, 2011 |
| | Business Opportunities for MSME in Banana in the *Block level (Thottiyam) Committee meeting* organized by Gramalaya Training Center, Kulakudipatti, Manamedu, Thottiyam, Tiruchirappalli, Tamil Nadu | 29 October, 2011 |
| | Export of green banana to Middle-east at Theni- Chinnamanur, Tamil Nadu | 13 November, 2011 |
| | Processed and Functional Foods in Banana in the International Conference on Functional Foods and Health organized by Dept. of Food Science at Periyar University, Salem, Tamil Nadu | 18-19 November, 2011 |
| | Technology and Entrepreneurship in Banana Value Chain in the International Training Programme on Agribusiness Incubation Consortia at ICRISAT, Hyderabad, A.P. | 22 November, 2011 |
| | Post harvest handling, packing, storage and ripening" in the Seminar on Banana Ripening – Challenges and Solutions at Breeze Residency, Tiruchirapalli, Tamil Nadu | 18 February, 2012 |
| Dr. C. Anuradha | Conservation strategies for *Musa* in UGC sponsored National Conference on Perspectives on Biodiversity Conservation held on at H. H.The Rajah's Govt. College, Pudukottai, Tamil Nadu | 10 December,2011 |
| | Sequencing Vectors in DBT Sponsored Short term training on cyanobacterial advanced research techniques" School of marine science, Bharathidasan University, Tiruchirapalli, Tamil Nadu | 29 Febuary, 2012 |

# 11. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

- Three Banana based value added products namely Banana Fig, Flour and Banana Flower Pickle have been commercialized to Mr. M. Prakash, Proprietor, Plantation Foods (P) Ltd. Pirattiyur, Trichy under Licensing of Technical Know-How on non-exclusive basis during November, 21-23, 2011.
- Five products namely, *Banana Fig, Banana Flower Pickle, Stem Pickle, Juice/RTS and Fiber Products* were given to M/s Gramalaya, Trichy, Tamil Nadu under Licensing of Technical Know-How during 1st February, 2012.
- As an expertise of the 'Lab Accreditation Facility for Virus indexing and Genetic fidelity testing of tissue culture plants' fifty batches of tissue culture plants at various stages of production (varieties Grand Naine, Dwarf Cavendish, Robusta and Ambamore) from 14 different tissue culture companies have been tested for their genetic fidelity using SSR and ISSR markers and reports issued.
- Under Technical Consultancy project on *'Development of tissue culture protocol for the multiplication of banana variety Sabri',* Scientist of HRC, Nagicherra, Tripura in developing tissue culture protocol for cv. Sabri from Sep. – November 2011.
- Leaf samples of tissue culture banana plants and mother plant suckers from 21 tissue culture industries, were indexed with ELISA, PCR and NASH based techniques. Totally 2764 samples for BBTV, 2775 for BSMYV, 2751 for BBrMV and 2926 for CMV were tested for the presence of virus and Rs. 22,27,579/- has been generated the revenue under contract service for virus indexing.
- The polyclonal antiserum produced for CMV and BBTV has been sold to tissue culture companies and also to the SAU's viz., TNAU and KAU. Approximately an amount of 69518/- has been realized from the sales of antiserum raised for banana viruses.
- Genetic fidelity testing was carried out for two batches of banana tissue cultured plants obtained from Ram Biotech and Sai Lara & co.

# 12. RAC/ IMC/ IRC MEETINGS

## 12.1 RAC Meeting

Research Advisory Committee (RAC) meeting of the centre was conducted during 22nd and 23rd December, 2011, wherein, all the members of RAC including the Chairman Dr. P.Rethinam, Former Executive Director, APCC, Indonesia attended the meeting. Recommendations generated from the meeting were approved by the Council and communicated the same to all the members.

### Recommendations were

- Multidisciplinary mission mode approach needs to be taken up to conserve the

| S. No. | Name | Position |
|---|---|---|
| 1. | Dr. P. Rethinam | Chairman |
| 2. | Dr. Y. N. Reddy | Member |
| 3. | Dr. B. M. C. Reddy | Member |
| 4. | Dr. R. Palaniappan | Member |
| 5. | Dr. K. V. Ramana | Member |
| 6. | Dr. Rema Menon | Member |
| 7. | Dr. M. M. Mustaffa | Member |
| 8. | Prof. B. Sivarama Krishnan | IMC Member |
| 9. | Dr. P. Sundararaju | Member Secretary |


Dr. P. Rethinam Chairing the RAC meeting

Manoranjitham landrace of banana at the Kolli Hills since it is becoming endangered due to severe infestation of Fusarium wilt, insect pests (both weevils) and nematodes (root- knot, root-lesion and spiral nematodes)

- The ornamental banana garden should be developed at NRCB farm. Many ornamental banana types available at East Coast hybrid coconut garden at Itikalagunda, Tadepalligudem , West Godawari Dist. have to be procured.
- More emphasis should be given on the improvement of existing commercial / popular varieties like Rasthali and Ney Poovan through conventional breeding.
- Dwarf gene has to be identified and dwarf varieties have to be developed to avoid staking and protection from wind damage.
- Measures should be taken to popularize the Udhayam cultivar among the farmers in different parts of the country. The varietal spread has to be estimated and if planting material is the constraint, it should be taken up by the NRCB through micro propagation.
- A multi disciplinary study may be initiated to manage the climate change and produce economic yield of Banana
- Awareness should be created among the banana growers on the benefit of marketing as individual hands after proper de-handing instead of bunches as whole
- Efforts should be made to demonstrate the nematode management package in nematode infested areas prior to the popularization of the technology to the banana farmers.
- Effective Bio-control Consortia is to be developed for the effective management of nematodes, wilt and weevils and tested in the field.

## 12.2 IMC Meeting

The fifteenth meeting of the Institute Management Committee (IMC) was held on

**Members present in the IMC meeting were**

| Sl. No. | Name & Address | Position |
|---|---|---|
| 1. | Dr. M.M. Mustaffa, Director, NRCB, Trichy | Chairman |
| 2. | Dr. N. Kumar, Dean (Hort), TNAU, Coimbatore | Member |
| 3. | Shri. S. Robert Vincent, DDH, Trichy | Member |
| 4. | Dr. C.K. Narayana, Head-PHT, IIHR, Bangalore | Member |
| 5. | Dr. Sukhada Mohandos, Principal Scientist, IIHR, Bangalore | Member |
| 6. | Dr. S. Uma, Principle Scientist, NRCB, Trichy | Member |
| 7. | Dr. V. Pandey, Principal Scientist, NRCB, Trichy | Member |
| 8. | Shri. K.K. Hamza, F & AO, SBI, Coimbatore | Member |
| 9. | Prof. S. Sivaramakrishnan, M/s. Shankara Group, Trichy | Member (non-official) |
| 10. | Smt. C. Gomathi, AF&AO, NRCB, Trichy | Special Invitee |
| 11. | Shri. B. Vijayakumar, AAO, NRCB, Trichy | Member Secretary |

7.5.2011 under the chairmanship of Dr. M. M. Mustaffa, Director, NRCB. During this meeting, the varies policy decisions were discussed and recommended for approval by the Council.

## 12.3 IRC Meeting

The Fifteenth Institute Research Council Meeting was held on 2.4.2011, 4.5.2011, 5.5.2011and 2.8.2011 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 and Scientist, NRCB in the IRC meeting

# 13. TRAINING/ REFRESHER COURSE/ SUMMER/ WINTER INSTITUTES/ SEMINARS/ CONFERENCE/ SYMPOSIA/ WORKSHOP ATTENDED BY THE SCIENTISTS

## 13.1 Trainings

| Name of the scientist | Name of the Training Programme/ Venue | Period |
|---|---|---|
| Dr. I. Ravi | Undergone three months NAIP sponsored International training on Allele Mining at IRRI, Los Banos, The Philippines | 18th April, 2011 to 17th July, 2011 |
| | SAS 9.3 statistical software training/ workshop for the Consortia-based Research Project Strengthening statistical computing for NARS for the nodal officers of Hub – 8 organized by NAARM, Hyderabad | 15-16th November, 2011 |
| Dr. M. Mayil Vaganan | Advance training in Biomolecules–Metabolomics under National Agriculture Innovation Project (ICAR) at Metabolomics Research and Core Facility, Department of Molecular and Cellular Biology & Genome Centre, University of California, Davis, USA under the guidance of Dr. (Prof.) Oliver Fiehn | 21st March to 18th June, 2012 |
| Dr . R. Selvarjan | Dipstick technology in diagnostics of plant viruses held at CPRI, Shimla | 16-20th April, 2011 |
| | Underwent training on Fluorescent *in situ* Hybridization (FISH) in the Crop Improvement lab of Sugarcane Breeding Institute, Coimbatore | 24 - 25th August, 2011 |

| Name of the scientist | Name of the Training Programme/ Venue | Period |
|---|---|---|
| Dr. S. Saraswathi | NAIP overseas training on MAS at University of Leicester, United Kingdom under the guidance of Prof. Pat Heslop Harrison | 7th April – 6th July, 2011 |
| | NAIP training on Conservation of Genomic Resources held at NBPGR, New Delhi | 12 and 25th March, 2011 |

## 13.2 Seminars/ conference/ symposia/ workshop/ meetings etc.

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| Dr.M.M. Mustaffa | Meeting called by the Hon'ble Union Minister of Agriculture at his office, New Delhi to discuss about the Leaf Spot Diseases problem in banana in Jalgaon area, Maharashtra | 4th April, 2011 & 3rd October. 2011 |
| | ICAR Instts. Horticulture Division Meeting ICAR, New Delhi | 11th April, 2011 |
| | National Conf. on Horti-Business Linking farmers with Market, Dehradun | 28-30 May, 2011 |
| | Scientific Advisory Committee Meetings of CREED/ Rover KVKs, Ariyalur / Perambalur | 17-18 June, 2011 |
| | Project Finalization of RTB Project funded by Bioversity International. CTCRI, Thiruvananthapuram | 22nd June, 2011 |
| | Sub Group Working Committee Meeting on Horticulture Crops for 12th FYP, New Delhi | 24th June, 2011 |
| | Scientific Workers' Conference, TNAU, Coimbatore | 27th June, 2011 |
| | Sub Group Working Committee Meeting on Horticulture Crops for 12th FYP, IIHR, Bangalore | 30th June, 2011 |
| | ICAR Instt. Directors' Conference, NASC, New Delhi | 15-16th July, 2011 |
| | AICRP (TF) Group Discussion, BCKVV, Kalyani | 18-20th July, 2011 |
| | NAGS Network Project finalization Meeting at NBPGR, New Delhi | 17-19th November, 2011 |
| | Consortium Advisory Committee Meeting of NAIP Project on Utilization of Banana Pseudostem Fibres and VAP at NAU, Navsari. | 22nd November, 2011 |
| | DLEC – NHM Meeting at Collectorate, Trichy. | 20th January, 2012 |
| | International Symposium on Banana, Chiangmai, Thailand | 23-26th January, 2012 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | Meeting on the Proposal on Micro Nutrient Biofortification of banana for India – TOT from QUT Australia to India, DBT – BIRAP, New Delhi | 13th February., 2012 |
| | ICAR Institutes Directors' Conference, ICAR, New Delhi | 17-18th February, 2012 |
| Dr. P. Sundararaju | Sensitization cum Training Workshop for the PME Cell in charge (Nodal Officer) for preparation of Half Yearly Progress Monitoring (HYPM) at NAARM, Hyderabad | 13th February, 2012 |
| | Sensitization Meeting of Nodal Officers for preparation of Results Framework Document (RFD)" at NAS Complex, New Delhi | 22nd February, 2012 |
| | Seminar on Banana Cultivation organized by the Theni Banana Growers Association at Erasainaikanur, K.K.Patti and Kudaloor, Tamil Nadu | 8th July, 2011 |
| | National Symposium on "Nematodes: A Challenge under changing climate and Agricultural practices" held at KAU, Vellayani, Kovalam, Kerala | 16 – 18th November, 2011 |
| | Seminar on Banana Cultivation including Value addition organized by the Department of Horticulture, Thalavadi, Tamil Nadu | 13th December, 2011 |
| | Institute Management Committee meeting of the Directorate of Oil Palm Research (DOPR), Pedavegi, Eluru, Andhra Pradesh and Second meeting at Directorate of Oil Palm Research (DOPR), Regional Station, Trivandrum, Kerala | 25th June, 2011 & 3rd March, 2012 |
| Dr. B. Padmanaban | National training programme on Structure, function and dynamics of Biomolecules used in pest management of Horticultural Crops at CTCRI, Bhubaneswar, Odisha | 10-23rd May, 2011 |
| | Group discussion of All India co-ordinated Research Project on Tropical fruits at Bidhan Chandra Krishi Viswavidyalaya , Kalyani, West bengal | 18-23rd July, 2011 |
| | National Meeting on agricultural Entomology for the 21st Century: The way forward, at NBAII, Bangalore. | 25-26th August., 2011 |
| | Meeting on National dialogue for application of nanotechnology in agriculture at CIFE, Mumbai | 8-9th October, 2011 |
| | II National Dialogue on Application of Nanotechnology in agriculture at TNAU Coimbatore | 11-12th November, 2011 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | ICAR Challenge Programme on borer pests of crops at NBAII, Bangalore | 9th December, 2011 |
| | Meeting on White coffee Stem borer in and finalized the project proposal organized by IIHR & Coffee Board at Coffee Board Office, Bangalore | 9th February, 2012 |
| | As a ICAR representative attended the interview meeting held for the post of subject matter Specialists recruitment at CENDECT, Krishi Vigyan Kendra, Kamatchipuram | 24th March, 2012 |
| Dr. S. Uma | Biosafety meeting as nominee of the Vice Chancellor at Bharathisadasan University, Trichirapalli | 7th April, 2011 |
| | DBT sponsored training program on 'Molecular and *in-vitro* techniques' organized at Jamal Mohammed College, Trichirapalli | 28th November 2011 |
| | Review meeting of the foreign aided project' at NASC complex, New Delhi | 6th June, 2011 |
| | IMC meeting' of NRCB, Trichirapalli | 7th May, 2011 |
| | AICRP meeting' held at BCKVV, Kalyani, West Bengal | 18-22nd July 2011 |
| Dr. I. Ravi | Prioritization of Plant Physiology and Biochemistry Research for 12th Five Year Plan. Division of Plant Physiology, IARI, Pusa, New Delhi | 3-7th August, 2011 |
| | NAIP training on Allele Mining (Horticulture) chaired by Dr H.P. Singh, DDG (Horticulture). NASC Complex, New Delhi | 5-8th September, 2011 |
| | National stake holder's consultation on Climate Change platform meeting CRIDA, Hyderabad | 18th to 21st September, 2011 |
| | Second National Dialogue on Nanotechnology applications in agriculture. TNAU, Coimbatore | 10-12th November, 2011 |
| | Interaction meet with scientists trained abroad in frontiers areas of agricultural sciences at Shinde auditorium, NASC complex, New Delhi | 27-30th November, 2011 |
| | National dialogue on climate resilient horticulture at IIHR, Bangalore | 28-29th January, 2012 |
| Dr. R. Thangavelu | One day Seminar on Banana Cultivation organized by the Theni Banana Growers Association at Erasainaikanur, K.K.Patti and Kudaloor, Tamil Nadu | 8th July, 2011 |
| | Group discussion of All India co-ordinated Research Project on Tropical fruits held at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West bengal | 18-23rd July, 2011 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | International Symposium on Banana, Chiangmai, Thailand | 23-26th January, 2012 |
| | Agricultural education day organized by NRC for Banana and explained about the various diseases of banana and their management | 28th February, 2012 |
| | Farmers Grievance day meeting organized jointly by Collectorate, Trichy and NRC for Banana, Trichy and explained about the management of diseases in banana | 21st March, 2012 |
| | Discussion on management of Sigatoka diseases of banana as one of the steering committee members of CROPSAP programme of Maharastra at Aurangabad, Maharastra | 31st January, 2012 |
| | Meeting with Honerable Minister of Agriculture Govt. of India along with DDG (Hort), Secretary (A&C), Horticulture commissioner (DAC) and Director (NRCB) for discussing about the management of leaf spot disease in the entire Maharastra state | 4th April 2011 & 3rd October, 2011 |
| | One day Seminar on Banana Cultivation including Value addition organized by the Department of Horticulture, Thalavadi, Tamil Nadu | 13th December, 2011 |
| | Deputed as subject matter expert in the selection committee meeting to select SMS for both Thanjavur and Tirunelveli KVKs at RVS Engineering College, Dingigul | 10th January, 2012 |
| Dr. M. Mayil Vaganan | Meeting to discuss project on micronutrient biofortification of Indian bananas at BIRAP-DBT, New Delhi | 8th April, 2011 |
| | Meeting with DDG (Engineering) to discuss project on formulation of project on 'Natural fibers' at ICAR, New Delhi | 19th September, 2011 |
| | Brainstorming session on formulation of project on Application of nanotechnology in agriculture at TNAU, Coimbatore | 11&12th November, 2011 |
| | Meeting to finalize the project on 'micronutrient biofortification of Indian bananas' at BIRAP-DBT, New Delhi | 13th February, 2012 |
| Dr. V. Kumar | National Seminar on Horti Business- Linking farmers with Traders held at Dehradun, Uttaranchal | 28-31st May, 2011 |
| | Summer School on Sensor Based Applications for Precision Farming to Improve Input use Efficiency held at CIAE, Bhopal | 5-25th July, 2011 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | Content Validation Workshop on ICAAP Knowledge Management Portal attended by Agricultural Scientists, Extension Professionals and Agri-Credit Institutions at Thanjavur, Tamil Nadu | 28-29th September, 2011 |
| | 37th Scientific Advisory Council Meeting of TNAU KVK, Sirugamani, Tiruchirapalli, Tamil Nadu | 16th November, 2011 |
| | State Level KVK Interface Meeting organized by the Zonal Director, ZONE-VIII in Star Residency, Thanjavur | 18th November, 2011 |
| | One day Seminar on Improved Cultivation Techniques for Tissue Culture Banana at Dept. of Horticulture Thalavadi, Thalavadi, Erode Dist., Tamil Nadu | 13th December, 2011 |
| | District Level Seminar on Horticulture organized by the Deputy Director of Horticulture, Dept. of Horticulture, Vellore, Tamil Nadu | 29th Feb., 2012 |
| | Interaction Seminar on High Density Planting in banana" during the 18th Foundation Day of NRCB | 21st August, 2011 |
| Dr. R. Selvarajan | South Asia conference on current approaches to the environmental risk assessment (ERA) of genetically engineered crops at New Delhi organized by centre for environmental risk assessment, ILSI research foundation and BCIL | 16-18th May, 2011 |
| | 3rd Global conference on Plant Pathology and Food Security organized by Indian society of mycology and plant pathology and Maharana Pratap University of Agriculture and technology at Udaipur | 10- 13th January, 2012 |
| | INSA – IARI workshop for reviewing the progress of plant virology in India at INSA, New Delhi | 7 - 8th December, 2011 |
| | National consultation cum training on diagnostic in horticultural crops at CPRI, Shimla | 16-20th April, 2011 |
| | National Dialogue for Application of nanotechnology in Agriculture at Central Institute of fisheries education, Mumbai | 8-9th October, 2011 |
| | 2nd National Dialogue on application of Nanotechnology in agriculture held at Department of Nano Science and Technology, Tamil Nadu Agriculture University, Coimbatore | 11-12th November, 2011 |
| | National Consultation Meet on Nano Agriculture Mission at NASC, Pusa, New Delhi | 11- 12th March, 2012 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | Interaction meet of the Hon'ble Union Minister of Agriculture & Food processing industries with NARS scientists in crops and Horticulture at NASC, Pusa, New Delhi | 27- 28th September, 2011 |
| | Interaction Meet with Scientists trained in abroad in frontier areas of Agricultural Sciences at New Delhi held at NASC, Pusa, New Delhi | 28-30th November, 2011 |
| | Fifth and sixth Institute Bio-safety committee meeting at NRCB | 4th June, 2011 & 21st Dec., 2011 |
| | DBT task force meeting on Agricultural Biotechnology and presented a project on the Evaluation of transgenic Hill banana against banana bunchy top virus at TNAU, Coimbatore | 23rd August, 2011 |
| | Doctoral committee meeting at School of Biosciences and Technology, Vellore Institute of Technology | 6th August, 2011 |
| Dr. K. J. Jeya baskaran | Management Development Programme on Data Mining and GIS for Decision Support in Agriculture (Sponsored by NAIP) at Indian Institute of Management, Lucknow | 28th March to 8th April, 2011 |
| | Workshop meeting regarding Socio-economic research platform – formulation of network project on Socio-economic research in Horticulture, at IIHR, Bangalore | 1st November, 2011 |
| Dr. K. N. Shiva | First Trichy Zonal Meeting of MSME, organized by CII at Hotel Sangam, Tiruchirappalli, Tamil Nadu | 12th May, 2011 |
| | 2nd Panel meeting of MSME, organized by CII at CII Chamber, Tiruchirappalli, Tamil Nadu | 22nd June, 2011 |
| | Interactive Session on Business opportunities for Indian companies at BAVARIA, Germany, organized by CII at CII Chamber, at Hotel Sangam, Tiruchirappalli, Tamil Nadu | 23rd June, 2011 |
| | Banana Grower's Meet, organized by SBI, Trichy & Thottiyam branches at Thottiyam, Tiruchirappalli, Tamil Nadu | 29th June, 2011 |
| | Interactive Thottiyam block level Federation meeting for promotion of banana products, organized by Gramalaya Training Center, Kulakudipatti, Manamedu, Thottiyam, Tiruchirappalli, Tamil Nadu | 29th October, 2011 |
| | Interactive Farmers' Meeting on Export of green banana to Middle-east organized by APK Farm Fresh Banana at Theni-Chinnamanur, Tamil Nadu | 13th November, 2011 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | International Conference on Functional Foods and Health organized by Dept. of Food Science at Periyar University, Salem, Tamil Nadu | 18-19th November, 2011 |
| | International Conference-cum-Exhibition on Food organized by FICCI- AP State Council at Hyderabad International Convention Centre, Novotel Hotel, Hyderabad, Andhra Pradesh | 20-22nd November, 2011 |
| | Technical discussion on Technology and Entrepreneurship in Banana Value Chain with Uganda delegates in the International Training Programme on Agribusiness Incubation Consortia at ICRISAT, Hyderabad, Andhra Pradesh | 22nd November, 2011 |
| | Workshop on Food Processing, organized by National Institute of Micro, Small and Medium Enterprises (ni-MSME), Hyderabad at Temple In Hotel, Thanjavur, Tamil Nadu | 15th February, 2012 |
| | Seminar on Banana Ripening – Challenges and Solutions, organized by RINAC Engineering Evolution, Chennai at Breeze Residency, Tiruchirappalli, Tamil Nadu | 18th February 2012 |
| | Workshop on AgrIP- 2012 and Review meeting of ITMU, organized by South Zone - ZTMC at Grand Hotel, Cochin, | 24-25 February, 2012 |
| | Agricultural Education Day, organized by NRC Banana at NRC Banana, Tiruchirappalli, Tamil Nadu | 28th February., 2012 |
| | Farmer's Grievance Day meeting, organized jointly by Collectorate, Trichy and NRC Banana at NRC Banana, Tiruchirappalli, Tamil Nadu | 21st March, 2012 |
| | Farmers – Scientists interaction meeting in the 4th Agri Expo, organized by Dhinamalar Newspaper at National College ground, Karumandapam, Trichy | 24-27th March, 2012 |
| Dr. M.S. Saraswathi | NBPGR – NAGS meeting for efficient Management and use of Plant Genetic Resources held at NBPGR, New Delhi and presented the Status of activities on Plant Genetic Resources at NRCB, Trichy | 29-30th July, 2011 |
| | NAIP Review meeting held at NASC, New Delhi and presented the Highlights of the NAIP overseas three months training on Marker Assisted Selection held under the chairmanship of Honorable DDG (Hort.) | 6-7th September, 2011 |

| Name of the scientist | Name of the Programme/ Venue | Period |
|---|---|---|
| | Interaction Meet with Scientists trained abroad in Frontier areas of Agricultural Sciences at NASC, New Delhi under the chairmanship of Honorable DG (Hort.) and Secretary DARE. | 28-30th November, 2011 |
| Dr. C. Anuradha | National Conference on Perspectives on Biodiversity Conservation at H. H.The Rajah's Govt. College, Pudukottai | 10th December, 2011 |
| | Participated in the National level seminar on Recent advances in Life Sciences during 28th and at Department of Zoology, H. H.The Rajah's Govt. College, Pudukottai | 29th Dececember, 2011 |

## 14. SEMINARS/MEETINGS/ WORKSHOPS/ CONFERENCES/ SUMMER INSTITUTES AND FARMERS TRAININGS ORGANIZED AT THE CENTRE

### Kissan Mela

The National Research Centre for Banana, Tiruchirapalli, has celebrated its 18th Foundation Day on 21. 08. 2011 by organizing a 'Banana Field Day' with a theme on i) 'High density banana planting to increase productivity and ii) Integrated management of leaf spot disease.

The Field Day was organized mainly to highlight and disseminate the use of various technologies developed by the Centre including integrated management of leaf spot disease, viral diseases, insect pests and nematodes in banana cultivation to increase banana productivity. In addition, there was a Scientists – 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 have participated and discussed about various production and protection constraints. During the discussion, the scientists of the Centre have advised the farmers about the various practices to be followed to avoid the occurrence of pests and diseases.


Dr. M.M. Mustaffa, Director, NRCB, Dr. R. Ram Subbu, Assoc. Editor, Dinamalar, Trichy addressing in the Kissan Mela

Farmers from different districts of Tamil Nadu at the Kissan Mela meeting

Dr. R. Ram Subbu, Associate Editor, Dinamalar, Tiruchirappalli, Dr. K. Azhagu Sundaram, Director, IICPT, Thanjavur, Thiru J. Sekar, Joint Director of Agriculture, Tiruchirappalli and Mr. K. Balamurugan, Regional Passport Officer, Tiruchirappalli has participated in the function and spoken on various topics. Dr. R. Rama Subbu opened the exhibition arranged and also presided over the field day inaugural function and distributed the awards to the progressive banana farmers. In the technical sessions, Scientists of NRCB delivered lectures on high density planting and management of leaf spot disease. Besides, an exhibition was also arranged to demonstrate various advanced technologies on banana production developed by NRC for Banana. Other input companies related to banana production and protection like tissue culture, fertilizers, pesticides, fungicides, biological agents have also participated in the Kisan Mela.

## NRC Banana - Gramalaya for promotion of value added products in Banana

An agreement was signed between the National Research Centre for Banana (NRCB) and Gramalaya, Trichy for promotion of value added products in banana under transfer of technology (Technical know-how). In a function organized on 1st February 2012 at NRCB


Campus, Dr. M.M. Mustaffa, Director handed over the participation certificate and MoU agreement copy of Licensing of know-how to Mr. S. Damodaran, Founder Director and Mrs. T.N. Nalini, Programme Coordinator, self-help group for women, Gramalaya. This would envisage hand holding support for production of value added products from banana for the next five years on non-exclusive basis. Prior to this, hands-on training was given to team members of self-help group for women, Gramalaya by NRCB.

## NRC Banana - Mahalir Thittam (scheme for women) for promotion of Fiber and Value Added Products in Banana

The National Research Centre for Banana (NRCB) and Mahalir Thittam [implemented by the Tamil Nadu Corporation for Development of Women Ltd. (TNCDW)], Trichy have jointly involved in the promotion of fiber- based products and edible - value added products in banana under SGSY-Skill Development Training. In this endeavor, NRCB imparted a three day training programmes on 'Extraction of banana fiber and production of handicrafts' (one batch) and 'Production of value added products from banana' for 90 trainees in three batches during 21-23, 27-29 February & 5-7 March, 2012 at this Centre.


In a function organized on 14th March 2012 at NRCB Campus, the Chief Guest, Shri. G. Govindarajan, IAS, Additional Director, Rural Development & Panchayatraj, Chennai gave away the certificates to the women –SHG members, who participated in the training programmes.

Dr. M.M. Mustaffa, Director, NRCB in his presidential address appreciated the initiatives taken by the *Mahalir Thittam* for the promotion of value added products of banana with the technical support of NRCB.

## Agriculture Education Day

National Research Centre for Banana (ICAR) Trichy has organized "**Agriculture Education Day**" on 28th February, 2012, to expose the recent developments in agricultural research particularly in banana and also to create an awareness and motivation among the students of various schools in Trichy District. On this day, the Research Centre was open to the students and other stake-holders to show-case the research activities of the Institute and also interaction with the scientists and researchers to motivate the students on the opportunities available in horticulture and agriculture as career. The Research Centre has also made elaborate arrangements by keeping all the important advanced technologies developed at this Centre besides the basic studies conducted as well.

In this function, more than 500 students from different schools were participated. The NRCB Scientists explained various research activities of the Centre like, Banana varieties, Tissue culture techniques, Drip irrigation system, Fertigation methods, Eco-friendly and Bio-control methods for managing insects pests, nematodes, fungal and viral diseases. The value added banana products prepared at NRCB was given to all students and good response was noticed among the visitors.

Dr. M.M.Mustaffa, Director, NRCB inaugurated the function and gave presidential address. In his address, he informed the students about the carrier opportunities available in agriculture and allied sector and invited all the students to visit the NRCB at any time.

## Grievance Committee Meeting

The Farmers Grievance Day of Tiruchirappalli District was held at NRCB on 21.03.12 which was organized by Collector, Tiruchirappalli District. In this monthly farmers' grivence day meeting, Mrs. Jayashree Muralitharan, District Collector pointed out that the banana growers in the district were yet to fully utilize the service and research programme being taken up by the NRCB for their economic growth. While the Scientists will transfer the fruits of the research to farmers, the agriculturists, on their part, would explain their experience-based strategy, she said.

In the technical sessions, Scientists of NRCB delivered several lectures on high density planting, fertilizer management, improved production, protection and postharvest utilization. Besides, an exhibition was also arranged to demonstrate various advanced technologies on banana production developed by NRC for Banana. Agriculture input related to agriculture departments of State Govt. like production, protection, tissue culture plants, fertilizers, pesticides and biological control agents have also participated in this function.

Visit of students from Trichy district to learn different technologies developed at NRCB


Director, NRCB, District Collector and Joint Director of Agriculture, Trichy attending Farmers Grievance Day at NRCB

## 15. DISTINGUISHED VISITORS

| Sl. No. | Name and Address | Date |
|---|---|---|
| 1. | Dr. N. Kumar, Dean (Hort), TNAU, Coimbatore | 07.05.11 |
| 2. | Dr. C.K. Narayana, Head-PHT, IIHR, Bangalore | 07.05.11 |
| 3. | Dr. Sukhada Mohandos, Principal Scientist, IIHR, Bangalore | 07.05.11 |
| 4. | Dr. K.V. Peter, Director- World Noni Research Foundation, Chennai, Tamil Nadu | 13.06.12 |
| 5. | Shri O. Paneer Selvam, State Finance Minister, Tamil Nadu | 18.06.11 |
| 6. | Shri K.A. Sengotaiyan, State Agriculture Minister, Tamil Nadu | 18.06.11 |
| 7. | Shri N.R. Sivapathi, State Sports & Education Minister, Tamil Nadu | 18.06.11 |
| 8. | Dr. K. Azhagu Sundaram, Director, IICPT, Thanjavure, TN | 21.08.11 |
| 9. | Thiru. J. Sekar, Joint Director of Agriculture, Tiruchirappalli | 21.08.11 |
| 10. | Mr. K. Balamugan IFS, Passport officer, Tiruchirappalli | 21.08.11 |
| 11. | Dr. M. Anandaraj, Project Coordinator, IISR, Calicut, Kerala | 21.10.11 |
| 12. | Dr. S. Ayyayappan, Secretary-DARE & Director General-ICAR, New Delhi | 23.10.11 |
| 13. | Dr. H.P.Singh, Deputy Director General-ICAR, New Delhi | 20.12.11 |
| 14. | Dr. P. Rethinam, Former - ADG, ICAR, Coimbatore | 22.12.11 |
| 15. | Dr. Y.N. Reddy, Kukat Palli, Hyderabad | 22.12.11 |
| 16. | Dr. B.M.C. Reddy, Former Director – CISH, Lucknow | 22.12.11 |
| 17. | Dr. R. Palaniappan, R.T.Nagar, Bangalore | 22.12.11 |
| 18. | Dr. K.V. Ramana, Former ADG (Hort.), Rajamundhry | 22.12.11 |
| 19. | Dr. Rema Menon, BRS, KAU, Kannara, Thrissur | 22.12.11 |
| 20. | Dr. M. Mahadeveppa, Ex. Chairman-ASRB, New Delhi | 11.01.12 |
| 21. | Dr. Srikanth Kulkarani, Former Prof. & Head, UAS, Dharwad, Karnataka | 31.01.12 |
| 22. | Dr. C.D. Mayee, Ex. Chairman-ASRB, New Delhi | 31.01.12 |
| 23. | Dr. D.K. Sharma, Director, CSSRI, Karnal | 13.03.12 |
| 24. | Shri. G. Govindarajan, IAS, Additional Director, Rural Development & Panchayatraj, Chennai, Tamil Nadu | 14.03. 12 |
| 25. | Mr. G. Radha, Project Director, District Rural Development Agency, Tiruchirapalli, Tamil Nadu | 14.03. 12 |
| 26. | Shri H. Raja, Ex. MLA & National Exec. Member- BJP | 20.03.12 |
| 27. | Mrs. Jayashree Muralitharan IAS, District Collector, Tiruchirapalli, Tamil Nadu | 21.03.12 |

Dr. S. Ayyayappan, Secretary-DARE & Director General-ICAR, New Delhi visits NRCB research farm on 23.10.11

Dr. C.D. Mayee, Ex. Chairman-ASRB, New Delhi visits NRCB research farm on 31.1.12


Dr. H.P. Singh Deputy Director General-ICAR, New Delhi visits NRCB on 20.12.11

Shri K.A. Sengotaiyan, State Agriculture Ministers& Shri O. Paneer Selvam, State Finance Minister, Tamil Nadu visit to NRCB research farm on 18.6.11

## Visitors

About 3950 banana farmers, Agricultural & Horticultural officers, self help groups and students visited the Centre.

Visit of Agriculture student from TNAU, Coimbatore, for one day study programme at NRCB

Visit of farmers from Perambalur district for one day training programme at NRCB

## 16. EMPOWERMENT OF WOMEN

About 1050 women students including SHG and other women entrepreneurs from different parts of country visited NRCB and learnt various technologies available at NRCB such as Crop improvement, Crop Production, Crop protection and Post harvest technologies.

Womens of SHGS attending classes on Post harvest technology at NRCB

## 17. PERSONNEL

### Promotion

1. Mr.P.Ravichamy, promoted from T4, Tech. Asst (Journalism) to T5-Technical Officer w .e. f. 10.5.2010.

2. Mrs. T. Anitha Sree, promoted from T4, Tech. Asst (Field) to T5-Technical Officer w .e. f. 10.5.2010.

### Superannuation

1. Mr. B. Vijayakumar, Administrative Officer, retired from the service on 30.9.2011.

### Scientific Staff

| S.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. I. Ravi | Senior Scientist |
| 6 | Dr. R. Thangavelu | Senior Scientist |
| 7 | Dr. V. Kumar | Senior Scientist |
| 8 | Dr. R. Selvarajan | 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

| S.No. | Name | Designation |
|---|---|---|
| 1 | Mr. 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. R. Pitchaimuthu | T-3, Field Technician |
| 8 | Mr. N. Marimuthu | T-3, Field Technician |
| 9 | Mr. V. Selvaraj | T-3, Lab. Technician |
| 10 | Mr. T. Sekar | T-3, Lab. Technician |
| 11 | Mr. K. Kamaraju | T-3, Lab. Technician |
| 11 | Mr. M. Bathrinath | T-3, Field Technician |
| 12 | Mr. A. Subramanian | T-2, Driver |
| 14 | Mr. P. Mohan | T-2 Tractor Driver |
| 15 | Mr. V. Manoharan | T-2, Driver |

## Administrative, Audits & Accounts and Supporting Staff

| S.No. | Name | Designation |
|---|---|---|
| 1 | Mr. B. Vijayakumar | Administrative Officer(up to 30.9.2011) |
| 2 | Mr. M. Krishnan | Administrative Officer |
| 3 | Mrs. C.Gomathi | Asst. Finance & Accounts Officer |
| 4 | Mr. M. Krishnamoorthy | Personal Secretary to Director |
| 5 | Mr. R. Krishnamurthy | Assistant |
| 6 | Mr. R. Sridhar | Personal Assistant |
| 7 | Mr. R. Neela Mega Shyamala Kannan | Steno Gr. III |
| 8 | Mrs. S. Durgavathy | Upper Division Clerk |
| 9 | Mr. M. Devarajan | Lower Division Clerk |
| 10 | Mrs. A.U. Suja | Lower Division Clerk |
| 11 | Mr. R. Mohanraj | Mali SSG-IV |
| 11 | Mr. V. Pandiyan | Mali SSG-III |
| 12 | Mr. V. Thangaraju | Messenger SSG-II |
| 14 | Mr. P. Kamaraj | Mali SSG-II |
| 15 | Mr. V. Ganesan | Mali SSG-I |
| 16 | Mrs. K. Mariammal | Safaiwala SSG-I |

# 18. OTHER INFORMATIONS

## Hindi Day Celebrations

National Research Centre for Banana had celebrated 'Hindi Week' from 1st to 7th October, 2011 at the Centre. As a part of the program, various competitions like, Hindi Essay Writing, Hindi Noting and Drafting, Hindi Song, Hindi Quiz (Official language) and Memory Test were conducted for promoting Hindi as an official language in Central Govt. offices under the auspices of the Indian Council of Agricultural Resear ch (ICAR), New Delhi. As a part of the celebrations, concluding ceremony and prize distribution was organized on 12th October, 2011 at the Centre. Shri S.G. Joshi, Chief Commissioner of Income Tax, Tiruchirappalli graced the occasion as Chief Guest and distributed prizes to the winners of various Hindi competitions. In his address, he emphasized the importance of promoting Hindi as official language and necessity of learning Hindi as 'Rajbhasha' by every citizen. At the beginning, Dr. K.J. Jeyabaskaran, Senior Scientist welcomed the gathering. Dr. M.M. Mustaffa, Director, NRC Banana, delivered the Presidential address and spoke on Hindi week celebrations. He appealed to the employees to use Hindi in the day to day office activities. 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.

Shri S.G. Joshi, Chief Commissioner of Income Tax, Trichy delivering chief guest address on the eve of Hindi Day celebrations

## Director General, ICAR visits NRCB, Tiruchirapalli

Dr. S. Ayyappan, Director General- ICAR and Secretary- DARE, Government of India, New Delhi, visited National Research Centre for Banana on 23.10.2011 and inaugurated the newely constructed administrative building at NRCB, Trichy. In his inaugural address Dr. S. Ayyappan informed that the Indian Council of Agricultural Research has introduced a new programme for the farmers called "Farmer's First" in which, priority will be given to find solutions to the problems faced by the farming community by the research organizations and a special fund will be provided to carry out the research programmes. The fund will be to the tune of 3% of the total outlay of the each research institute in India. In addition to primary agriculture, more emphasis will be given to "Secondary agriculture" which involves

Dr. S. Ayyappan, Director General- ICAR opening the new annexure building for administration

Visit of Director General - ICAR to NRCB research farm

processing, storage, business incubators and value addition of the produce. He encouraged the scientists to go for more patenting of the technologies. In this endeavour, ICAR has identified 27 research platforms covering agriculture, horticulture, animal husbandry, fisheries and allied sectors in the 12th five year projections.

Dr. S. Ayyappan, visited the NRCB research farm, all laboratories and exhibition. He reviewed all the ongoing projects of the institute and advised the scientist to give more emphasis for the team work and work on a "Consortia mode" to find the solutions of the farmer's problems and also to give priority for the waste utilization in banana. Dr. S. Ayyappan also appreciated the technologies developed at NRC for banana for the benefit of the farmers and also the infrastructure developed for carrying out the frontline research activities to solve the problems of the banana farmers by which, the productivity and production of banana could be achieved to the target of 36 million tons which is set for the year 2020.

# 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**

2000711003 : Crop improvement of banana through non-conventional breeding
**S.Uma, M.S.Saraswathi and S.Backiyarani**

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 genes in banana
**S.Backiyarani, S.Uma and M.S.Saraswathi, P.Sundararaju and M.Mayilvaganan**

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**

2000713004 : Studies on micronutrients in banana
**K.J.Jeyabaskaran and V.Kumar**

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, M.M.Mustaffa and K.J.Jeyabaskaran**

2000716002 : Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance
**I.Ravi, M.M.Mustaffa, M.Mayilvaganan and S.Uma**

2000716003 : Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance
**I.Ravi, M.M.Mustaffa, M.Mayilvaganan and K.J.Jeyabaskaran**

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

## 3. Crop Protection

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

2000715002 : Studies on banana nematodes and their management
**P.Sundararaju, M.Mayilvaganan 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**

## 4. External funded projects

1. Network project on Transgenic in crops – Functional genomics in banana (Sigatoka and Drought)
**S.Uma, M.S.Saraswathi, R.Thangavelu, R.Selvarajan, S.Backiyarani and I.Ravi**

2. Network project on transgenics in crops – Transgenic component –Developing transgenic banana resistant to BSV and BBTV
**R.Selvarajan and C.Anuradha**

3. DBT-Development of transgenic hill banana resistant to BBTV
**R.Selvarajan**

4. DBT - Accredited test laboratory under national certification system for TC plants
**R.Selvarajan**

5. Net work Project on Phytophthora, Fusarium & Ralstonia diseases of Horticultural and field crops
**R.Thangavelu and S.Backiyarani**

6. Net work Project on harnessing arbuscular mycorozhiae for biofertilization in horticultural crops
**R.Thangavelu**

7. Regeneration and safety duplication of priority *Musa* collections
**S.Uma, M.S.Saraswathi and R.Selvarajan**

8. Screening of *Musa* germplasm for drought for the benefit of resource poor farmers
**S.Uma, I.Ravi and S.Backiyarani**

## 5. AICRP Programmes

1.2.1. Collection, characterization, conservation and evaluation of germplasm

1.2.3. Improvement through hybridization and mutation breeding

1.2.3. (b) Mutation breeding

1.2.4. (a) Development of mapping populations

4.2.2. Evaluation of different varieties of bananas for fibre extraction

5.2.3. (g) Management of banana rust thrips, *chaetanophothrips signipennis* (bagnall) using biopesticides.

6.2.1. Survey for fungal, bacterial and viral diseases of banana

6.2.5. (a) Studies on sigatoka leaf spot disease

6.2.6. Diagnosis of banana viruses in germplasm and planting materials used in experiments

6.2.7. Management of erwinia disease of banana

6.2.8. Screening of germplasm against rhizome rot

# ANNEXURE – II

## Meteorological Data

| Month | Max. Temp. (°C) | Min. Temp. (°C) | Relative Humidity (%) | Rain Fall (mm) |
|---|---|---|---|---|
| April 2011 | 37.63 | 26.20 | 86.13 | 8.30 |
| May 2011 | 39.61 | 27.22 | 77.96 | - |
| June 2011 | 37.53 | 27.36 | 75.33 | 5.10 |
| July 2011 | 37.19 | 26.41 | 74.61 | 7.50 |
| August 2011 | 36.32 | 26.25 | 79.32 | 176.37 |
| September 2011 | 35.53 | 25.93 | 78.70 | 211.42 |
| October 2011 | 33.29 | 25.93 | 89.51 | 355.18 |
| November 2011 | 30.20 | 23.43 | 90.13 | 301.11 |
| December 2011 | 29.96 | 22.06 | 89.90 | 18.50 |
| January 2012 | 31.19 | 20.41 | 89.54 | 6.49 |
| February 2012 | 33.82 | 21.37 | 89.17 | - |
| March 2012 | 37.16 | 23.74 | 83.09 | - |


# राष्ट्रीय केला अनुसंधान केंद्र

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

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