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(Indian Council of Agricultural Research)

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PREFACE

It is my pleasure to present the Annual Report for the year 2009-10. During the year, the Centre has developed many innovative technologies and products to increase the productivity and profitability of the banana farmers in India. Banana has witnessed significant increase in area and production. The production has reached 26.21 million tonnes during the last year. A change in the climate causing un-seasonal rains and drought was witnessed during the last year and the Centre has taken initiatives to mitigate the climate changes in terms of drought and has re-oriented the research programs accordingly.

The Centre has progressed well during the reporting period and the salient research achievements are presented in this annual report. With an aim to reduce the cost of production of Tissue Culture banana plants, initiatives are made to use low cost alternate materials like R.O. water, sago and table sugar which could produce the micro-propagated plants effectively at a lower cost. In addition, macro propagation techniques utilizing decortication has been standardized for faster multiplication of traditional varieties by the farmers themselves.

The production group has come out with many improved production techniques to reduce the cost of cultivation and also to increase the productivity and profitability of the farmers especially in Udhayam banana. Studies have indicated that use of bentonite sulphur has increased the fertilizer use efficiency of the applied fertilizers with higher up take of nutrients, thereby the yield can be increased. Phenotyping and molecular indicators have been identified for evaluating drought resistance in banana and also for salt stress.

In the area of protection, semio-chemicals have been identified as attractant for corm and stem weevils which are the major pests in banana. α- bisabol-ol and 2-methyl-4-heptanol have shown promising results in attracting corm and stem weevils respectively. Application of VAM along with *Paeciliomyces lilacinus* and *Trichoderma viride* simultaneously reduced the nematode population in Ney Poovan banana. Effective endophytic organisms have been identified against Fusarium pathogen. Molecular characterization of Foc pathogens has been completed and efforts are on for the effective control of Fusarium wilt disease in banana using bio-control agents.

Standardized techniques for the simultaneous detections of banana viruses using Real Time PCR and poly-clonal antiserum for recombinant coat protein of Bract Mosaic Virus have been initiated. Complete genome of Bract Mosaic Virus isolated from Nendran banana has been sequenced with 9711 nucleotides. Efforts to produce transgenic plants against banana Bunchy Top Virus in Hill Banana is in progress.

During the year the Centre has organized a Kissan Mela and "Brain Storming Session on Banana Value Addition and Post Harvest Technology" for the benefit of the farmers and entrepreneurs. Progressive banana farmers' awards were given to the farmers and entrepreneurs. In addition, the Centre has organized a "National Conference on Production of Healthy Planting Material in Banana" at Jalgaon, Maharashtra in which more than 400 farmers have participated and were benefited. One National Consultative Meeting on "Disease

diagnostics in Horticultural Crops" was organized at this Centre and more than 30 leading horticulture virologists have participated in the meeting.

Under HRD programme, two scientists were deputed to Guangzhou, China to attend the "International Banana Symposium on Global Perspective on Asian Challenges" and one scientist to San Diego, USA to attend "Plant and Animal Genome XVIII Conference".

The Centre has participated in many conferences and seminars for the transfer of technology to the farmers. One off-campus training at Agartala, Tripura and seven on-campus training programmes were organized as a part of HRD activity and more than 8000 banana samples were tested for viruses under contract research activity.

I specially appreciate and acknowledge Dr.B.Padmanaban, Principal Scientist, Dr.V.Pandey, Principal Scientist and Dr.M.Mayilvaganan, Senior Scientist, Chairman and members of the Publication Committee respectively for preparation and bringing out this Annual Report in a befitting manner.

I would like to place on record the guidance and encouragements received from Dr. H. P. Singh, Deputy Director General (Horticulture), ICAR and Dr. Mangala Rai, Former Director General, ICAR, New Delhi.

Tiruchirapalli
07-07-2010

(M.M. Mustaffa)
Director

2 कार्यकारी सारांश

फसल सुधार

प्राथमिक एवं द्वितीयक स्रोतों से केले के ३१ स्वदेशी जनन द्रव्यों का संग्रह तथा अन्तर्राष्ट्रीय स्तर पर, ऊष्ण फसल सुधार केन्द्र, बेल्जियम से ७२ विदेशी जनन द्रव्य संग्रहों को प्राप्त किया गया। तीन सौ दस अन्तरतम जनन द्रव्य संग्रहों के डी ऑक्सी आक्सी राइबो न्यूक्लिक अम्ल को - २०° सेग्रे तापमान पर भण्डारित करके रखा गया और दो से तीन वर्ष की लम्बी अवधि तक भण्डारण के पश्चात् इनकी गुणात्मक स्थिरता को भी सुनिश्चित किया गया। कम लागत की ऊतक संवर्धन तकनीक विकसित करने के क्रम में ऐसा पाया गया कि प्रतिलोम रसाकर्षण प्रकिया से प्राप्त साधारण जल, ठोस पदार्थ के लिए साबूदाना का चूर्ण (१३%) और कार्बन के स्रोत के लिए साधारण शर्करा (३%) समुचित पदार्थ हैं। लकड़ी के बुरादे को दीर्घ प्रवर्धन के लिए सबसे अच्छा वृद्धि माध्यम पाया गया। वैस्कुलर आरबस्कुलर माइकोराइजा को अकेले या इन्डोल ब्यूटायरिक अम्ल और *एजोस्पायरिलम* के साथ मिलाकर वृद्धि माध्यम के रुप में उपयोग किये जाने वाले लकड़ी के बुरादे में मिलाने से कलियों की वृद्धि में सतत सुधार पाया गया।

रसथाली एवं नेन्द्रन किस्मों में सोमैटिक भ्रूण बनने के लिए पिक्लोराम आधारित वृद्धि माध्यम अधिक सक्षम पाया गया। भ्रूणजनित कोषा अवलम्बन तकनीक से ब्युत्पादित रसथाली एवं नेन्द्रन किस्म के पौधों एवं पुत्तियों पर प्रक्षेत्र दशाओं में परीक्षण से ज्ञात हुआ कि उपज के दृष्टिकोण से सभी तरह के पौधे एक समान थे।

टेट्राजोलियम क्लोराइड (०.१%) से उपचारित केले के बीजों के भण्डारण पर अध्ययन से पता चला कि भण्डारण की अवधि बढ़ने से अंकुरण क्षमता कम हो जाती है। संकरित भ्रूणों की तुलना में, जंगली केले के भ्रूण आसानी से अंकुरित होते पाये गये । अपरिपक्व भ्रूणों में कैलसीकरण अधिक पाया गया जो कि परिपक्वता का स्तर बढ़ने के साथ सभी प्रकार के वृद्धि माध्यमों में घटता गया। पूर्ण रुप से विकसित भ्रूणों में कैलसीकरण नहीं हुआ बल्कि वो सीधे पौधे के रूप में विकसित हो गये । उत्परिवर्तन प्रजनन पर अध्ययन से पता चला कि प्रयोगशाली की दशाओं में कल्ले के मृदूतकों के मुरझा रोग के प्रति प्रतिरोधकता पर परीक्षण के लिए रोगकारी फ्यूजेरियम फूफूंद (प्रजाति संख्या १) का ३% संवर्धन छनित द्रव का मुराशिज एवं स्कुग वृद्धि माध्यम में मिश्रण पर्याप्त होता है।

आनुवंशिक संबंध मानचित्र तैयार करने के दृष्टिकोण से किये गये आरम्भिक परीक्षणों से पता चला है कि द्विगुणित एए (AA - एक्यूमिनाटा) और बीबी (BB - बल्बीसियाना) समूह में मध्यम रुप से विभिन्नताएं थीं परन्तु असमान युम्मनजता की प्रवृत्ति के कारण आरंभिक संततियों, जैसे प्रथम पीढ़ी की संततियों, को भी आनुवंशिक संपर्क मानचित्र तैयार करने में व्यवहार में लाया जा सकता है। भारत सरकार के जैव तकनीक विभाग की मान्यता प्राप्त परीक्षण प्रयोगशालाओं की मानक कार्य विधियों का अनुसरण करके, आई एस एस आर चिन्हकों के प्रयोग से केले की आनुवंशिक शुद्धता मापने की विधियों का मानकीकरण किया गया ।

घटनशील गोपनीय कोष (सप्रेशिव सबट्रैक्टिव लाइब्रेरी) तकनीक का अवलम्बन करके, टीकाकरण के छठवें दिन, केले की कार्थोम्बियम किस्म की जड़ो से जड़ धब्बा सूत्रकृमि *(प्रैटीलेंकस काफी)* के १४०० संग्रह स्थापित किये गये हैं। इस संग्रह में से ६१ क्लोन्स का क्रमांकन किया गया है जिनके बलास्ट एक्स विश्लेषण से पता चला है कि लगभग १३% जीन सूत्रकृमि प्रतिरोधी या प्रतिरक्षा संबंधी जीन से प्रभावित थे। इनमें से *म्यूसा* वंश के मेटैलोथायोनिन वर्ग (६२%) और अम्लीय काइटिनेज वर्ग III (७५%) के दो जीन, प्रतिकूल भौतिक अवस्थाओं से सम्बन्धित थे।

कैलोरीमीट्रिक एवं रियल टाइम पी सी आर विश्लेषणों से, *माइकोस्फीरेल्ला यूम्यूजी* नामक पत्ती धब्बा रोगकारी फफूंद से संक्रमित होने के १० से ३६ घण्टों की अवधि में, सफाईकारी कैटेलेज, परॉक्सीडेज और पॉलीफिनाल आक्सीडेज इन्जाइम्स की सक्रियता सबसे अधिक होने का पता चला।

फसल उत्पादन

'उदयम' प्रजाति के पौधों को कम दूरता पर रोपण करने से पौधों की ऊंचाई में बढ़ोत्तरी हुई परन्तु घैर निकलने में विलम्ब (४७२.६ दिन) और घैर के वजन में कमी जबकि उत्पादन (७२.१ टनङ्गहे.) में तुलनात्मक रूप से अधिक दूरता पर रोपण की अपेछा सुधार देखा गया. फल उत्पादन को किलोग्राम प्रति हेक्टेयर प्रति दिन के आधार पर आंकलित करने पर यह पाया गया कि अधिक पौध सघनता पर फल उत्पादन (११५.५४ किग्राङ्गहे.ङ्गदिन), कम पौध सघनता की अपेछा तुलनात्मक रूप से अधिक हुआ। पौध रोपण की सघनता बढ़ने पर केले के जड़ों के आसमास की मिट्टी में ग्रंथिल सूत्रकृमि की संख्या में बढ़ोत्तरी पायी गयी ।

'उदयम' किस्म की पहली रोपण फसल में प्रति पौधा २०० ग्राम नत्रजन + ४०० ग्राम पोटेशियम व्यवहार करने पर पौधों की ऊँचाई और तने की मोटाई सबसे अधिक पायी गई । अधिक उर्वरक (४०० ग्रा.ङ्गनत्रजन + ५०० ग्राम पोटैशियमङ्गपौधा) व्यवहार करने पर पत्ती में सम्पूर्ण हरीतिमा की मात्रा (२.८६ मिग्रा. ङ्ग ग्राम ताजी पत्ती का भार) सबसे अधिक पायी गयी । सबसे अधिक घैर का वजन (३१.१ किग्रा.) ४०० ग्राम नत्रजन + ४०० ग्राम पोटैशियम प्रति पौधा के व्यवहार से प्राप्त हुई। पौधों में रासायनिक उर्वरकों के प्रयोग की मात्रा बढ़ाने से जड़ों एवं आसपास की मिट्टी में जड़ ग्रंथिल सूत्रकृमि की संख्या में कमी पायी गयी ।

उच्च पी एच मान की दशाओं में, पौध रोपण के तीन महीने के बाद २० ग्राम प्रति पौधा बेन्टोनाइट सल्फर के मृदा में प्रयोग से, नेन्द्रन किस्म के पौधों की ऊँचाई, पत्तियों की संख्या, पत्तियों का कुल क्षेत्रफल, प्रति घैर फलों की संख्या, घैर के वजन और पत्तियों में नत्रजन, फास्फोरस, पोटैशियम, कैल्शियम, मेग्नीशियम और सल्फर की मात्रा में सुधार देखा गया। सल्फर के साथ फेरस सल्फेट और जिंक सल्फेट (प्रत्येक ५ ग्रामङ्खपौधा) का मिट्टी में और ०.५% बोरेक्स के पत्ती पर छिड़काव से, घैर के वजन (१२.५ किग्रा) में साधारण पौधों की तुलना में १०६.७ प्रतिशत तक की बढ़ोत्तरी पायी गयी। सल्फर के उपयोग से, केले के पौधों में पोटैशियम चयापचय की दक्षता में भी सुधार देखा गया।

उर्वरक समायोजन समीकरणों के आधार पर यह आंकलित किया गया कि पूवन किस्म की दूसरी फसल (पहली पेड़ी) में प्रति हेक्टेयर एक टन फल की उपज प्राप्त करने के लिए क्रमशः ११.५२, १.५७ और २२.६६ किलोग्राम नत्रजन, फास्फोरस और पोटेशियम की आवश्यकता होती है। इसी तरह से कर्पूरवल्ली किस्म की दूसरी (पहली पेड़ी) फसल में भी प्रति हेक्टेयर एक टन फल की उपज प्राप्त करने के लिए क्रमशः १२.८, १.४ और १८.७ किलोग्राम नत्रजन, फास्फोरस और पोटैशियम की आवश्यकता होती है। उपरोक्त दोनों किस्मों की दूसरी फसल (पहली पेडी) में मिट्टी, कार्बनिक खादों और रासायनिक उर्वरकों के व्यवहार से मिलने वाली नत्रजन, फास्फोरस एवं पोटैशियम की मात्रा के अनुपातों का भी आंकलन किया गया।

मानव मूत्र की ५० लीटर मात्रा को ५०० लीटर पानी में मिलाकर, पौध रोपण के तीन महीने पश्चात से लेकर नौ महीने तक की छ महीने की अवधि में प्रति सप्ताह समानुपातिक रुप से सिंचाई पानी के साथ बूंद-बूंद सिंचाई पद्धति से व्यवहार करने से, पूवन किस्म के पौधों की वृद्धि, फलों की उपज एवं गुणवत्ता में सुधार देखा गया और साथ-साथ उर्वरक की आवश्यकता में भी २५ % तक की कमी देखी गयी । इस तरह से कुल मिलाकर रु. ४५,१७५ङ्क- प्रति हेक्टेयर आर्थिक लाभ प्राप्त हुआ जिसमें रु. ८,६२५ङ्क- उर्वरकों की खपत में बचत से और रु. ३६,२५०ङ्क- घैर की बजन में बढ़ोत्तरी से शामिल था । प्रति पौधा १.५ किग्रा पी एस ओ ६ (एक तरह की कुक्कुट की खाद) और प्रति हेक्टेयर ५०,००० लीटर पी एस ओ ६ द्रवण के साथ उर्वरकों की ७५% मात्रा व्यवहार करने से पूवन (२५०० पौधा ङ्क हेक्टेयर) किस्म के पौधों की वानस्पतिक वृद्धि में सुधार एवं उपज में ३२.२६% तक की बढ़ोत्तरी पायी गयी ।

पुत्तियों से व्युत्पादित पौधों पर प्रेक्षणों से पता चला कि २५-२७° सेग्रे औसत तापक्रम एवं ६०% आपेक्षिक आर्द्रता पर प्रतिसप्ताह सबसे अधिक पत्तियाँ (एक से अधिक) निकलीं जबकि औसत तापमात्रा में २५-२७° सेग्रे से कम होने से पत्तियों के निकलने की दर में कमी (प्रतिसप्ताह एक से कम) पायी गयी ।

प्रति दस लाख भाग पानी में दो भाग ब्रासीनोलाइड्स और २५ भाग जिब्रेलिक अम्ल के मिश्रित द्रवण का विकाशील फलों पर छिड़काव करने से]नेय पूवन{,]पूवन{ और]सबा{ किस्मों के फलों के आकार में सुधारात्मक वृद्धि पायी गयी । इसी तरह से रोबस्टा पूवन, नेय पूवन और रसथाली किस्म के विलासशील फलों पर १.५ से २.० प्रतिशत पोटैशियम सल्फेट के छिड़काव से फलो के आकार में सुधारात्मक वृद्धि पायी गयी।

सिंचित पौधों की तुलना में (-०.२७ से -०.३६ मेगा पास्कल) प्रबल सूखे से ग्रसित *म्यूसा बल्बीसियाना* जाति और मंथन, सबा, पूवन, ग्रांड नेने और नेन्द्रन किस्म के पौधों की पत्तियों की रसशीलन क्रियाशीलता (-०.३५ से - ०.७७ मेगा पास्कल) में वृद्धि आंकी गयी। सूखा सुग्राही नेन्द्रन किस्म की तुलना में, सूखा सहिष्णु]म्यूसा बल्बीसियाना{ जाति तथा सबा, मंथन और पूवन प्रजाति के पौधों की पत्तियों में प्रोलीन की मात्रा (२४० - २६० मिग्राङ्कग्राम ताजा भार), कोशिका भित्ति स्थिरता सूचकांक (६८-७०) और कुल पर्ण हरीतिमा की मात्रा अधिक पायी गयी ।

घैर निकलने और फल परिपक्व होते समय सूखा सुग्राही नेय पूवन, नेन्द्रन और रोबस्टा प्रजातियों (४.५२ से १७.५६) की तुलना में, सूखा सहिष्णु सबा और कर्पूरवल्ली किस्मों की पत्तियों (मध्य शिरा एवं पत्र फलक) में पोटैशियम : सोडियम का अनुपात अधिक (>200) पाया गया।

मृदा लवणता की सुग्राही ग्रांड नेने किस्म में एबसिसिक अम्ल के छिड़काव से पौधों पर होनेवाले मृदा लवणता के प्रतिकूल प्रभावों में कमी लाना संभव हो सका। साधारण मिट्टी में इगाये गये पौधों की ऊपेछा, मृदा लवणता से प्रभावित पौधों में लगभग ४५ से ५२ दिन विलम्ब से घैर निकली। लवणता सुग्राही किस्मों की तुलना में, सहिष्णु]सबा{ और]नेय पूवन{ किस्मों के फलों में छिलकाः गूदा का अनुपात आपेक्षिक रुप से अधिक था। मृदा लवणता प्रभावित दशालों में केले के फलों के छिलकों में कुल शर्करा की मात्रा अधिक पायी गयी जिससे यह प्रदर्शित हुआ कि अति मृदा लवणता से प्रभावित दशाओं में शर्करा का स्टार्च में रुपान्तरण प्रभावी ढंग से नहीं हो पाता है। सूखाग्रस्त परन्तु विषाणु रोग के लक्षणों से मुक्त पौधों की तुलना में, सूखे से प्रभावित और धारीदार विषाणु के रोगी लक्षणों से प्रभावित पौधों की पत्तियों में पर्ण हरितिमा (३.३६ मिग्राङ्कगाम स्वच्छ भार) और कैरोटिनायड (०.३२३ मिग्राङ्कग्राम स्वच्छ भार) की मात्रा अपेछाकृत अधिक पायी गयी।

केले के पौधों की जड़ों में, जड़ धब्बा सूत्रकृमि (*प्रैटीलेंकस काफी*) के शुक से टीकाकरण के ३० दिन बाद, सूत्रकृमि सुगाही रोबस्टा और नेन्द्रन किस्मों की पत्तियों की आपेक्षिक वृद्धि दर में कमी देखी गयी जबकि प्रतिरोधी]अनाईकोम्बन{ एवं]{यंगम्बी के एम ५'{ किस्में अप्रभावित रहीं। जड़ धब्बा सूत्रकृमि की सुग्राही]रोबस्टा{ एवं

]नेन्द्रन{ किस्मों की तुलना में प्रतिरोधी]अनाईकोम्बन{ एवं]यंगम्बी के एम ५{ किस्मों की जड़ों में परॉक्सीडेज इन्जाइम की क्रियाशीलता में टीकाकरण के सात दिन बाद तक आपेक्षिक रुप से अधिक वृद्धि पायी गयी। इसी प्रकार से सुग्राही रोबस्टा और नेन्द्रन किस्मों की अपेक्षा, जड़ धब्बा सूत्रकृमि प्रतिरोधी]अनाईकोम्बन{और]यंगम्बी के एम ५{ किस्मों में पालीफिनॉल आक्सीडेज, फिनायल एलानीनलाइयेज, सिन्नेमायिल अल्कोहाल डिहायड्रोजिनेज, लिग्निन, विलेय फिनालिक्स, प्रोएन्थोसायनेडीन्स और टैनिन की मात्रा में भी तुलनात्मक रूप से अधिक अभिवृद्धि पायी गयी।

बिना तना बेधक कीट से ग्रसित स्वस्थ ऊतकों की तुलना में, तना बेधक कीट से ग्रसित केले के तने के आन्तरिक और आवरण भाग के ऊतकों में परॉक्सीडेज, पालीफिनॉल ऑक्सीडेज, फिनॉल्स, टैनिन्स और प्रोएन्थोसायनेडीन्स की मात्रा में अभिवृद्धि पायी गयी।

तेल की मात्रा ८०% से घटाकर ६०% करने से, केले के फूल के आचार की गुणवता, रूप और भण्डारण क्षमता में कमी देखी गई। कर्पूरवल्ली और रोबस्टा किस्म के फलों को एक किलोग्राम क्षमता वाले लहरदार दफ्ती के डिब्बों में भरकर, २२° सेग्रे के कम तापमान पर, ११ दिनो तक भण्डारित किया जा सका जबकि साधारण तापमात्रा (२८.५° सेग्रे) पर इन फलों को केवल चार दिनों तक ही भण्डारित किया जा सका।

सोडियम हायड्राक्साइड (०.५% या १.०%) के इपचार अथवा यांत्रिक निष्कर्षण की अपेछा, ०.१% सोडियम हायड्राक्साइड के इपचार करने से केले की कर्पूरवल्ली (०.४५%) और पूवन (०.४६८%) किस्मों के पर्णवृत्त आवरण से, शुष्क वजन के आधार पर रेशे की अधिक इपज प्राप्त हुई। सोड़ियम हायड्राक्साइड् क्षार द्वारा इपचारित और निष्कर्षित रेशों की अपेछा, यांत्रिक निष्कर्षण वाले रेशों में सेल्यूलोज और पेक्टिन की मात्रा अधिक पायी गयी जबकि लिग्निन की मात्रा क्षार इपचारित रेशों में अधिक पायी गयी। पर्णवृन्त (०.६७२%) की अपेक्षा, पर्ण शिराओं (१.६३%) में रेशे की मात्रा अधिक पायी गयी।

फसल सुरक्षा

तमिलनाडु के नामक्कल जिले की कोल्ली पहाड़ी क्षेत्रों में सर्वेक्षण से लाडन{]पहाड़ी केला{ एवं कर्पूरवल्ली किस्मों में जड़ धब्बा सूत्रकृमि एवं सर्पिल सूत्रकृमि के बहुतायत से संक्रमण एवं इसके कारण इत्पादन में सार्थक रुप से कमी होने का पता चला। प्रक्षेत्र दशाओं में, केले की नेय पूवन किस्म में वैस्कुलर आरबसकुलर मायकोरायजा के साथ जैविक खादों एवं जैव नियन्त्रकों *(पीसिलोमाइसीज लिलैसिनस और ट्राइकोडर्मा विरिडि)* के प्रयोग से सूत्र कृमियों की संख्या में सार्थक रुप से कमी देखी गयी। प्रयोगशाला दशाओं में *एक्टिनोमाइसिटीज* को जड़ धब्बा सूत्रकृमि को नियंत्रित करने में प्रभावी पाया गया।

पूवन एवं नेन्द्रन किस्मों के घन कंद से वाष्पशील यौगिकों को अलग करके पहचान किया गया है। परीक्षण किये गये कुल ३७ संश्लेषित रासायनिक यौगिकों में से]{अल्फा-बीसाबोल-आल{{ रसायन के प्रति घन कंद बेधक की आकर्षक प्रतिक्रिया सबसे अधिक थी । पराश्रयी पौधे के वाष्पशील यौगिकों के साथ, २-मिथॉयल ४-हेप्टानाल व्यवहार करने पर घन कंद बेधक सबसे अधिक आकर्षित हुआ । घन कंद बेधक की सबसे अधिक मृत्यु दर (८८%) *व्यूवेरिया बेसियाना* (एन आर सी बी-३४) और इसके बाद *मेटारायजियम अनीसोप्ली* (एन आर सी बी-३२) के व्यवहार से पायी गयी।

सर्वेक्षण एवं मिट्टी के नमूनों (३०८) के परीक्षण से भारत के पश्चिमी घाट के केला इत्पादक तड़ियानकुड़िसाई, एरकॉड और कोल्ली पहाड़ी क्षेत्रों में *ब्यूवेरिया बैसियाना* (१७ नमूनों में), *मेटारायजियम अनीसोप्ली* (२५ नमूनों में) और *बैसिलस थूरिनजिएन्सिस* (२४ नमूनों में) के पाये जाने का पता चला। महाराष्ट्र राज्य के जलगांव, पुणे और शोलापुर जिलों मे केले के घन कंद एवं तना बेधक कीट के पाये जाने की पुष्टि हुई। महाराष्ट्र के रावेर (जलगांव) एवं जुन्नार (पुणे) तालुकों से, फलों को क्षतिग्रस्त करने वाले केले के धब्बेदार कीट की पहचान की गयी।

केले के कंद बेधक कीट को]{फीरोमोन समूहन तकनीक {{ द्वारा आकर्षित करने के लिए, मिट्टी में समुचित नमी की अवस्था को एक क्रान्तिक कारक के रुप में पहचाना गया। प्रक्षेत्र दशाओं में]{अल्फा-बीसाबोल-आल{{ नामक एक रासायनिक यौगिक को प्रक्षेत्र दशाओं में घन कंद बेधक कीड़े की इपस्थिति के लिए चेतावनी सूचक के रूप में प्रभावी पाया गया। *हेटेरोहैब्डाइटिस इंडिका* (@१x१०^{६} संक्रामक शुक ङ्क मिली) के जेल् मिश्रण से इपचारित तने को बीचों बीच से फाड़कर तैयार किये लम्बवत टुकड़े को प्रक्षेत्र दशाओं में तना बेधक के नियन्त्रण (६०% मृत्युदर) में प्रभावी पाया गया।

फ्यूजेरियम मुरझा रोग प्रतिरोधी केले के २२ जननद्रव्य संग्रहों से निकाले गये १६७ इण्डोफायटिक जीवाणुओं की प्रजातियों को १० वर्गों में वर्गीकृत किया जा सका । इनमें से १४ प्रजातियों ने *फ्यूजेरियम* मुरझा रोगकारी फफूंद के प्रति बहुआयामी प्रभाव दर्शाया ।

फ्यूजेरियम मुरझा रोग प्रतिरोधी केले के २४ जनन द्रव्य संग्रहों से *एक्टिनोमाइसिटीज* प्रजाति की कुल ३० समजातियां विलग की गयीं। इसी तरह से *फ्यूजेरियम* मुरझा रोग प्रतिरोधी केले के १३ जननद्रव्य संग्रहों से *ट्राइकोडर्मा* फंफूद की ४३ समजातियां विलग की गयीं जिनमें *ट्राइकोडर्मा विरिडि* की २६, *ट्राइकोडर्मा हारजिएनम* की १३ और *ट्राइकोडर्मा स्यूडोकोनिंगाई* की एक समजाति के रुप में पहचाना गया। इन सभी को *फ्यूजेरियम* मुरझा रोगकारी फफूंद के बीजाणु अंकुरण को रोकने में प्रभावशाली पाया गया।

ट्राइकोडर्मा की १६ प्रजातियों में से, *ट्राइकोडर्मा* हारजियेनम, *ट्राइकोडर्मा स्यूडोकोनिंगाई,* ट्राइकोडर्मा कोनिंगाई और *ट्राइकोडर्मा विरिडि* प्रजातियां *फ्यूजेरियम मुरझा* रोगकारी फफूंद का बीजाणु अंकुरण एवं कायिक वृद्धि रोकने में प्रभावी पायी गयीं। *ट्राइकोडर्मा* फफूंद की चार समजातियां मृदा फास्फोरस के विलेयन में भी प्रभावी पायी गईं। तमिलनाडु, महाराष्ट्र और त्रिपुरा में सर्वेक्षण के इपरान्त संग्रह किये गये २५ नमूनों में से *ट्राइकोडर्मा* की बारह और शाकाणुओं की आठ समजातियां विलगित की गयीं। सम्पूर्ण भारत से संग्रह की गयीं *फ्यूजेरियम* रोगकारी की १८० समजातियों को जैव तकनीक के अवलम्बन से सात मुख्य समूहों में वर्गीकृत किया जा सका। गमलों में पौधे लगाने से पहले, *ट्राइकोडर्मा कोनिंगाई* और *ट्राइकोडर्मा स्यूडोकोनिंगाई* के साथ *एक्टिनोमाइसिटीज* को मिट्टी के मिश्रण में मिलाने से ऊतक संवर्धित पूवन किस्म में पौध लगाने के बाद छः महीने तक *फ्यूजेरियम* रोग के विकास को रोका जा सका ।प्रयोशशाला की दशाओं में कार्बेन्डाजिम (०.१%) का इपयोग फ्यूजेरियम मुरझा प्रबन्धन में प्रभावशाली पाया गया। रोपण से पहले पुत्तियों को कार्बेन्डाजिम (०.१%) विलयन से इपचारित करने के बाद लगाने, बृद्धिकारी पौधों में जड़ क्षेत्र की मिट्टी को सिंचित करने (@१-२ ली द्रवण पौधे की २, ४ और ६ मास की अवस्था में) और पौधे के तने में टीकाकरण (@ २ मिली पौधे की २, ४ और ६ मास की अवस्था में) करने से, प्रक्षेत्र दशाओं में नेय पूवन किस्म में *फ्यूजेरियम* मुरझा रोग को प्रभावशाली रुप से नियंत्रित किया जा सका है।

आन्ध्र प्रदेश के कड़प्पा और कोदूर जिलों में सर्वेक्षण से परंपरागत पुत्तियों और ऊतक संवर्धित पौधों से लगाये गये केले के रोपणों में अग्र शिरा गुच्छा रोग विषाणु के पाये जाने का पता चला तमिलनाड के पलनी और कोल्ली पहाड़ी क्षेत्रों में]{पहाड़ी{{ किस्म में अग्र शिरा गुच्छा रोग विषाणु; तूतीकोरिन और तिरुनेलवेल्ली जिलों में धारीदार एवं सहपत्र पच्चीकारी विषाणु जबकि पुदूकोट्टै, तन्जावुर, कड़लूर और नागपट्टीनम जिलों में अग्र शिरा गुच्छा विषाणु, धारीदार, सहपत्र पच्चीकारी एवं खीरा पच्चीकारी विषाणु विस्तृत रुप में केले के पौधों पर पाये गये। पूवन किस्म की पहली पेड़ी की फसल के धारीदार विषाणु संक्रमित पौधों में इर्वरकों की अधिक मात्रा का प्रयोग करने से भी इपज में वृद्धि नहीं हो सकी जबकि पूवन एवं नेन्द्रन किस्मों की पहली पेड़ी के सहपत्र पच्चीकारी विषाणु संक्रमित पौधों में इर्वरकों की बढ़ी हुयी मात्रा के प्रयोग से इपज में सुधार पाया गया। शेवाराय पहाड़ी क्षेत्रों, कोड़ईकनाल और मेघालय से संग्रहीत किये गये केले के अग्र शिरा गुच्छा रोग विषाणु के नमूनों में कोट प्रीटीन (सीपी) जीन से संबंधित जैव आण्विक आध्ययनों से नमूनों में आनुवंशिक विविधता का पता चला।

नेन्द्रन किस्म से विलगित किये गये सहपत्र पच्चीकारी विषाणु के संपूर्ण जीनोम का क्लोनीकरण एवं क्रमांकन किया गया जिसमें ६७११ न्यूक्लियोटाइड्स पाये गये। केले से विलगित किये गये खीरा पच्चीकारी विषाणु का सीपी जीन कान्सट्रक्ट तैयार किया गया। सहपत्र पच्चीकारी विषाणु के पुनर्संयोगी आवरण प्रोटीन के लिए पालीक्लोनल एण्टीसीरम का इत्पादन किया गया ।अग्र शिरा गुच्छा रोग विषाणु के रिप्लीकेज (रिप) जीन को स्पष्टकारी वेक्टर के माध्यम से *इशरशिया कोलाई* विषाणु में रुपान्तरित किया गया। केले के विषाणुओं को एक साथ पहचानने के लिए, *रीयल टाइम पी सी आर* तकनीक का मानकीकरण किया गया।

अग्रशिरा गुच्छा रोग विषाणु प्रतिरोधी पहाड़ी केले की ट्रान्सजीनिक किस्म विकसित करने के क्रम में प्रयोगशाला दशाओं में अध्ययनों से ५२ पौधों में रिप्लीकेज और गस जीन के प्रति सकारात्मक प्रतिक्रिया पायी गयी है, इनमें से आठ ट्रान्सजीजिक पौधों ने साइदर्न ब्लाट तकनीक के प्रति भी सकारात्मक प्रतिक्रिया दर्शायी। मुद्रा के भुगतान पर आधारित सेवाओं के अन्तर्गत, केले के लगभग ७,६६६ पौध नमूनों का विभिन्न विषाणुओं की इपस्थिति के लिए परीक्षण किया गया।

वर्ष २००६-१० की अवधि में, इस केन्द्र के वैज्ञानिकों ने चार रेडियो वार्ताओं, तीन दूरदर्शन वार्ताओं और क्षेत्रीय तथा राष्ट्रीय स्तर की सोलह प्रदर्शनियों में भाग लिया। परास्नातक इपाधियों के लिए, इस केन्द्र के वैज्ञानिकों द्वारा चौदह क्षात्रों को इनकी इनकी शोध परियो जनाओं ङ्क शोध ग्रन्थों के लिए परामर्शङ्कदिग्दर्शन प्राप्त हुआ। इस केन्द्र के वैज्ञानिकों को विभिन्न वैज्ञानिक ङ्क व्यवासायिक समितियों ङ्क संगठनों द्वारा छः पुरस्कार प्राप्त हुए। केन्द्र के वैज्ञानिकों द्वारा इस वर्ष आठ शोध पत्र, २४ लेख, प्रशिक्षण पुस्तिकाओं में १० लेख, पुस्तकों में १४ अध्याय, क्रमशः अन्तर्राष्ट्रीय एवं राष्ट्रीय सम्मेलनोंङ्कसंगोष्ठियोंङ्कबैठकों में १२ और ३८ संक्षिप्त लेख प्रस्तुतङ्कप्रकाशित किये गये । केन्द्र द्वारा जैव प्रौद्योगिकी, फसल सुधार, फसलोत्पादन, पादप सुरक्षा एवं फलों की तुड़ाई के पश्चात की प्रौधोगिकी जैसे विषयों पर परिसर से बाहर एक एवं परिसर के अन्दर सात प्रशिक्षण कार्यक्रम आयोजित किये गये। इस अवधि में १३ अति महत्वपूर्ण व्यक्ति एवं ३८२५ कृषक ङ्क कर्मचारी इस केन्द्र पर भ्रमण पर आये जिन्हें केन्द्र की गतिविधियों से अवगत कराया गया। गत वर्ष के दौरान केन्द्र द्वारा कुल रु. ३२,४८,५८३ङ्क- के धनराशि का राजस्व इपार्जन हुआ।

3 EXECUTIVE SUMMARY

CROP IMPROVEMENT

Indigenous accessions (31) were collected from primary and secondary sources and 72 exotic accessions were received from ITC, Belgium. Gene bank consisting of core germplasm collections was established and 310 accessions' DNA was stored at -20°C and their qualitatively stability over a period of 2 - 3 years of storage was confirmed.

Tissue cultured plants of Udhayam cultivar were supplied to progressive farmers for field demonstration. Use of low cost materials as alternatives in mass multiplication of Udhayam cultivar indicated Reverse Osmosis water, Sago (13%) and table sugar (3%) were equally effective. Saw dust was observed as the best medium for de-cortication in macro-propagation. Use of VAM alone and IBA + Azospirillum in the saw dust media consistently improved the bud proliferation.

Storage studies of banana seeds using 0.1% tetrazolium chloride indicated that germination per cent was reduced with increase in storage period. Embryos of wild bananas germinated easily compared to hybrid embryos. Callus induction was more in immature embryos and it decreased with embryo maturity irrespective of the media composition. Fully matured embryos failed to induce callus and exhibited direct regeneration into plantlets. Incorporation of 3% Culture Filtrate (Fusarium wilt race 1) in the MS medium was found to be optimum for screening of shoot meristems for wilt resistance under in vitro conditions.

Preliminary studies on the development of genetic linkage maps in Musa indicated that though all the AA and BB parents were moderately diverse and heterozygous F1 progenies could be used directly for the development of linkage maps. Protocol for genetic fidelity testing using ISSR markers was standardized as per the Standard Operative Procedure of DBT Accredited Testing Laboratory.

Suppressive subtractive library, containing more than 1400 colonies, was created from P. coffeae inoculated roots of cv. Karthombiumtham at six days after inoculation. From this library, 91 clones were sequenced. The BLAST X analysis indicated that 13% of putative genes were hit with resistance/ defense related genes out of which two genes were hit with stress related genes namely type II metallothionins (92%) and class III acidic chitinase gene (75%) of *Musa*.

Using calorimetric and Real Time PCR techniques, the activity of scavenging enzymes like Catalase, Peroxidase and Polyphenol oxidase was found to be at peak at its peak after 10-36 hrs of inoculation with Mycosphaerella eumusae.

CROP PRODUCTION

Planting of 'Udhayam' cultivar at closer spacing increased plant height, delayed shooting and decreased bunch weight but improved the fruit yield and productivity (72.1 t/ha) when compared with wider spacing. Productivity per day basis was also observed to be more at (115.54kg/ha/day) at higher plant density than lower plant density. Closer spacing recorded lowest phyllochron (6.3 days). Higher plant density increased the population built up of root knot nematode in soil rhizosphere.

In plant crop of Udhayam, maximum plant height and stem girth was recorded in 200g N + 400g K per plant application. Total chlorophyll content (2.86 mg/g of fresh leaf weight) increased due to higher fertilizer application. Maximum bunch weight (31.1kg) was recorded at 400g N + 400 g K per plant. Root knot nematode population in rhizosphere decreased with increasing doses of fertilizers.

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. Application of sulphur with FeSO4 and $ZnSO_4$ (each 5 g/plant) in soil and foliar spray of 0.5% borax improved the fruit yield (12.5kg) in Nendran cultivar (109.7%) over control. Sulphur application improved the efficiency of potassium metabolism also.

Based on fertilizer adjustment equations, it was estimated that 11.52 kg N, 1.57kg P and 22.96kg K is required for production of one ton fruit in first ratoon of Poovan cultivar. Similarly, 12.8kg N, 1.4kg P and 18.7kg K was required for production of one ton fruits in first ratoon of Karpuravalli cultivar. In addition N P K contribution from soil, organic manure and applied fertilizer was worked out in first ratoon crops of Poovan and Karpuravalli cultivars.

Application of 50 litre of human urine diluted with 500 liter water over a period of six months starting from three months after planting till ninth month daily through drip irrigation saved NPK fertilizers by 25 % and improved the plant growth, fruit yield and quality of Poovan banana. Additional monetary benefit of Rs 45, 175/- per hectare could be obtained due to saving of fertilizers (Rs. 8, 925) and increased bunch weight (Rs. 36, 250/-).

Application of 1.5 kg solid PSO_6 (a type of poultry sludge) per plant in combination with

50,000 litre liquid PSO_6 per hectare along with 75% recommended dose of fertilizers improved the plant growth and resulted in 32.29% more fruit yield of Poovan (2500 plants/ha) cultivar.

Observations on sucker derived plants revealed that the rate of leaf emergence was more than one per week if temperature was more than 25-27°C coupled with 90% RH. Decrease in mean temperature below 25-27°C reduced the rate of leaf emergence (< one week). Combined spray of two to six ppm brassinolides and 25 ppm GA3 on developing fruits improved the fruit size of Ney Poovan, Poovan and Saba cultivars. Similarly spray of 1.5 to 2% potassium sulphate on developing fruits improved the fruit size of Robusta, Poovan, Ney Poovan and Rasthali cultivars. Higher drought stress increased the leaf osmotic potential (-0.35 to -0.77MPa) when compared with irrigated plants(-0.27 to -0.36 MPa) of *Musa balbisiana* species and in Monthan, Saba, Poovan, Grand Naine and Nendran cultivars. Proline content (240 - 290 µg/ g fresh weight), Membrane Stability Index (68-70) and Total chlorophyll content were higher in drought tolerant *Musa balbisiana*, Saba, Monthan and Poovan cultivars when compared with susceptible Nendran cultivar. 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. Application of abscissic acid could alleviate the adverse effects of salt stress in susceptible Grand Naine cultivar. Salt stress delayed the shooting of banana by 45 to 52 days when compared to normal plants. Salt stress tolerant Saba and Ney Poovan cultivars had higher pulp: peel ratio than susceptible cultivars under salt stressed conditions. Total sugar content in peel was observed to be higher than pulp due to salt stress which indicated the non-conversion of sugar to starch under salt stress conditions. Increased leaf chlorophyll and carotenoid content in drought stressed and Banana Streak Virus infected but symptom less plants was observed when compared to plants with expressed symptoms.

Infestation of root lesion nematode (*Pratylenchus coffeae*) caused decrease in Relative Growth Rate of leaf in susceptible Robusta and Nendran cultivars but resistant Anaikomban and Yangambi km5 cultivars remained unaffected at 30 days after inoculation. Peroxidase activity gradually increased up to 7th day in resistant 'Anaikomban' and 'Yangambi km 5' cultivars which was more when compared with susceptible Robusta and Nendran cultivars. Similarly, polyphenol oxidase, phenyl alanine lyase, cinnamyl alchohol dehydrogenase, lignin, soluble phenolics, proanthocyanidines and tannin content also increased due to inoculation of root lesion nematode in resistant 'Anaikomban' and 'Yangambi km 5' cultivars when compared with susceptible Robusta and Nendran cultivars. The tissues of inner core and sheath infested with pseudostem weevil contained more peroxidase, polyphenol oxidase, phenols, tannins and proanthocyanidines when compared with un-infested healthy plant tissues.

Reduction in oil content to 60 per cent from 80 per cent reduced the quality, appearance and storage life of banana flower pickle. Karpuravalli and Robusta fruits packed in one kilogram capacity Corrugated Fiber Board boxes could be stored for 11 days at 22°C when compared with only four days at room temperature (28.5°C). Maximum fiber yield from leaf sheath of Karpuravalli and Poovan was recorded in 0.1% NaOH treatment as compared to either with 0.5% or 1% NaOH or machine extraction. Cellulose and pectin content were more in machine extracted fibers but lignin content was more in fibers extracted by alkali treatment. Leaf midrib contained more fiber than peduncle.

CROP PROTECTION

Root lesion nematode (*Pratylenchus coffeae*) and spiral nematode (*Helicotylenchus multicinctus*) were widely distributed and caused significant reduction in plant growth and yield in Ladan/ Hill banana and Karpuravalli cultivars in Kolli hills of Namakkal district of Tamil Nadu. Application of Vascular Arbuscular Mycorrhizae(VAM) along with bio-fertilizers and bio-control agents(*Paecilomyces lilacinus & Trichoderma viride*) significantly reduced the nematode population with increased yield in Ney Poovan cultivar under field conditions. Actinomycetes were found effective in controlling the root lesion nematode under in vitro conditions.

Volatile compounds associated with corm were isolated and identified from Poovan and Nendran cultivars. Of the 37 semiochemicals tested, maximum olfactory response by corm weevil was recorded to α-bisabol-ol. Maximum attraction (88%) of stem weevil was recorded due to use of 2- Methyl 4-heptanol in combination with host volatiles. Maximum mortality (88%) of stem weevil was recorded due to application of *Beauveria bassiana* (NRCB-34) followed by *Metarrhizium anisopliae* (NRCB-32). Survey and analysis of soil samples (308) indicated the presence of *Beauveria bassiana* (17 samples), *Metarhizium anisopliae* (25) and *Bacillus thuringiensis* (24 samples) in banana growing areas of Thadiankudisai, Yercaud and Kolli hills of Western Ghats of India. Survey revealed the infestation of banana weevil in Jalgaon, Pune and Sholapur districts of Maharashtra. Banana spotting bug damaging fruit was recorded in Raver (Jalgaon)

and Junnar(Pune) taluks of Maharashtra. Optimum soil moisture was observed to be a critical factor in corm weevil attraction by aggregation Pheromone Technique. A semiochemical " α- Bisabol-ol" was found effective for banana corm weevil monitoring under field conditions. Longitudinally split banana stem traps treated with gel formulation of *Heterohabditis indica* (1 x 10^9 Infective Juveniles/ml) were effective in killing of 60% stem weevil under field conditions.

Endophytic bacterial strains (197) belonging to 10 groups were isolated from 22 *Fusarium* wilt resistant banana accessions. Of these, 14 strains showed multiple action against Fusarium pathogen. A total of 30 isolates of endophytic *Actinomycetes spp* were isolated from Fusarium wilt resistant 24 banana accessions. Similarly, 43 isolates of *Trichoderma* were isolated from fusarium wilt resistant 13 banana accessions; of which 29 were *T. viride,* 13 were *T. harzianum* and one was *T. pseudokoningii*. All these were effective in inhibiting spore germination of *Fusarium* pathogen. Of the 19 *Trichoderma* spp., *T. harzianum, T. pseudokoningii, T. koningii* and *T. viride* were found effective in inhibiting the spore germination and mycelial growth of wilt pathogen. Four isolates of *Trichoderma* spp. were identified to be effective in phosphate solublization. Surveys were conducted in Tamil Nadu, Maharashtra and Tripura and 12 *Trichoderma* spp and eight bacterial strains were isolated from 25 samples. From 180 isolates collected from all over India, Fusarium wilt pathogen could be classified in to seven major groups by molecular characterization. Before planting in pots, application of Actinomycetes along with *Trichoderma koningii* and *Trichoderma pseudokoningii,* inhibited the wilt disease development up to six months in tissue cultured Poovan cultivar. Application of Carbendazim was observed to be effective in Fusarium wilt management under *in vitro* conditions. Carbendazim (0.1%) dipped 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.

Surveys revealed the presence of banana bunchy top virus disease in both tissue cultured and conventional suckers raised plantations in Kodur and Cuddappa districts of Andhra Pradesh. Pulney and Kolli hills had incidence of bunchy top virus on hill banana. In Tuticorin and Tirunelveli, banana streak virus and bract mosaic virus incidence were recorded whereas, in Pudukottai, Thanjavur, Cuddalore and Nagapattinum districts bunchy top, streak, bract mosaic and cucumber mosaic viruses were observed on banana plants. Increased dose of fertilizers could not improve the fruit yield in streak virus infected ratoon plants of Poovan cultivar but in bract mosaic virus infected first ratoon plants of Poovan and Nendran cultivars, there was improvement in fruit yield due to increased fertilizer dose.

Molecular characterization revealed genetic variability in respect of cp gene in bunchy top virus samples collected from Shevroy hills, Kodaikanal and Meghalaya. Complete genome of bract mosaic virus isolated from Nendran cultivar was cloned and sequenced which had 9,711 nucleotides. A cp gene construct isolated from banana was prepared. Polyclonal anti-serum for recombinant coat protein of bract mosaic virus was produced. Bunchy top virus rep gene was cloned into expression vector and transformed into *Escherichia coli* bacterium. Real Time-PCR technique for simultaneous detection of banana viruses was standardized. Staining and visualizing different stages of chromosomes in Poovan cultivar was standardized for locating endogenous para-retroviral sequences of banana streak virus. In an attempt to develop transgenic Hill banana resistant to bunchy top virus, laboratory studies revealed 52 plants to be positive for both replicase and gus genes out of which eight transgenic banana plants were positive to Southern Bloat Technique. Under contractual services, about 7,969 banana plant samples were tested for presence of different viruses.

Transfer of Technology

During 2009-10, the scientists of the center participated in four radio talks on All India Radio,Tiruchirapalli , three television talks and 16 exhibitions organized at regional or National levels. Fourteen students were guided for their project/ thesis work for the award of M. Sc. Degree by the scientists of this centre. The scientists of the center got six awards from different professional/scientific societies/organizations. Eight research papers, 24 articles, 10 chapters in training manuals, 14 chapters in books and 12 abstracts in International and 38 abstracts in National Seminars/ Symposia/ Conferences were presented/ published by the scientists of the center. One Off -Campus and Seven On- Campus trainings on various aspects of Biotechnology, Crop Improvement, Crop Production, Crop Protection and Post Harvest Technology of banana were organized by the center. As many as 13 VIPs and 3,825 farmers / officials visited and were apprised of the activities of the Centre.

Revenue Generation

A total of Rs. 32. 5 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 and biochemistry, entomology, nematology, fungal, bacterial, viral pathology and post-harvest technology research.

In late nineties, 10 collections 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 Center (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 2025 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.

The mandates of the Centre are:

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

Salient Achievements

Crop Improvement

A total of 1200 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. In the germplasm collection, two wild banana species from Andaman and Nicobar islands and a wild species viz., *Musa acuminata ssp burmannica* from TBGRI, Kerala have been added. Among the collections, 92 accessions are highly resistant and 25 are resistant to Sigatoka leaf spot disease. The collected germplasm has been narrowed down to 310 core collection by eliminating the synonyms using both morphotaxonamic and molecular markers viz., RAPD, IRAP and SSR. Use of microsatellite markers led to the identification of diverse Pagalapahad wild x Borkal Baista and Bhimthia and Beehekela parental combinations. NRCB selection Udhayam, which belongs to Pisang Awak sub group, is a high yielder, tolerant to Sigatoka leaf spot disease and nematodes. 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. Putative diagnostic RAPD markers linked to Sigatoka and nematode resistance have been identified for early screening of hybrid progenies. FHIA-23 was found highly susceptible to pseudostem weevil in various multilocation trials. 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 'Macropropagation' has been developed to meet the need of small and marginal farmers.

Crop Production

Poovan plants supplied with 20 liter 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 per cent recommended fertilizers dose as fertigation in Robusta, Grand Naine and Red Banana. Application of 15 kg rice husk ash + 25 g VAM + 80% recommended NPK gave an additional profit of Rs. 32,500/ha. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, increased the bunch weight of Ney Poovan banana by 43.5% over control, resulting in an additional net profit of Rs. 38,000/ha. Fertilizer adjustment equations for Poovan and Karpuravalli bananas were developed by following the Soil Test Crop Response and Targeted Yield Concept. Under high soil pH conditions, application of bentonite sulphur @20g/plant at three month after planting improved the plant height, number of leaves, total leaf area, number of fruits, bunch weight and leaf N, P, K, Ca, Mg and S content of Nendran cultivar. 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 banana varieties. Saba, Karpuravalli and Ney Poovan have been identified as tolerant varieties to salt stress. Drought tolerant Saba and Karpooravalli 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. Disease defense and cell wall synthesizing enzymes activities was found peaking on 7th day after infection of P. coffeae.

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.

Crop Protection

Mass production technique for *Paecilomyces lilacinus,* (an egg parasite of root-knot nematode) using banana petiole and pseudostem has been developed. Integration of *P. lilacinus* with either neem cake or *Tagetus* or *S. torvum* is useful for effective management of root-knot nematode.

Swabbing 0.06% Chlorpyrifos 20 EC on the pseudostem to a height of 1.2 m 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 7th 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.

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. Propiconazole (0.1%) or Hexaconazole (0.1%) alternated with Chlorothalonil (0.25%) controlled Sigatoka leaf spot disease and increased the yield significantly. Anthracnose disease of banana was controlled by spraying of 25% percent leaf extract of Solanum tarvum. Application of *Trichoderma viride* (109/ml) (or) *Pseudomonas spp* (106/ml) (or) *Bacillus spp*. (106/ml) (or) Propiconazole (0.1%) spray was also effective in controlling the disease anthracnose. 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.

Polyclonal antiserum to BBTV was produced and ELISA technique has been standardized for detection. NA probe based 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.

Transfer of Technology

Virus free banana plants have been supplied to the hill banana growers of lower Pulney hills. Technologies on value added products were transferred to several clients. 22 video programmes were recorded by Department of Agribusiness Management, Ministry of Agriculture, New Delhi for dissemination of the technology at national level. Several trainings sponsored by NHB were conducted for the farmers from different states. NRBC participated in the several exhibitions organized at the regional and national levels.

HRD and Education

The scientists have been deputed regularly to undergo training and to pursue higher studies to update their skill and knowledge. Under education and training, over 450 M. Sc., B. Tech. and M. Tech. students from different universities have been guided for their project work in various aspects of banana.

Linkages and Collaboration

The Centre has developed good linkages with international institutes viz., Bioversity, France; CIRAD, France; KUL, Belgium; IAEA, Austria and QDPI, Australia. It collaborates with different national research institutions for different activities viz., NBPGR, New Delhi; BARC and CIRCOT, Mumbai; IICT, Hyderabad; 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 MoUs with UAS, Bangalore; Bharathidasan University, Tiruchirapalli and IPIRTI, Bangalore on research, guiding students and particle board development respectively.

Revenue Generation

An amount of Rs. 32.5 lakhs was generated from virus indexing and sale of farm produces respectively during this reporting period.

BUDGET DETAILS (REVISED ESTIMATE) FOR THE YEAR 2009-'10

Head of Account	PLAN Amount (Rs. in lakhs)	NON-PLAN Amount (Rs. in lakhs)
Establishment Charges	0	274.11
OTA	0	0.04
Travelling Allowances	5.00	1.59
Other Charges	65.70	49.64
Human Resource Development	4.00	0
Equipments	48.50	0
Works	50.00	3.35
Furniture & Fixtures	0.00	0
Library books	0.80	0
Information Technology	1.00	0
Total	**175.00**	**328.73**

5 RESEARCH ACHIEVEMENTS

5.1 CROP IMPROVEMENT

5.1.1 Genetic Resource Management

Introduction

One hundred four accessions were imported from ITC, Belgium through NBPGR, New Delhi under the NRCB – NBPGR – Bioversity collaborative project.

Collection

Exploration in North Bihar resulted in 24 collections which included ABB, AAB and BB accessions and were field planted. Seven accessions consisted of three landraces and four wild species were collected from Tripura and established in the field genebank. Thirteen germplasm accessions were collected from Assam Agricultural University and Bidhan Chandra Krishi Viswavidhyalaya, West Bengal. Elite clones of Rasthali from Andhra Pradesh and Grand Naine identified from the farmer's field at Thottiyam and Sivagiri areas of Tamil Nadu respectively and are being multiplied for field evaluation.

Conservation

Field genebank of 345 accessions with three replications and a separate germplasm block of exotic accessions with 53 new collections from ITC, Belgium were planted.

Development of *Musa* DNA Bank and assessment of quality

DNA was isolated from 335 Core collection accessions and stored in the DNA bank. DNA quality and integrity was checked after a storage period of 2 - 3 years. The DNA has remained qualitatively stable on storage at -20 ^{o}C which is indicated by the high intensity of fluorescence emitted by the stored DNA samples during agarose gel electrophoresis. Critical period for DNA storage in liquid form is yet to be assessed.

Morphotaxonomic and Molecular characterization

The final batch of 35 accessions of the Core collection were characterized using ten primer combinations of IRAP markers and data were analysed to construct a dendrogram. IRAP markers have clearly discriminated the indigenous and exotic accessions. (Fig 1).

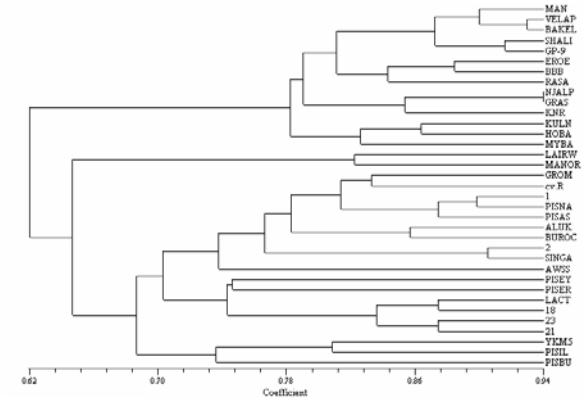


Fig. 1: Dendrogram showing the diversity among core collection accessions

Standardization of macropropagation

Preliminary studies with 12 different media revealed that saw dust is the best media for decortication. Damaging of meristem was found to be better than excavation of the complete meristem at all the stages of decortication.

Use of VAM alone and IBA + Azospirillum enhanced the number of buds proliferation consistently. Other biofertilizers like *Trichoderma viride* and *Bacillus subtilis* were also found to be beneficial. Plantlets of 10-15 cm with two young leaves and 3-4 ramified roots is the apt time for rooting. Among different plant hardening media tried, saw dust + vermicompost + sand (2:1:1) was observed to be the best rooting medium and establishment of plantlets.

Screening of *Musa* germplasm against major nematode *Pratylenchus coffeae* and *Meloidogyne incognita*

Fifty two core collections of *Musa* germplasms belonging to 21 diploids (AB-5; AA-2 & BB-14), 28 Triploids (AAA-6; AAB-15 & ABB-7), 2 Tetraploids (ABBB-2) and one hybrid (H-201) were screened against root-lesion nematode, (*Pratylenchus coffeae*) and root-knot nematode (*Meloidogyne incognita*) separately in pots under shade net condition.

Evaluation of *Musa* germplasm for nutritional status

Nutritional status of 44 accessions with breeding potential was analysed for macro and micro-nutrient status including carotenoids. This resulted in the identification of diploid and triploid parents with better nutritional status. Nutritional diversity of 40 banana cultivars was studied for six minerals and carotenoids.

5.1.2 Improvement of banana through Conventional Breeding

Crosses were made in 1034 bunches both at NRCB, Tiruchirapalli and Agali breeding blocks. Of which, 237 bunches set seeds and 99 unique crosses produced 38,884 seeds. Only seeds of 19 crosses germinated successfully. The details of crosses and germination are provided in Tables 1, 2 and 3.

Table 1. Details of crosses made

Particulars	NRCB breeding block Podhavur	Agali breeding block Coimbatore	Total
No. of crosses made	615	419	1,034
No. of seeds obtained	12,871	26,013	38,884
No. of combinations set seeds	111	126	237
No of unique combination	49	50	99
No. of combination germinated	5	14	19
No of seeds germinated	380	156	536

Table 2. Details of seeds set and germinated combinations

Sl. No.	Cross combination	NRCB, Podhavur, Tiruchirapalli No. of combinations		Agali , Coimbatore No. of combinations	
		Seed set	Germination	Seed set	Germination
1	AA x AA	17	1	33	13
2	BB x BB	2	2	-	
3	ABB x AA	18	1	10	-
4	AAB x AA	4	-	-	
5	ABBB x AA	3	-	-	
6	AAA x AA	1	-	3	-
7	AA x AAA	1	-	-	
8	AA x BB	2	-	-	
9	Rhodochlamys x Emusa	1	1	-	-
10	Eumusa x Rhodochlamys	-	-	3	1
11	AAAA x AA	-	-	1	-

Table 3. Details of crosses successfully germinated

Details of hybrids germinated at NRCB	Details of hybrids germinated at Agali
M.ac. burmannica x Chengdawt	Anaikomban x Matti
Pagalaphad Wild (BB) x Borkal Baista	Anaikomban x Calcutta 4
Elavazhai (BB) x Pagalaphad Wild (BB)	Sanna Chenkadali x Calcutta 4
Ankur II (ABB) x Pisang Jajee (AAw)	Calcutta 4 x Pisang Lilin
M.velutina x Pisang Lilin	Anaikomban x Pisang Lilin
	Calcutta 4 x Cv. Rose
	Cv. Rose x Lairawk
	Cv. Rose x Pisang Lilin
	Anaikomban x Pisang Lilin
	Pisang Jajee x Calcutta 4
	Namarai x Pisang Lilin

Parental polymorphism in BB genome using microsatellite markers

Polymorphism among the parents Karpuravalli and Pisang Jajee and their progenies were studied using 12 pairs of microsatellite markers. Results of the molecular characterization was in accordance with morphotaxonomic characterization indicating all the progenies were genetically closer to the female parent except one which was closer to the male parent (Fig. 2).

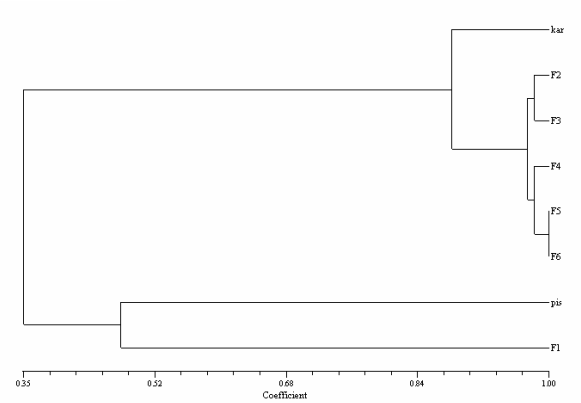


Fig. 2 Dendrogram showing the genetic relationship among the parents and progenies of the cross Karpuravalli x Pisang Jajee

Correlation studies in banana

The correlation studies among different banana genome group on vegetative and fruit characters revealed that number of days from flowering to harvest showed a negative correlation with bunch weight (Table 4). This suggested that selection of hybrids for shortest duration (Flowering to harvest) is one of the criteria for selection of high yielding hybrids. In general, bunch weight had a positive correlation with al the fruit traits namely number of fruits per hand, number of hands per bunch, number of fruits per bunch, fruit length, fruit weight, flesh weight and peel weight where as it had a negative correlation with pulp TSS content. A highly positive significant correlation was observed between number of hands per bunch and number of fruits per bunch, days to flowering and days to harvest as well as between fruit weight and flesh weight. A negative correlation was observed between fruit length and number of fruits per hand which suggested that that selection for more number of fruits may leads to selection of small sized fruits.

Screening of F1 progenies for drought tolerance

F1 Progenies of Karpuravalli (ABB) x Pisang jajee (AA), Matti (AA) x Anaikomban (AA), Manoranjitham (AAA) x Anaikomban (AA), Matti (AA) x Cultivar Rose(AA), Pisang Jajee (AA) x Matti (AA) , Anaikomban (AA) x Pisang Jajee (AA), Anaikomban (AA) x Namarai (AA) F1 progenies and parents were screened for drought tolerance using Relative Water Content (RWC), Membrane Stability Index (MSI) parameters. All the progenies and parents recorded higher MSI after imposition of drought at five month after planting and differential response towards RWC. Among the tested materials, Karpuravalli x Pisang Jajee progenies recorded higher RWC and Anaikomban (AA) x Namarai (AA) progenies for MSI. In Karpuravalli x Piang Jajee progenies , RWC values were closer to Karpuravalli and MSI with Pisang Jajee. Among the tested F1 progenies , Karpuravalli x Piang Jajee (02-2/05, 02-6/05) performed well under drought till flowering.

Evaluation of banana germplasm against Fusarium wilt

The pot culture and field evaluation of 23 parents and 10 hybrids against Fusarium disease showed that out of 23 parents, five parents (Pisang jajee, cv. Rose, Burrow Cemsa, H3 and Tongat) and out of 10 hybrids, one hybrid (13 (06/05) had no incidence of fusarium wilt under field or pot culture conditions.

Viability studies on banana embryos

Standardization of seed viability test was carried out using 0.1% 2,3,5- triphenyl tetrazolium chloride. Fresh seeds were cut open longitudinally and embryos were excised and incubated in TZ solution from 0-54 hrs. Incubation for 24 hrs with 0.1% TZ was found most suitable for studying embryo viability in both varieties and hybrid seeds (Fig. 3).

Fig. 3. Testing of Seed Viability using tetrazolium chloride

Fresh Seeds | 12 hrs after | 24 hrs after | 48 hrs after

Study on hormones on *in-vitro* embryo germination

Studies on the effect of hormones on *in-vitro* germination of embryos using basal MS medium fortified with 1BA (1 mg/l) and a combination of IBA (1mg/l) + IAA (0.5 mg/l) along with control (MS medium). Results indicated that embryos of wild bananas germinated easily with germination rate ranging from 36.8% to 43.2% (in hybrids) and 84.0% to 88.00% (in pure diploids). But in 3x X 2x crosses, embryos failed to germinate irrespective of media composition. In both pure diploids and hybrid diploids, embryo recorded 24-27 days to complete plantlet formation.

Table 4. Correlation studies on banana

Parameters	Plant height (cm)	Pseudo stem girth (cm)	Days to flowering	Days to harvest	Days from flowering to harvest	Bunch Weight (Kg)	No. of fruits per hand	No. of hands per bunch	No. of fruits per bunch	Fruit length (cm)	Fruit weight (g)	Pulp weight (g)	Peel weight	Pulp TSS (° Brix)
Plant height (cm)	1.0000	0.6969*	0.6019*	0.6104*	0.2960	0.3797	0.1400	0.3094	0.2575	0.2477	0.3266	0.3398	0.1937	0.1495
Pseudostem girth (cm)		1.0000	0.6674*	0.6906*	0.5081*	0.3417	0.1449	0.3629	0.3161	0.0764	0.1346	0.1626	0.0195	0.0795
Days to flowering			1.0000	0.9789**	0.3222	0.2283	0.1212	0.2979	0.2481	-0.0642	0.0275	0.0911	-0.1148	0.2642
Days to harvest				1.0000	0.5081*	0.1623	0.0936	0.2738	0.2202	-0.1062	-0.0396	0.0183	-0.1524	0.2907
Days from flowering to harvest					1.0000	-0.2054	-0.0786	0.0157	-0.0227	-0.2118	-0.2932	-0.2928	-0.2170	0.2331
Bunch Weight (Kg)						1.0000	0.4839*	0.6568*	0.6593*	0.5621*	0.7460*	0.7583*	0.4975	-0.1977
No.of fruits per hand							1.0000	0.5801*	0.7475*	-0.0563	0.0056	0.0368	-0.0796	-0.1345
Number of hands per bunch								1.0000	0.9598**	0.1566	0.1400	0.1833	-0.0193	0.0369
Number of fruits per bunch									1.0000	0.1094	0.1035	0.1492	-0.0479	-0.0157
Fruit length (cm)										1.0000	0.7702*	0.7567*	0.6138*	-0.2365
Fruit weight (g)											1.0000	0.9625**	0.7956*	-0.2402
Pulp weight (g)												1.0000	0.6576*	-0.2072
Peel weight													1.0000	-0.2496
Pulp TSS (° Brix)														1.0000

Effect of plantlet age (in embryogermination medium) on regeneration

Effect of age of plantlet and embryo germination medium on overall plant growth and final regeneration was studied on hybrid embryos derived from Pagalaphad wild (AA) and Borkal Baista (BB). Duration of embryo held in germination medium exhibited a parabolic curve with respect to final survival. Plantlets of 80-90 days age old were the best for shifting to primary hardening (with 5-6 leaves and 3-4 roots) beyond which it reduced the survival drastically (Fig. 4).

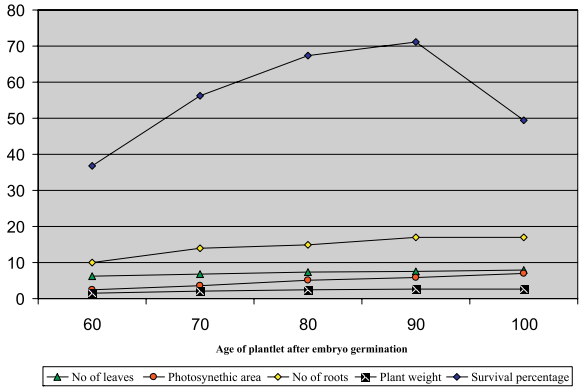


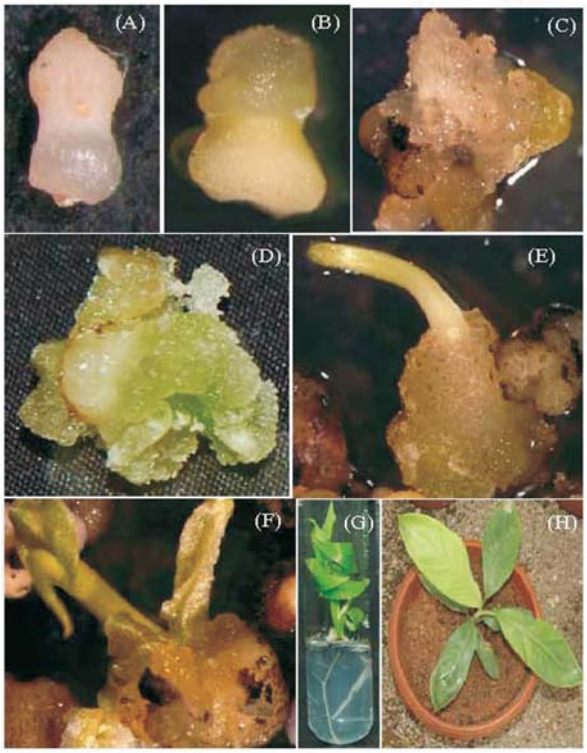
Fig. 4. Effect of embryo age on growth parameters

Effect of seed age and soaking treatments on *in-vivo* seed germination and regeneration

Different seed treatments like water soaking and soaking in GA3 for 48 hours had no significant effect on germination and other growth parameters. The age of the seed had significant influence on all the parameters studied. Freshly harvested seeds recorded the highest germination (77.87), earliest to germinate, to produce root and shoot and also exhibited minimum days for complete plantlet formation (47.33 days). Even with wild hybrid progenies, age of the seed is the most crucial factor due to dormancy.

Factors affecting embryo rescue and plantlet regeneration in *Musa* spp.

Embryo at various stages of development (70, 80, 90, 95 and 100% maturity) was initiated on MS medium fortified with different growth regulators. The results (Fig.5) indicated that the effect of embryo maturity on callus induction was highly significant. Percent callus induction was more in immature embryos (70%) irrespective of the media composition and it decreased with embryo maturity. 100% embryos failed to induce callus and instead they exhibited direct regeneration into plantlets (organogenesis) irrespective of media composition.



In vitro culture and plant regeneration via indirect organogenesis from Pisang Jajee

(A) Immature zygotic embryo
(B) Primary response of embryo
(C) Induction of callus
(D) Callus proliferation
(E) monopolar regeneration
(F) First leaf emergence
(G) Tissue cultured plantlet ready for rooting
(H) *In vitro* regenerated Pisang Jajee plant regenerated growing on soil

Fig. 5. Effect of different plant growth regulators on embryo germination

5.1.3 Improvement of banana through non-conventional approaches

Evaluation of Embryogenic Cell Suspension Culture

Plants derived from Embryogenic Cell Suspension of cv. Rasthali were compared with tissue culture raised and normal sucker raised plants for biometric parameters. The performance of ECS derived plants exhibited growth and yield performances at par with normal suckers and tissue cultured plants (Table 5). This suggests that ECS could be a better alternative for large scale in-vitro multiplication in banana.

Factors affecting longevity of Embryogenic Cell Suspension Cultures

Different factors like initial suspension density, quantity of medium used for initiation, gradual scaling up of medium, subculture period, rpm selected etc. which directly affect the longevity of suspension were studied. Observations revealed

Table 5. Comparative evaluation of ECS derived plants with sucker and tissue culture plants of cv Rasthali (1st ratoon)

Parameters	Sucker (T1)	T.C (T2)	ECS T3	General Mean	Sig/ N.Sig	CD @ 1 %	CV
Pseudostem Height (Cm)	298.5	282.3	291.5	290.77	NS	-	3.12
Pseudostem Girth (Cm)	73.3	75.2	78.9	75.80	**	4.5922	3.14
No. of leaves at shooting	13.6	12.7	13.16	13.15	**	0.6038	2.38
Petiole length (cm)	55.3	53.4	52.7	53.80	**	2.2859	2.20
Leaf Area (X 104)	13.50	12.82	12.66	12.99	NS	-	5.52
Days taken for shooting	303	310.5	301.6	305.03	**	5.5966	0.95
Days taken for bunch maturation	118.6	124.4	132.5	125.17	**	5.6436	2.33
Duration (Days)	411.6	424.9	431.1	421.20	**	8.3395	1.00
Bunch weight (Kg)	14.33	13.45	12.65	13.48	*	1.4963	5.75
No. of hands per bunch	7.1	6.8	7.8	7.23	NS	-	10.41
No. of fruits per hand	12.3	12.4	12.6	12.43	NS	-	6.85
Total no. of fruits	98.6	91.12	88.67	92.80	**	5.3533	2.99

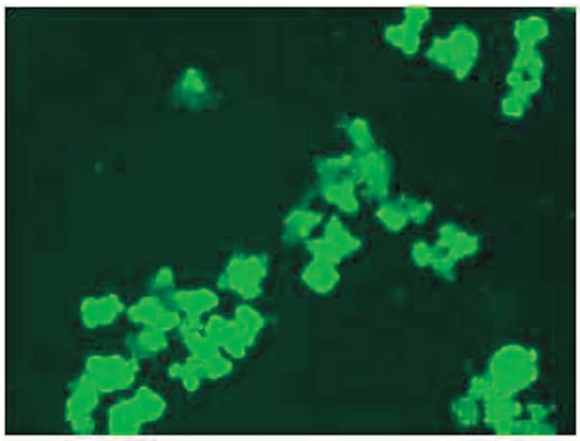
that in order to obtain homogenous cell lines (a) Ideal callus selection of (b) New embryogenic clusters initiation of 3-5 ml medium (c) Medium scaling up to 15-20ml in 2-3 months and (d) Maintaining 3-5 % SCV while subculturing to increase the proliferation rate are to be followed. To increase the longevity of ECS: (a) Subculture should be done when cells are in exponential phase (b) Increasing the period of subculture from 2 to 10 days based on age of culture (c) Decreasing the rpm from 70 to 50.

Viability test for ECS have been standardized using FDA for routine studies. Suspension exhibiting >80% viability was used for genetic transformation, mutation and other studies. Culture deterioration was expressed in terms of fluorescence intensity, fresh the suspension, more is the fluorescence and dead cells were indicated as grey clumps (Fig. 6. a & b)

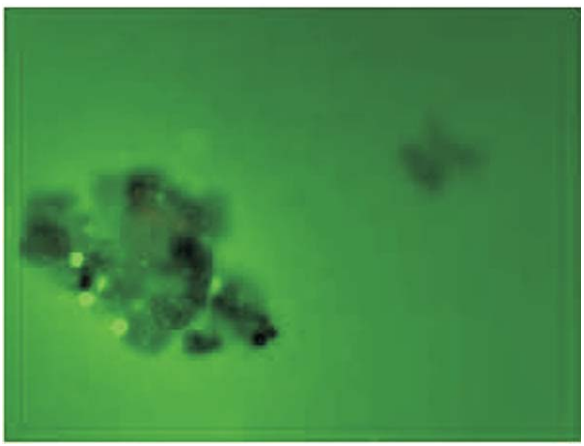
Identification of diverse lines of BB for use in the development of genetic linkage maps

Six BB diploids along with a AA diploid were characterized using 20 pairs of microsatellite markers to identify the most diverse parents for genotyping work. Out of the 20 primers tested, 13 primers produced discrete and reproducible bands with an average polymorphism of 93.07% indicating substantial variation at the DNA level. Results indicated that both the parental combinations of

Fig. 6. Effect of age of culture on viability



(a) **8 months old suspension**



(b) **18 months old suspension**

Table 6. Polymorphism in various microsatellite markers

Primer pairs	Monomorphic bands	Polymorphic band	Total No. of bands	Polymorphism (%)
AGMI 95 / 96	0	10	10	100
AGMI 103 / 104	2	2	4	50
AGMI 105 / 106	0	7	7	100
AGMI 129 / 130	0	6	6	100
AGMI 24 / 25	0	9	9	100
AGMI 133 / 134	0	12	12	100
AGMI 123 / 124	0	5	5	100
Ma - SSR 8a / 8b	0	8	8	100
Ma - SSR 18a / 18b	0	7	7	100
Ma - SSR 24a / 24b	1	4	5	80
Mb - SSR 1 - 146	0	5	5	100
Mb - SSR 1 - 149	1	4	5	80
Mb - SSR 1 - 49	0	4	4	100
TOTAL	4	83	87	1210
AVERAGE	0.30	6.38	6.69	93.07

IIHR (Bhimithia x Beeheekela) and NRCB (Pagalaphad wild x Borkal Baista) were equally diverse with 28% variation (Table 6 & 7),(Fig. 7).

Preliminary studies on the development of genetic linkage maps in Musa using SSR markers

As a whole 10 % of primers produced no bands in *M. acuminata* wild Assam, Anai komban, Kanai bansi and Namarai. Of the total, 13.33 % of primers did not produce scorable bands in *M. acuminata* Wild Arunachal Pradesh, Lairawk, *Musa acuminata* Assam. Similarly, 23.3% of primers did not produce any detectable bands in Balukpong Wild while 16.67% of primers did not produce any scorable

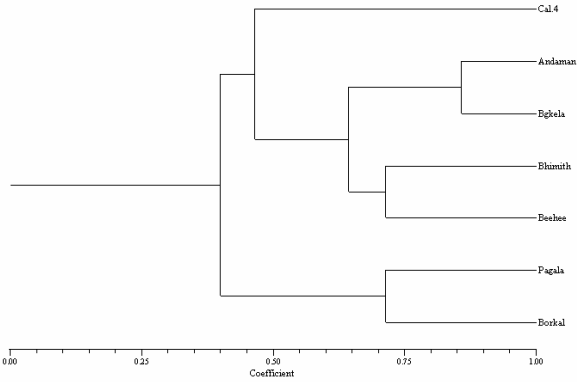


Fig. 7. Dendrogram showing the diversity among the BB parents for use in the development of genetic linkage maps

Table 7. Clone specific bands produced in various microsatellite markers

Primer Pairs	Specific bands						
	Cal-4	Andaman balbisiana	Beejikela	Bhimithia	Beehee kela	Pagalaphad wild	Borkal baista
AGMI 95 / 96	4	-	-	-	1	-	-
AGMI 103 / 104	-	-	-	-	1	1	-
AGMI 105 / 106	2	-	-	-	-	-	1
AGMI 129 / 130	4	-	-	-	1	1	-
AGMI 24 / 25	5	-	-	-	-	-	-
AGMI 133 / 134	1	-	-	-	5	-	-
AGMI 123 / 124	-	-	-	-	-	1	-
Ma - SSR 8a / 8b	2	-	-	-	-	-	-
Ma - SSR 18a / 18b	1	-	-	-	-	-	-
Ma - SSR 24a / 24b	1	-	-	-	-	-	-
Mb - SSR 1 - 146	-	3	-	-	-	-	-

bands in Chengdawat, GP-15 and Pagalapahad wild. In *Musa acuminata burmaniccoides,* 36.6% of primers did not produce any detectable bands. As many as 26% of primers did not detect any scorable bands in Sanna Chenkadali and *Musa acuminata ssp. burmannica.*

Out of 30 primers, 44.89 % of primers produced single bands in all AA diploids and 27% of the primers produced double bands in 17 accessions. Only 13 % of primers produced three bands in 10 accesssions excluding *Musa acuminata* Wild Arunachal pradesh, Anaikomban, Balukpong Wild, Chengdawat, GP-15, *Musa acuminata ssp. burmanni ccoides* and Pagalapahad wild.

As a whole, 10 per cent of primers produced no bands in Attikol, Athiakol, Bhimkol (0597), Borkal Baista, Elavazhai, Jungle Kela-1, Khungsong Wild and Pagalapahad Wild (1182). Of the total 13.33 per cent of primers produced no scorable bands in *Musa balbisiana* (Andaman), Jungle Kela-2, *Musa balbisiana*, Pagalapahad Wild (1184), Phirima Wild and in Sasra Bale. In all , 6.67 per cent of primers did not produce any detectable bands in Bacharia Malbhog, Beeji Kela and Manohar , while 3.33 per cent of primers did not produce any scorable bands

Table 8. Number of primers producing homo / heterozygous alleles in various BB diploids

Sl. No.	Accession No.	No. of alleles produced			
		Single	Double	Triple	No bands
1.	1353	23	3	0	4
2.	0011	18	9	0	3
3.	0444	14	9	4	3
4.	0446	18	8	2	2
5.	1914	17	7	4	2
6.	0007	19	5	1	5
7.	0597	20	7	0	3
8.	0018	12	13	2	3
9.	0167	17	6	4	3
10.	1912	21	4	2	3
11.	1913	19	5	2	4
12.	1168	13	10	4	3
13.	0067	17	9	3	1
14.	0047	19	7	2	2
15.	0508	26	0	0	4
16.	1182	23	4	0	3
17.	1184	14	10	2	4
18.	1186	23	3	0	4
19.	0449	19	6	1	4

in Maguthamang. In Bhimkol (0007) 16.67 per cent of primers did not produce any detectable bands.

Out of 30 primers, 58.39 per cent of primers produced single bands in all BB diploids, 23.15 per cent of primers produced double bands in 18 accessions excluding *Musa balbisiana.* In *Musa balbisiana,* all the primers produced single bands. Only 8.46 per cent of primers produced three bands in 13 accesssions excluding Bhimkol (0597), *Musa balbisiana,* Pagalapahad Wild (1182), Phirima Wild, *Musa balbisiana* (*Andaman)* and Attikol (Table 8).

All AA and BB diploids tested are heterozygous except *Musa balbisiana.* It was concluded that all the AA and BB diploids could be conveniently used in conventional breeding for development of segregating population. Due to heterozygosity and moderately diverse nature early generation progenies of AA and BB diploid F1 could be used for development of linkage maps.

Standardization of low cost technology for micropropagation of Udhayam banana

Five cheap sources of water *viz.,* single distilled water, R.O. water, tank water, tap water and Cauvery water were tried, along with double distilled water for the tissue culture media preparation. Reverse Osmosis water and tank water were observed to be the best substitutes for double distilled water as the per cent greening and days taken for greening of shoot tips were at par with control (Table 9, Fig.8)

Table 9. Effect of water sources on the initial establishment of shoot meristems

Sl. No.	Water source	No. of days taken For greening	Greening (per cent)
1.	Control (Double distilled water)	5.6	80
2.	Single distilled	7.0	75
3.	Reverse Osmosis water	5.4	75
4.	Tank water	6.2	60
5.	Tap water	7.8	60
6.	Cauvery water	6.4	60
	Level of significance	**	-
	CD (p = 0.01)	1.32	-
	CV per cent	11.59	-

Three gelling agents namely Sago, Corn flour and Isabgol were tried at different concentrations along with routine agar as control. Sago at 13 per cent concentration was found as the optimal dose

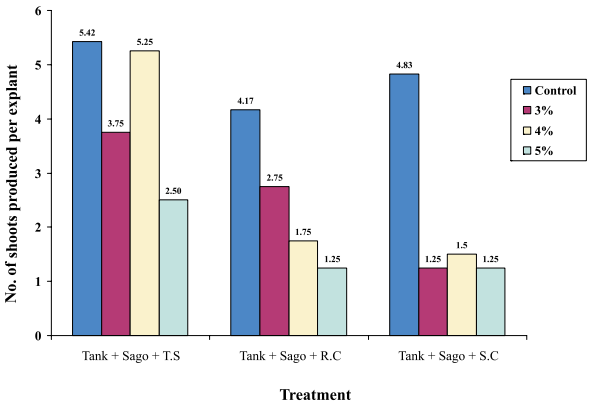


Fig. 8. Effect of Tank water and different carbon sources on shoot proliferation

since, it produced maximum greening in a shorter time like that of control medium which contained agar as gelling agent (Table 10). Minimum greening (10 - 20 %) was observed in corn flour treatments and drying of shoot meristems makes it unfit as gelling agent in tissue culture media. Though use of Isabgol as an alternate gelling agent in plant tissue culture media has been reported by several workers, in the present study, it could not facilitate the inoculation of shoot meristems.

Table 10. Effect of concentrations of gelling agents on the initial establishment of shoot meristems

Sl. No.	Treatments	No. of days taken For greening	Greening (per cent)
1.	MS + 10 per cent Sago	10.6	70
2.	MS + 12 per cent Sago	9.6	70
3.	MS + 13 per cent Sago	9.2	80
4.	MS + 10 per cent Corn flour	12.6	10
5.	MS + 11 per cent Corn flour	12.8	10
6.	MS + 12 per cent Corn flour	12.2	20
	Level of significance	**	-
	CD (p = 0.01)	1.00	-
	CV per cent	5.47	-

Three different carbon sources namely sugar, Rock candy (RC) and Small candies (SC) were tried at varying concentrations namely 3%, 4% and 5% as a substitute for sucrose. These substitutes were tried in the MS media which were prepared with Reverse osmosis and Tank water containing Sago (13%) as gelling agent. Among the various treatments tried, the treatment R.O+ Sago+ T.S at 3% concentration was optimum as it produced the maximum buds (5.75 nos.) within a short span of 5.00 days (Fig.9).

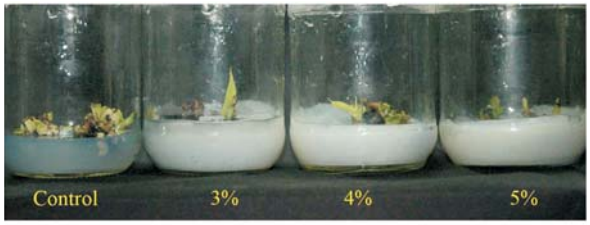


Fig. 9. Effect of various concentrations of Table sugar on shoot proliferation in cultivar Udhayam

Substitution of Agar and sucrose with other low cost alternatives has substantially brought down the cost. Cost of the gelling agent was reduced by 85.71 per cent when Sago was used as a substitute for agar. Similarly cost of the carbon source was reduced by 94.0 per cent when sucrose was substituted by table sugar. There was 83.10 per cent reduction in the cost of preparation of one litre MS medium used for tissue culture of banana cultivar Udhayam (Table 11).

Table 11. Economics for the low cost alternatives for tissue culture multiplication of cultivar Udhayam

Particulars	Cost of medium (Rs./litre)	
	Normal medium	Low cost medium
Macronutrients	2.30	2.30
Micronutrients	0.55	0.55
Organics	0.03	0.03
Iron	0.09	0.09
BAP	0.76	0.76
Ascorbic acid	0.01	0.01
Agar	35.00	-
Sucrose	22.00	-
Sago (13%)	-	5.20
Table sugar (3%)	-	1.32
Total	60.78	10.26

Commercial multiplication of Udhayam

About 300 shoot tips of Udhayam were initiated under *in vitro* multiplication and 300 plants of Udhayam could be successfully hardened. One hundred tissue cultured plants of cultivar Udhayam tissue cultured plants were supplied to KVK, Mohanur (Tamil Nadu) for front line demonstration. One hundred rooted Udhayam cultivar and mother cultures have been supplied to HRC, Nagicherra (Tripura) .

5.1.4 Identification and characterization of nematode resistance gene (s) in banana

Creation of suppression subtractive library

Root RNA were isolated from *P. coffeae* inoculated and uninoculated plants of cv. Karthobiumtham during 6th DAI. Suppressive Subtractive Hybridization (SSH) library, containing more than 1400 colonies, was created by using these RNA. The clones were confirmed by PCR (Fig. 10) as well as *Eco RI* restriction analysis. A total of 91 clones were sequenced and EST sequences were trimmed by using Vec screen software and trimEST. The edited nucleotide (cDNA) sequence size ranged from 86 bp (S-113) to 1000 bp (S-31) with an average read length of 400 bp based on the insert size. These sequences were divided into five sub groups based on insert size (Fig. 11 & 12). Maximum number of clones was grouped under the 80-200 read length followed by 200-300 read length (20 clones). The results confirmed that ligation efficiency improved with decreasing sequence length.

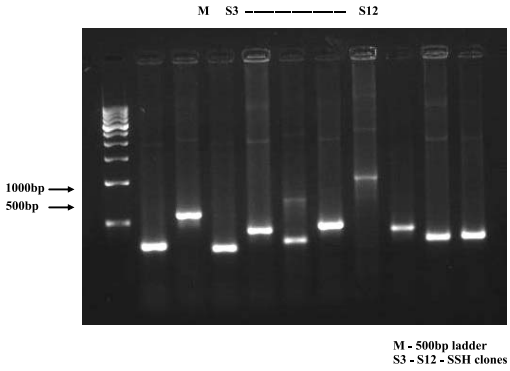


Fig. 10. Colony PCR of SSH library clones with nested primers

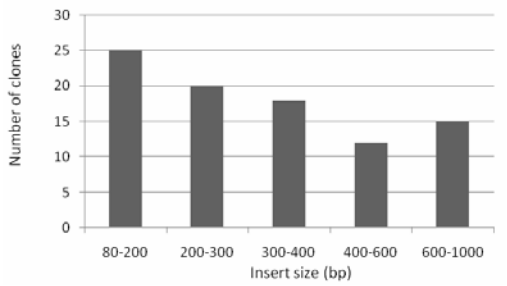


Fig. 11. Number of clones having different insert sizes

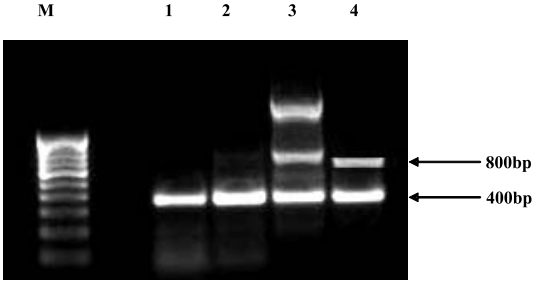


Fig.12. Amplification of RGA in cDNA and Genomic DNA by using LRRF and LRR reverse primer

By using CAP3 software, these sequences were clustered into 72 longest possible consensus, which generated 9 contigs and 63 singletons. The BLAST X analysis revealed that 13% of putative genes were hit with resistance/defense related genes. Out of which, two genes were hit with stress related genes namely type II metallothioenins (92%) and class III acidic chitinase gene (75%) of *Musa*. Nearly 15% of the putative genes were hit with *Musa* genes, out of which 50% of genes were hit with *Musa acuminata* BAC clone.

By using SSR primer II software, SSR primers were designed among the 63 singletons and 9 contigs. Only one primer pair was obtained from these consensus. It was designed in the Singleton 38 for (CTT)4 repeats with the primer sequence of 5 ' G G T T G G C T C C T C T T C T T C 3 ' a n d 5'ATGATGACTTGGCTCTCTTG3'. The expected size of the amplified product was 239.

RGA studies in nematode resistant accession

a) Isolation of RGAs from nematode resistant cultivars

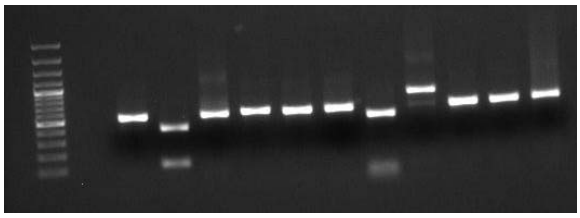
A total of 20 RGAs were isolated from the resistant cultivars namely cv. Karthobiumtham and cv. Attikol by using five different sets of primers. Out of which, only 9 had un interrupted open reading frame.

The BLAST analysis of clones obtained from LRR forward and reverse primers revealed that they were not hit with any of the NBS-LRR sequences. This confirmed that LRR region is highly variable and devoid of any conserved domains. But it has hit with R protein namely ubiquitin carboxyl-terminal hydrolase family protein and cysteine-type endopeptidase/ ubiquitin thiolesterase (UBP9) mRNA. These enzymes are involved in disease resistance mechanism (Fig. 13).

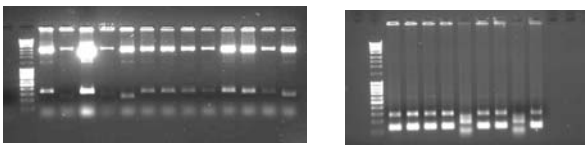
b) Isolation of functional RGAs from cDNA

For amplifying the NBS LRR region from cDNA of both Karthobiumthum and Attikol cultivars LRR primer set was used. But polymorphic banding pattern was observed only in gDNA not in cDNA (Fig. 12), Polymorphism was also observed among the gDNA of two cultivars, whereas in cDNA only one band at 400 bp alone was observed irrespective of cultivars. Hence cDNA amplified product of cv. Karthobiumtham alone was cloned. Based on RFLP analysis of clones by using different enzymes, clones

were grouped into two (Fig 13). One clone has been selected from each group and sequenced. Both cDNA and gDNA derived sequences were analysed for homology percentage. It was found that two sequences which are derived form cDNA and gDNA had 100% homology whereas ,other two clones had only 26% homology. But the BLASTn analysis revealed that all the sequences were hit with the same type of putative genes.



HAE III



*Eco*RI *Taq*I

Fig. 13.Characterization of RGAs through restriction enzyme analysis

NBS-LRR primers have been used for amplifying the RGAs from cDNA and DNA of cultivar Karthobiumtham. This study revealed that though equal amount of template were taken from both cDNA and DNA, the banding intensity was very low in case of cDNA than gDNA. Different banding pattern was observed in between genomic DNA of two resistant cultivars. As the amplification at 800 bp was observed in only cv. Karthobiumtham both in gDNA and cDNA.

5.1.5 Improvement of Rasthali through induced mutagenesis

Determination of LD_{50} for chemical mutagen Diethyl sulphate for the shoot meristem explants of cv. Rasthali

The shoot meristems of cv. Rasthali were treated with 5, 10, 15, 20 and 25 mM for 2, 3, 4 and 5 hours in an incubator shaker (110 rpm at 20°C). Treated shoot meristems were inoculated in MS medium containing 4.0 mgl^{-1} BAP. The effect of various concentrations of Diethyl sulphate (DES) and incubation periods and their interaction effect on per cent gain in fresh weight (Table- 12) and days taken for greening of shoot meristems(Fig -14) were highly significant. But the effect of various concentrations of DES and incubation periods and their interaction effect on number of buds produced per explant were at par.

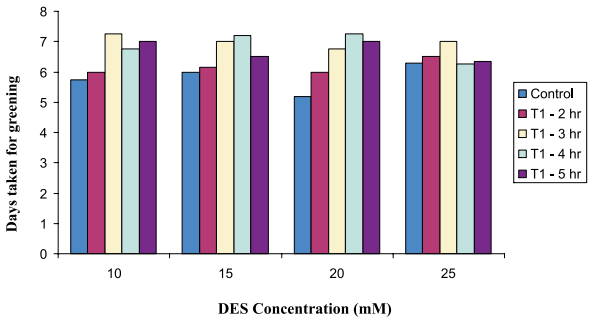


Fig.14 Effect of DES on days taken for greening in proliferating buds

Table 12. Effect of DES on Fresh Weight Gain (FWG) of shoot meristems

	FWG (g) at various concentrations of DES			
Treatments	**10 mM**	**15 mM**	**20 mM**	**25 mM**
Control	5.93	7.25	5.62	5.10
	(100)	(100)	(100)	(100)
T1- 2 hrs	3.74	6.73	4.07	5.04
	(63.07)	(92.83)	(72.42)	(98.82)
T2- 3 hrs	3.05	6.33	2.60	4.52
	(51.43)	(87.31)	(46.26)	(88.62)
T3- 4 hrs	3.00	5.83	2.01	3.40
	(50.59)	(80.41)	(35.77)	(66.67)
T4- 5 hrs	2.98	3.79	1.87	2.57
	(50.28)	(52.28)	(33.27)	(50.39)
Level of significance	**	**	**	**
CD (p=0.01)	0.15	0.27	0.12	0.27
CV per cent	2.18	2.54	2.13	3.58

Fresh Weight Gain (FWG) was nearer to 50% in C1T5 followed by C1T3 and C1T4 and were at par. Though FWG for C4T5 (50.39 per cent) was also

Table 13. Effect of DES on number of buds produced per explant in proliferating buds

	DES Concentration (mM)			
Treatments	**10**	**15**	**20**	**25**
Control	6.15	5.25	4.75	5.00
T1 - 2 hr	5.20	5.10	4.75	4.00
T2 - 3 hr	4.15	3.75	4.20	3.50
T3 - 4 hr	3.50	3.00	2.65	2.00
T4 - 5 hr	2.10	2.00	3.15	2.15
Level of significance	**	**	**	**
CD (p=0.01)	0.18	0.61	0.15	0.17
CV per cent	2.40	8.88	2.11	2.85

close to 50, it was considered better to select a longer incubation period with lower concentration as it decreases damage causing hydrolytic by products, which in turn improves the mutagenic efficiency. Therefore , LD50 was fixed as 10 mM DES for 5 hours which produced 50% FWG over control. The number of days taken for greening was minimum in control and it was maximum in C1T3, C2T4 and C3T4 and were on par. Number of buds produced per explant was always maximum in control and it decreased as the incubation period increased at all concentrations of DES (Table 13).

In vitro screening for Fusarium wilt resistance using Culture filtrate

Mutated shoot buds of Rasthali were inoculated in MS medium containing 3, 6 and 9% concentrations of Culture filtrate with twenty replications each.

Effect of culture filtrate concentrations on percent survival was highly significant. As the concentration of the Culture filtrate increased, the percent survival decreased. 100% survival was observed in control followed by 3% culture filtrate (80%), which were on par with each other (Fig.15). Hence incorporation of 3% culture filtrate in the MS medium was determined as the optimal dose for screening of shoot meristems for Fusarium wilt resistance under *in vitro* conditions.

GAMMA IRRADIATION

Proliferating buds

Proliferating buds obtained from the 3rd or 4th subculture were irradiated at doses viz., 10, 15, 20 and 25 Gy using the facilities available at BARC, Mumbai. Each treatment had 10 replications.

As the concentration of the Culture filtrate increased, the percent survival decreased significantly. 100% survival was observed in Control while 50% survival was observed at 20 Gy. Hence 20 Gy was determined as the LD50 for proliferating buds of cv. Rasthali (Fig. 16).

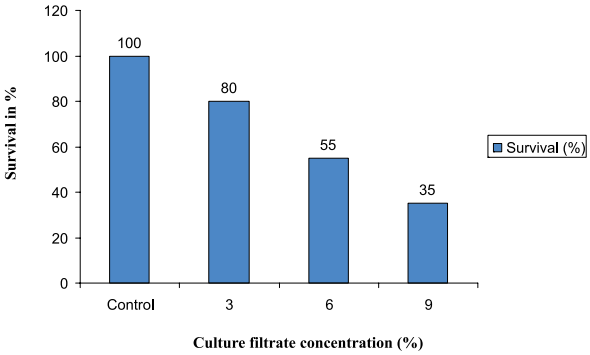


Fig. 15. Effect of different concentrations of Culture filtrate on the initial establishment of shoot tips of cv. Rasthali

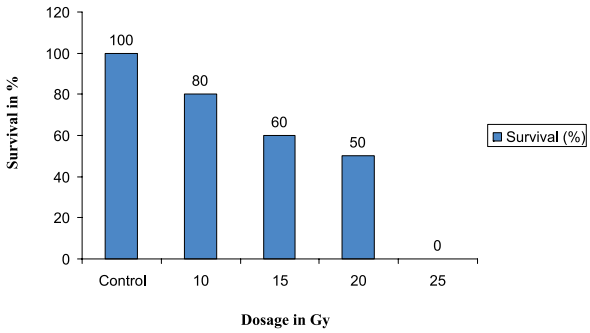


Fig. 16. Effect of different doses of gamma irradiation on the initial establishment of proliferating buds of cv. Rasthali

5.2 CROP PRODUCTION

5.2.1 Standardization of agro techniques for banana production and productivity

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

An experiment with three levels each of N and K fertilizers at four different spacing was conducted. At flowering, the closest spacing of 1.8 X 1.8 m recorded the highest plant height (432.0 cm) where as wider spacing of 2.1 x 2.4 m recorded the lowest plant height and maximum plant girth (94.5 cm). Among fertilizer doses, 200:400g N&K recorded the highest plant height (426.3 cm) and plant girth (94.1 cm). The number of healthy leaves at flowering was significantly more in plants at 2.1 x 2.4 m spacing with 300g / N&K each plant. The plants fertilized with 300g N and 500g K recorded the maximum number of healthy leaves.

Wider spacing of 2.1X2.4m with 300:400g N&K/ plant exhibited earliest flowering (413.7 days) whereas, the closest spacing (1.8X1.8m) with 200:300g N&K/ plant recorded the maximum days (501.4 days) for flowering. Among the four different spacings, the wider spacing of 2.1X2.4m recorded the least time for flowering (431.4 days).

At flowering stage, the highest concentration of leaf N (2.87%) and K (2.96%) were recorded in plants at 2.1X2.1m spacing with 400:400g N&K/ plant, while 1.8X1.8m spacing with 300g N and 500g K / plant recorded the highest leaf P content (0.58%).

Time taken for maturity ranged from 137.2 days to 159.9 days among different treatment combinations. Combination of 2.1X2.4m spacing with 200:400g N&K/plant recorded significantly less time for maturity (137.2 days) while 2.1 x2.1m spacing with the lowest fertilizer dose of 200:300g N&K recorded the longest days for fruit maturity (159.9 days).

The bunch weight was the highest (35.7 kg) in wider spacing (2.1 X2.4m) with 300g N and 400g K/ plant. Whereas closest spacing (1.8 x1.8m) with lowest fertilizer dose (200g N & 300g K/plant) recorded the lowest bunch weight (18.2 kg) (Fig. 17).

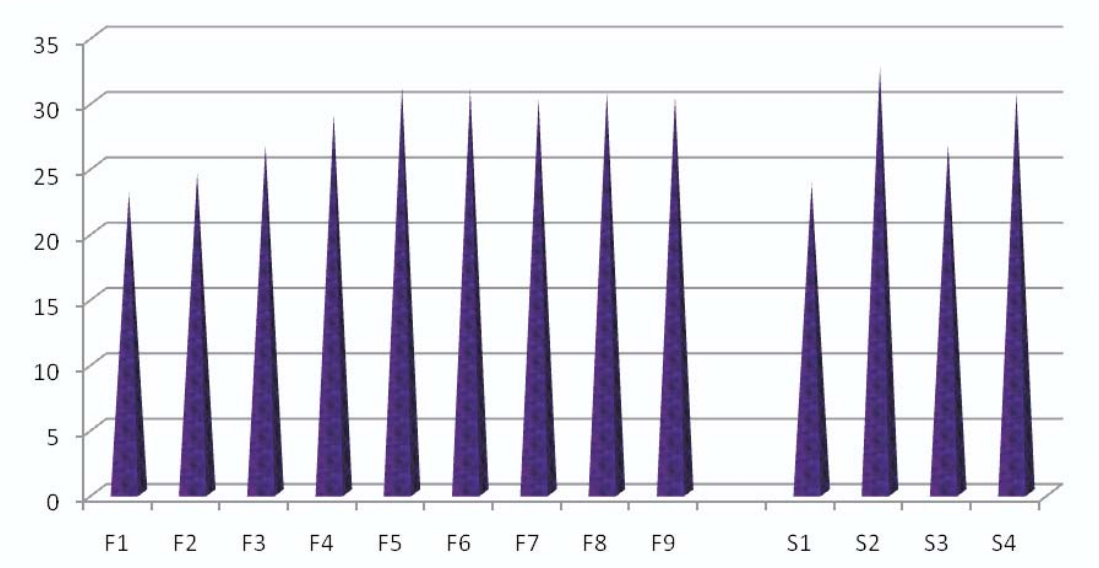


Fig. 17. Bunch weight (kg) as influenced by spacing and nutrients in Udhayam banana

Studies on the nematode populations from both soil and root samples revealed that population build up of root-knot nematode, (*Meloidogyne incognita*) was higher in closer spacing with lower fertilizers.

With increase in dosages of N and K, significant reduction in nematode population was observed and negligible nematode population was observed in 2.1m X 2.4m with 400g N & 500g K/ plant.

5.2.2 Studies on Micronutrient in Banana

Under micronutrient trial with Nendran, sulphur application increased the plant growth

parameters like plant height, pseudostem girth, total number of leaves and total leaf area significantly over without sulphur application (7.36, 6.60, 8.0 and 9.35 per cent, respectively) and increased the bunch weight significantly (38.6 %) than control.

Sulphur application increased the leaf nutrient concentrations like N, P, K, Ca, Mg and S significantly (7.2, 8.1, 11.4, 35.1, 17.6 and 42.0 per cent) respectively than without sulphur application. Soil application of 5g $FeSO_4$, 5g $ZnSO_4$ and 5g Borax per plant without sulphur recorded the highest bunch weight (9 kg) with an net additional profit of Rs. 61250/- per hectare.

Soil application of 5g $FeSO_4$ and 5g $ZnSO_4$ and 0.5% foliar spray of Borax with sulphur application recorded 12.5kg with net additional profit of Rs. 85100/- per hectare.

With S application, the bunch weight was highly correlated with leaf S concentration (0.468**) and leaf K concentration (0.442**). But, without S application, the bunch weight was highly correlated with leaf S concentration (0.444**) only, which indicated the role of sulphar in reducing the leaf K thus affecting the carbohydrate synthesis in leaf (Fig. 18).

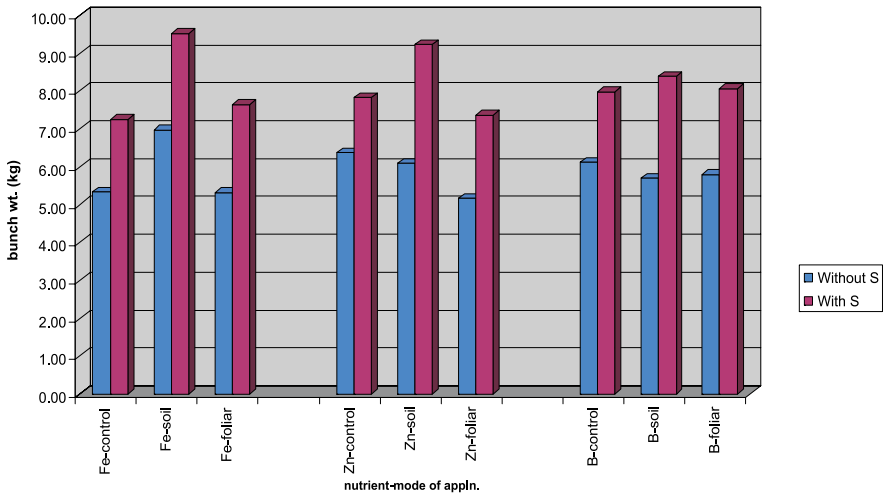


Fig.18. Effect of micronutrients on yield of Nendran banana

5.2.3 Fertiliser tailoring equations for Karpuravalli and Poovan (ratoon-I)

Requirement of N, P_2O_5 and K_2O for producing one ton of Poovan (ratoon-I) banana was worked out as 11.52, 1.57 and 22.96 kg, respectively. In Poovan (ratoon-I) banana production, 51.2, 37.8 and 58.3 % of N, P_2O_5 and K_2O was contributed from soil while, applied fertilizers contributed to an extent of 58.2, 42.6 and 58.7 % N, P_2O_5 and K_2O and from organic manure 18.3, 16.1 and 24.8%, N, P_2O_5 , K_2O respectively.

Requirement of N, P_2O_5, K_2O for producing one ton of Karpuravalli (ratoon I) banana was worked out as 12.8, 1.4, 18.7 kg respectively. In Karpuravalli (ratoon I) banana production, 57.8, 45.2 and 40.9% of N, P_2O_5 and K_2O from soil, while applied fertilizers contributed 58.6, 49.6 and 76.9% of N, P_2O_5 and K_2O and from organic manure 16.9, 12.3 and 20.1%, N, P_2O_5 and K_2O respectively were contributed for banana production.

The fertilizer adjustment equations for Poovan (ratoon-I) are FN = (19.8 x T) - (0.88 x SN) - (0.31 x ON); FP = (3.69 x T) - (0.89 x SP) - (0.38 x OP); FK = (39.11 x T) - (0.99 x SK) - (0.42 x OK). The fertilizer adjustment equations for Karpuravalli (ratoon-I) are FN = (21.8 x T) - (0.98 x SN) - (0.29 x ON); FP = (2.82 x T) - (0.91 x SP) - (0.24 x OP); FK = (24.3 x T) - (0.53 x SK) - (0.26 x OK), where, FN, FP & FK are NPK requirement through fertilizer (kg/ha), SN, SP & SK are NPK available in the soil (kg/ha), ON, OP & OK are NPK requirement through organic manure (kg/ha) and T is yield target (t/ha).

5.3. CROP PHYSIOLOGY, BIO CHEMISTRY AND POST- HARVEST TECHNOLOGY

5.3.1 Crop Physiology

5.3.1.1 Climatic factors on leaf development in Grand Naine Banana

Vegetative growth of sucker derived Grand Naine revealed that the rate of leaf production was more than one per week at mean diurnal temperature of 25- 27°C with less than 90 % RH and the rate decreased (<1 per week) at lower mean temperature (25-26°C) and RH.

5.3.1.2 Improvement of banana bunch development

Brassinolides (BR) with Gibberalic acid (GA) spray (BR 2, 4, 6, 8, 10 ppm + 25 ppm of GA) increased the finger length and circumference in Ney Poovan , Poovan and Saba cultivars. The response was low at more than 8 ppm BR + GA 25 ppm.

The effect of Potassium sulphate spray (1%, 1.5%, 2% and 2.5%) on bunches of cultivars Poovan, Robusta, Ney Poovan and Rasthali was more prominent on finger circumference than length. The effect of spray of Potassium sulphate on finger circumference was prominent at 1.5 % concentration and was on par with 2.0 % concentration.

5.3.1.3 Drought stress tolerance in banana: Understanding the physiological, bio chemical and molecular mechanism of drought tolerance

To study the mechanism of drought tolerance, four drought tolerant genotypes viz., *M.balbisiana* (BB), Monthan (ABB) Saba (ABB) and Poovan (AAB) and two susceptible banana genotypes, viz., Grand Naine (AAA) and Nendran (AAB) were subjected to soil moisture deficit stress. The osmotic potential was higher in drought stressed plants (-0.35 to - 0.77 MPa) as compared to irrigated control (- 0.27 to - 0.36 MPa) through out the treatment period (three weeks). In *M.balbisiana*, the osmotic potential did not decreases (- 0.414 MPa) significantly even after one week of drought imposition, whereas, in all other genotypes, the osmotic potential showed an increasing trend till the end of drought stress period. Relieving of drought stress after three weeks, indicated increase of OP in all genotypes except in Nendran (susceptible cultivar). The Osmotic adjustment of *M.balbisiana* was not greater than other genotypes. The proline content of *M.balbisiana*, Monthan, Saba and Poovan, recorded higher content (240-290 ug/g fr.wt.) than Nendran (128.30 ug/g fr.wt.). The Membrane Stability Index (MSI) recorded higher in *M. balbisiana*, Monthan and Saba (68-70) than Nendran (58). Under drought stress conditions, *M. balbisiana*, Monthan and Saba maintained higher chlorophyll pigments, membrane stability index and vegetative growth than susceptible genotypes.

5.3.1.4 Salt stress tolerance in banana: Understanding the physiological, bio-chemical and molecular mechanism of salt tolerance

Banana plants grown in the salt affected field (EC1:2.5 = 8.56; pH 8.1) were analysed for Sodium (Na+) and Potassium (K+) ions at flowering and harvest in various plant parts. At flowering stage, sodium ions in 2nd and 3rd leaf lamina stage were analysed in five cultivars .Among cultivars Poovan, Nendran and Robusta cultivars accumulated more Na ions (0.25 to 0.625%) than Saba and Karpuravalli (0.001%). However, in all the varieties , Na+ ions were found to more in leaf midribs. Karpuravalli corms accumulated significantly less Na+ ions (0.001%) as compared to other varieties (0.375 to 1.875%). At harvest Na+ ions in the peel and pulp of middle hands of Saba and Karpuravalli cultivars recorded less (0.001 to 0.25%) than other cultivars (0.375 to 0.5%). Magnesium and Calcium were mobilized from banana corm in salt tolerant cultivars unlike susceptible cultivars.

At flowering, Saba and Karpuravalli cultivars had higher potassium ions (K+) (6.312 -8.12%) than remaining cultivars in leaf midrib and at harvest, the corm mobilized more K+ ions than other developing sinks. Saba and Karpuravalli maintained higher K+/Na+ ratio (> 200) in lamina and leaf midrib at flowering as well as at harvest as compared with Poovan , Nendran and Robusta cultivar (4.52 to 17.56). It was concluded that tolerant varieties had more K+/Na+ ratio in the lamina and in the midrib at flowering and at harvest.

Salt tolerant cultivar Saba accumulated higher nitrogen in 2nd and 3rd leaf petioles and high N, P and K in inner core of corm as compared to susceptible cultivars under field condition. The 2nd and 3rd leaf blades of Saba cultivar had very low phosphorus content (0.001%). Higher K was in the inner core of Saba corm at harvest when compared to all other susceptible cultivars. In salt stress imposed Grand Naine plants, treatement with Abscisisic acid (ABA) and Butylated Hydroxy Toluene (BHT) significantly increased carotenoid pigment content when compared with control. The Malondialdehyde content (indication of lipid peroxidation) decreased in ABA and BHT treated plants. The ABA treated salt stressed plants recorded higher ascorbic acid and proline content than control. Increase in Epicuticular wax in leaves was observed in sodium chloride salt stressed plants due

to ABA application. It was concluded that application of ABA on plants could alleviate the adverse effects of sodium chloride salt stress.

The number of days to flowering under salt stressed condition was extended upto 45 to 52 days. There was significant increase in fruit volume, pulp/peel ratio between 30 and 60 days after flowering in Saba and Ney Poovan cultivars when compared with Nendran and Robusta cultivars.Saba cultivar accumulated lesser total sugar than other cultivars in pulp and peel during fruit development. In susceptible Robusta and Nendran cultivars, there was no fruit development. The total sugars content was significantly higher in peel than pulp throughout fruit development. It was observed that under high salt stress condition, sugars are not properly converted into starch which results in lower bunch weight.

5.3.1.5 Effect of Soil moisture deficit stress on symptomatic and non-symptomatic BSV affected Poovan banana

The BSV infected Poovan (AAB) plants (with expressed and non expressed symptom) were subjected to soil moisture deficit stress for three weeks in 75 kg capacity cement pots. The total chlorophyll (3.36 mg/g fr.wt.) and carotenoid contents (0.323 mg / g fr.wt.) were higher in non-symptomatic plants than the drought stressed symptomatic plants of cultivar Poovan Chlorophyll (2.537 mg / g fr.wt) and carotenoids (0.030 mg / g fr.wt.). Total sugar content was analysed in the corm of treated plants. It was recorded that water stressed symptomatic plants accumulated two times higher sugar in corm than non-symptomatic plants while reverse trend was observed for starch content.

5.3.2 Biochemistry

5.3.2.1 Biochemical mechanism of resistance of bananas to root leison nemotode

Physiological parameters and biochemical contents were studied in roots of resistant (Anaikomban and Yangambi km5) and susceptible (Nendran and Robusta) cultivars for 90 days after inoculation with root lesion nematode, *Pratylenchus coffeae*. Infestation of the nematode affected the relative growth rate of leaf area at 30 days after inoculation in nematode susceptible Robusta and Nendran cultivars but not in resistant (Anaikomban and Yangambi km5) cultivars. Relative growth rates of plant like height, pseudostem girth and chlorophyll and carotenoid pigments due to infestation of nematodes were not affected in all the cultivars.

Constitutively, the peroxidase activity in resistant and susceptible cultivars was 15 nanokatals/mg proteins. After inoculation with nematodes, the activity in resistant cultivars increased from 4th day, peaked at 7th day (218 nanokatals) and subsequently decreased to 95 nanokatals at 90th day. In susceptible cultivars the level of induction of peroxidase activity was lower (60 nanokatals) at 7th day after inoculation than the resistant banana cultivars. On 9th day, the activity of peroxidase was only 25 nanokatals in susceptible cultivars. The constitutive activity of Poly Phenol Oxidase (PPO) in resistant cultivars was more (27 nanokatals) when compared to susceptible cultivars (22 nanokatals,). The PPO activities also showed similar trend. PPO activity in resistant varieties was more (170 nanokatals/mg protein) when compared with susceptible cultivars (80 nanokatals) at 7th day after inoculation of the nematode. At 90th day, the PPO activities in resistant (53) and susceptible (41 nanokatals) cultivars varied widely.

The constitutive activity of Phenyl Alanaine Lyase (PAL) was more in resistant varieties (26 picokatals/mg protein) when compared with 22 picokatals in susceptible cultivars before inoculation of the nematode. After inoculation, the activity increased and peaked in resistant cultivars at 7 and 10 days (177 picokatals in Anaikomban and 102 picokatals in Yangambi km5. But in susceptible cultivars, PAL activity peaked only at 7 days (46 nanokatals) and further decreased till the observation at 90 days. In both resistant and susceptible cultivars, the PAL activity levels at 90th day was higher than the activity levels observed before inoculation. The constitutive activity of Cinnamyl Alcohol Dehydrogenase (CAD) was more (20 picokatals/mg protein) in resistant varieties when compared with susceptible cultivars (13 picokatals). After inoculation of the nematode, the

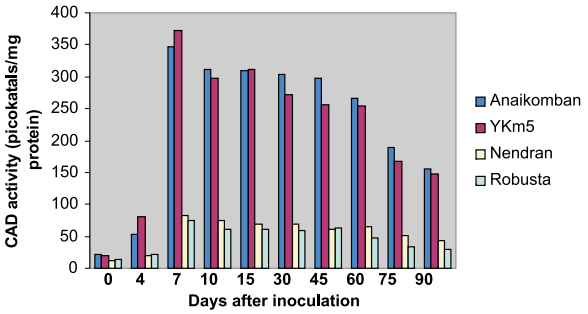


Fig.19. Cinnamyl Alcohol Dehydrogenase (CAD) in roots of banana cultivars.

activity of CAD peaked at 7 and 10 days was very high (360 picokatals in resistant Anaikomban and Yangambi km5 cultivars) when compared to susceptible cultivars (78 picokatals) . The induction levels of activity in susceptible cultivars were several folds lower than the resistant varieties. From 10th day, the activities of CAD decreased and even

at 90th day, the CAD activity was more in resistant cultivars (156 picokatals) than the susceptible (43 picokatals) cultivars (Fig.19).

At pre-inoculation stage, lignin contents in all the four cultivars was 45 mg/g which increased in both resistant (380 mg/g) and susceptible (72 mg/g) cultivars at 7 days after inoculation and decreased but remained higher than the levels detected before inoculation. The increase in lignin content was nine times high in resistant but only two times in susceptible cultivars at 7 days after inoculation of the nematode. The contents of lignin at 90 days after inoculation of the nematode were more in resistant (113 mg/g) than in susceptible (67 mg/g) cultivars. The constitutive soluble phenolic content in the cultivars were between 0.043 and 0.054 mg/g tissue with higher content in resistant (Anaikomban) than the susceptible cultivars. In *P. coffeae* inoculated roots of Yangambi km5 and Anaikomban cultivars phenolic content increased (0.224 and 0.235 mg/ g) respectively after 7 days which was comparatively more than the contents in susceptible Nendran (0.072 mg/g) or Robusta (0.085 mg/g) cultivars. After 7 days, the phenolics in both resistant and susceptible cultivars were found to be slowly decreasing till 90 days of observation. At 90th day, the differences in phenolic content in resistant (0.112mg) and susceptible (0.091mg) started subsiding tendency.

Constitutively, the roots of resistant and susceptible cultivars contained 45 and 30 µg/g of total hydrolysable tannins, respectively. In post-inoculation, the tannins increased and reached maximum at 7th day with 120 µg/g root tissue in resistant cultivar and 40 µg/g in susceptible cultivars. At 90th day, the total tannin contents were 83 µg in resistant cultivars (Anaikomban and Yangambi km5) and 42 µg in susceptible cultivars (Nendran and Robusta). Before inoculation, the resistant cultivars contained higher proantho cyanidins than susceptible cultivars. At 7th days after inoculation, the contents of condensed tannins increased (0.425 at A550) in both resistant or susceptible cultivars (0.290 at A550) . From 7th day onwards the proanthocyanidins content decreased and was observed to be 0.389 (A550) in resistant and 0.283 (A550) in susceptible cultivars at 90th day after inoculation.

5.3.2.2 Biochemical studies inrelation to pseudostem weevil infestation

Peroxidase (PO) and Poly Phenol Oxidase (PPO) activities and phenols, tannins and proantho cyanidins contents were studied in inner sheaths and centre core of stem of Karpuravalli cultivar in relation to pseudostem weevil infestation. In uninfested tissues of sheaths, the activities of peroxidase and polyphenol oxidase were 6 and 15 nanokatals/mg of protein, respectively. In the tissues at the site of the infestation (feeding point of grubs) of the weevil, the activity levels were higher than the un -infested tissues with 9 and 29 nanokatals of peroxidase and polyphenoloxidase activity, respectively. In the un -infested tissues of core stem, the enzyme activities were 14 and 27 nanokatals/mg of protein, in resistant and susceptible cultivars respectively whereas, the activities of peroxidase and polyphenoloxidase were more (17 and 35 nanokatals repectively) at the site of infestation.

Total phenols, tannins and proanthocyanidins in un-infested inner sheaths of pseudostem were 0.060 mg, 0.025 mg, 0.536mg/g (A550), respectively. At the site of infestation i. e., feeding point of weevil grubs, the contents of phenols, tannins and proanthocyanidins were 0.072 mg, 0.041 mg and 0.632 (A550)/g respectively, which were higher than the contents in uninfested tissues. In uninfested tissues of core stem, the total phenols and tannins contents were 0.075 mg and 0.04 mg/g tissue and in tissues of feeding point the phenols and tannin contents were 0.104 and 0.063 mg/g tissues.

5.3.3 Post-Harvest Technology

5.3.3.1 Re-standardization of banana flower pickle

Flower pickles with 80% and 60% oil and 95% and 92% vinegar and replacing vinegar with citric acid (4.6%) were prepared and storage studies were carried out. Fungal growth was observed in the pickle prepared with citric acid within a month. Though the parameters such as acidity and pH of the pickles prepared with reduced oil and vinegar were similar to the control, the appearance and consistency of the pickles prepared with reduced oil and vinegar were poor and overall acceptance assessed by sensory evaluations differed with control.

5.3.3.2 Studies on small unit packages for retail marketing of bananas

Testing the quality of Karpuravalli and Robusta hands packed in 1 kg volume CFB boxes and stored at RT (28.5°C) and 22°C indicated that fruits stored at 22 °C with or without packaging had longer shelf life of 11 days against 4 days when stored at room temperature. The quality of fruits stored at low temperature had higher starch and lower sugar at the end of storage period.

5.3.3.3 Evaluation of banana cultivars for fibre extraction

The fibre yield was more in Poovan than Karpuravalli cultivar. The yield of fibre was higher by alkali treatments than the machine extraction in Karpuravalli whereas, 0.1% NaOH treatment yielded fibre at par with machine extraction in Poovan (Table 14).

The fibre yield decreased when the concentration of Na OH increased (0.5% or 1%). Machine extracted fibre contained higher cellulose and pectin in Karpuravalli but, machine extracted and 0.1% alkali treated fibre contained lower lignin like substances. In Poovan, 0.1% alkali treated fibre and machine extracted fibre contained lower cellulose and lignin but higher pectin contents.

5.3.3.4 Extraction of peduncle and midrib fibre

Midrib of Poovan yielded more fibre (1.63%) and peduncle yielded more fibre (0.672% when extracted with machine followed by 0.5% alkali boiling for 1 hr. Chemical analysis of fibres showed that the fibre extracted from Poovan cultivar contained 53% cellulose, 0.85% pectin and 7% lignin and the fibre extracted from peduncle contained 65% cellulose, 0.075% pectin and 11.75% lignin.

Table 14. Yield and chemical properties of fibre extracted by chemical retting and machine from Poovan and Karpuravalli

Cultivars	Treatments	Yield (%) Dry wt. basis	Cellulose (%)	Pectin (%)	Lignin (%)
Karpuravalli	0.1% NaOH	0.450	52.00	1.26	14.13
	0.5% NaOH	0.326	60.66	0.73	16.03
	1% NaOH	0.307	62.00	0.61	17.46
	Machine extraction	0.253	65.33	2.00	12.20
Poovan	0.1% NaOH	0.498	54.66	0.75	13.30
	0.5% NaOH	0.445	63.93	0.52	21.00
	1% NaOH	0.435	59.66	0.58	16.30
	Machine extraction	0.499	55.50	1.78	13.68

5.4 CROP PROTECTION

5.4.1 Studies on Banana Nematodes and their Management

5.4.1.1 Survey for nematodes in banana growing areas of Tamil Nadu

Survey carried out in banana growing areas of Kolli Hills revealed wide spread occurrence of root-lesion nematode (*Pratylenchus coffeae*) and spiral nematode, *Helicotylenchus multicinctus* in var.Ladan (hill banana) and Karpuravalli. The nematode population varied from 90 to 420 per g and 40-120 per g of root *H. multicinctus* and *Pratylenchus coffeae,* respectively. These nematodes infestation caused significant reduction in plant growth and yield.

Effect of VAM alone and in combination with biofertilizers and biocontrol agents for the control of major nematodes

A mixture of VAM (*Glomus fasciculatum* and *G.mosseae*) alone and in combination with biofertilizers and biocontrol agents (*Paecilomyces lilacinus* and *Trichoderma viride*) were evaluated on cv. Ney Poovan under field conditions against major nematodes. The results revealed that significant reduction in nematode population (92%) with increased yield (30%) was recorded in plants treated with VAM and two biocontrol agents together than as individual treatment or with biofertilizers.

Evaluation of endophytic bacteria against the root-lesion nematode

Two strains of Actinomycetes isolated from soil and leaves of banana were evaluated against root-lesion nematode, (*P.coffeae*) under *in vitro* conditions which revealed 100 per cent nematode mortality at 100% concentration in both soil and leaves.

Studies on principal compounds of promising botanical *Tithonia* sp.

Effect of aqueous, solvent extract and individual fractions of solvent extracts of Tithonia and Tagetus were tested against *P.coffeae* under *in -vitro* conditions resulted in per cent mortality of nematodes in crude extracts of methanol and ethyl acetate. Maximum of seven fractions and a minimum of five fractions were isolated in hexane and methanol and dichloromethane solvents respectively. Among the individual fractions of ethyl acetate, cent per cent mortality of nematode was recorded in the first four fractions isolated in hexane, methanol and dichloromethane solvents respectively.

5.4.2 Management of Banana weevils

Isolation and identification of banana corm volatiles

Banana corm weevil is attracted to banana corm due to the emission of terpenoid volatile components. These volatiles were utilized for weevil management and volatile components were collected by air-entrainment technique and identified by GC/MS. The following volatile components viz., Tetradecane, Pentadecane , Hexadecane , Heptadecane and Pentadecane were identified from Cv.Nendran banana corm . In cv.Poovan corm, Verbenene , 1-methyl 2-Phenyl cyclopropane , p-ethyl benzaldehyde , Cycloheptane , 2-caren-10-al were identified.

Screening of semiochemicals against banana corm weevil

Olfactory response of 37 semiochemicals belonging to five groups were evaluated by electroantennography. Among the semiochemicals maximum olfactory response (Fig.20) was recorded in alpha-bisabol-ol (140%) followed by 3-octanone (130%) 1-hexanol (127.5%) p-anisaldehyde (125.5%) and R-carvone (125.5%) .

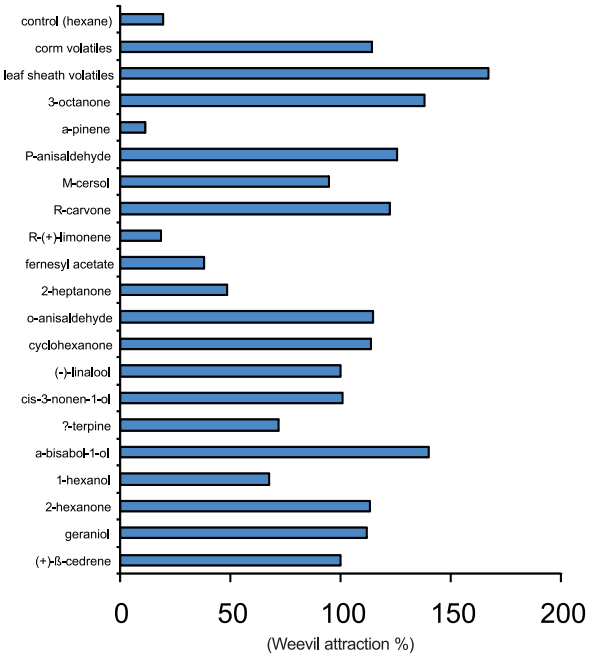
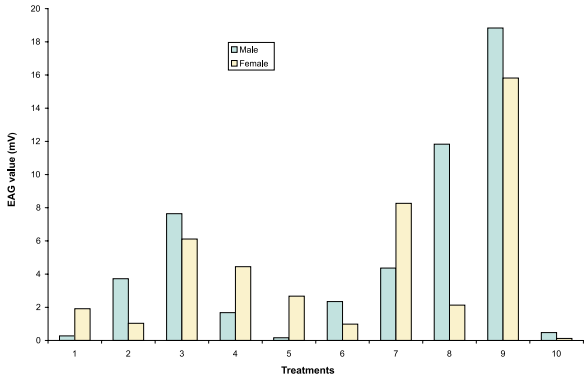


Fig. 20. Evaluation of semiochemicals against banana corm weevil, *Cosmopolites sordidus* by electroan tennography. (Per cent weevil attraction).

Evaluation of 2 -methyl 4-heptanol against banana stem weevil

A semiochemical viz., 2- methyl 4- heptanol and volatiles released by male and female weevil and host plant volatile (cv.Nendran) alone and in different combinations was evaluated against banana stem weevil by various methods (Electroantennography, Y-tube olfactometry, 4 way olfactometry, wind tunnel and field evaluation) .

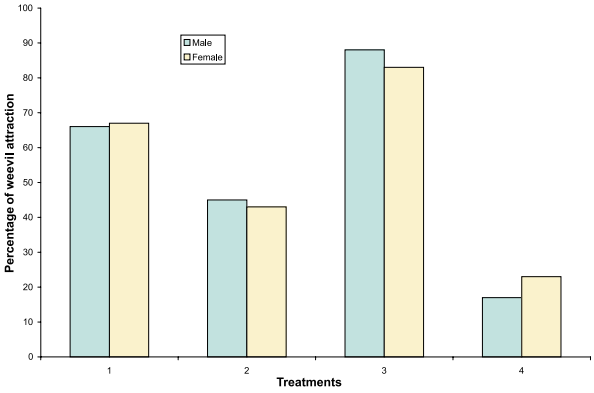
Ofactory response of 2 -methyl 4 -heptanol, volatiles of male and female weevil and host plant volatile of cv.Nendran was screened by electro antennography. Maximum EAG response was observed in host volatile + 2-methyl 4 -heptanol to male (18.830 mV), followed by female weevils (15.816 mV) . Female extract + host volatile recorded 11.829 mV responses to male weevils. With male extract + host volatile, the EAG value was 8.262 mV to male weevil. Host plant volatile indicated a maximum response of 7.644 mV to male weevils and 4.445 mV to female weevils. It was observed that 2-methyl-4 heptanol alone evoked a low response (1.679 mV) to male and medium response (4.445 mV) to female weevil (Fig.). Studies on Y-tube olfactometry indicated a maximum attraction (84 %) to 2-methyl-4-heptanol + host volatile to male and 80 per cent to female weevils (Fig.21).



T1-Male Extract, T2-Female Extract, T3-Host Extract, T4- 2-methyl 4-heptanol,T5-Male + host + 2-methyl 4-heptanol, T6-Female+ host+ 2-methyl 4-heptanol, T7-Male Extract + host, T8-Female Extract + host, T9-Host extract + 2-methyl 4-heptanol, T10-control (hexane).

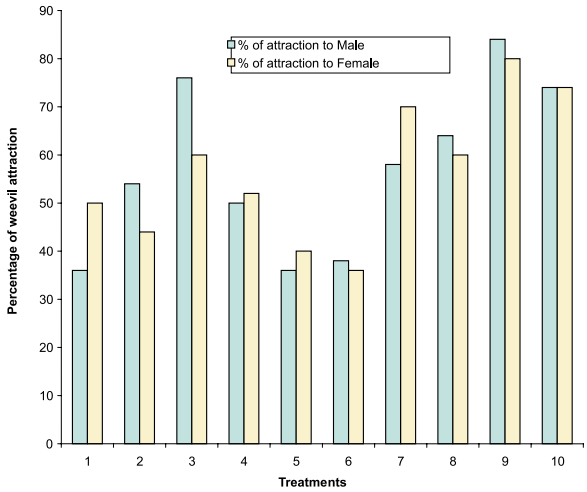
Fig. 21. EAG response of banana stem weevil, to 2-methyl 4-heptanol.

Based on the results obtained from Electroantennography and y-tube olfactrometry , wind tunnel bioassay was conducted with four treatments. Observations on the attraction weevil to 2-methyl-4 -heptanol + host volatile revealed maximum 88 % attraction was recorded in host + 2-methyl-4 heptanol to male weevil and 83 per cent for female weevils. Host volatile of cv.Nendran recorded 66 per cent attraction to male weevil and 67 per cent to female weevils. There were no differences in the per cent attraction between male and female weevil. Weevil response of 40 per cent to male and female stem weevil was observed due to 2-methyl-4 heptanol. Results indicated that weevil attraction was higher in 2-methyl-4-heptanol in combination with host volatile (Fig.21,22,23).



T1- BT (banana tissue. Cv.Nedran), T2-2-methyl 4-heptanol, T3-BT (banana tissue. Cv.Nedran)+ 2-methyl 4-heptanol, T4-control (hexane).

Fig. 22. Wind tunnel bioassay of banana stem weevil against 2 -methyl 4-heptanol



T1-Male Extract, T2-Female Extract, T3-Host Extract, T4-2-metyl 4-heptanol, T5-Male +host +2-methyl 4-heptanol, T6-Female+host+2-methyl 4-heptanol, T7-Male Extract +host, T8-Female Extract +host, T9-Host extract +2-methyl 4-heptanol, T10-control (Banana tissue cv .Nendran)

Fig. 23. Olfactory response of banana stem weevil, to 2-methyl 4-heptanol

Isolation, characterization and evaluation of biocontrol agents

Biocontrol agents evaluated against insect pests indicated stem weevil mortality of 80 % by Beauveria bassiana (NRCB 34). *Metarhizium anisopliae* (NRCB 32) indicated 62 % mortality on banana stem weevil and 48% mortality on corm weevil. *Bacillus thuringiensis* (NRCB 18) indicated 15 % mortality on corm weevil and no mortality on banana stem weevil.

Survey for insect pests and biocontrol agents

During the survey, soil samples (n=308) were collected from Thadiyankudisai (Kanalkadu),

Yercaud hills (Nagalur), Kolli hills (Solaikadu) of Western ghats of India resulted in the isolation of the following entomopathogenic microorganisms viz., *Beauveria bassiana* (107), *Metarhizium anisopliae* (25) and *Bacillus thuringiensis* (24).

Survey conducted in selected banana growing areas of Maharastra (Jalgoan , Pune and Sholapur districts) indicated infestations of stem weevil, corm weevil and rust thrips . Banana fruit spotting bug infestation was recorded in Raver Taluk (Jalgaon District) and Junner taluk (Pune District). The bug makes small puncture using stylet and the puncture mark becomes distinct and black in colour. The infestation affects cosmetic value of the fruit and pulp damage as a result the farmers get less price of their produce.

IPM Strategy for banana corm weevil

Banana corm weevil pheromone (Cosmolure) was evaluated under field conditions which attracted 3-36 corm weevils/ trap. Observations indicated that optimum soil moisture is a critical factor in corm weevil trapping. One ml of 1 % α - bisabol-ol was identified as a semiochemical for monitoring corm weevil under field conditions.

Gel formulation of *Heterorhabditis indica* was evaluated against banana corm weevil, *Cosmopolites sordidus* at 1 x 10 9 IJ's /ml using longitudinal split banana stem trap . Weevil mortality to the tune of 67.0 and 60.0 per cent recorded under laboratory and field conditions, respectively.

5.4.3 Investigation on fungal and bacterial diseases of banana and their management Fusarium wilt disease

Isolation, identification and evaluation of endophytic *Actinomycetes* spp. isolates against *Fusarium* pathogen

Thirty endophytic *Actinomycetes* spp. were isolated from fusarium wilt resistant 24 accessions of banana and evaluated against *fusarium* pathogen by spore germination, chitinase, siderophore and protease production and phosphate solubilization. The result indicated that six strains produced chitinase, eight strains showed siderophore production, 15 strains showed protease production, one strain showed phosphate solubilization activity seven strains showed IAA (13 ug/ml) production. Among these, five strains showed versatility in action against fusarium pathogen.

Evaluation of endophytic *Trichoderma* spp. against Fusarium pathogen

Isolates of endophytic *Trichoderma* spp. (43) were isolated from 13 different fusarium disease resistant banana. The results on morphological studies indicated that 13 isolates belonged to T. *harzianum*, 29 isolates to T. *viride* and one isolate to *T. pseudokoningii* group. All the 43 isolates were screened against fusarium pathogen under in vitro condition by eight different methods (spore germination, dual culture and non volatile and volatile production for mycelial inhibition, HCN production, phosphate solubilization, chitinolytic activity and IAA production). The results of *in vitro* screening indicated that out of 43 isolates tested, 12 isolates of endophytic *Trichoderma* spp. (Pcc4, Br1, Bc1, Bc2, Prr1, Cr1, Plr2, Pjr1, GVr1, Pc2, Prr2 and Dsr1) had multiple actions including phosphate solubilization. Interestingly, all these isolates recorded 100% inhibition in spore germination of fusarium pathogen.

Evaluation of rhizospheric *Trichoderma* spp. against Fusarium pathogen

Trichoderma spp. isolates (19) were screened against *Fusarium oxysporum* fsp. cubense (Foc) isolates by eight different methods. The results of the study indicated that among these 19 isolates, four isolates of *Trichoderma* spp. viz, *T. harzianum*, *T. pseudokoningii*, *T. koningii* and *T. viride* were effective in either inhibiting the mycelial growth or the spore germination of the pathogen. Among these four effective isolates, *T. harzianum* isolate recorded 100% inhibition of spore germination of Foc and also maximum mycelial inhibition in dual culture (65.7%) and non-volatile production (82.5%). The same isolate has the ability to solublize the insoluble phosphate under *in vitro* condition.

Identification of isolates of *Trichoderma* spp. for phosphate solubilization

Quantification of phosphate solubilization by different effective *Trichoderma* spp. of rhizospheric and endophytic in nature indicated that among 29 isolates, 4 isolates (Kbc1, 140c, Dsr1 and TV-NRCB1) recorded the release of more than 6 g/ml of available phosphorus compared to control (0.9 g/ml).

Isolation of and identification of bio chemical compounds from *Trichoderma* spp. against Fusarium wilt pathogen

Principle biochemical compounds from the culture filtrate of effective *Trichoderma viride* isolate NRCB-1 was isolated by NH_4SO_4 precipitation (20 to 100% conc.) method. The inhibitory effect of the NH_4SO_4 precipitate against *Foc* under *in vitro* condition by spore germination method was observed only at 20 and 30 % conc. The further purification and identification of the compound are in progress.

Survey of banana growing regions of India for isolation and evaluation of effective microbes against fusarium wilt pathogen

Surveys were taken up in Tamil Nadu (Salem, Nammakal and Madurai - 20), Maharastra (5) and Tripura (10) and collected 25 soils samples and identified 12 *Trichoderma* spp. isolates and eight bacterial isolates. The screening of these isolates against fusarium wilt pathogen under *in vitro* condition indicated the presence of four isolates of bacteria and five isolates of *Trichoderma* spp. which showed multiple actions.

Molecular characterization

Molecular characterization of *endophytic* and rhizhospheric *Trichoderma* spp.

Molecular characterization of 27 *endophytic* and 16 *rhizhospheric Trichoderma* spp. effective against Fusarium pathogen was carried out by rDNA-ITS - RFLP analysis using six restriction enzymes viz. *EcoRI, HhaI, HinfI, TaqI, MspI, AluI.* The analysis indicated the presence of totally 29 ITS genotypes which included both *endophytic* and *rhizhospheric Trichoderma* spp. isolates. From the phylogenetic analysis, it was concluded that the rDNA-ITS -RFLP analysis separated all the *Trichoderma* isolates into two major *endophytic* and *rhizospheric* groups. However, this phylogenetic analysis could not differentiate the Foc effective *Trichoderma* spp. isolates from the Foc ineffective *Trichoderma* spp. isolates(Fig. 24 d).

Identification and evaluation of non-pathogenic Fusarium (npf) isolates

Evaluation of 31 isolates of npf isolated from 22 different fusarium wilt resistant banana accessions against Foc isolate 0124 indicated three isolates (Pjr1, Cvrr1 & Dsr5) to inhibit 100% spore germination of Foc.

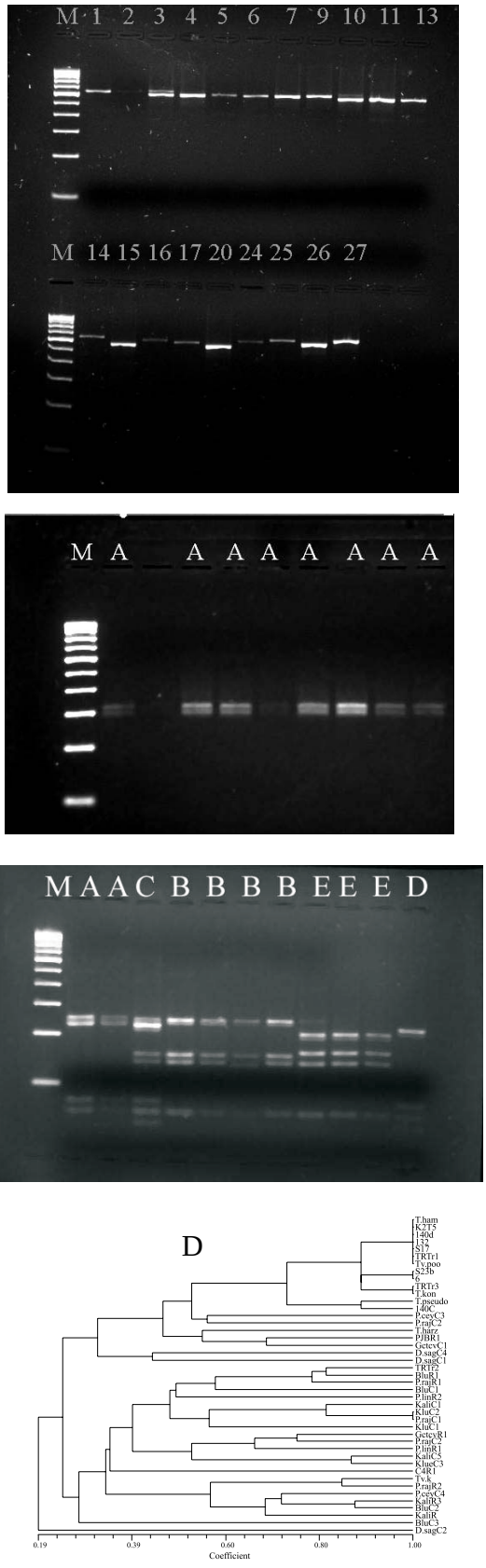
Identification of effective botanicals for the management of wilt disease

Out of 33 medicinal plant extracts screened against Foc, extracts of six plant species viz. *Alpinia galangal, Rhinacanthus nasutus, Hibiscus rosasinensis, Allium sepa x Allium sativum (Zimmu), Occimum gratissimum* and *Vitex leucoxylon* recorded 100% inhibition of spore germination. The inhibition zone was more than one centimeter in agar well diffusion method.

Evaluation of endophytic bacterial isolates against wilt disease

Among the eight endophytic bacterial isolates tested initially under pot culture condition in cv. Ney Poovan, bacterial endophyte Sac1 recorded significant reduction in disease score (3.5) compared to control (4.8).

Fig.24. Phylogenetic analysis of native rhizospheric and endophytic isolates of *Trichoderma* spp.



Evaluation of endophytic actinomycetes and rhizosphere *Trichoderma* spp. against fusarium disease

Evaluation of soil application of endophytic actinomycetes strain 17r1 in combination with 6 different isolates rhizospheric *Trichoderma* spp (isolates 140C, Tv Poovan, K2T5, *T. harzianum*, T. *koningii, T. pseudokoningii*) for the management of Fusarium wilt disease under pot culture condition in tissue cultured banana plants *cv. Grand naine* indicated that the application of Actinomycetes + Rhizosphere application of *Trichoderma harzianum* and *T. viride* at the time of planting had very low score of 1.2 as against 3.7 in the only Foc inoculated plants after six months of planting. The same treatment also increased the growth parameters such as height (42%), girth (45%) and no. of leaves (15%).

Evaluation of endophytic actinomycetes in combination with rhizosphere *Trichoderma* spp. in cv. Ney Poovan

Evaluation of soil application of endophytic actinomycetes strain in combination with six different isolates of rhizospheric *Trichoderma* spp (isolates 140C, Tv Poovan, K2T5, *T. harzianum*, *T. koningii, T. pseudokoningii*) for the management of Fusarium disease under pot culture condition using tissue cultured banana plants cv. Ney Poovan indicated that application of Actinomycetes + Rhizosphere application of *Trichoderma koningii* + *T. pseudokoningii* at the time of planting, recorded no incidence of the disease (ie. 100% inhibition) as against 4.6 score recorded in only Foc inoculated plants after six months of planting. This was followed by Actinomycetes + *Trichoderma* spp. isolate Tv Poovan (Score-1.4), Actinomycetes + *Trichoderma* spp. isolate K2T5 (Score-1.5).

Evaluation of fungicides against Fusarium wilt pathogen

Evaluation of fungicides viz., Carbendazim, Propiconazole, Difenaconazole Hexaconazole, Tridemorph and Mancozeb at five different concentrations (0.01 to 1%) under *in vitro* condition indicated that, Carbendazim at all concentrations showed 100% inhibition of mycelial growth of Foc which was followed by Difenaconazole (100% inhibition) but only at 0.5 and 1% concentration.

Evaluation of type and method of fungicide application against Fusarium wilt disease

Carbendazim, Propiconazole, Difenaconazole, Hexaconazole, Tridemorph and Mancozeb fungicides were tested under Fusarium sick plot condition by six different methods of application viz, Dipping the suckers at the time of planting, drenching the soil around the pseudostem on 2nd 4th and 6th month after planting, stem injection on 2nd 4th and 6th month after planting, dipping + drenching, dipping + injection and drenching + injection and dipping + drenching + injection in cv. Ney Poovan (AB) suckers. The results indicated that Carbendazim applied as dipping the suckers + drenching + injection at 2nd, 4th and 6th month after planting recorded an internal score of 1.3 as against 4.00 in control.

SIGATOKA LEAF SPOT PATHOGENS

Isolation and identification of leaf spot pathogen

Live samples of banana leaf affected by leaf spot pathogen were collected from Tamil Nadu, Maharashtra and Tripura and seventy samples were isolated from different varieties of banana such as Nendran, Rasthali, Ney Poovan, Poovan, Williams, Robusta, Grand Naine, Nendran, Red Banana, Dwarf Cavendish, Karpuravalli, Hill banana, Monthan, Kachkel, Sabari, Nendra Kunnan, *Musa balbisiana*, Vannan, Ladan etc. on the basis of spore characters, were confirmed as *Mycospharella eumusae.*

Molecular characterization sigatoka leaf spot pathogen

The rDNA- ITS sequencing of 18 isolates of Sigatoka leaf spot pathogen confirmed all these isolates were belong to *Mycospharella eumusae.* All these sequences were submitted in Genbank. However, some of these isolates (Sirumalai, Nendra kunnan, Vannan, Ladan and Nendran) are also giving positive reaction to the *M. fijiensis* specific primer obtained from Queensland Department of Primary Industries, Australia and work is in progress.

Diversity analysis

The phylogenetic analysis carried out using these sequences indicated that there are two major groups among 18 isolates of *M. eumusae*. Other two isolates (11M and 8M) obained from var. Sahaji and Vannan respectively, were separated as a distinct group from the two major groups of *M. eumusae* isolates.

Isolation and identification of effective microbes for the management Sigatoka leaf spot disease

Eighty endophytic and five epiphytic bacterial isolates and 27 isolates of epiphytic fungi were

isolated from different parts of banana resistant to leaf spot disease. These were evaluated against Sigatoka leaf spot pathogen *M. eumusae*. The results showed that among 88 isolates, four isolates showed inhibition of more than 95% spore germination, two strains showed mycelial inhibition, one strain showed IAA production, eight strains showed siderophore production and nine strains showed HCN production. Among these, Klebsiella (6Mb), Micrococci (2M), Actinomycetes (14 Mb) and epiphytic *Bacillus spp.* (1Eb) were found to be versatile in inhibiting the *Mycospharella spp*. under *in vitro* condition

Evaluation of botanicals against Sigatoka leaf spot disease

Out of 32 botanicals screened under *in vitro* conditions indicated only three plant extracts viz. *Cassia senna, Rhinacanthus nasutus* and *Allium sepa* x *Allium sativum* (Zimmu) were found effective against *M. eumusae* with 100% inhibition of spore germination in comparison to other extracts.

RHIZOME/ CORM ROT DISEASE

Development of integrated management practices for the control of Erwinia rot disease

The observations on disease incidence and growth parameters indicated that use of healthy suckers + soil application of bleaching powder @ 4 g /plant applied at 0^{th} + 1^{st} + 2^{nd} + 3^{rd} + 4^{th} month after planting + growing three crops of sunn hemp in the interspaces recorded maximum reduction of disease incidence (66. 66 %) and maximum increase in plant growth parameters such as height (50.06%), girth (36.31%), number of leaves (7.07%) and leaf area (79.18%) followed by use of healthy suckers + soil application of *Pseudomonas fluorescens* + *Trichoderma viride* @ 2 l/ plant @ 50g/lit at 0^{th} + 2^{nd} + 4^{th} + 6^{th} MAP + growing three crops of sun hemp in the interspaces.

POST HARVEST DISEASES

Isolation and identification of bio-chemical compounds from the extract of *Solanum torvum* for the management of post-harvest diseases of banana

Principle compounds from the effective plant extract *Solanum torvum* were isolated by preparative TLC. Totally 16 compounds were isolated and purified. The efficacy analysis of each compound against mycelial inhibition of *Colletotrichum musae* under *in vitro* condition indicated that among the 16 bands, band number 16 (Rf value 0.70) recorded 100% inhibition of mycelial growth followed by band number B10 (Rf value 0.38) and B 12 (Rf value 0.49) which recorded 93.75%. The inhibitory effect lasted upto 11 days after the application of the compounds.

5.4.4 Studies on viral diseases and their management

Survey for viral diseases

Surveys were conducted in Kodur and Cuddappa districts of Andhra Pradesh and observations indicated higher incidence of BBTV (1 to 90.5%) both in tissue culture grown and ratoon crop of conventional sucker grown plants. The incidence of BBTV in Pulney hills (Kodaikanal) and Kolli hills was 14 to 72% and one to 19 %, respectively in Hill banana. In Tuticorin and Tirunelveli districts of Tamil Nadu, the incidence was 1.0 to 32.5 % and 1.0 to 13.33 per cent for BSV disease and BBrMV disease, respectively. Pudukotai, Thanjavur, Cuddalore and Nagapattinam districts of Tamil Nadu indicated the incidence BBTV, BSV, BBrMV and CMV to the tune of 1.69, 5.48, 21.25 and 0.13 per cent, respectively

Management of viral diseases by nutrition

In ratoon crop of BSV infected Poovan, there was no response with the application of increased dose of fertilizer whereas in case of BBrMV infected ratoon crop, there was an increase in yield (11.61%) with increased dose of fertilizers. In the 2^{nd} crop of Nendran, application of 125 and 150 kg RDF increased the bunch yield to an extent of 4.5 and 7.94 %, respectively (Fig . 25).

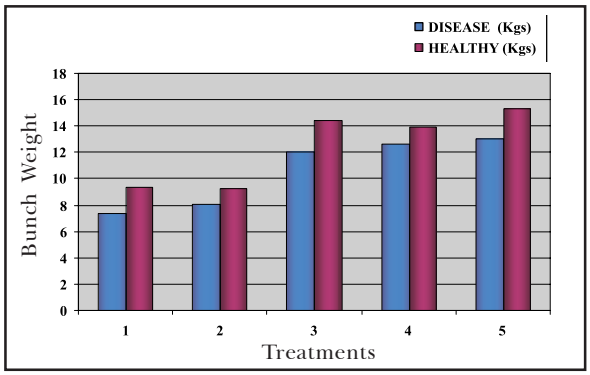


Fig. 25. Management of BBrMV through application of higher dose of fertilizer in cv. Nendran

Molecular Characterization of banana viruses

Sequence analysis of BBTV coat protein (cp) and replicase (rep) gene from different isolates *viz.*, Karnataka, Maharashtra, Bihar, West Bengal, Kerala, Gujarat and Delhi were amplified and

sequenced to study the genetic diversity BBTV. BBTV isolates of Shevroy hills, Kodaikanal and Meghalaya had considerable variability with respect to cp gene but not in rep gene. Complete genome of BBrMV from infected Nendran cultivar was cloned and characterized. The 5' UTR, P1, HC-Pro, P3, 6K1, C1, 6K2, VPg, NIa-Pro, NIb, CP and 3' UTR regions were cloned and sequenced. The viral genome contained 9711 nucleotides. The variability ranged from 91-97% as compared with the published complete genome sequence of a BBrMV Philippines isolate. Partial BSV fragments were amplified from 18 isolates collected from Tirunelveli, Tuticorin and Cuddalore districts of Tamil Nadu and sequenced. The sequence analysis revealed that there was less variability among these isolates in contrast to isolates of Karur and Thanjavur districts.

In silico analysis for integrated BSV sequences in BAC clones was done and designed primers for amplification of integrated sequences. Using these primers, the fragments were amplified, cloned and sequenced from cv. Poovan samples. A cp gene construct for Cucumber Mosaic Virus -Banana isolate was prepared. This construct was transformed into *E. coli* and mobilized into Agrobacterium strain LBA 4404.

Production and use of polyclonal antiserum for recombinant viral protein

DAC-ELISA was standardized using polyclonal antiserum raised from recombinant cp of CMV and validated the technique using field collected samples. Polyclonal antiserum for recombinant coat protein of BBrMV was produced. BBTV rep gene was cloned into Expression vector and transformed into *E. coli.* The MBP tagged fusion protein was expressed by induction using IPTG. The expressed protein was in insoluble fraction and expressed master rep protein of BBTV was confirmed through SDS-PAGE analysis and western blotting techniques using MBP specific polyclonal antiserum.

Diagnostic techniques for banana viruses

Multiplex RT-PCR was standardized for detecting all the four banana viruses which include DNA viruses. The total RNA was isolated from plants infected with DNA viruses and PCR was performed after reverse transcription. A duplex RT-PCR to detect BBTV and BSMysV was developed and validated using field and commercial tissue cultured banana samples. This technique is reliable, sensitive and does not amplify integrated banana streak viral sequences. Direct Binding PCR for BSMysV and BSOLV was compared using three different makes of PCR tubes and results revealed that there was no significant difference amongst tubes for capturing the DNA.

5.4.5 Host- virus interaction in Banana

Developing severity index for BSV

The incidence of streak virus disease expression increased in Poovan cultivar due to possible episomal virus released from integrated sequences in the fifth ratoon crop. However the rate of increase was not substantial over the years. RNAi hairpin construct derived from sense replicase gene of BBTV along with antisense truncated rep fragment (450bp) was developed.(Fig. 26).

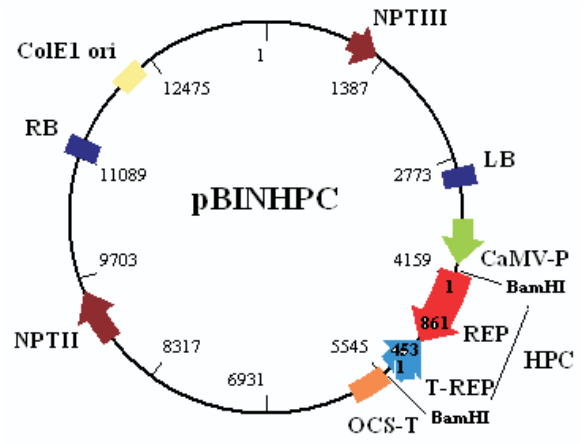


Fig. 26.RNAi hairpin construct

As a pre-requisite for Fluorescent *in situ* Hybridization (FISH) to locate endogeneous para-retroviral sequences (EPRV's) of BSV in banana and plantain, a technique was standardized for staining and visualizing different stages of chromosomes in cv. Poovan and other 'B' genome harboring clones. The technique of Fluorescent Staining with DAPI for observing chromosome was standardized.

In silico analysis of intergenic region of BSMysV -Try isolate (EU 140339) was done in search of plant CIS acting elements. Putative promoter elements present in the intergenic region was most similar to widely used promoter derived from 35 S CaMV. Co-cultivation of leaf disc and infiltration methods of transient gus assay for BSV derived promoters in *N. benthamiana* was done using GUS as reporter gene. Preliminary result showed good expression of GUS gene with BSV promoter comparable with CaMV promoter. When BSMysV symptomatic plants were subjected to water stress, more mortality was recorded than non-symptomatic, non stressed plants.

To study the integration of BSMysV genome in Poovan banana, a southern blotting analysis using probe of 589bp size of RT/RNase - BSMyV labeled with 32P was done. Only in three symptomatic samples, the bands corresponding to episomal viral genome of BSMyV got hybridized with the probe.

5.5 EXTERNALLY FUNDED PROJECTS

5.5.1 Transgenic in crops - Functional Genomics (Sigatoka and Drought)

Sigatoka (*Mycosphaerella eumusae*)

Real time PCR studies

Real time PCR studies revealed that the peak level of expression of scavenging enzymes like catalase, peroxidase and polyphenol oxidase was observed from 10 hrs to 36 hrs after infection by *Mycosphaerella emusae*.

Suppressive Subtractive Hybridization studies

Subtractive hybridization studies with resistant (Manoranjitham) and susceptible cultivar (Robusta) which resulted in the identification of 254 ESTs responsible for Sigatoka resistance.

Majority of identified ESTs were Metallo thioneins (10. 9 - 42.51 %). Physiological regulatory proteins like Cystine Protease (23 - 8.97%), Rubisco Activase B (15 - 5.85%) and Cytochrome C Oxidase (7 - 2.73%) were identified to be functioning in adverse / altered physiological conditions to biotic stresses. Serine / Threonine Kinase (15 - 5.85%), Catalase II (4 - 1.56%), AMP protein (3 - 1.17%) etc. were identified as they were induced during biotic stresses. Patens Predicted Proteins (14 - 5.46%) were also found. Sixty four new ESTs (24.96%) were isolated which did not align with any of the ESTs available with the GenBank.

All the isolated ESTs were subjected for BLASTX and functionally important 254 were deposited at NCBI-Genbank (NCBI Accn. Nos. - GT067848 to GT06788; GT086299 to GT086405; GT153720 to GT153739; GT153740 to GT153761; GT153911to GT153943; GT154752 to GT154769).

Drought studies

Real Time PCR studies

Based on the real time PCR studies carried out with few scavenging enzymes like peroxidase, catalase, superoxide dismutase and poly phenol oxidase indicated 30% field capacity optimum to induce drought conditions in cvs. Nendran and Calcutta 4.

5.5.2 Induced mutation- A crop improvement strategy for developing Dwarf and Sigatoka leaf spot resistant banana cv. Grand Naine (funded by Dept. Atomic Energy, Mumbai)

Irradiation of proliferating buds and embryogenic cell suspension

Both embryogenic cell suspension and proliferating meristems of cv. Grand Naine were irradiated at 10- 50 Gy using ^{60}Co source at SBI and BARC .Cell clusters (ECS) irradiated below 30 Gy produced somatic embryos but failed to develop into plantlets whereas ECS irradiated at doses at 30 Gy and above failed to produce somatic embryos in regeneration medium.Based on the results obtained from preliminary study, the plantlets obtained after irradiation of shoot tips and ECS of cv. Grand Naine were screened for positive mutants (resistant to Sigatoka leaf spot).

Screening irradiated plantlets for Sigatoka resistance

Irradiated plants were hardened and challenged with *Mycosphaerella eumusae* (Septoria leaf spot). Symptom expressions were visible after 50 days of inoculation. Twenty two plants out of 107 showed partial tolerance with 10% expression of spots over control.

Development of markers for dwarfness

A total 50 samples each of normal and dwarf types were collected and subjected to RAPD analysis for developing SCAR markers using 32 random oligonucleotide primers from Operon Technologies Inc. (Alamada, CA). 20 primers resulted in consistent and informative profiles. Out of 20 OPA-05 (Operon Tech., 5'- AGGGGTCTTG-3') amplified , a band of 900 bp in single plant corresponded to dwarfism. Hence, the above amplicon as identified as a discrete band which could be used as a diagnostic marker after converting it into SCAR and reconfirmation using the same sample.

Regeneration and safety duplication of priority *Musa* collections (Funded by GCDT/ Bioversity, France)

The work on first set of sixty accessions was initiated *in vitro* in four replications. After confirming the survival under *in vitro* and freeness from field born bacterial contamination, two cultures each of sixty accessions were shifted to NBPGR, New Delhi during June 2009 to January 2010.

5.5.3 Accreditation Test Laboratory for Certification of Tissue culture raised plant material NCS-TCP (Funded by DBT, New Delhi)

Standardization of protocol for genetic fidelity testing using ISSR markers

Attempts were made in the present the study to standardize the concentration of template and primer to refine the protocol given in SOP-ATL for genetic fidelity testing using ISSR markers. Accordingly 5 different concentrations of template viz. 5, 10, 15, 20 and 25 ng and 4 different concentrations of primers viz., 0.5, 1.0, 1.5 and 2.0 µM were tried. 20 ng template and 0.5 µM primer produced the best banding profile. Hence PCR was carried in a 25 µl reaction containing 20 ng of genomic DNA, 1X PCR buffer (Genei, India), MgCl2 0.5mM, 200 µM each of four dNTPs, 2.0U of Taq polymerase (Genei, India) and 0.5 µM of ISSR primer. Secondly, the annealing temp. for various ISSR primers were standardized erature on gradient PCR (Table No. 15).

Table No. 15

S.No.	ISSR primer	Annealing temp.(°C)
1.	UBC 807	46.8
2.	UBC 808	50.6
3.	UBC 836	43.7
4.	UBC 811	46.1

Minor modifications were made in the PCR programme suggested by SOP-ATL and it consisted of an initial denaturation at 94°C for 5 min, followed by 40 cycles of denaturation at 94°C for 45 sec, annealing at specific temp for 45 sec, followed by extension at 72°C for 2 min and terminated by a final extension of 72°C for 10 min followed by incubation at 4°C.

5.5.4 Utilisation of human urine as liquid organic manure in Poovan banana cultivation

Application of 50 litres of human urine (1:10 urine : water) per plant with 75% of RDF was superior by recording more plant height (32.1%), more pseudostem girth (25.6%), more number of leaves (71.5%) and more leaf area (68.8%), more leaf nitrogen (25.0%) more phosphorus (52.6%) and more leaf potassium (6.5%) than normally grown banana plants without urine application (control). The same treatment recorded 43.6% more leaf calcium concentration, 34.5% more magnesium and 44.8% more sulphur than normally grown banana plants without urine application (control). The same treatment recorded more Total Soluble Solids (TSS) (16.3%) and high TSS/acidity ratio (51.9%) but less acidity (30.4%) than control. The highest bunch weight (23.9kg) was recorded with application of 50 litres of urine per plant along with 75% RDK alone and it was followed by 22.5kg with application of 50 litres of urine with 100% RDK alone. Application of 100% NPK alone (without urine) recorded a bunch weight of 21kg. Application of 50 litres of urine along with 75% RDK alone could accrue an additional net profit of Rs. 45,175/- per hectare as compared to 100% (RDN+RDP+RDK) alone (how much), ie., normally grown Poovan banana without urine application of which Rs. 36,250/- is due to increased bunch weight and Rs. 8,925/- is due to saving in 100% N and P fertilizers and 25% K fertilizers in Poovan banana cultivation.

5.5.5 Effect of PSO6 - Solid and liquid organic manures on Ney Poovan banana

The experiment was conducted at two locations *Viz.,* Kattuputhur and Thottiyam on Ney Poovan banana.

Location : Kattuputhur

Significant variations due to effects of NPK x PSO6 interaction on the bunch weight was observed and it varied from 10.50kg to 15.34kg . The highest bunch weight (15.34 kg) was observed with application of 1.5kg solid PSO6 + liquid PSO6 along with 75% NPK and was 35.3% more than control (11.34kg). The highest bunch weight was at par (15.16kg) with application of 1.5 kg solid PSO6 along with 75% NPK. The highest Benefit/Cost ratio (B:C ratio) of 2.07 was observed with application of 75% recommended NPK along with 1.5kg solid PSO6 alone and also the same Benefit/Cost ratio of 2.07 was arrived with application of 75% recommended NPK along with 1.5kg solid PSO6 + liquid PSO6. It was also found that application of 1kg solid PSO6 along with 75% recommended NPK recorded a B:C ratio of 1.94 and it was at par with 100% NPK application alone. Thus, application of 1kg solid PSO6 could save 25% NPK fertilizers to produce banana yield with the same B:C ratio as that with 100%NPK alone.

Location : Thottiyam

The bunch weight varied significantly from 10.90 to 14.42kg. The lowest bunch weight (10.90kg) was recorded with application of liquid PSO6 without any NPK fertilizer which was at par without PSO6 and NPK. The maximum bunch weight (14.42kg) was recorded with application of 1.5kg solid PSO6 + liquid PSO6 with 75% NPK to a tune of 32.29% over control.

The maximum Benefit/Cost (B:C ratio) (2.00) was recorded with the application of liquid PSO6 along with only 50% recommended NPK followed by application of 1.5kg solid PSO6 along with 75% recommended NPK fertilizers(1.95) in Ney Poovan banana.

5.5.6 Network Project on Transgenic in Crops

Developing transgenic banana resistant to BSV and BBTV (cp mediated)

Out of 256 shoot tips co-cultivated with Agrobacterium harbouring the pBINAR BBTV coat protein, only eight survived in the selection medium. Out of eight, two PCR positive plants were hardened and transferred to transgenic glass house.

Eight transgenic plants were obtained through in planta transformation. Totally 60 explants were used in planta method. Eight plants obtained were PCR positive and 54 were negative. The total DNA isolated from 10 PCR positive plants were blotted onto NCM for southern analysis and two of the plants were positive.

Development of transgenic Hill banana resistant to BBTV (rep mediated)

Totally 82 putative transgenic plants were screened for the presence of replicase and scorable marker, gus by PCR. Among those plants, 52 plants were positive for both replicase and gus. Southern analysis using radio-labelled replicase probes was done for PCR positive plants. Among 52 plants, 10 were positive for southern analysis.

5.5.7 ATL scheme for virus indexing

Testing of tissue cultured banana plants against viruses

Totally 7,969 samples were diagnosed for the presence of banana viruses. The total samples tested for the presence of BBTV was 4097, BSMysV was 1337, BBrMV was 2033 and CMV was 502 for CMV.

5.5.8 Harnessing arbuscular mycorrhizae for bio-fertilization in horticultural crops

Evaluation of Arbuscular Mycorrhizae Fungi (AMF) and AMF associated bacterial isolates against soil borne diseases

Survey were conducted in Tamil Nadu (Tiruchirapalli, Thanjavur, Pudukottai, Madurai, Virudhunagar, Cuddalore and Salem), Maharashtra (Jalgon) and Tripura states and 52 soil samples were collected from rhizosphere region of different varieties of banana. From these samples, 43 isolates of *Glomus* spp. were isolated. The pure culture of all these isolates were initially mass produced using onion as funnel culture and then transferred to pots raised with maize for further mass production. The soil analyses for quantification of *Glomus* sp. spores indicated that there were 175 spores/ 100g of soil and the VAM colonization was about 54.8% in a month.

Besides, soil samples were also collected from rhizosphere region of 18 different banana accessions at NRCB, Tiruchirapalli, which were found resistant to Fusarium wilt disease. The isolation of VAM from these soil samples indicated that the *Glomus spp*. was dominant and about 50 to 125 spores/ 100 gm of soil were present.

Totally 10 MHB isolates were isolated from Mycorrhizae spores obtained from the soil samples.

With regard to isolation of AMF associated bacteria, totally 182 bacterial isolates were isolated from the rhizosphere soil samples collected from different banana growing regions. Among these, 23 were Azotobacter, 16 were phosphate solubilizing, 22 were potash solubilizing and 10 were chitinolytic bacteria.

The evaluation of these bacteria against Fusarium wilt isolates (VCG 0124) by spore germination method indicated that the isolates Jal 1, 5, Pc1, TR1, TR4a, and TR4b recorded 100% inhibition of spore germination under *in vitro* condition.

54 isolates of AMF bacteria and 16 isolates of phosphate solubilizing bacteria evaluated and 19 and seven were positive for siderophore production.

Among 150 isolates of AMF bacteria evaluated for IAA production, the MHB isolate Pc1 showed 100% inhibition of spore germination of Fusarium wilt pathogen and maximum (64 g/ ml) production of IAA.

Among 54 isolates of AMF bacteria screened for HCN production, only two isolates showed positive reaction.

5.5.9 ICAR - Outreach projects on *Phytophthora*, *Fusarium* and *ralstonia* diseases in horticultural and field crops

Isolation, characterization and evaluation of endophytic bacterial isolates with multiple actions against Fusarium pathogen

Endophytic bacterial strains (197) were obtained from Fusarium wilt disease resistant 22 *Musa*

accessions. The colony morphology and biochemical characterization led their classification in to 10 different groups of bacteria viz., *Bacillus, Staphylococcus*, *Micrococci*, *Pseudomonas*, *Actinomycetes, Azotobacter, Klebsilla, Serratia, Enterobacter* and *Citrobacter*. The evaluation of these 197 endophytic bacteria against *Fusarium* wilt pathogen by 9 different methods indicated that 15 strains recorded 100% inhibition of spore germination, 10 strains recorded more than 80% mycelial inhibition, 12 strains recorded HCN production, 6 strains recorded maximum chitinase production, 2 strains recorded positive for phosphate solubilization, 17 strains recorded protease production, 30 strains recorded siderophore production, 15 strains showed IAA production. Among these effective strains, 14 strains showed multiple actions against fusarium disease pathogen.

Molecular characterization of Fusarium wilt isolates by ISSR analysis

Molecular characterization by ISSR analysis was carried out for 180 isolates of Foc obtained from different parts of the banana growing regions of the country by using ISSR primer UBC 861. The result of the study based on phylogenetic analysis indicated that there are 7 major groups present in Foc isolates of India. This ISSR analysis has clearly distinguished the Foc isolates based on the variety from which it was isolated. Interestingly, the virulent isolate of Foc from var. Robusta and Poovan were found to be same through ISSR analysis. It was also observed that there was wide variation among the isolates of Foc isolated from each variety. This study also clearly indicated that the effective management practices are also to be evolved depending on the strains present in each banana growing regions (Fig. 27 a&b).

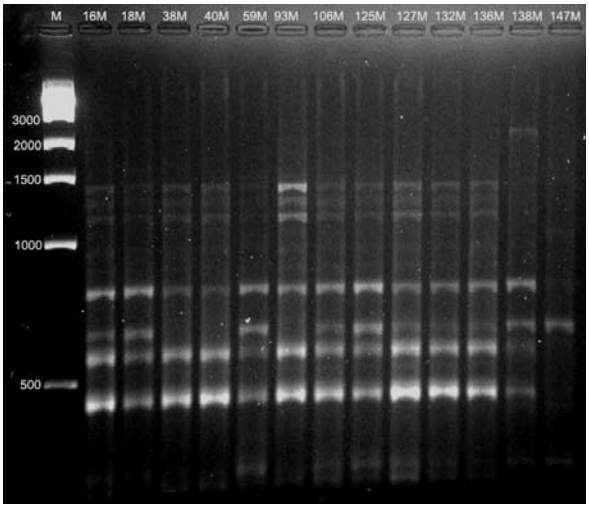


Fig.27a.Characterisation of FOC isolates of cv. Monthan by ISSR analysis using UBC 861 primer

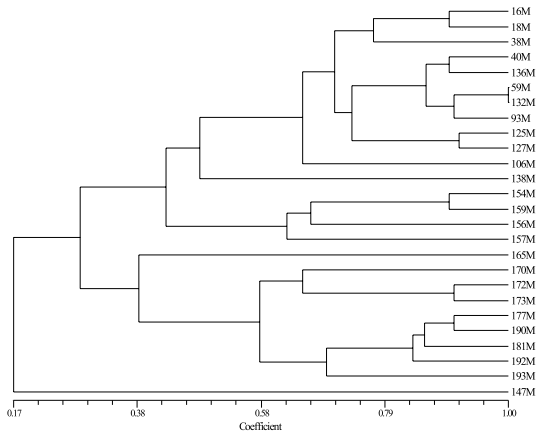


Fig.27b.Phylogenetic analysis of FOC isolates of cv. Monthan

6 TECHNOLOGY ASSESSED AND TRANSFERRED

Radio Talks

Jeyabaskaran, K.J. Fertilizer management in banana (Q & A) (in Tamil), broadcasted on 19. 6. 2009 from AIR, Tiruchirapalli.

Jeyabaskaran, K.J. Fertiliser management in banana (in Tamil) - a Live Phone in Programme. broadcasted on 19. 1. 2010 from AIR, Tiruchirapalli.

Padmanaban, B. Integrated management of insect pests of banana (Q & A) (in Tamil) broadcasted on 11. 3. 2010 from AIR, Tiruchirapalli.

Kumar, V. Weed management in banana cultivation (in Tamil broadcasted on 10 .3.2010 from AIR, Tiruchirapalli.

Television Talks

Padmanaban, B. Management of banana weevils (in Tamil). Telecasted in *Makkal* TV on 12. 6. 2009.

Jeyabaskaran, K.J. Use of human urine in banana cultivation (in Tamil). Telecasted in *Makkal* TV on 20. 7. 2009.

Kumar, V. Modified high density planting for enhancing production and productivity of banana. Telecasted in *Makkal* TV on 21. 3. 2010.

Exhibitions

Sl. No.	Name of the Events	Organised by/venue	Date(s)
01	Sangam Horticulture-2009	NHB and ICAR, Pragati Maidan, New Delhi	22-24, May 2009
02	National Seminar on Agriculture- 2009	ICAR & State Agril. Dept. Mahmada, Pusa, Bihar	27-30, May 2009
03	Banana Festival- 2009	Tamil Nadu Tourism Development Corporation, Chennai, Tamil Nadu	25-26, May 2009
04	Exhibition-cum-Workshop on Tree Breeding	Thiruvarur Tree Growers Association, Thiruvarur TamilNadu	3-5, August 2009
05	Kissan Mela cum Exhibition- 2009	NRCB, Tiruchirapalli	21, August 2009
06	Kissan Mela- 2009	Sugarcane Breeding Institute, Coimbatore, Tamil Nadu	16-19, September 2009
07	Second National Conference on Banana,	Production of Healthy Planting Material in Banana AIPUB, NRCB and Jain Irrigation system Pvt Ltd, Jain Hills, Jalgaon, Maharashtra	03-06, October 2009
08	Technology Week	KVK, TNAU, Sirugamani, Tiruchirapalli, TN.	10, October 2009
09	Technology Week	Saraswathi KVK, Puluthery, Karur, TN.	10, October 2009
10	Recent advances in production and post harvest technology on banana	NRC Banana and Govt. of Tiripura at Nagichara, Agartala	21-24, October 2009
11	Seminar cum Exhibition on Banana cultivation	IIHR & Hithkary Nursery Bangalore	28, October 2009

Sl. No.	Name of the Events	Organised by/venue	Date(s)
12	Agri. Expo 2010	Dinamalar and TNAU, Trichy Tamil Nadu	20-24, January 2010
13	National Kissan Mela-2010	IIVR, Varanasi, UP.	30&31, January 2010
14	Rastriya Kissan Mela-2010	NRC for Citrus, Nagpur Maharastra	21&22, February 2010
15	National Conference on Production of Seed and Healthy Planting Material Management in Horticultural Crops	Govt. of India and ICAR, NASC, New Delhi	11-14, March 2010
16	National Seminar on Banana Processing & Value Addition	Sri Sankara Educational Trust and NRCB, Tiruchirapalli Tamil Nadu	27&28, March 2010

Dr. H. P. Singh, DDG (Hort) visiting the NRCB stall and explaining the activities of NRCB to visitors during the Sangam Horti-2009 at New Delhi on 22.5.2009.

Mr.K.S. Sripathy I.A.S, Chief Secretary and Mr. V. Iraianbu I.A.S., Secretary, TTDC, Govt. of Tamil Nadu visiting the NRCB stall during the Banana Festival at Chennai on 25.5.2009.

7 EDUCATION AND TRAINING

All scientists of NRC Banana were actively involved in impart training on Improved Production Technology including Post Harvest Management and Value Addition in Banana to the banana farmers/entrepreneurs/horticultural officers/ college students etc. from banana growing states in the country during the period under report.

Participants of Improved production technology including post harvest management and value addition in banana

Field visit by Dr. M.M. Mustaffa and Dr. V. Pandey during off-campus training at Tripura

In addition, the students were involved in following project guidance to the M.Sc/ M.Phil. students of Bharathidasan University. The following students were guided during the period

Student Name	Degree	Project Title	Guide Name
M. Malathi	M. Phil.	Screening for Novel Transcripts in Subtracted cDNA Library against Sigatoka Leaf Spot Disease in Banana	Dr. S. Uma
B. Sandhya	M. Sc.	EST based probing and identification of genes (Glyoxalase) for yellow Sigatoka leaf spot resistance in banana	Dr. S. Backiyarani
G. Paul Ebenezer	M. Sc.	Developing salt stress lines in banana through *in-vitro* screening of shoot meristem	
M. Manikandan	M. Sc.	EST based probing and identification of novel cDNAs against yellow Sigatoka resistance in banana cv. Robusta	Dr. M. S. Saraswathi
P. Lakshmi Kanthan	M. Sc.	Development of cDNA library from Mycosphaerell a infected leaves of cv. Robusta	
S. Jothi Priya	M. Sc.	EST (Metallothionein) Based Probing for Identification of Novel Transcripts Against Yellow Sigatoka Resistance in Banana cv. Robusta	
R. Hemalatha	M. Sc.	Developing salt tolerant lines in banana (cv. Robusta) through *in vitro* screening of shoot meristem	
C. Menaka	M. Sc.	Isolation and characterization of resistance gene analogues from fusarium wilt resistant cultivar of banana (*Musa* sp.)	
R. Priyadharsini	M. Sc.	Cloning and characterization of differentially expressed genes from nematode resistant cultivar	
S. Rohini	M. Sc.	Isolation of Functional Resistance Gene Analogues from Fusarium Resistant Cultivar of Banana (*Musa* sp.)	
S.R.Remya	M. Sc.	Preliminary studies on the development of genetic linkage maps in banana using SSR markers and time lag assessment of DNA quality stored in DNA bank.	
T. Muthulakshmi	M. Sc.	Identification of heterozygous *M. acuminata* (AA) parents and their phylogenetic analysis using SSR markers and time lag assessment of DNA quality stored in DNA bank.	
M. Saranya	M. Sc.	Preliminary trials on the use of low cost alternatives in banana tissue culture of variety Udhayam.	
S. Praveena	M. Sc.	Studies on refinement of tissue culture protocol in banana variety Udhayam	

8 AWARDS AND RECOGNITIONS

Awards

International

'Best Poster Award' was given to the paper entitled 'Seed as an alternative source of DNA for molecular research of inaccessible wild *Musa* species' authored by S. Uma, M.S. Saraswathi and D. Anto in the ISHS/ Pro*Musa* banana symposium on Global perspectives on Asian challenges held between 14 & 18, September 2009 at Guangzhou, China.

National

Dr. S.Uma was awarded the 'Punjabrao Deshmukh Best woman Agricultural Scientist award- 2009 during ICAR Foundation Day on 17th July 2009 at NAAS New Delhi.

Dr. S. Uma receiving Best Women Agricultural Scientist Award - 2009

Dr. S.Uma was awarded the 'Best Woman Researcher Award' during Agri- Expo 2010 on 24th; January 2010 sponsored by national daily - Dinamalar and TNAU, Coimbatore.

Dr. S.Uma was awarded the 'Life time Achievement award for germplasm conservation in *Musa*' during the Mupperum Vizha – Pasumai Vazham –organised by the All India Radio (Ministry of Broadcasting, Coimbatore, Tamil Nadu, India on 6th December 2009.

Dr. V. Pandey (Principal Scientist-Hort.) was conferred with the Fellow of the Indian Society for Horticultural Research and Development.

Dr. V. Pandey (Principal Scientist-Hort.) received the Award for Best Poster Paper Presentation. Inter-space utilization in Young mango orchard for pine apple production under water saving irrigation and soil moisture conservation techniques. National Symposium on Conservation Horticulture held at Dehradun during March 21-24, 2010.

Dr.M.S.Saraswathi was awarded the 'Best Ph.D Dissertation Award' by AIPUB in the Second National Conference on 'Production of Healthy Planting Material in Banana' held at JISL, Jalgaon during 2 -4, October 2009.

Dr.R.Thangavelu and Dr.M.M.Mustaffa received award for the book entitled 'Vazhai sakupadiyil pudhiya thozhilnutpangal' (in Tamil) from the Govt.of Tamil Nadu for the year -2009.

Recognitions

Dr. B.Padmanaban Co-chaired the session on 'Quality Management' during the 2nd National Conference on banana on 'Production of healthy planting material in banana' organized by AIPUB and NRCB, Trichy, held at Jain Hills, Jalgaon, Maharashtra from 3-6th October 2009.

Dr.B.Padmanaban acted as rapporteur for the session on Insect Pest Management during the 16th group meeting of the AICRP (TF), held at KAU, Thrissur from 16-19th November 2009.

Dr.B. Padmanaban was nominated as a Member of the Board of Examiners for doctoral thesis of Ph.D scholars of University of Kerala, Thiruvananthapuram and Bharathiar University, Coimbatore.

Dr. B. Padmanaban was nominated as Executive Committee Member and Joint Secretary of the AIPUB, Tiruchirapalli.

Dr. S.Uma has been recognised as the invited member of Institute Biosafety Committee of Bharathidasan University, Tiruchirapalli.

Dr. S.Uma compiled and presented the 'Progress of Regeneration systems in various horticultural Crops' during the 2nd national conference on Horticultural Biotechnology held at IIHR, Bangalore , 28th October 2009.

Dr. S.Uma worked as rapporteur for the concluding session during the 2nd national conference on Horticultural Biotechnology held at IIHR, Bangalore from 29th October 2009.

Dr. S.Uma Co-chaired the session on 'Quality Planting Material Management' along with Dr. Mathura Rai (Director, IIVR- Chair) and Dr. NK Mohan, Ex Dean AAU, Assam uring the 2nd National Conference on banana on 'Production of healthy planting material in banana' organized by AIPUB and NRCB, Trichy, held at Jain Hills, Jalgaon, Maharashtra from 3-6th October 2009.

Dr. S.Uma acted as co-chair person for the first session on Banana Varietal development during the 16th group meeting of the AICRP (TF), held at KAU, Thrissur from 16-19th November 2009.

Dr. R.Selvarajan was nominated to act as external examiner to conduct viva-voice exam for a Ph.D scholar at Mangalore University.

Dr. R.Selvarajan was nominated by DBT, to act as selection committee member for selection of research fellows and technical assistant for the DBT (GOI) project at Bharathidasan University, on 18th August, 2009.

9 LINKAGES AND COLLABORATIONS IN INDIA AND ABROAD

- Developed linkages with Global Crop Trust Diversity Trust, Rome, and two projects have been funded for three years.
- Collaborated with NBPGR for testing the banana germplasm before *in vitro* conservation and cryo-preservation for international exchange.
- Colloborated with AICRP-Centres for virus indexing of germplasm conserved in the field gene bank of respective centres.
- NRCB and CPCRI worked together to find out the presence of Phytoplasma from the root wilt affected coconut trees and the samples were collected from Kayankulam and Kasaragod and proved the presence of Phytoplasma through PCR for the first time.

10 PUBLICATIONS

Research Papers

Manimekalai, R., Soumya, V. P., Sathish Kumar, R., Selvarajan, R. Reddy, K., Thomas, G. V., Sasikala, M., Rajeev, G. and Baranwal, V. K. 2010. Molecular detection of 16SrXI group phytoplasma associated with root (wilt) disease of coconut (*Cocos nucifera*) in India - Disease notes. *Pl. Dis.* 94(5):636.

Nithya Devi, A., Ponnuswami, V., Sundararaju, P., Van den Bergh, I. and Kavino, M. 2009. Histopathological changes in banana roots caused by *Pratylenchus coffeae, Meloidogyne incognita* and *Radopholus similis* and identification of RAPD markers associated with P. coffeae resistance. *Acta Hort.* 828: 283-290.

Padmanaban, B., Thangavelu, R., Gopi, M. and Mustaffa, M.M. 2009 Effect of mass multiplication media on sporulation, field efficacy and shelf life of *Beauveria bassiana* against rhizome and pseudostem weevils of banana. *J. Biol. Control.* 23(3): 277-283.

Selvarajan, R. Suganya Devi, P. Thangavelu, R. Kumudha, R. and Mustaffa, M. M. 2009. Genetic diversity among *Fusarium oxysporum* f.*sp. cubense race*-1 isolates. In: Banana New Innovations (Eds. Singh, H.P. and Musatffa, M.M.). Westville Publishing House, New Delhi. pp: 308-313.

Selvarajan, R., Balasubramaniyan, V., Jeyabaskaran, K. J., Pandey, S. D. and Mustaffa, M. M. 2009. Management of bract mosaic disease through higher dose of fertilizer in banana cv. Ney Poovan (AB). *Ind. J. Hort.* 66(3): 301-305.

Sundararaju, P. 2009. Vertical and horizontal distribution of plant parasitic nematodes associated with banana. *Ind. J. Nematol.* 39: 80-84.

Sundararaju, P. and Thangavelu, R. 2009. *Influence of Pratylenchus coffeae and Meloidogyne incognita* on the Fusarium wilt complex of Banana. *Ind. J. Nematol.* 39: 71-74.

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Mayil Vaganan, M. and Mustaffa, M. M. 2010. Improved post-harvest management techniques and value addition in banana. Souvenir: National Seminar on Banana Processing and Value Addition, 27&28, March. Tiruchirapalli, Tamil Nadu. 67-75.

Mayil Vaganan, M., I. Ravi and Mustaffa, M. M. 2009. Post-harvest management and value addition in banana. Souvenir: National Conference on A Road Map to Emerging Trends in Food Processing and Marketing, 17&18, Sept., PAJANCOA, Karaikal, Puducherry. 5-8.

Mustaffa, M. M., Kumar, V., Jeyabaskaran, K. J. and Pandey, V. 2009. Nutrition and Water Management for Micro Propagated Plants. Souvenir: Second National Conference on Banana, 3-6 Oct., Jalgaon, Maharashtra, pp. 51-61.

Mustaffa, M.M. and Mayil Vaganan, M. 2009. Production, processing and utilization of banana fibre. In Book of Papers of International Conference on Emerging Trends in Production, Processing and Utilization of Natural Fibres. 16-18, April. Mumbai, Vol. 2. 544-550.

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Pandey, V., and Mustaffa, M. M. 2010. R&D in Banana: A Flag bearer in Golden Revolution. Souvenir: National Symposium on Conservation Horticulture, Mar 21-24, Dehradun, Uttarkhand.

Ravi, I., Mayil Vaganan, M. and Mustaffa, M. M. 2010. Effect of abiotic stress on banana production. Souvenir: National Seminar on Banana Processing and Value Addition, 27&28, March, Tiruchirapalli, Tamil Nadu. 50-53.

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Saraswathi, M. S. and Uma, S. 2010. Significance of genetic fidelity testing in tissue cultured bananas. Souvenir of the National Seminar on Banana Processing and Value addition. 27-28, March, Tiruchirapalli,, Tamil Nadu.

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Selvarajan, R. 2010. Diagnostics for clean planting material in banana. Souvenir: National Conference on Production of Quality seeds and Planting material - Health Management in Horticultural Crops, 11-14 March, New Delhi. p.114-123.

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11 CONSULTANCY SERVICES AND COMMERCIALISATION OF TECHNOLOGIES

Resource generation through contract service-virus testing in banana

Tissue culture banana plants and mother plant suckers from 19 tissue culture industries were indexed with ELISA, PCR and NASH technology at the Centre. In this financial year 7,969 samples had been tested for the presence of virus, out of which 4097 is for BBTV, 1337 for BSV, 2033 for BBrMV and 502 for CMV and approximately an amount of Rs.16,68,748 has been received by the centre during the period under report under contract service for virus indexing.

Evaluation of new fungicide, Pyraclostrobin, against Sigatoka leaf spot diseases of banana, an amount of for Rs. 1,37,000/- was generated.

Revenue generated from students project works - Rs. 3,40,000/-.

12 RAC / IMC / IRC MEETINGS

RAC Meeting

The first meeting of the newly constituted Research Advisory Committee under the chairmanship of the Dr.P. Rethinam was held on 7 and 8, December 2009. This was the 11th RAC meeting of the Centre, which commenced with field visit of Chairman and members of the Committee and with the Director and Scientists of the Centre to Research Farm in the morning of 7th December, 2009. The Chairman and members reviewed the ongoing experiments in the field. The Director and Scientists explained various ongoing research activities in the farm. All the experiments under various projects were explained to the RAC Chairman and members by the concerned scientists. The Chairman and members of the RAC appreciated about the well maintenance of research farm and the research work under different programmes. After the field visit, the RAC visited all the research laboratories to see the infrastructure facilities available and were explained on the research activities by the respective scientists.

Dr. M.M. Mustaffa, Director, National Research Centre for Banana, Trichy after welcoming the Chairman and members of RAC, gave a brief account on the salient research achievements made by the NRCB during the last one year. The Action Taken Report on the recommendations of 10th RAC was presented by Dr. B. Padmanaban, Member Secretary-I/c. The Chairman and the members were satisfied with the action taken on the recommendations of previous RAC meeting and approved the minutes of 10th RAC. This was followed by presentations by Head of Sections on the various research activities on banana.

RAC Members visit the NRCB research farm

Dr. P. Rethinam Chairing the RAC meeting

Sl. 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.B. Padmanaban	Member Secretary (IC)

IMC Meeting

The twelfth meeting of the Institute Management Committee was held on 9.12.09 under the chairmanship of Dr.M. M. Mustaffa, Director. In the meeting, the following policy decisions were discussed and recommended for approval by the Council: Annual Plan Budget: 2009-'10; Recognition of Authorized Medical Attendants for the benefit of staff and family members and Post-facto approval for dropping of some equipments.

Dr. M.M. Mustaffa, Director, NRCB Chairing the 12th IMC Meeting

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

IRC Meeting

The Fourteenth Institute Research Council Meeting was held on 4 and 5, March 2010. The salient research achievements of previous year and technical programmes for the next year were presented by respective project leaders of institute and externally funded projects. The Director and Chairman of IRC reviewed the research achievements made under each project and gave critical inputs for refinement of the research programmes.

13 TRAININGS/ WORKSHOPS/ SEMINARS/ CONFERENCES/ WINTER & SUMMER COURSES/ MEETINGS ATTENDED BY SCIENTISTS

Scientist	Title of the Programme/ Venue	Period
M. M. Mustaffa	International Conference on Natural Fibre, Mumbai.	16-18.4.2009
	Brainstorming Session on Management of Horticultural Crops Genetic Resources, NBPGR, New Delhi.	21.4.2009
	Research Council Meeting of Directorate of Oil Palm, Palode , Thiruvananthapuram.	21.4.2009
	Swadesh Prem Jagriti Sangosthi-2009, Mahmada, Samastipur, Bihar.	28-30.4.2009
	Stakeholders Meeting on Production and Marketing of Banana - ETA Star Groups, Chennai.	10.5.2009
	ICAR Foundation Day - Directors' Conference, ICAR, New Delhi.	16 &17.6.2009
	Brainstorming Session on Horticulture Development in Kodagu, CHES-IIHR, Chethalli, Karnataka.	8.8.2009
	Workshop on IT Application in Horticultural Crops, CPRI, Shimla.	24 & 25.8.2009
	Third Consortium Advisory Committee of NAIP Fibre Project, CIRCOT, Mumbai.	27.8.2009
	National Seminar on Enhancing Agricultural Productivity and Profitability, CMFRI, Kochi	29&30.8.2009
	ISHS/ProMusa Symposium on Global Perspective on Asian Challenges, Guangzhou, China.	14-19.9.2009
	Second National Conference on Banana - Jalgaon Maharastra.	3-6.10.2009
	Scientific Advisory Committee Meeting/ Farmers Meet - Saraswathi KVK, Karur, T.N.	13.10.2009
	Scientific Advisory Committee Meeting, KVK, Perambalur	14.10.2009
	National Conference on Natural Fibres - ANGRAU, Hyderabad	26 & 27.10.2009
	National Seminar on Horticulture Biotechnology, IIHR, Bangalore	28 & 29.10.2009
	Review Meeting - Mega Project on Natural Fibre, ICAR, New Delhi	31.10.2009

	Bioversity - SANPGR Meeting, NASC, NewDelhi	3 & 4.11.2009
	National Conference on KVK-2009, TNAU, Coimbatore	6-7.11.2009
	16th Group Meeting AICRP (TF) KAU, Thrissur, Kerala	16-19.11.2009
P. Sundararaju	Banana Grower's Meet, Jalgaon, Maharshtra	2. 4. 2009
	Second National Conference on Banana, Jalgaon, Maharashtra.	3-6.10.2009
	ICAR Zonal Technology Management & Business Planning and Development Meeting-cum-Workshop 2009-10, Central Institute of Fisheries Technology, Cochin, Kerala	12 &13.2010
	National Workshop for the Sensitization of the ARIS in-charges about the uniformity guidelines for websites, NBPGR, New Delhi.	19.3.2010
	National Seminar on Banana Processing and Value Addition, Tiruchirappalli, T. N.	27&28.3.2010
	Integrated Pests Management Farmers' Field School (IPM-FFS) on Banana at Perunthalaivar Kamaraj Krishi Vigyan Kendra (PKKVK), Kurumbapet, Pondicherry.	30.3.2010
B. Padmanaban	Brainstorming session on Sucking insect pests and mealy bugs held at CISH, Lucknow.	11-12.6.2009
	Organic farming workshop held at Yercaud, T. N.	18.7.2009
	Brain Storming session on coconut root wilt disease, NRCB, Tiruchirapalli.	21.8.2009
	II National conference on Production of Healthy Planting Material in Banana held at Jalgaon.	3-6.10.2009
	Group discussion of the AICRP and Adhoc schemes on tropical fruits held at KAU, Thrissur.	16-19.11.2009
	Interactive meeting on management of mealybugs, IIHR, Bangalore.	5&6.12.2009
	Brainstorming session on the application of Nanotehnology in Agricultural Sciences, CIAE, and Mumbai.	27-28. 3.2010
S. Uma	Preliminary meeting on Developing DUS procedure for Agri, Horti and Grass crop species, NAAS, New Delhi.	23.4.2009
	ICAR Foundation Day ceremony, NAAS complex, New Delhi.	17.7.2009
	Second National Conference on Production of Healthy Planting material in banana, Jalgaon, Maharashtra.	03-6.10.2009
	International conference on Global Perspectives on Asian Challenges on Banana production, Guangzhou, China.	14-17.10.2009

	8th PROMUSA - Meeting of Crop Improvement working Group, Guangzhou, China	18.10.2009
	National Seminar on Horticultural Biotechnology, IIHR, Bangalore.	28 & 29.10.2009
	16th group meeting of the AICRP (TF), KAU, Thrissur, Kerala	16-19.11.2009
	Project Appraisal Committee meeting of the PPV and FRA and presented the proposal on Networking on development of DUS guidelines for banana, New Delhi.	17. 3.2010
	Project proposal on Managing Changing needs: Innovative research using fruit tree germplasm for adapting to climate change and improve fruit growers 'livelihoods', BIOVERSITY- South Asia Regional Office, New Delhi	18.3.2010
	National Seminar on Banana Processing and Value addition, Tiruchirapalli, Tamil Nadu	27&28.3.2010
V. Pandey	National Conference on Banana, Jalgaon, Maharashtra	29 &30 .5.2009
	Banana Farmers' Seminar organized by SBI, Alangudi Branch, Alangudi, Pudukottai.	7.7.2009
	Brain Storming Session on Post Harvest Technology and Value Addition in Banana at NRC for Banana, Tiruchirapalli.	21.8.2009
	National Conference on Banana, Jalgaon, Maharashtra	3-4.10.2009
	National Symposium on Conservation Horticulture, Dehradun	21-24.3.2010
	National Seminar on Banana Processing and Value Addition- Entrepreneur to Enterprise, Tiruchirapalli, T. N.	27-28.3.2010
	Workshop on Organic Farming at Yercaud Salem	18.7.2009
	XVI Biennial Group Meeting of AICRP on Tropical Fruits at KAU, Thrissur, Kerala	16-19.11.2009
	Course on Creative Writing in Agriculture at IIMC, New Delhi	5-9.10.2009
	Course on Vigilance Administration at NAARM, Hyderabad	29-31.10.2009
I. Ravi	Workshop on Information Technology applications in Horticultural crops, CPRI, Shimla	24 &25.8.2009
	Training on Molecular Markers: Discovery and Validation Central Plantation Crop Research Institute, Kasaragod, Kerala	18-22.1.2010
	Reviewing the Progress of Foreign Aided Projects, New Delhi	9.9.2009
	National Conference on Frontiers in Plant Physiology towards Sustainable Agriculture, AAU, Jorhat	5-7. 1.2010

	Brainstorming Session on Application of Nanotechnology in Agriculture Sciences, CIFE Mumbai	27& 28.3.2010
R. Thangavelu	Banana Grower's Meet, Jalgaon, Maharashtra	2.4.2009
	Second National Conference on Production of Healthy Planting Materials in Banana, Jalgaon, Maharashtra	3-6.10.2009
R. Selvarajan	Workshop on Organic Farming at Yercaud Salem	21.6.2009
	Review committee meeting of DBT sponsored net work project on Development of virus resistant transgenic crops, M.K.U, Madurai.	6 &7.7.2009
	3rd Institute biosafety committee meeting, NRCB, Tiruchirapalli	13.8.2009
	International Workshop on Banana Bunchy Top Disease (BBTD) and Banana Xanthomonas Wilt (BXW), Arusha, Tanzania	24-28.8.2009
	National conference on Quality Production of Healthy Planting Material in Banana, Jalgaon, Maharashtra.	3-6.10.2009
	A training programme on Recent advances in EST analysis and their annotation, IISR, Calicut.	20-23.10.2009
	Second National Seminar on Horticultural Biotechnology, IIHR, Bangalore.	28-30.10.2009
	XVI Biennial Group Discussion on AICRP on Tropical Fruits held at KAU, Thrissur	16-19.11.2009
	National Conference on Production of Quality seeds and Planting material- Health Management in Horticultural Crops, New Delhi.	4.3.2010
	National Seminar on Banana Processing and Value Addition, Tiruchirappalli, T. N.	27-28.3.2010
V. Kumar	Inter-state Horti. Fair-SANGAM 2009, New Delhi	22-24.5.2009
	National Conference on Technology-Led Economic Development of Horticulture for Rural Development, PUSA, Samastipur, Bihar	29 & 30.5.2009
	Banana Farmers Seminar organized, Alangudi, Pudukottai.Banana Festival, Chennai	7.7.2009
	Brain Storming Session on Post Harvest Technology and Value Addition in Banana, NRC Banana, Tiruchirapalli	21.8.2009
	Interaction Meeting on Tools and Machinery for the development of Horticulture, CPCRI, Kasaragod	18 &19.12.2010
	National Seminar on 'Banana Processing and Value Addition- Entrepreneur to Enterprise' at Tiruchirapalli	27 & 28.3.2010
M. Mayil Vaganan	Post-harvest management and value addition in banana at Meeting of farming for export, CIAL, Cochin	2.6.2009

	Global scenario of banana and value added products of banana at Export seminar for agriculture and food products, Krishnagiri, Tamil Nadu.	18.7.2009
	Brainstorming Session on 'Post-Harvest Management including Handling, Storage and Ripening of Banana', NRCB, Tiruchirapalli.	21. 8.2009
	Post-harvest technologies and value addition in banana at National Seminar on A road map to emerging trends in food processing and marketing, PAJANCOA, Karaikal, Puducherry.	17&18.9.2009
	Value addition and value added products of banana at Technology week celebration, Sarasvathi KVK, Puzhutheri, Karur, Tamil Nadu.	14.10.2009
	Improved post-harvest technologies in banana and value addition in banana in Training on improved cultivation practices including post-harvest technologies, NRCB, Trichy.	28.10.2009
	Training on *In-vitro* techniques and application of molecular markers in banana plantains, NRCB, Tiruchirapalli.	21-30.11.2009
	Extraction of quality fibre form banana at SHG training on banana products, Sarasvathi KVK, Puzhutheri, Karur, Tamil Nadu.	22.12.2009
	Value addition in banana. At Training on improved cultivation practices including post-harvest technologies, NRCB, Trichy.	10.2.2010
	Meeting-cum-Workshop on 'Zonal Technology Management & Business Planning Development', CIFT, Cochin	12 &13.3.2010
	Value addition and value added products of banana at Farmers field school, Perunthalaivar Kamarajar KVK, Puducherry.	16.3.2009
	Brainstorming Session on Application of Nanotechnology in Agriculture Sciences and presented a concept note on Banana flavonoids and fructans in nanoform as nutraceuticals, CIFE, Mumbai	27 & 28.3.2010
K. J. Jeyabaskaran	Organic Farming-Workshop at Yercaud and delivered a lecture on "Organic farming in banana	18.07.09
	".Second National Conference on Production of Healthy Planting Material in Banana, Jalgaon, Maharashtra.	3-6.10.2009
	National Ecosan Manual Workshop organized by UNICEF for DDWS, GOI at New Delhi.	26 & 27.11.2009
	Workshop on Role of potassium nutrition to sustain crop production in Tamil Nadu organized by Faculty of Agriculture, Annamalai University, Chidambaram.	22.1.2010
	Meetings on Level-I and Level-II experts of Kisan Call Centre at TNAU, Coimbatore	10.9.2009, 11.1.2010 and 12.3.2010

S.Backiyarani	Brainstorming session on Application of Nanotechnology in Agricultural Sciences, CIE, Mumbai	27-28.3.2010
	Zonal Technology Management & Business Planning and Development Meeting - cum-Workshop, CIFT, Kochi, Kerala	12-14.3.2010
	Training programme on Bioinformatics component, IISR, Calicut, Kerala	27.1- 2.2.10
	XVIII International Conference on Plant & Animal Genomes, San Diego, CA, USA	9-13.1.2010
	National Seminar on Horticultural Biotechnology, IIHR, Bangalore, Karnataka	28-29.10.2009
	Second National Conference on Production of Healthy Planting material in banana, Jalgaon, Maharashtra	3-6.10.2009
	Nineth meeting of the Task Force on Plant Biotechnology, DBT, New Delhi	16.4.2009
M. S. Saraswathi	Nineth meeting of the Task Force on Plant Biotechnology, DBT, New Delhi.	6.4.2009
	Oil Palm interface meet, NRCB, Tiruchirapalli	29.4.2009
	Apex body meeting of the DBT-ATL, DBT, NewDelhi.	11.8.2009
	Review meeting of the foreign aided projects, IARI, New Delhi	9. 9.2009
	National Seminar on Banana Processing and Value addition, Tiruchirapalli, Tamil Nadu	27-28.3.2010
	Bio-informatics training on Molecular markers : Discovery and validation, CPCRI, Kasaragod, Kerala	18-22.1.2010
	Second National Conference on Production of Healthy Planting material in banana, Jalgaon, Maharashtra.	3-6.10.2009
	Review meeting of externally funded projects NARS Complex, New Delhi.	9-11.9.2009
	Review meeting of the DBT - ATL, DBT Complex, New Delhi.	7-8. 8.2009
C. Anuradha	A short course on in vitro techniques and applications of molecular markers in banana and plantain, NRCB, Tiruchirapalli.	21-30.11.2009
	National Consultative Meeting on Disease Diagnostics for Horticultural Crops, NRCB, Tiruchirapalli.	22-24.1.2010
	A training programme on Protein structure prediction and docking, TNAU, Coimbatore	15-19.2.2010
	Brainstorming session on Application of Nanotechnology in Agricultural Sciences, CIFE, Mumbai	27&28. 3.2010

14 SEMINARS/ MEETINGS/ WORKSHOPS/ CONFERENCES/ SUMMER INSTITUTES AND FARMERS TRAINING ORGANIZED AT THE CENTRE

National Conference on Banana

A National Conference on 'Production of Healthy Planting Material in Banana' was organized by the Association for the Improvement in Production and Utilization of Banana (AIPUB) and National Research Centre for Banana (NRCB), Tiruchirapalli. The conference was hosted by M/s Jain Irrigation Systems Ltd. (JISL), Jalgaon, Maharashtra. The conference was organized at Jain Hills, Jalgaon during 3-6 October, 2009. The conference was participated by more than 450 delegates representing research scientists, entrepreneurs, extension workers, farmers and government officials from 10 banana growing states in the country. Large number of representatives from tissue culture companies participated in this conference.

The conference was started on 3rd morning with welcome address to the guests and dignitaries by Shri Atul Jain, Director, JSIL. The Organizing Committee Chairman, Dr. M.M. Mustaffa explained about the activities of the AIPUB and also the objective of this conference. Prof. Rony Swennen, KUL, Leuven, Belgium, who was the guest of honour of the inaugural function spoke about the importance of germplasm and its need for conservation and storage for posterity. He also emphasized the importance pests and diseases affecting banana and more than Rs. 8,000 million are lost, due to the pests and disease problems. Hence, there is a need to develop resistant varieties against viral diseases and progress has been made through transgenic to develop resistant varieties.

The Inaugural address was given by Dr. H.P.Singh, DDG (Hort.), ICAR, the Chief Guest of the function. In his address, he informed that India produces the maximum production but the quality of the banana is poor and is not suitable for export market. In addition, due to improper post harvest handling, the export is very negligible (0.01%). But smaller countries like Philippines are exporting to the tune of 26%. In China and Philippines infrastructure facilities like conveyor belts, motorized cable, crates packing, trolley and refrigerated vans have been developed for proper handling and storage of banana. Storage of banana at 13°C, enhances the shelf life and also suitable for export. Even though, there is a great potential for value addition, not much progress has been made in this aspect. The NRC Banana has developed more than 15 value added products but the adoption of value addition in very low in Maharashtra, in spite of four universities are located in Maharashtra. There is a great scope for banana wafer (chips) to the tune of Rs. 500 crores and also for banana wine making. He also emphasized the importance of global warming in banana production and drew the attention of the farmers about the wide spread occurrence of Sigatoka leaf spot disease incidence in Jalgoan during 2008, which was not observed five years back. Because of the global warming the banana producing area may shift to subtropical region, which is at present not suitable for banana cultivation.

Dr. M.M. Mustaffa, Chairman Organizing Committee

The Chief Guest of the function, Dr.H.P.Singh released two publications viz., Souvenir of the 2nd National Conference and Abstract booklet. Dr. Singh conferred the 'Kadali Puraskar' Award for 2009 to Prof. Rony Swennen, KUL, Leuven, Belgium for his contributions in banana germplasm conservation and cryo-preservation. Dr.D.P. Ray, VC-OUAT was also awarded the 'Kadali Puraskar' Award for his outstanding contributions for the development of horticulture and particularly for banana in Orissa state.

Dr. H.P. Singh, DDG (Hort.) ICAR New Delhi delivering the inaugural address in the Second National Conference on Banana

Dr. H.P. Singh giving away " Kadali Puraskar" award to Prof. Rony Swennen

The Nalla Vazhai Award which recognizes the contribution of entrepreneur, extension workers and banana growers in production and utilization of banana was presented to Dr. Karianna, an entrepreneur and nursery man from Bangalore and Shri A.P. Karuppaiah, a progressive farmer and entrepreneur from Chinnamanur, Theni Dist. for their significant contribution in adoption of improved production and post harvest technologies. A special Appreciation prize was given to Mr. Nathar Meeran, Uthmapalayam, Theni Dist. for his significant contribution in banana production by adopting hi-tech production technologies.

The Best Dissertation Award was conferred to Dr. M.S. Saraswathi for her Ph. D. thesis work on 'Morpho-molecular characterization and Marker based screening for BSV integrants in B-genome rich Musa germplasm'. On this occasion, the AIPUB conferred 'Fellow of AIPUB 2009' to Dr. Agustin B. Molina, Regional Coordinator, BAPNET, Philippines in-absentia for his life time contribution made in banana research and development.

The 'Life Time Achievement Award' was conferred upon Shri Bhawarlal H.Jain, Chairman, Jain Group of Companies, Jalgaon for his outstanding contribution and visionary leadership to agriculture in general and banana cultivation in particular. The second 'Life Time Achievement Award' was conferred upon to Dr. C.D. Mayee, Chairman, Agricultural Scientists Recruitment Board, New Delhi for his outstanding contribution to agriculture and education.

Dr. H.P.Singh was conferred 'Achievers Award' by the Banana Growing Association of India for his outstanding contribution to the horticulture especially banana, which has improved the livelihood of millions of people and has set a tone for golden revolution in India.

In the Presidential address Shri. Bhawarlal Jain spoke about the role of Jain Irrigation in banana production and the measures taken by the company in the production of tissue culture plants which has revolutionized the production scenario of banana in India, particularly in Maharashtra state.

At the end, Dr. P.Sundararaju, organizing Secretary proposed a vote of thanks to the dignitaries, participating farmers, delegates and all participants.

The Second National Conference on Banana was concluded in the afternoon of 5th October, 2009 with plenary session. The Session was chaired by Dr. Mathura Rai, Director, IIVR, Varanasi. Dr. M.M. Mustaffa, Director-NRCB acted as the co chairman. Dr. P. Sundararaju, acted as convenor. The chairman's of various committees presented the recommendations of various sessions.

Kissan Mela

The National Research Centre for Banana (NRCB), Tiruchirapalli celebrated its 16th Foundation Day on 21. 8. 2009 organizing a 'Brainstorming Meet' with a theme on 'Post-Harvest Management including Handling, Storage and Ripening of Bananas. The brainstorming session consisted of eight technical sessions on pre- and post-harvest management of banana produces, an exhibition, demonstration of post-harvest management practices, field visit and an interactive session. More than 200 banana farmers and entrepreneurs participated in the meet. Dr. H. P. Singh, Deputy Director General (Horticulture), ICAR, New Delhi was the Chief Guest and also chaired the inaugural function. Dr. M. M. Mustaffa, Director, NRCB welcomed the gathering of banana farmers and entrepreneurs.

In his presidential address, Dr. Singh congratulated the farmers for making India as the number one country in production of banana and exhorted the farmers to adopt the technologies developed by the NRCB in managing the post-harvest stages of banana fruits to minimize the losses due to poor handling of bananas and to get maximum return from banana cultivation. An exhibition was also arranged including various research institutes located in southern part of India, private fertilizers, pesticides, tissue culture companies other input agencies participated.

Dr. H.P. Singh receiving " Achievers Award "

Dr. H. P. Singh, DDG (Hort.), ICAR, New Delhi delivers inaugural address at the Brainstorming Meet

National Consultative Meeting on Disease Diagnostics for Horticulture Crops

A National consultative meeting on Disease Diagnostics for Horticulture Crops was held at National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, and India from January 22-24, 2010. The conference was organized jointly by National Research Centre for Banana, Tiruchirapalli, Tamil Nadu and Indian Institute of Spice Research, Calicut, Kerala. Dr. H. P. Singh, Deputy Director-General (Horticulture) of the Indian Council of Agricultural Research inaugurated the event and released four Banana virus diseases fact sheet and a book of technical papers. The meeting was presided by Dr. M. M. Mustaffa, Director, NRCB, Tiruchirapalli and Dr. M. Anandaraj, Project Coordinator, Spices and Dr. B.P. Singh, Joint Director, CPRI, Modipuram spoke in the inaugural session.

The meeting was aimed at to take the stock of molecular diagnostics research activities in different horticultural crops under NAR system and to identify the future research needs on diagnostics for major diseases of important horticultural crops. About 35 leading scientists from various ICAR institutes and SAU's of NARS participated in the meeting. The three day meeting had three major sessions tackling various issues viz., 1) Current status, initiatives and uses of diagnostics, 2) Review of the work in the ongoing projects on disease diagnostics and 3) Future needs. Twenty three lead papers were presented by invited speakers working on disease diagnostics in various horticultural crops. Diagnostic techniques developed by NRCB for four major banana viruses have widely been utilized for certification of TC plants under National Certification System for Tissue Culture raised plants. This programme has been implemented as state of art model in India. Many such diagnostic techniques have also been developed for citrus, potato, tuber crops, spice, vegetables and ornamental crops. Road maps have also been developed for different virus diagnostics and it was decided to augment the production of diagnostic kits so that the technique would be cost effective. These technologies would be commercialized for adoption widely in the tissue culture and seed industries for the production of quality planting material in many horticultural crops.

Dr. H. P. Singh, DDG (Hort.), delivering the inaugural addresss in the National consultative meeting on Disease Diagnostics for Horticulture Crops

ICAR sponsored short course on In vitro techniques and application of molecular markers in banana and plantains was organized in the Crop Improvement Division during 21-30, Nov. 2009 with Dr.S. Uma as Course Director and Dr.M.S. Saraswathi and Dr.S. Backiyarani as Course coordinators.

List of Trainings Offered

Sl.No.	Topic	Date	Participants
01	Improved production technology including post harvest management and value addition in banana	20-27.7.2009	Kerala
02	Short-term training programmes on Preparation of Value Added Products from banana	20-27.7.2009	All States
03	Recent Advances in Production and Post Harvest Technology of banana	21-24.10.2009	Tripura.
04	Improved production technology including post harvest management and value addition in banana	26-30.10.2009	Assam
05	Improved cultivation Practices and Post Harvest Technology in Banana	23-28.11.2009	Bihar
06	A short course on productions of Value added products from banana	04-11.1.2010	Tamil Nadu
07	Improved production technology including post harvest management and value addition in banana	08-13.2.2010	Madhya Pradesh
08	Banana Processing and Value Addition-Entrepreneur to Enterprise	27&28.3.2010	All States

15 DISTINGUISHED VISITORS

Sl. No.	Name & Address	Date
1.	Dr. R. Shankar, Prof. & Head Dept. of Sociology, Bharathidasan University, Tiruchirapalli.	25.4.2009
2.	Dr. N. Jayabalan, , Prof. & Head, School of Plant Science, Bharathidasan University, Tiruchirapalli.	25.4.2009
3.	Dr. C. Devakumar, Principal Scientist, IARI, New Delhi	5.6.2009
4.	Dr. H. P. Singh, DDG (Hort), ICAR, New Delhi	13.7.2009
5.	Dr. H. P. Singh, DDG (Hort), ICAR, New Delhi.	21.8.2009
6.	Dr. G.V. Thomas, Director, CPCRI, Kasaragod, Kerala.	21.8. 2009
7.	Dr. M. Kochubabu, Director, DOR, Pedavegi, AP.	21.8. 2009
8.	Dr. S. K. Naskar, Director, CTCRI, Tiruvandram, Kerala.	21.8. 2009
9.	Dr. M. J. Modayil, Member, ASRB, ICAR, New Delhi .	02.9.2009
10.	Dr. A. Karmugilan, Director of Seed Certification, Coimbatore.	17.12.2009
11.	Dr. N.K. Tyagi, Member, ASRB, New Delhi.	18.12.2009
12.	Shri. Rajaram IAS, Managing Director - TANCEN, Chennai	22.10.2009
13.	Dr. M. Anandaraj, Project Coordinator, Spices .	22.1.2010
14.	Dr. B.P. Singh, Joint Director, CPRI, Modipuram.	22.1.2010
15	Dr. H. P. Singh, DDG (Hort), ICAR, New Delhi	24.1.2010

Dr. H. P. Singh, DDG (Hort.), ICAR, New Delhi reviewing the progress of research works with the Director and Scientists of the Centre on 13.7.2009

Dr. M. J. Modayil, Member, ASRB, New Delhi visiting PHT laboratory of the Centre on 02.9.2009

Farmers visit

More than 3825 banana farmers, Agricultural & Horticultural Officers, Self Help Group members and students visited the Centre.

Horticultural Officers from various districts of Tamil Nadu visited NRCB for one day training programme

Banana Farmers from Theni District, Tamil Nadu on one day Training programme

16 EMPOWERMENT OF WOMEN

More than 350 women students studying in Horticulture, Agriculture, Microbiology, Biotechnology and Veterinary from Universities and colleges located in different places visited NRCB and learned about NRCB activities.

During foundation day celebration Ms.Andal of Kuzhumani was honoured for her contributions in Banana value addition and manufacture of handicrafts items from banana fiber.

Six self-help group comprising 250 women participated in one day training programme on Banana value added products and fiber extraction

Women Self help groups visited NRCB Training Programme on Value Added Banana Products

17 PERSONNEL

Appointments

1. Dr. Vikramaditya Pandey joined as Principal Scientist (Hort.) from Indian Institute of Horticulture Research (Regional Station) Bhuvaneshwar w. e. f. 11. 5. 2009.
2. Dr. C. Anuradha has been appointed as Scientist (Plant Biotechnology) w. e. f. 18. 6. 2009

Promotions

1. Mr. D. Ramachandramurthi, T-3, Technical Assistant (Civil Overseer) promoted to T4 w .e. f.,11.8.2008.
2. Dr. S. Backiyarani, Senior Scientist cleared her probation w.e.f .,29.8.2009.
3. Mr. R. Mohanraj, SSG-III (Supporting Staff) promoted to SS-IV, w. e. f., 6.1.2010

Scientific Staff

Name	Designation
Dr. M. M.Mustaffa	Director
Dr. P. Sundararaju	Principal Scientist
Dr. B. Padmanaban	Principal Scientist
Dr. S. Uma	Principal Scientist
Dr. V. Pandey	Principal Scientist (from 11.5.2009)
Dr. I. Ravi	Senior Scientist
Dr. R. Thangavelu	Senior Scientist
Dr. R. Selvarajan	Senior Scientist
Dr. V. Kumar	Senior Scientist
Dr. M. Mayil Vaganan	Senior Scientist
Dr. K. J. Jeyabaskaran	Senior Scientist
Dr. S. Backiyarani	Senior Scientist
Dr. M. S. Saraswathi	Scientist (Sr. Scale)
Mr. R. Natarajan	Scientist
Dr. C. Anuradha	Scientist (from 18.6.2009)

Technical Staff

Name	Designation
Mr. S. Palanichamy	T-5 Technical Officer
Mr. P. Durai	T-5 Technical Officer
Mr. P. Ravichamy	T-4 Tech. Asst. (Journalism)
Mrs. T. Anitha Sree	T-4 Lab. Technician
Mrs. C. Sagayam Jacqueline	T-4 Computer Programmer
Mr. D. Ramachandramurthi	T-3 Civil Overseer
Mr. R. Pitchaimuthu	T-3 Field Technician
Mr. N. Marimuthu	T-3 Field Technician
Mr. V. Selvaraj	T-3 Lab. Technician
Mr. T. Sekar	T-3 Lab. Technician
Mr. K. Kamaraju	T-3 Lab. Technician
Mr. A. Subramanian	T-2 Driver
Mr. P. Mohan	T-2 Tractor Driver
Mr. V. Manoharan	T-2 Driver

Administrative, Audit & Accounts and Supporting Staff

Name	Designation
Administrative, Audit and Accounts	
Mr. B. Vijayakumar	Asst. Administratative Officer
Mrs. C.Gomathi	Asst. Fin. & Ac. Officer
Mr. M. Krishnamoorthy	Per. Asst. to Director
Mr. R. Krishnamurthy	Assistant
Mr. R. Neela Mega Shyamala Kannan	Steno Gr. III
Mr. R. Sridhar	Steno Gr. III
Mrs. S. Durgavathy	Upper Division Clerk
Mr. M. Devarajan	Lower Division Clerk
Supporting	
Mr. R. Mohanraj	Mali SSG-III
Mr. V. Pandiyan	Mali SSG-III
Mr. V. Thangaraju	Messenger SSG-II
Mr. P. Kamaraj	Mali SSG-II
Mr. V. Ganesan	Mali SSG-I
Mr. C. Kumaran	Mazdoor SSG-I
Mrs. K. Mariammal	Safaiwala SSG-I

18 OTHER INFORMATIONS

Hindi Week

The Hindi Week was observed from 23 - 29, September 2009. Various competitions such as reading, writing, speaking, translation from Hindi to English and vice versa and elocution were held during the period. Hindi week meeting was celebrated on 29.9.2009, wherein Mr. S. Chandrasekaran, Secretary-OLIC, Southern Railway, Tiruchirapalli Zone was the Chief Guest and Dr. M.M. Mustaffa, Director, NRCB presided over the function. In his speech, Mr. Chandrasekaran has observed that as an Indian national, one should learn Hindi as it is spoken more or less throughout the country. He also emphasized that knowledge of Hindi has personal advantage in addition to official benefit. Finally, the Chief Guest distributed the prices to the winners of various competitions held in Hindi.

ANNEXURE - I

List of On-going Institute Projects

I. Crop Improvement

1. 2000711002 : Crop improvement of banana through conventional breeding
M.M. Mustaffa

2. 2000711003 : Crop improvement of banana through non-conventional breeding
S. Uma

3. 2000711004 : Improvement and management of banana genetic resources in Indian subcontinent
S. Uma

4. 2000711005 : Identification and characterization of nematode resistance genes in banana
S. Backiyarani

5. 2000711006 : Improvement of Rasthali through induced mutagenesis
M.S. Saraswathi

II. Crop production

6. 2000713001 : Standardization of agro-techniques for banana production and productivity
V. Kumar

7. 2000713004 : Studies on micronutrients in banana
K.J. Jeyabaskaran

8. 2000713006 : Fertilizer tailoring for targeted banana yield and sustainable soil health
K.J. Jeyabaskaran

9. 2000716001 : Studies on physiology of flowering and fruit development in banana
I. Ravi

10. 2000716002 : Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance
I. Ravi

11. 2000716003 : Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance
I. Ravi

12. 2000716004 : Physiological and biochemical mechanism of nematodes and pseudostem weevil resistance and identification of 'biomarker metabolites' in banana
M. Mayil Vaganan

III. Crop Protection

13. 2000715006 : Management of Banana weevils
B. Padmanaban

14. 2000715002 : Studies on banana nematodes and their management
P. Sundararaju

15. 2000715003 : Investigation on fungal and bacterial diseases of banana and their management
R. Thangavelu

16. 2000715005 : Studies on viral diseases of banana and their management
R. Selvarajan

17. 2000715007 : Host-virus interactions in Banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's
R. Selvarajan

ANNEXURE – II

Meteorological Data

Month	Max. Temp. (°C)	Min. Temp.(°C)	Relative Humidity (%)	Rain Fall (mm)
April 2007	36.7	25.0	85.0	-
May 2007	38.1	25.3	77.2	17.8
June 2007	38.3	26.2	75.6	-
July 2007	37.6	26.6	75.5	-
August 2007	36.5	26.4	79.4	58
September 2007	35.1	25.1	78.8	-
October 2007	35.1	24.8	89.1	-
November 2007	30.8	23.6	81.5	239
December 2007	28.1	22.6	91.3	57
January 2008	29.4	20.0	89.8	-
February 2008	33.8	21.7	87.2	-
March 2008	36.3	24.1	88.5	-