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(भारतीय कृषि अनुसंधान परिषद)

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NATIONAL RESEARCH CENTRE FOR BANANA

(Indian Council of Agricultural Research)

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Dr.M.M. MUSTAFFA
Director

Compiled & Edited by
Dr.M. M. Mustaffa
Dr.M. Mayil Vaganan
Dr.R. Thangavelu
Mr.P. Ravichamy

Hindi Translation by
Dr.V. Pandey

Photographs (Gen.) by
Mr.P. Ravichamy

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Tel : 0422-2450133
E-mail : sakthi_press@yahoo.co.in

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PREFACE

I am very happy to present the Annual Report for the year 2008-'09. The Centre has adopted many innovative approaches to solve the production constraints of the banana growers, which would benefit the small and marginal banana farmers in an ecofriendly way and also increase the profitability of the farmers.

The salient research achievements and initiatives are presented in this Annual Report. The Centre has developed a DNA bank for *Musa* germplasm conservation, a novel approach in this direction. The core collections of this Centre are molecularly characterized with advanced IRAP markers to consolidate the germplasm and also finger printing of available *Musa* accessions. In addition, germplasm accessions have been screened for its nutritive values for nutritional security of the common people and farmers. A farmer-friendly mass production of banana planting material protocol was standardized to meet the need of the small and marginal farmers for seed replenishment of the traditional varieties.

Studies on the identification of resistant genes for leaf spot disease and nematodes are in progress using nonconventional approaches for the development of the resistant plants against its major production constraints. In addition, development of resistant Rasthali plants against wilt disease is also in progress.

The production group has come out with fertilizer adjustment equations for Poovan and Karpuravalli bananas for reducing the cost of production and maximizing the profitability. In addition, studies on abiotic stresses like salt and drought has given encouraging results to mitigate the ill-effects.

The protection scientists have come out with many effective biocontrol agents for the control of weevils, nematodes and major diseases. Many useful isolates against weevils, nematodes, wilt and leaf spot disease have shown encouraging and positive results, which would benefit banana farmers in an eco-friendly manner, thereby reducing the environmental ill-effects.

This Centre has organized an International Conference on 'Quality Production of Banana for Domestic and Export Market' in association with the Association for the Improvement in Production and Utilization of Banana (AIPUB). This has created an awareness for the production of quality fruits, which is the need of the hour and has great potential for the domestic and export market.

The Centre has organized a *Kissan Mela* for the benefit of the local banana farmers for the dissemination of the technologies developed by the Centre. The Centre has participated in many conferences and transferred the technologies developed by the Centre to the banana farmers. In addition, the Centre has organized two International Programmes namely, BAPNET Steering Committee Meeting and TAG Working Group Meeting in which banana experts from 23 countries have participated and has developed a road map for the development of the Global Banana.

I specially acknowledge Dr. M. Mayil Vaganan, Senior Scientist and Chairman-Publication Committee and his team involved in bringing out this Annual Report in a nice manner.

I thank Dr. H. P. Singh, Deputy Director General (Hort.) and Dr. Mangala Rai, Director General, ICAR, New Delhi for their constant support, guidance and encouragement.

Tiruchirapalli
October 2009

(M.M. Mustaffa)
Director

2 कार्यकारी सारांश

फसल सुधार

केले के आठ विदेशी संग्रहों का मार्फोटैक्सोनामिक लक्षणीकरण एवं २२५ संग्रहों के साथ ***म्यूसा*** जननद्रव्य का डी एन ए संग्रह कोष स्थापित किया गया। छः जीनोम समूहों के ७८ द्विगुणित, त्रिगुणित एवं चतुर्गुणित क्लोन्स के आकार, रंजकशीलता (जननशीलता) एवं अंकुरणशीलता का अध्ययन किया गया । अध्ययनों से पता चला कि पराग अंकुरण क्षमता द्विगुणित क्लोन्स में सबसे अधिक, चतुर्गुणित क्लोन्स में मध्यम एवं त्रिगुणित क्लोन्स में सबसे कम होती है। अत्यधिक कम तापक्रम पर जननद्रव्य संग्रह (क्रायोप्रिजर्वेशन) का इसकी आनुवंशिक शुद्धता पर प्रभाव जानने के लिए साठ रैंडम प्राइमर्स का उपयोग करते हुए आर ए पी डी पालीमारफिज्म द्वारा केले का जैव मापी एवं आण्विक विश्लेषण किया गया और स्पस्ट रुप से यह पाया गया कि अतिन्यून तापक्रम पर संग्रह करने का केले के जनन द्रव्य संग्रहों की आनुवंशिक शुद्धता पर कोई प्रभाव नहीं होता है।

केले की रसथाली प्रजाति की साधारण पुत्तियों एवं ऊतक संवर्धित और ई सी एस पद्धति द्वारा व्युत्पादित पौधों का तुलनात्मक अध्ययन किया गया और यह पाया गया कि अध्ययन किये गये वानस्पतिक वृद्धि एवं उत्पादन के अधिकांश लक्षणों के संदर्भ में तीनों प्रकार से व्युत्पादित पौधे एक समान थे। आर ए पी डी मार्कर का व्यवहार करके आण्विक विश्लेषण से भी यह सुनिश्चित हुआ कि ई सी एस व्युत्पादित पौधों और ऊतक संवर्द्धित ङ्क साधारण पुत्ती द्वारा प्राप्त पौधों में अधिक विविधता नहीं थी । ***रोडोक्लेमिस*** संग्रहों में आनुवंशिक विविधता और आर ए पी डी मार्कर पद्धति से ***'यूम्यूसा'*** उपभाग के पौधों के साथ इनके आनुवंशिक सबंधों का पता लगाया गया और आनुवंशिक स्तर पर रोडोक्लेमिस जनन द्रव्य संग्रहों में वास्तविक विविधता का संकेत मिला। प्रेक्षणों से ऐसा ज्ञात हुआ कि 'अत्तीकोल' प्रजाति को ***रोडोक्लेमिस*** समूह में रखा जाना संदेहजनक है और इसका सुनिश्चितीकरण किया जाना चाहिए । छः जोड़े इन्टर रेट्रा - ट्रान्शपोजान पालीमारफिज्म मार्कर के उपयोग द्वारा १७१ जननद्रव्य संग्रहों के आण्विक लक्षणीकरण के आधार पर यह ज्ञात हुआ कि इन आई आर ए पी मार्कर्स का उपयोग न केवल जनन द्रव्य संग्रहों को जीनोम समूहों एवं कुछ मामलों में उप-समूहों तक में वर्गीकृत करने लिए ही, वरन कुछ अद्वितीय जननद्रव्य संकलनों जैसे ए बी बी संग्रहों (उदाहरणार्थ 'रिगाची') को पहचानने में भी किया जा सकता है। विभिन्न जीनोमिक समूहों के फलों के विश्लेषण से पता चला कि बी बी जीनोम समूह के फलों का पोषण मान अन्य जीनोम समूहों के फलों के पोषण मान से तुलनात्मक रुप में अधिक होता है एवं सभी चतुर्गुणित जनन द्रव्य संग्रहों में से किसी एक समूह के भी फलों में उत्तम पोषण मान नहीं पाया गया । पत्ती धब्बा रोग कारी कवक (***मायकोस्फीरेल्ला*** स्पीशीज) के संक्रमण से प्रतिरक्षा एन्जाइम की अभिव्यक्ति पर अध्ययन ने दर्शाया कि पालीफेनाल आक्सीडेज एन्जाइम की सबसे अधिक अभिव्यक्ति संक्रमण के २४ घंटे के बाद और सबसे कम संक्रमण के ३६ घंटे बाद परिलक्षित होती है। केले में भ्रूण रक्षा तकनीक का मानकीकरण किया गया और इस विधि द्वारा ***म्यूसा*** स्पीशीज के परिपक्व भ्रूणों का अंकुरण १५-२० दिनों में प्राप्त किया जा सकता है। काइटिनेज एवं सूक्ष्म जीव विरोधी प्रोटीन से सम्बन्धित जीन का स्थानान्तरण करने के लिए 'गस' जीन का उपयोग करके ***एग्रोबैक्टिरियम*** की मध्यस्थता से केले में जीन रुपान्तरण की विधि का मानकीकरण किया गया है। केले के जननद्रव्यों में से कुल १२१ सफल संयुग्मों के लिए संगतशीलता एवं प्रजनन स्वभाव पर आधारभूत सूचनाएं संकलित की गईं जो भविष्य के केला प्रजनन कार्यक्रमों में उपयोगी हैं। फ्यूजेरियम मुरझान प्रतिरोधी केले की प्रजातियां विकसित करने के लिए फ्यूजेरिक अम्ल परीक्षण विधि द्वारा आवश्यक फ्यूजेरिक अम्ल की समुचित सांद्रता का पता लगाया गया जो ०.०२५ माइक्रो मोल थी।

केले के जनन द्रव्य संग्रहों के परीक्षणों से पता चला कि कार्थोम्बियम्थम और कलकत्ता-४ संग्रह सूत्र कृमि प्रतिरोधी हैं जवकि नेन्द्रन प्रजाति अत्यधिक सुग्राही है। इन प्रजातियों में प्रतिरक्षा जीन - चालकोन सिंथेज के अर्द्ध मात्रात्मकं आर टी- पी सी आर विश्लेषण से पता चला कि सुग्राही पौधों की अपेछा प्रतिरोधी पौधों में ट्रान्शक्रिप्ट्स का संघटन स्तर अधिक था जो टीकाकरण के बाद छठवें दिन तक बढ़ता रहा तथा सातवें दिन के बाद घटने लगा। पत्ती धब्बा प्रतिरोधी 'मनोरंजीतन' एवं सुग्राही 'रोबस्टा' प्रजातियों में ***माइकोस्फीरेल्ला म्यूजीकोला*** कवक के कृत्रिम टीकाकरण के बाद चयनित घटावशील संकरण विश्लेषण करके सी-डी एन ए के अनुक्रम का पता लगाने से सूक्ष्मजीव प्रतिरोधी प्रोटीन की उपस्थिति का पता चला जो कि भविष्यगत अध्ययनों के लिए लाभकारी सावित हो सकता है।

फसल उत्पादन

परम्परागत रोपण की तुलना में केले की 'ग्रांड नैने' प्रजाति को २ मी x ३ मी की दूरता पर तीन पुत्ती ङ्क थाला की दर से सघन रोपण (५००० पौधेङ्क्हे.) के साथ उर्वरक की अभिस्तावित मात्रा का ७५ प्रतिशत टपक सिंचाई माध्यम से देने पर फलों की गुणवत्ता में सुधार हुआ एवं उपज में ३२ प्रतिशत की अभिवृद्धि पायी गयी ।

'मृदा परीक्षण फसल अनुक्रिया' और 'लक्षित उपज' संकल्पना का अनुसरण करके केले की 'पूवन' और 'कर्पूरवल्ली' प्रजातियों के लिए उर्वरक समायोजन समीकरण विकसित किये गये। केले की 'कर्पूरवल्ली' और पूवन प्रजातियों में एक टन फल की उपज प्राप्त करने के लिए क्रमशः १३.६ किग्रा : १.७ किग्रा : १६.२ किग्रा और १४.४ किग्रा : १.७४ किग्रा : २६.७ किग्रा नत्रजन, फास्फोरस एवं पोटैशियम की आवश्यकता का पता लगाया गया।

केले की नेन्द्रन और कर्पूरवल्ली प्रजातियों में अन्य उपचारों की तुलना में पोटैशियम सल्फेट (२%) का दो बार, प्रथम घेर निकलने के

ठीक बाद और दूसरा पहले के १५ दिन पश्चात, छिडकाव करने से घेर के वजन में १.५ किग्रा की बढोत्तरी पायी गयी। जल अभावग्रस्त 'ग्रांड नैने' किस्म के पौधों में एबसिसिक अम्ल (१०० पी पी एम) और एसिटिल सैलिसिलिक अमल के बाहरी प्रयोग से दैहय कार्यिकी से संबंधित लक्षणों में सुधार पाया गया जिससे यह पता चला कि जल अभाव के नकारात्मक प्रभावों का केले के पौधों में असर कम करने के लिए इन पादप बृद्धि नियामकों का बाहरी प्रयोग किया जा सकता है।

केले की विभिन्न प्रजातियों का प्रक्षेत्र दशाओं में लवण प्रभावित मिट्टी (ई सी १.२५ से ३.३४ और पी एच मान ८.१ में परीक्षण करने से पता चला कि तीन प्रजातियां, 'सबा', 'कर्पूरवल्ली' और 'नेय पूवन' लवणता सहिष्णु हैं। जब इन किस्मों की पुत्तियों को लवण प्रभावित मिट्टी में उगाया गया और एबसिसिक अम्ल (१०० पी पी एम), ब्यूटाइलेटेड हाइड्राक्सी टाल्यूइन (१०० पी पी एम) और एसिटाइल सैलसिलिक अमल (१०० माइक्रो मोल) से उपचारित किया गया तो यह पाया गया कि विशिष्ट रुप से ब्यूटाइलेटेड हाइड्राक्सी टाल्यूइन के उपचार से पौधों में प्रकाश संश्लेषण रंजक, हरीतिमा स्थिरिता संकेतक, प्रोलीन एवं आक्सीजनीकरण विरोधी एन्जाइम की मात्रा में बृद्धि जबकि लिपिड पैरा-आक्सीजनीकरण की मात्रा में बिना उपचारित पौधों की तुलना में कमी हुई। यह भी पाया गया कि सोडियम क्लोराइड लवण प्रभावित ''ग्रांड नैने'' प्रजाति में एबसिसिक अम्ल के उपचार से पौधों में पर्ण हरीतिमा और कैरोटिनायड की मात्रा में वृद्धि हुई जिससे लवणता के दुष्प्रभावों का पौधों पर कम असर हुआ।

केले में जड धत्बा सूत्रकृमि (***प्रैटीलेंकस काफी***) के प्रति प्रतिरोधकता के जैवरासायनिक आधारों पर अध्ययन से पता चला है कि सूत्रकृमि के टीकाकरण से पौधों की जडों में फीनोलिक्स और प्रो-एन्थोसाइनिडिन्स की मात्राओं तथा टीकाकरण के बाद सात दिन तक परांक्सीडेज एवं पालीफेनॉल आक्सीडेज की गतिविधियों, विशिष्ट रूप से प्रतिरोधी किस्मों जैसे 'अनाईकोम्बन' और यंगम्बी के एम ५, में अभिवृद्धि होती है।

जड़ धब्बा सूत्रकृमि (***प्रैटीलेंकस काफी***) से बिना टीका करण किये गये पौधों की जड़ों की तुलना में टीकाकृत प्रतिरोधी पौधों की जडों में पौध परजीवी जीव का एक नया समप्रतिरुप भी पाया गया । लघु एवं सीमान्त किसानों की पौध आवश्यकताओं को पूरा करने के लिए 'दीर्घ प्रवर्धन' नाम से केला पौध उत्पादन की कृषक हितकारी तकनीक का विकास किया गया है। इस विधि द्वारा लगभग ६० से ६५ दिनों की कम अवधि में ही प्रति घन कंद समान आकार के औसतन २० से २५ पौधे पैदा किये जा सकते हैं।

फसल सुरक्षा

तमिलनाडु के विभिन्न केला उत्पादक क्षेत्रों में सर्वेक्षण से तीन सूत्रकृमियों मांदकारी सूत्रकृमि (***रैडोफीलस सिमिलिस***), सर्पिल सूत्रकृमि (***हेलीकॉटीलेंकस मल्टीसिंक्टस***) और जड ग्रंथिल सूत्रकृमि (***मेलायडोगायनी इनकागनीटा***) की उपस्थिति पायी गयी जिनमें मांदकारी सूत्रकृमि प्रमुख था।

म्यूसा जनन द्रव्य के अंतरतम संग्रहों (१२-द्विगुणित ए बी और ४८ - त्रिगुणित ए ए बी) का जालीदार छाया घरों में जड़ धब्बा सूत्रकृमि (प्रैटीलेंकस काफी) के प्रति परीक्षणों से पाया गया कि द्विगुणित 'कुन्नान', 'गैगेरिक सरपरा', 'नारमाइन' और त्रिगुणित 'दसामन', 'कोट्टावजाई' और 'सक्कर चायना' जैसे जननद्रव्य संग्रह इस सूत्रकृमि के प्रतिरोधी जबकि त्रिगुणित 'सिरुमलाई', 'मोरोमाइना', 'मलै वजाई' और 'पचा' इस सूत्रकृमि के प्रति सहिष्णु थे।

वेसीकुलर आरबसकुलर माइकोरायजा (***ग्लोमस*** स्पीशीज) के साथ ***ट्राइकोडर्मा विरिडि*** और ***पीसिलोमाइसेस लिलैसिनस*** कवकों की १० ग्राम मात्रा प्रति पौधा की दर से मिट्टी में प्रयोग करने से सूत्रकृमियों की संख्या में सार्थक रुप से कमी तथा पौधो की अधिक वानस्पतिक वृद्धि हुई। ***इन विट्रो*** दशाओं में ***बैसिलस सबटिलिस*** जीवाणु की दो उपजाजियों (बी एस एन आर सी बी १०७ और बी एस एन आर सी बी ३५) के १००% सांद्रता वाले संवर्द्धित छनन द्रव से उपचारित करने के २४ घंटे के अन्दर ग्रंथिल सूत्रकृमि के नवजातों की शत प्रतिशत मृत्यु पायी गयी। इन्हीं आइसोलेट्स से जब 'नेय पूवन' किस्म के पौधों की जडों को प्रक्षेत्र दशाओं में उपचारित किया गया तो पौधों की वृद्धि में बढोत्तरी देखी गई और सूत्रकृमि संख्या तथा जड़ ग्रंथि संकेतक में भी कमी पाई गई।

वर्टीसिलियम लेकानाई नामक कवक की एक ऐसी उप प्रजाति की पहचान की गई जो केला के माहू (पेण्टालोनिया नीग्रोनर्वोसा) को प्रयोगशाला की दशाओं में शत प्रतिशत मारने में सफल रहा। गेंहू के चोकर को सबस्ट्रेट के रुप में प्रयोग करके इस कवक के उत्पादन की विधि का भी मानकीकरण किया गया। प्रक्षेत्र दशाओं में भी इस कवक का प्रयोग करके केले के मांहू को ८०.६ % तक मारने में सफलता मिली है जो कि अन्य व्यवासायिक उत्पादों की तुलना में तीन गुना अधिक है।

केले की नेन्द्रन किस्म की पत्ती के मध्य शिरा एवं घन कन्द से निकाले गये वाष्पशील पदार्थों का गैस क्रोमैटोग्राफी ङ्क मास स्पेक्ट्रोफोटोमीटरी विश्लेषण करके कुल १३ विभिन्न प्रकार के तारपीन यौगिकों की पहचान की गई। इन यौगिकों का घन कंद बेधक कीड़े को आकर्षित करने की क्षमता का मूलांकन करने से ज्ञात हुआ कि ए-पाइनिन नाम के एक यौगिक ने सबसे अधिक (८०%) घन कंद बेधक की मादा कीड़ों को आकर्षित किया । घन कंद बेधक कीड़े को कीट रोगकारी सूत्रकृमि ***हेटेरोहैबडिटिस इंडिका*** संक्रामक शुक **(25×10^3** की दर**)** से शोधित करने पर ***इन विट्रो*** दशाओं में इन कीड़ो की ६३.३% तक मृत्यु देखी गई और यह पाया गया कि इसका प्रभाव मोनोक्रोटोफॉस कीटनाशी के प्रभाव के समतुल्य था। प्रक्षेत्र दशाओं में

घन कंद बेधक कीड़े को अधिकाधिक संख्या में आकर्षित करने के लिए केले की कन्थाली किस्म के तने के ४०-६० सेमी आकार के लम्बवत टुकड़े सर्वोत्तम पाये गये ।

घन कंद बेधक कीड़ों की रोकथाम के लिए गमलों में लगाये गये केले के पौधों पर किये गये अलग-अलग परीक्षणों से पता चला कि पुत्तियों को रासायनिक विधियों में मोनोक्रोटोफॉस (१४ मिली ङ्क ली) या गैर रासायनिक विधियों में निम्बिसिडीन (१%) अथवा जैवकारी ***बीयूवेरिया बासियाना*** से पुत्तियों का उपचार करने से इन कीडों की ८०-६०% तक मृत्यु हो सकती है।

पहली बार कैवेन्डिश और पूवन किस्मों में भी फ्यूजेरियम मुरझान रोग देखा गया। प्रयोगों में देखा गया कि कैवेन्डिश किस्म से निकाले गये ***फ्यूजेरियम आक्सीस्पोरम*** एफ एस क्यूबेन्स का आइसोलेट अन्य किस्मों जैसे कर्पूरवल्ली (एबीबी), रसथाली (एएबी), नेय पूवन (ए बी) और मंथन (ए बी बी) में भी फ्यूजेरियम मुरझान रोग उत्पन्न कर सकता है। इसके अतिरिक्त फ्यूजेरियम मुरझान रोगकारी कवक के आइसोलेट-१ एवं आइसोलेट-२ में विपरीत प्रतिक्रिया भी पायी गयी। फ्यूजेरियम मुरझान रोग से प्रतिरोधी किस्मों से निकाली गयी इन्डोफिटिक एक्टिनोमासिटीज की उपप्रजाति १७ आर ए एवं ***क्लेबसिएल्ला*** स्पीशीज की उप प्रजाति, १७ आर बी ने फ्यूजेरियम रोगकारी की वृद्धि में ६०% तक अवरोध उत्पन्न किया। इन्डोफिटिक आइसोलेट क्लेबसिएल्ला (६ एम बी), ***माइक्रो कोकाई*** (२ एम), एक्टिनोमाइसिटीज (१४ एम बी) और इपिफाइटिक आइसोलेट बैसिलस स्पीशीज (१ ईबी) को पत्ती धब्बा रोगकारी कवक (***माइकोस्फीरेल्ला स्पीशीज***) की वृद्धि को रोकने में अत्यधिक प्रभावी पाया गया। ये भी पाया गया कि में इन्डोफाइट एवं इपीफाइट्स कार्बेन्डाजिम कवकनाशी के साथ मिलनशील थे और परिणामों से यह आशा परिलक्षित हुई कि इन प्रतिरोधी उपजातियों को कवकनाशी के साथ मिलाकर प्रयोग करने से पत्ती धब्बा रोग का प्रभावी प्रबंध किया जा सकता है।

प्रायोगिक दशाओं में पूवन किस्म में अभिस्तावित मात्रा से २५% अधिक उर्वरक प्रयोग करके, केले के ब्रैक्ट मौजैक विषाणु रोग के कारण होने वाली उपज में २५% कमी को निष्प्रभावी किया जा सका है। विविधता का विश्लेषण करने के लिए कर्नाटक, आंध्रप्रदेश, केरल, बिहार और महाराष्ट्र से से संग्रह किये गये केले के शीर्ष गुच्छा विषाणु के आइसोलेट की कोट प्रोटीन एवं रिप जीन और असम तथा अरुणाचल प्रदेश के आइसोलेट से रिप जीन की क्लोनिंग और सीक्वेंशिग की गयी। तमिलनाडु के विभिन्न क्षेत्रों से संग्रह किये गये केला के स्ट्रीक विषाणु के ४० आइसोलेट्स के आर टीङ्क आर एन एन एच प्रखण्ड का विश्लेषण करने से अधिक विविधता होने का अनुमान लगा। केले के सभी चार विषाणुओं जैसे खीरा मोजेक, ब्रैक्ट मोजैक, शीर्ष गुच्छा एवं स्ट्रीक विषाणु के डुपलेक्स पी सी आर का मानकीकरण किया गया। केले के शीर्श गुच्छा रोग के विषाणु कोपी सी आर बिधि से पहचानने के लिए 'टेम्पलेट' तैयार करने की संवेदनशील, सस्ती एवं सरल निष्कर्षण विधि का विकास किया गया।

प्रौद्येगिकी हस्तांतरण

राष्ट्रीय केला अनुसंधान केन्द्र पर विकसित केले की ऊतक संवर्धन तकनीक का विभिन्न राज्य सरकारों के उद्यान अधिकारियों को हस्तान्तरण किया गया जिनमें विशिष्ट रुप से उत्तम गुणवत्ता के ऊतक संबर्धित पौधों के चयन का ज्ञानार्जन करवाया गया। धान की भूसी पर उगाये गये कीट रोगकारी ***वर्टीसिलियम लेकानाई*** कवक को केले के मांहू (***पेन्टालोनिया नीग्रोनर्वोसा***) की रोकथाम के लिए प्रक्षेत्र दशाओं में छोड़ा गया। प्रक्षेत्र मिट्टी में उपस्थित फ्यूजेरियम रोगकारी कवक का दमन करने के लिए धान की भूसी पर उगाये गये ***ट्राइकोडर्मा विरिडि*** (एन आर सी बी-१) को 'ट्राइकोगोल्ड' के नाम से विमोचित किया गया ।

इसके अतिरिक्त, ***पीसीलोमाइसेज लिलैसिनस*** एवं ***स्यूडोमोनास फ्लूरोसेन्स*** के दो होनहार सूत्रकृमि जैवनियंत्रकों को भी एन आर सी बी निमेसिनस-१ और एन आर सी बी निमेसिन्स-२ के नाम से विमोचित किया गया। इस केन्द्र ने उन्नतशील केला उत्पादन, पौध संरक्षण एवं फल तुडाई उपरान्त प्रौधौणिकी तथा मूल्य संवर्धित उत्पाद तैसार करने जैने विषयों पर तमिलनाडु, केरल, मध्य प्रदेश, असम और मिजोरम के किसानों तथा अधिकारियों को प्रशिक्षण भी दिया। विभिन्न प्रक्षेत्र दिवस, किसान मेला, प्रशिक्षण और संगोष्ठियों में इस केन्द्र की ओर से प्रदर्शनी का भी आयोजन किया गया।

सम्पर्क एवं सहयोग

तीन वर्षों के लिए बायोवर्सिटी, फ्रांस द्वारा रु. २७ङ्क- लाख की धनराशि से पोषित ''प्रमुख म्यूसा संग्रहों के पुनर्जीवन और सुरक्षित प्रतिलिपिकरण नामक'' एक परियोजना का शुभारम्भ किया गया। शिक्षण एवं प्रशिक्षण के अन्तर्गत ३५ स्नातक एवं परास्नातक क्षात्रों को विभिन्न विश्वविद्यालयों के अधीन केले के विभिन्न पहलुओं पर आधारित अनुसंधान परियोजना पर शिक्षण और दिग्दर्शन दिया गया ।

राजस्व उपार्जन

कुल १२ लाख रुपये का राजस्व विभिन्न निजी कंपनियों के लिए केले के नमूनों के विषाणु परीक्षण से अर्जित किया गया तथा प्रक्षेत्र उत्पादों के विक्रय से रु ५ लाख की धनराशि अर्जित की गई।

3 Executive Summary

The National Research Centre for Banana (NRCB) has undertaken research and developmental activities during the last one and half decade after its establishment in 1993 to increase the production and productivity of banana and to raise the socio-economic status of the banana farmers and other stakeholders involved in banana industry. The four major thrust areas of research are: Crop Improvement, Production Technology, Post-Harvest Management and Value Addition and Crop Protection. The Centre is working on multidisciplinary approaches to alleviate the problems faced by the banana growers and will be working on the future thrust areas in research as envisaged in the Perspective Plan-Vision 2025. The main focus of research on banana is to minimize the cost of inputs for maximum production and productivity of banana. The salient achievements of the NRCB for the research year 2007-'08 are presented in this annual report.

Crop Improvement

The Centre has developed a 'DNA Bank for *Musa* Germplasm' with 225 accessions and morphotaxonomic characterization was carried out for eight exotic collections. Studies were undertaken on pollen morphology, pollen stainability (fertility) and pollen germinability for 78 accessions of diploid, triploid and tetraploid comprising six different genomic groups. The results indicated that diploids recorded the maximum germination percentage followed by tetraploid and triploid. Cryopreservation effect on genetic fidelity of banana by biometrical and molecular analyses were studied by RAPD polymorphism using 60 random primers, which indicated that cryopreservation did not affect the genetic fidelity of the banana accessions tested.

Comparative studies between ECS derived plants var. Rasthali with normal suckers and tissue culture plants indicated that ECS derived plants did not differ with suckers and tissue cultured plants for most of the growth parameters and yield traits studied. The molecular analyses conducted using RAPD marker system also confirmed that there was no much variation between ECS derived and suckers derived /tissue culture plants. The estimation of genetic variability among Rhodochlamys members and its genetic relationship with section 'Eumusa' using RAPD marker system indicated the presence of substantial variations at genetic level. It was also observed that the cv. Attikol of Eumusa also grouped with Rhodochlamys members, which needs confirmation.

Based on the molecular characterization of 171 accessions of core collection using six pairs of Inter Reterotransposan Amplified Polymorphism (IRAP) markers, it was found that these IRAP markers could be used effectively not only to cluster the accessions according to their genomic groups and in some cases up to subgroup levels but also to identify the unique accessions like ABB accession (e.g. Rigatchi). Among the different genomic groups screened for nutritive value, BB genome recorded highest nutritive value as compared to other genomic groups.

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. By this method, about 20-25 uniform plant lets per plant can be produced in a short span of 60-65 days.

A study on the expression of defense enzyme due to the infection of Sigatoka leaf spot pathogen (*Mycosphaerella* spp.) in banana indicated that the expression of polyphenol oxidase was maximum at 24th hour and minimum at 36th hour after inoculation. The protocol for embryo rescue has also been standardized and by this method germination of mature embryos of *Musa* spp. can be achieved within 15-20 days. An *Agrobacterium* mediated genetic transformation protocol has been standardized in banana using GUS gene, for transferring chitinase and Anti Microbial Protein (AMP) genes. Baseline information on compatibility and breeding behavior has been developed for 121 successful combinations which will be useful for future breeding programmes. To develop *Fusarium* wilt resistant varieties using fusaric acid, the optimal concentration of fusaric acid required for screening was standardized as 0.025 mM.

The screening of banana accessions against nematode indicated that cvs. Karthombiumtham and Calcutta-4 were found to be resistant and Nendran as highly susceptible cultivar. The semi-quantitative RT-PCR analysis of defense gene-chalcone synthase in these varieties revealed that the resistant plants had higher constitutive levels of transcripts as compared to susceptible plants and the expression of chalcone synthase gene was increased up to 6th day after nematode inoculation and declined from 7th DAI. The sequence of cDNA obtained through Selective Subtractive Hybridization analyses which was carried out in the *Mycosphaerella musicola* artificially inoculated banana vars. Manoranjitham (resitant to Sigatoka) and Robusta (susceptible) showed the presence of antimicrobial protein which would be useful for further studies.

Crop Production and Post-Harvest Technology

The Grand Nain banana grown with 3 suckers / hill at a spacing of 2x 3m (5000 plants / ha) with weekly fertigation of 75% recommended dose of fertilizers recorded 32% higher yield and also better quality of the fruits compared to conventional planting.

Fertilizer adjustment equations for Poovan and Karpuravalli bananas were developed by following the 'Soil Test Crop Response' and 'Targeted yield concept'. The fertilizer requirement of $N:P_2O_5:K_2O$ for producing one ton of Karpuravalli and one ton of Poovan were worked out as 13.6 : 1.7 : 16.2 kg and 14.4 : 1.74 : 26.7 kg respectively.

The exogenous application of ABA (100ppm) and ASA (0.1Mm) in water stressed banana plants var. Grand Nain, improved the physiological parameters indicating these hormones could be used to alleviate the negative effect of water stress in banana.

The field screening of banana cultivars under salt affected field (EC 1:2.5 = 3.34 and pH 8.1) resulted in the identification of three salt tolerant varieties viz**.,** Saba, Karpuravalli and Ney Poovan. When these varieties were grown under saline condition and treated with chemicals like ABA (100 ppm), Butylated Hydroxy Toluene (BHT), (100 ppm), and Acetyl salicylic acid (100 ìM), particularly BHT increased the photosynthetic pigments, Chlorophyll Stability Index (CSI), proline content, antioxidative enzymes and reduced the lipid peroxidation as compared to control. It was also found that the ABA treatment in the salt (sodium chloride) stressed banana plants var. Grand Nain alleviated the ill-effect of salt stress by increasing chlorophyll and carotenoid content significantly.

The studies on the biochemical mechanism of resistance of bananas to root lesion nematode *P. coffeae* revealed that the inoculation of the nematode, increased the total phenolics and proanthocyanidins content and also the activities of peroxidase and polyhenol oxidase significantly up to 7 days after inoculation particularly in resistant varieties like Anaikomban, and Yangambi Km5. A new isoform of PPO was also observed in *P. coffeae* inoculated roots of resistant plants compared to uninoculated control plant roots.

The critical temperature for storage of NeyPoovan fruits was found to be 13.5 °C. A recipe for banana flower based ready to make soup and a steeping solution for storage of banana stem for further use and bulk production technique of banana wine were standardized. Chemical retting followed by manual extraction yielded more fibre from pseudostem of Poovan.

Crop Protection

A survey conducted in different banana growing areas of Tamil Nadu indicated the presence of three different nematodes viz., burrowing nematode (*Radopholus similis*) spiral nematode (*Helicotylenchus multicinctus*) and root-knot nematode, (*Meloidogyne incognita*) and burrowing nematode was predominant. Screening of core collection of *Musa* germplasm (12 diploids-AB and 48 Triploids-AAB) against root-lesion nematode, *P. coffeae* under shade net condition revealed that diploids *viz*. Kunnan, Gragric sarpara, Narmine and triploids *viz*. Dasaman, Kottavazhai and Sakkar Chyana were resistant and triploids like Sirumalai, Garomoina, Malaivazhai and Pacha were tolerant to *P. coffeae.*

The soil application of VAM (*Glomus* spp.) along with *Trichoderma viride* and *Paecilomyces lilacinus* @ 10g each / plant resulted in significant reduction of nematode population with enhanced plant growth. The treatment of culture filtrate of two isolates of *Bacillus subtilis* **(**$BSNRCB_{107}$ and $BSNRCB_{35}$) at 100% conc. recorded 100% mortality of young juveniles of root-knot nematode in 24 hrs of exposure under *in vitro* condition. The same isolates when studied under *in vivo* condition in cv. Ney Poovan exhibited maximum plant growth and significant reduction in nematode populations as well as root-knot indices.

An isolate of *Verticillium lecanii* (NRCB VL-7) which caused 100 % mortality of banana aphid, *Pentalonia nigronervosa* under laboratory conditions was identified. The mass production and storage methods using wheat bran as substrate have been standardized. The field evaluation carried out against the aphid using this isolate (NRCB VL-7) recorded 80.9% aphid mortality, which is three fold higher than the commercial formulation.

Totally 13 different terpene components were identified in the volatiles collected from the corm and banana leaf sheath of cv. Nendran by GC / MS analyses. The evaluation of these compounds for corm weevil attraction showed that the component á-pinene recorded the highest attraction of 80% of the of corm (female) weevil. The treatment of banana corm weevil with Entomopathogenic nematode, *Heterorhabditi indica* @ 25 x 10^3 IJ's resulted in the maximum mortality of 93.3% under *in vitro* condition and the effect was comparable to the chemical Monocrotophos. Among different sources of stem traps, the traps from var. Kanthali of 40 to 60 cm size were found to be the best for the attraction of maximum number of corm weevils under field condition.

Fusarium wilt incidence was observed in cv. Cavendish and Poovan. The cross inoculation studies using Cavendish *Foc* isolate revealed that new *Fusarium* isolate caused disease in other varieties like Karpuravalli (ABB), Rasthali (AAB), Ney Poovan (AB) and Monthan (ABB). Besides, cross reaction among the race-1 and race-2 Fusarium wilt isolates was also observed. The endophytic actinomycetes strain 17Ra and *Klebsiella* spp. strain 17Rb isolated from Fusarium wilt resistant varieties showed more than 90% inhibition of Fusarium wilt pathogen. With regard to Sigatoka leaf spot pathogen (*Mycospharella* spp), endophytic isolates *Klebsiella* (6Mb), *Micrococci* (2M) and *Actinomycetes* (14 Mb) and epiphytic isolates *Bacillus* spp (1Eb) were found to be highly inhibitory. It was also found that all these effective endo and epiphytes were compatible with the fungicide Carbendazim and there is scope to use these antagonistic strains with fungicides for the effective management of Sigatoka diseases.

Application of 25% more than the recommended dose of fertilizer in cv. Poovan had almost neutralized the effect of yield reduction due to banana bract mosaic viral disease. Coat protein and rep gene of BBTV isolates collected from Karnataka, AP, Kerala, Bihar, Maharashtra and rep gene from Assam, Arunachal Pradesh isolates and cp gene for Andaman BBTV isolate were cloned and sequenced for diversity analysis. The sequence analyses partial BSV fragments covering RT/RNase-H region of 40 BSV isolates collected from different banana growing regions of Tamil Nadu revealed the existence of high variability among the isolates. Duplex PCR for all the four viruses CMV, BBrMV, BBTV and BSV has been standardized. A sensitive, cost effective, simple extraction protocol for template preparation has been developed to detect banana bunchy top virus by PCR.

Transfer of Technology

Rice chaffy grains formulation of entomopathogenic fungus, *Verticillium lecanii* (NRCB VL -7) was released for controlling banana aphid, *Pentalonia nigronervosa*. Similarly rice chaffy grain formulation of *Trichoderma viride* (NRCB -1) was also released in the name of Trichogold for controlling the Fusarium wilt pathogen of banana present in soil. In addition, two promising bio-control agents *viz*., *Paecilomyces lilacinus* and *Pseudomonas fluorescens* for the management of nematodes in banana were also released in the name of NRCB Nemacinus I and Nemacens II. Our centre has given training to farmers of Tamil Nadu, Kerala, Madhya Pradesh, Assam and Mizoram on improved production technologies including post harvest management and value addition in banana sponsored by NHB, Gurgoan. Our centre has participated in the exhibitions held in various seminars, trainings, field days, *kissan melas*, etc.

Linkages, Collaboration and HRD

A new project entitled 'Regeneration and safety duplication of priority *Musa* collection' funded by BIOVERSITY, France has initiated with budget of Rs. 27/- lakhs for a period of three years. A MoU was signed between NRC for Banana and UAS, Bengaluru for doing collaborative research programmes, student guidance, human resources, etc. Also, a MoU was signed with IPIRTI, Bangalore for the development of particle board using banana sheaths. A MoU was signed between NRC for Banana and Bharathidasan University, Tiruchirapalli in the field recognition of guides, doing research and guiding students. Under education and training, 35 graduates and post graduate students of various universities have been guided for research project work on various aspects of banana.

Revenue Generation

A sum of Rs.12/- lakhs was generated from virus testing of banana samples by various tissue culture companies and Rs. 5/- lakhs was generated through sale of farm produce.

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 (lTC), 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 1100 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. The collections include AA, AB, BB diploids, AAA, ABB, AAB triploids, AAAA, AAAB, AABB, ABBB, AAAh tetraploid collections and Fe'i bananas. 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. NRCB selection Udhayam, which belongs to Pisang Awak sub group, is a high yielder, tolerant to Sigatoka leaf spot disease and nematodes. A protocol with modified MS media without growth regulators for embryo culture has been standardized for Pisang Awak (ABB), Bluggoe (ABB), Pome (AAB), wild *Musa balbisiana, M. nagensium* and *M. ornata.* 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. Different cultivars of Cavendish sub-group were distinguished using duplex RAPD markers and Thella Chakerakeli (AAA) could be differentiated from other AAA clones using RAPD primers. 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

Application of 25% N as FYM + 50% N as neem cake + 25% N as inorganic fertilizer increased the yield by 20 per cent in Rasthali, Poovan, Robusta, Monthan and Karpuravalli cultivars. 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. Application of 15 kg rice husk ash or 5 kg poultry manure per plant resulted in an additional profit of Rs. 23,750 / ha and Rs. 34,250 / ha respectively in Poovan banana. 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 Nain 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. Photosynthetic activity was more in Rasthali at flowering stage than other commercial cultivars of banana. 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.

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

Application of 500 g neem cake per plant reduced the root lesion nematode. Application of *Trichoderma viride* effectively controlled the root knot and root-lesion nematodes. Mass production technique for *Paecilomyces lilacinus*, (an egg parasite of root-knot nematode) using banana petiole and pseudostem has been developed. Application of *T. viride* and *P. fluorescens* were found superior in controlling the nematodes and increased the plant growth parameters of Robusta. 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. A total of 13 different terpene volatiles compounds were detected from the corm and banana leaf sheath of cv. Nendran.

141 nit mutants of *Foc* were developed from 100 *Foc* isolates and 9 different VCG have been identified. 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. Different isolates of *Colletotrichum musae* have been characterized morphologically and based on amplicon size 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* (10^9 / ml) (or) *Pseudomonas* spp (10^6 / ml) (or) *Bacillus* spp. (10^6 / ml) (or) Propiconazole (0.1%) spray was also effective in controlling the disease anthracnose.

All the banana viruses could be detected from their vectors by either PCR or RT - PCR. 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. A quick PCR based technique has been developed to detect the EPRV's present in the host genome.

Complete genome of BSV infecting Poovan has been cloned and sequenced which revealed that the virus is closely related to BSOLV, but there was a deletion of 450 bp in the genome. Promoter sequences from BBTV were cloned and sequenced. Duplex PCR for all the four viruses CMV, BBrMV, BBTV and BSV has been 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. Virus indexing trainings were imparted to technical personnel of many tissue culture companies, scientists, assistant professors and students involved in banana research. 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.

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 400 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

Rs.12/- lakhs and Rs. 5/- lakhs were generated from virus indexing and sale of farm produces respectively during this reporting period.

BUDGET DETAILS (REVISED ESTIMATE) FOR THE YEAR 2008-'09

Sl. No.	Head of Account	PLAN Amount (Rs. in lakhs)	NON-PLAN Amount (Rs. in lakhs)
1.	Esst. Charges	0	178.00
2.	OTA	0	0.10
3.	Travelling Allowances	5.00	2.50
4.	Other Charges	66.00	40.00
5.	Human Resource Development	3.00	0
6.	Equipments	75.00	0
7.	Works	75.00	9.0
8.	Furniture & Fixtures	0.00	0
9.	Library books	2.00	0
10.	Vechiles	0.00	12.0
11.	Information Technology	0.00	0
	TOTAL	**226.00**	**241.60**

5 Research Achievements

5.1 CROP IMPROVEMENT

5.1.1 Genetic Resource Management

Morphotaxonomic characterization

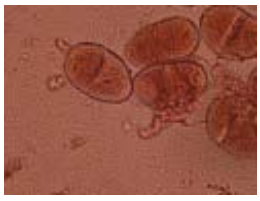
Eight more exotic collections were morpho-taxonomically characterized and documented. Minimum descriptor with 13 photographs at various stages of development has been assembled for 31 accessions.

Musa DNA bank

Developed 'DNA Bank for Musa Germplasm' initially with 225 accessions and is in progress, to complete all 340 accessions in the core collections.

Pollen studies

Comparative study were undertaken for pollen morphology, pollen stainability (fertility) and pollen germinability for 78 numbers of diploid, triploid and tetraploid clones comprising of six different genomic groups (AA, AB, AAA, AAB, ABB and ABBB). The pollen grains of banana are circular with clear demarcation of different wall layers. Morphologically sterile pollen grains were found in abundance in all varieties of banana except wild species of *M. acuminata* and *M. balbisiana*. In meiotic studies, diad (Kothia) (ABB) and tetrad (Chakkia, ABB) stages were only observed (Fig. 1). Pollen germination was recorded from 10th node onwards. The germinability increased from 10th to 30th node and then slowly declined with the age of the bud. However, the highest tube length was observed at the 20th node (Cherapadathi, AAB). In general, diploids recorded the maximum germination percentage followed by tetraploid and triploid. Eventhough more than 50% fertility was observed in triploid pollen grains, the germination percentage was very low (>10%) (Table 1).



Kothia (ABB) - Diad stage

Chakkia (ABB) – Tetrad stage

Fig. 1: Stages of pollen development

Cryo preservation on genetic fidelity of banana

Growth and yield parameters were recorded for the tissue culture control, cryocontrol, normal suckers and cryomaterials of cv. Kallu Monthan plant crop. The statistical analysis revealed that nonsignificant differences for major growth and yield parameters and confirmed that cryopreservation did not affect the genetic fidelity.

The growth and yield parameters of tissue culture control, cryocontrol, normal suckers and cryomaterials of cv. Sommarani Monthan ratoon crop were recorded. Growth and yield parameters did not differ significantly even in ratoon crop except for delayed crop duration and plant height (Table 2).

Genetic fidelity using RAPD polymorphism was assessed in the cryopreserved Sommarani Monthan using a set of sixty random primers. The study included tissue culture control, cryocontrol, normal suckers and its green mutant as references. Among the 60 primers tested, 57 primers (95%) amplified products, resulting in discrete, repeatable amplicons and were considered for the genetic analysis.

From the 57 primers which produced discrete, repeatable amplicons, a total 499 bands were identified with a mean of 8.75 bands per primer.

Table 1. Mean of fertility and germination percentage across banana genome

Sl. No.	Genome	Pollen Out put		Stainability percentage	Germinability %
		Per Anther	Per Flower		
1.	AA	14454	72268	62.0	31.0
2.	BB	46260	231300	89.4	60.6
3.	AB	6473	32336	49.4	26.5
4.	AAA	20567	102833	58.0	9.8
5.	AAB	4930	23833	56.8	9.6
6.	ABB	4707	23534	36.6	9.2
7.	ABBB	22450	112250	58.4	20.4

Table 2. Evaluation of cryopreserved germplasm cv. Sommarani Monthan (ratoon crop) for growth and yield

Parameters	T_1	T_2	T_3	T_4	General Mean	Sig	CD 1 %	CV %
Pseudostem Height (cm)	366.60 [b]	361.70 [b]	348.90 [a]	338.50	353.93	**	9.25	2.15
Pseudostem Girth (cm)	63.60	63.50	64.10	63.90	63.78	NS	1.75	2.26
No. of leaves at shooting	14.00	14.00	14.50	13.50	14.00	NS	0.79	4.61
Petiole length (cm)	61.80 [a]	62.80 [a]	63.90 [b]	60.20	62.18	**	1.72	2.27
Leaf Area ($X10^4$)	14.48 [b]	13.12 [a]	13.64 [a]	12.154	13.35	**	1.157	7.12
Days for shooting	276.60	282.40	268.70	281.60	277.33	NS	5.59	1.63
Days for bunch maturation	99.70	102.70	100.50	99.40	100.58	NS	6.25	5.11
Duration (Days)	376.40	385.10	369.20	381.00	377.93	NS	6.99	1.51
Bunch weight (Kg)	16.20	17.10	16.95	16.95	16.80	NS	0.64	3.17
No. of hands per bunch	8.30	8.50	8.90	8.70	8.60	NS	0.75	7.15
No. of fruits per hand	14.60	13.40	13.60	13.40	13.75	NS	0.79	4.82
Total no. of fruits	125.60	118.00	125.70	120.90	122.55	NS	11.93	8.12

T_1 - Sucker control T_2 - Tissue cultured control T_3 - Cryo control T_4 - Cryo treated

Five bands specific for ashyness was observed in OPB 1 (745, 870 and 2098 bp) and OPV 20 (837 and 1415 bp). OPD 10 produced a band of size (2392 bp), which was present exclusively in the green mutant (Fig. 2).

Fig. 2: RAPD primers showing polymorphism for ashyness and green mutant

The dendrogram consisted of two main clusters showing 90% similarities (Fig. 3). The sucker derived plantlets were different from the rest of the test materials and the green mutant with 10% dissimilarities. *Musa* germplasm was genetically stable and neither cryopreservation nor regeneration after a time lag ditnot cause genetic changes.

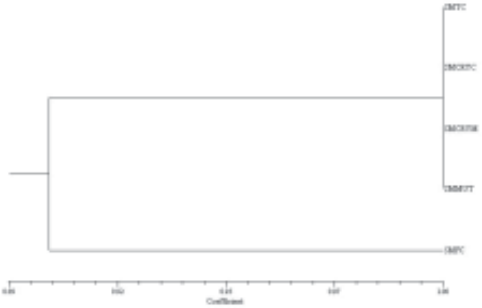


Fig. 3: Dendrogram showing the stability of the cryopreserved plantlets with other planting materials of cv. Sommarani Monthan

Evaluation of ECS derived plants

Growth and yield parameters of ECS derived Rasthali plants were compared with normal suckers and tissue culture plants for the plant crop. Results indicated that ECS derived plants were on par with suckers and tissue cultured plants for most of the yield traits. ECS derived plants exhibited growth parameters on par with tissue culture plants for plant height, stem girth, number of leaves and total crop duration (Table 3).

ECS derived Nendran plants also exhibited similar yield performances on par with normal suckers and tissue culture plants. Highly significant results were obtained for stem girth, number of leaves at shooting (Table 4).

Genetic fidelity testing of ECS derived cv. Rasthali

The genetic fidelity among plants derived from tissue culture and cell lines were compared with sucker raised plants using RAPD marker system in cv. Rasthali. Low polymorphism (13.6%) indicated that not much variation among the Rasthali plants among three different sources (Fig. 4a & b). Field and tissue culture derived plantlets were 90% similar. 13% dissimilarity between ECS derived and plants derived from normal sucker and tissue culture. But this genotypic variation is not expressed phenotypically under field conditions because of the maintenance of ECS under *in vitro* conditions for a long duration of 2-3 years

RAPD polymorphism for Red banana and their green mutants was studied using a set of 12 random primers of OPB series and were genetically different with 15% dissimilarities (Fig. 5a & b).

Table 3. Evaluation of ECS derived plants of cv. Rasthali for growth and yield parameters

Parameters	T_1	T_2	T_3	General Mean	Sig./ N.Sig.	CD 1 %	CD 5 %
Pseudostem Height (cm)	291.4[c]	271[a]	288.5[b]	283.63	**	6.48	4.80
Pseudostem Girth (cm)	72.3[b]	72.7[b]	68.5[a]	71.17	**	2.55	1.89
No. of leaves at shooting	14.4[a]	14.5[a]	15.6[b]	14.67	*	0.75	0.55
Petiole length (cm)	53.7	54.1	54.4	54.06	NS	1.88	1.39
Leaf Area (X 10^4)	12.33	12.70	13.12	12.71	NS	0.99	0.73
Days taken for shooting	314	313.7	316.6	314.77	NS	7.31	5.41
Days taken for bunch maturation	128.5	128.2	130.2	128.97	NS	4.24	3.14
Duration (days)	432.4[b]	413.9[a]	441.6[b]	434.63	*	24.22	17.56
Bunch weight (in kg)	13.18	12.33	11.98	12.39	NS	0.83	0.61
No. of hands per bunch	7.3	7.4	7.7	7.47	NS	0.61	0.45
No. of fruits per hand	12.6	13.5	12.2	12.77	NS	0.84	0.62
Total no. of fruits	96.6	104.2	102.6	101.13	NS	7.72	5.72

T1 : T.C Control T2 : Sucker T3: ECS

Table 4. Evaluation of ECS derived plants of cv. Nendran for growth and yield parameters

Parameters	T_1	T_2	T_3	General Mean	Sig./ N.Sig.	CD@ 1%	CD@ 5%	CV %
Pseudostem Height (cm)	281.89[a]	287.7[b]	289.3[b]	286.67	*	6.78	5.02	1.91
Pseudostem Girth (cm)	56.2[a]	56.2[a]	60.8[b]	57.73	**	2.91	2.15	4.07
Petiole length (cm)	42.3	42.4	43.9	42.87	NS	2.30	1.71	4.34
No. of lvs. at shooting	12.7[a]	13.8[b]	13.8[b]	13.43	**	0.73	0.54	4.37
Leaf Area (X10^4)	10.0[a]	12.5[b]	12.8[b]	11.8	**	1.08	0.83	7.40
Days for shooting	254.2[a]	255.6[a]	271.5[b]	260.43	*	5.47	4.05	1.70
Days for bunch maturation	99.7	102	100.4	100.70	NS	6.66	4.93	5.34
Duration (Days)	353.9	357.6	371.9	361.13	NS	9.80	7.26	2.19
Bunch weight (in Kg)	11.8	11.95	11.6	11.78	NS	0.82	0.61	5.60
No. of hands per bunch	6.3	6.4	6.4	6.37	NS	0.63	0.46	7.94
No. of fruits per hand	13.4	13.4	11.7	12.83	NS	0.92	0.68	5.79
Total no. of fruits	87.8[b]	89.9[b]	78.4[a]	85.23	*	11.28	8.36	10.68

T1 : T.C. Control T2 : Sucker T3 : ECS

Estimation of genetic variability among Rhodochlamys members

The diversity and phylogeny among the members of the section Rhodochlamys, and its genetic relationship with section Eumusa were also analysed using RAPD marker system.

1. The average polymorphism was 98.66%. This indicated the existence of substantial variations among the test accessions at genetic level.
2. Test accessions were grouped into two clusters sharing 60% similarities.
3. Cluster-1 had *Musa acuminata* ssp. *burmaniccoides* which was grouped with *M. laterita.*
4. Attikol also grouped with Rhodochlamys members which is ambiguous and needs confirmation.
5. All accessions originated from North Eastern India had grouped together suggesting their co-evolution.

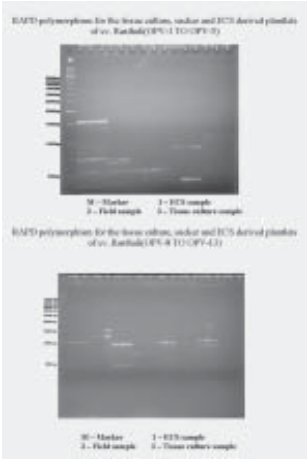


Fig. 4a: RAPD polymorphism for tissue culture, suckers and ECS derived plants of cv. Rasthali

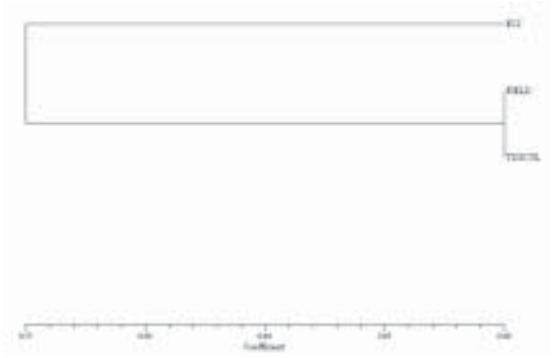
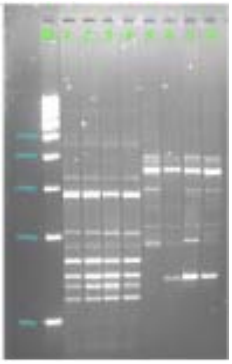


Fig. 4b: Dendrogram showing genetic similarities among TC, Suckers and ECS derived plants of cv. Rasthali



Lanes 1 – 4 : Primer OPB 19 Lanes 5 – 8 : Primer OPB 20
Lanes 1,2,5 & 6 : Green Mutants Lanes 3,4,7 & 8 : Red Banana

Fig. 5a: RAPD polymorphism between Red banana and their green mutants

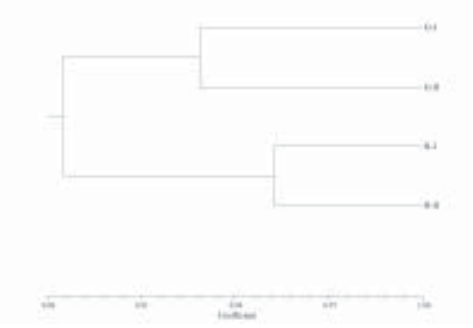


Fig. 5b: Dendrogram showing the genetic similarity between Red banana and their green mutants

Robustness of core collection using IRAP markers

171 accessions were characterized using six pairs of IRAP markers. It was able to cluster the accessions according to their genomic groups and in some cases upto subgroup levels. The robustness of the core collection was proved and the diversity and phylogenetic relationships in *Musa* could be comfortably analysed using IRAP markers. (Fig. 6a). Cluster II included all *acuminata* diploids, triploids and bispecific clones which shared more than 64% similarities. B-rich triploids and tetraploids (ABB and ABBB) have grouped in one cluster with more than 76% similarities indicating same genomic composition. *Acuminata* diploid and triploids have grouped with more than 90% similarities which indicated their genetic closeness. All the AAB cultivars have clustered in one and with aforesaid *acuminata* members indicating their genetic relatedness than ABB members. The results obtained from IRAP markers suggested that all the tested 57 accessions proved their uniqueness.

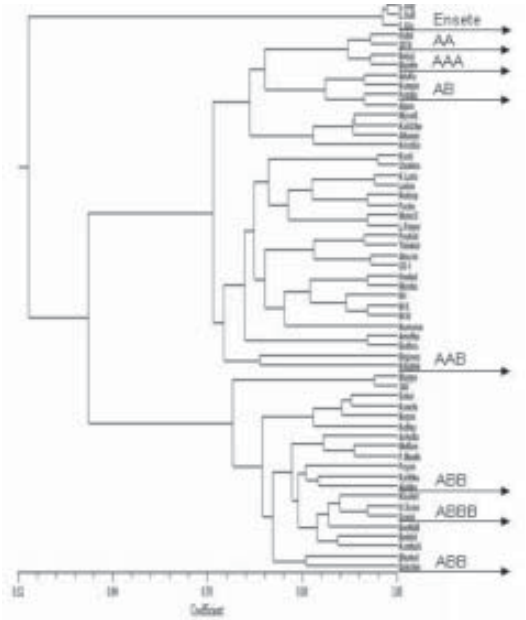


Fig. 6a: Dendrogram showing the genetic relationship among the core collection accessions

The sections Eumusa and Rhodochlamys have grouped in to two major clusters with 30% dissimilarities (Fig. 6b). All the AAB, AB and few accessions belonging to ABB have grouped in Cluster I. Except three AAB members *viz.*, CO 1, Kottavazhai and Padathi, all other AAB have grouped in to one subcluster. Nineteen accessions belonging to different genomic groups (AB, ABB and AAB) have grouped in one cluster indicating that one of the genome either "A" or "B" might have been derived from one common ancestor. Cluster II comprised all the ABB types and Rhodochlamys species and this clustering pattern is not clear and

needs further reconfirmation through advanced markers like AFLP, SSR, etc.

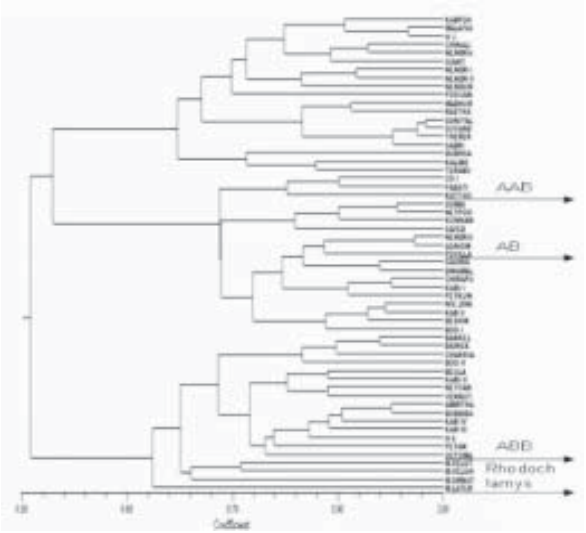


Fig. 6b: Dendrogram showing the genetic relationship among the core collection accessions

The IRAP markers clearly delineated the diploids from triploids (Fig. 6c). Among the diploids, it clearly demarcated AA, BB and the bispecific AB clones. Triploids were grouped in to two different clusters i.e., AAA and AAB in one cluster and ABB in another cluster. Genome AAB could be differentiated up to their subgroup levels *viz*., Silk, Pome and Mysore. Similarly, genome ABB could also be differentiated upto their subgroup levels namely Pisang Awak, Monthan, Bluggoe and Bontha. IRAP could also identify the unique ABB accessions like Rigatchi.

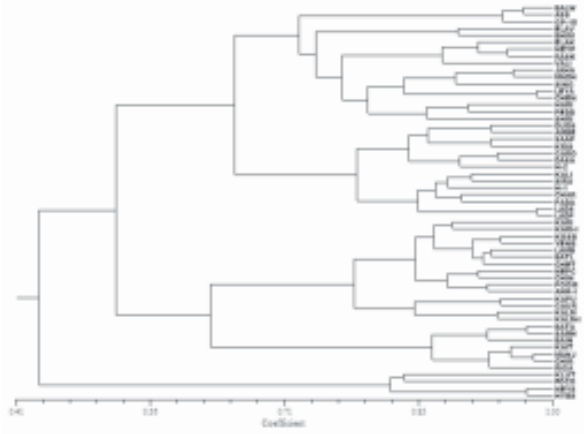


Fig. 6c: Dendrogram showing the genetic relationship among the core collection accessions

Screening for nutritionally rich bananas

The nutritional content of different genomic groups namely diploid (AA, BB, AB), triploid (ABB, AAA, AAB) and tetraploid were estimated. In general, BB genome recorded highest nutritive value *viz*., phosphorous (0.186%), potassium (2.89%), TSS (21.57 °brix) and less amount of sodium (0.34%) and acidity (0.17%) whereas ABB genome was rich in calcium (0.915%) and magnesium (2.363%). None of the tetraploid accessions scored highest nutritive value.

Macropropagation – a novel farmers' friendly method

Standardized a prtocol for the large scale multiplication of plantlets from corms. This technique is cost effective and can be multiplied by the farmers. Cross cuts / incisions were made on the growing meristem of the corm so as to stimulate the production of lateral buds. It produced 20-25 uniform shoots per corm in a short span of 60-65 days and it is an alternate method suitable for small and marginal farmers need (Fig. 7)

Decorticated corm | Primary decortication

Well developed shoots | Multiple shoot production

Fig. 7: Various stages of macropropagation

5.1.2 Improvement of banana through non-conventioanl approaches

Studies to improve the quality and longevity of ECS

ECS was initiated with few embryogenic clumps in 3-5 ml of liquid medium and gradual scaling up to 15 ml in 90 days to increase the efficiency of homogenous suspension. Sixty days old embryo mixture were regenerated on solid (control) and liquid germination media with various duration of 7, 15, 30 and 45 days. Liquid medium was better to produce uniformly mature embryos from 15-30 days.

ECS once developed has the capacity to multiply and regenerate beyond 18-24 months. The regeneration and germination capacity decreased with age of the suspension and it drastically reduced after 12 months (Table 5).

Table 5: Establishment and regeneration capacity of ECS

Sl. No.	Cultivars	No. of Buds Initiated	Callus Obtained	Ideal Callus	Suspension Initiated
1.	Robusta	135	Yes	Yes	Yes
2.	Grain Naine	154	Yes	Yes	Yes
3.	Rasthali	Many	Yes	Yes	Yes
4.	Nendran	Many	Yes	Yes	Yes
5.	Kallu Monthan	78	Yes	No	No
6.	Udhayam	Many	-	-	-

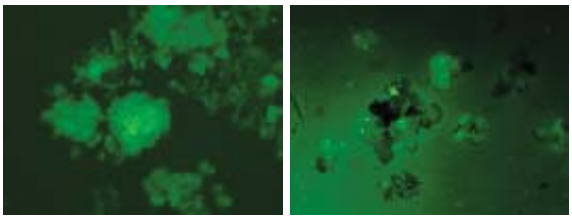
Sl. No.	Treatment(ECS as explant)	No. of replicates	Response in regeneration and germination capacity	
			Regeneration capacity	Germination capacity
1.	6 months old	4	+++	+++
2.	18 months old	4	++	+

\+ - Low regeneration and germination capacity
++ - Moderate regeneration and germination capacity
+++ - High regeneration and germination capacity

In vitro screening of banana for salt stress

In vitro screening for salt stress was carried out on cv. Rasthali using two different explants, *viz.*, shoot meristem and embryogenic cell lines. Stress was induced using different NaCl concentration. Plant growth was affected both qualitatively and quantitatively at all concentrations and found 0.7% and above was lethal for shoot tips.

In case of ECS, both viability and settled cell volume (SCV) decreased with increase in salt concentration from 0.1% to 1.0%. First proembryo was visible in control after 50 days whereas it took 65 days, 82 days and 98 days respectively for other cultures raised in salt concentration 0.1%, 0.25% and 1.0% (Fig. 8).



Control 1.0% NaCl

Fig. 8: Effect of salt stress on ECS of cv. Rasthali

cDNA and enzyme expression studies

The cDNA was synthesized from the total RNA isolated from resistant Manoranjitham and susceptible Robusta cultivars of genome AAA using chalcone syhthase primer to analyze the enzyme expression during plant defence reactions.

The expression of Peroxidase is very high at 18th hr after inoculation in both resistant and susceptible cultivars (Fig.9). Similarly the expression of Poly Phenol Oxidase is increasing in trend from 18 – 24 hrs after inoculation of *Mycosphaerella* spore suspension in both susceptible and resistant cultivars. This confirms that the optimum period for studying the host pathogen interaction, the sample should be collected at 18 – 24 hr after infection.

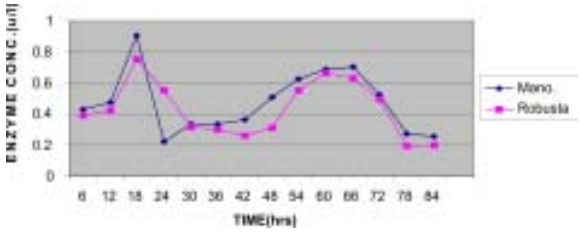


Fig. 9: Expression of peroxidase at different time interval

Agrobacterium mediated transformation

Agrobacterium mediated genetic transformation protocol has been standardized in banana using GUS gene, for transferring Chitinase and Anti Microbial Protein (AMP) genes.

Chitinase gene

The Embryogenic Cell Suspension (ECS) which is derived from immature male flower bud of Rasthali were used as target tisues and *Agrobacterium tumefaciens* strain LBA4404 harboring the binary vector pCAMBAR-chi11 was used for transformation. Transformation was done by infecting ECS with *Agrobacterium* cells which harbored chitinase gene (*Chi*11). The transformed plants were confirmed through PCR southern hybridization. Genomic DNA was isolated from both transformed and non transformed plants and PCR was performed using chitinase primers. The PCR product amplified from plasmid was used as probe for southern hybridization. Autoradiogram clearly showed that 700bp in putatively transformed plants but not in untransformed plants. Genomic southern was performed by digesting the genomic

DNA with *Cla* I, the digested product was hybridized with chitinase and it confirmed the integration of chitinase gene (Fig. 10).

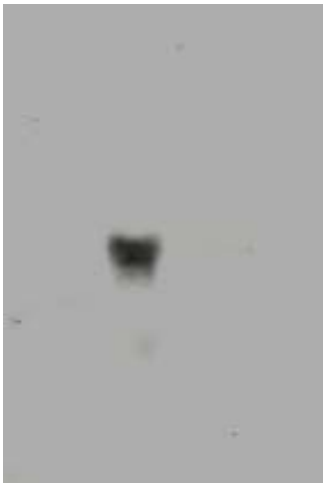


Fig. 10: Genomic southern analysis

Anti Microbial Protein (AMP) gene

The construct of AMP gene which was obtained from IIHR, Bangalore was digested with *Pst* I to release approximately 1kb fragment which has confirmed the presence of AMP gene (Fig. 11). The confirmed plasmid was mobilized into *Agrobacterium tumefacience* LBA4404.

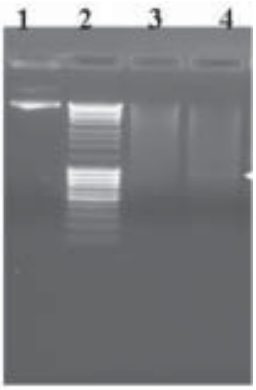


Fig. 11 : Confirmation of AMP gene

1. Undigested DNA ;
2. Marker ;
3. Digested with Kpn I (Enzyme was contaminated) and
4. Digested with Pst I (1kb fragment is released confirming the presence of the gene)

5.1.3 Improvement through Conventional breeding

Different crops combinations were made involving AA diploids, diploids with AAB and ABB types and produced 1,50,500 hybrid seeds from which 59 hybrid progenies were obtained and planted in the field for evaluation.

Ten hybrid progenies with Karpuravalli genetic background were planted in field and are being evaluated. Among cooking bananas, approximately 22,000 seeds of various combinations were produced and only six combinations germinated successfully especially with Saba, Kothia and Chakia. Presently, twelve Saba based hybrid progenies were planted.

A total of 40 progenies were evaluated for their agronomic traits and assigned their genomic status through 15-character score card system. 23 hybrid progenies have been evaluated for agronomic, yield traits and for their reaction to Sigatoka. Second set of 26 F1 progenies are being evaluated for agronomic and yield traits

Compilation of compatibility and breeding behavior of *Musa* parents used in the improvement programme has been completed for 68 parents with 429 cross combinations.

A separate F1 progenies field, where a total of 580 F1 segregating progenies of different combinations of BB x AA and BB x BB were planted and are being maintainedfor recording phenotypic data for various traits.

Baseline information on compatibility and breeding behavior

A total of 121 successful combinations with details on compatibility seed set , seed viability, germination success and seedling establishment has been compiled as base line information for future breeding programmes.

Pisang Jajee

Crossed with seven diploids with good set seeds. All the combinations produced higher numbers of seeds (50-60 per fruit). Pisang Jajee x Lairawk produced the maximum number of seeds (480) with 95% good seeds. All cross combination seeds could be germinated within 30 days and minimum number (17 days) was recorded for Pisang Jajee x Lairawk.

Sanna Chenkadali

Among ten crosses tried, only seven combinations set seeds. Maximum seed set was recorded in Sanna Chenkadali x Lairawk (11-200 / bunch) and minimum in Sanna Chenkadali x cv. Rose (2-3 seed per fruit). Progenies of Sanna Chenkadali x Lairawk combination showed better field establishment.

Germination studies on *Musa* hybrids

Basic work on embryo rescue is being initiated to improve the progeny output and distant crosses by standardizing the protocols using wild species. *M. acuminata* ssp. *burmannicoides* and Pisang Jajee. Embryos at various stages of maturity, 70%, 80% and 90% were initiated and factors affecting germination are being studied.

Embryo rescue studies

Embryo rescue studies was initiated with different concentrations of MS medium in 4 wild species of banana, *viz*., *M. acuminata* (AA), *M. ac. ssp. burmannicoides*, (AA), *M. ac. ssp. burmannica* (AA), and Pisang Jajee (AA) at different maturity (70%, 80%, 90%) level. It was observed that, the cultutred embryos (with half strength of MS) of *M. acuminata* (AA) (wild) has germinated at 70 % maturity level (Fig. 12).

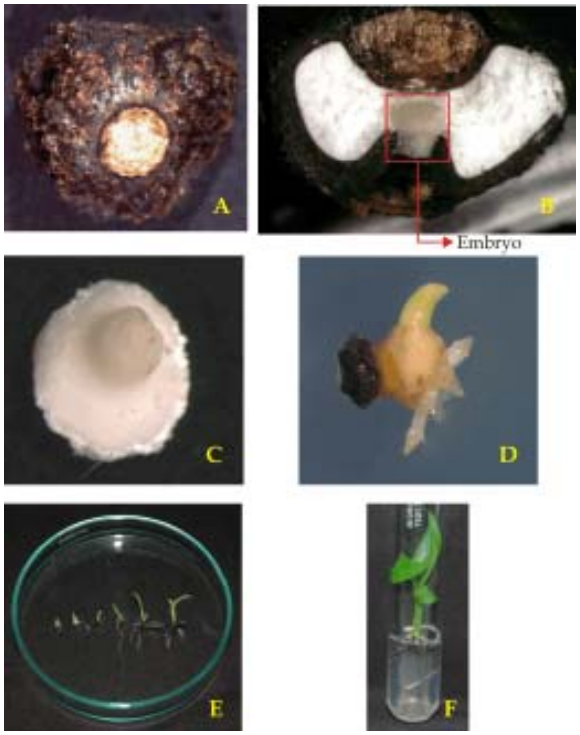


Fig. 12: Stages of embryo rescue (A). Mature seed; (B). Embryo embedded in endosperm; (C). Excised embryo; (D). Chlorophyllous plumule after 20 days; (E). Different stages of plantlets development and (F). Ready to root plantlet after 40 days

5.1.4 Improvement of Rasthali through induced mutagenesis

LD_{50} studies in Rasthali shoot meristems

The shoot meristems of cv. Rasthali were treated with two chemical mutagens namely EMS and NaN_3 for 2, 3, 4 and 5 hours. The treatment was given in an incubator shaker maintained at 28 ºC with continuous shaking 110 rpm. EMS was tried at four different concentrations namely 0.5, 1.0, 1.5 and 2% and NaN3 was tried at three different concentrations namely 0.02, 0.03, and 0.04%. Treated shoot meristems were inoculated in MS medium containing 4.0 mgl^{-1} of BAP and the data on Fresh Weight Gain (FWG %) at the time of first subculture and number of buds produced were recorded. LD_{50} was determined based on 50 % FWG over control.

The LD_{50} is fixed as 2% for 3 hours (Table 6). The results clearly indicated that 50 % FWG could be achieved at 0.02% sodium azide for 5 hours, 0.035% for 4 hours, 0.0425% for 3 hours and 0.045% for 2 hours. It is further inferred from the graph that the damage due to the exposure of shoot meristems to Sodium azide for 2 hours was slower in comparison to 5 hours incubation. Hence the lethal dose for sodium azide is fixed as 0.02 % sodium azide for 5 hours. There was no significant variation among the various incubation periods on the days taken for greening of shoot meristems. Days taken for greening of shoot meristems was delayed as the treatmental duration of sodium azide increased. Number of buds produced per explant decreased as the sodium azide concentration and the treatmental duration increased (Fig. 13).

Table 6 . Effect of EMS on Fresh Weight Gain (FWG) of shoot meristems

TREAT MENT	EMS CONCENTRATION 0.5% Initial	0.5% Final	0.5% Weight Gain	1.0% Initial	1.0% Final	1.0% Weight Gain	1.5% Initial	1.5% Final	1.5% Weight Gain	2.0% Initial	2.0% Final	2.0% Weight Gain
C	237.70	241.20	3.50g (100)	233.02	236.74	3.72g (100)	238.41	241.31	2.90g (100)	236.92	241.55	4.63g (100)
T1- 2 hrs	241.90	244.95	3.05g (87.14)	231.05	233.95	2.90g (77.95)	235.90	238.65	2.75g (94.82)	229.17	232.65	3.84g (82.94)
T2- 3 hrs	229.17	231.38	2.63g (75.14)	236.62	239.36	2.74g (73.65)	234.80	237.06	2.26g (77.92)	228.54	230.90	2.36g (50.98)
T3- 4 hrs	235.31	237.61	2.30g (65.71)	228.44	230.79	2.35g (63.17)	267.97	269.86	1.89g (65.17)	231.62	232.30	0.68g (14.69)
T4- 5 hrs	235.16	237.13	1.97g (56.28)	235.25	237.14	1.89g (50.80)	270.23	271.02	0.79g (27.24)	247.60	247.89	0.29g (6.26)
SEd			0.0359			0.0316			0.0562			0.0837
CD(0.05)			0.0765			0.0674			0.1199			0.1783

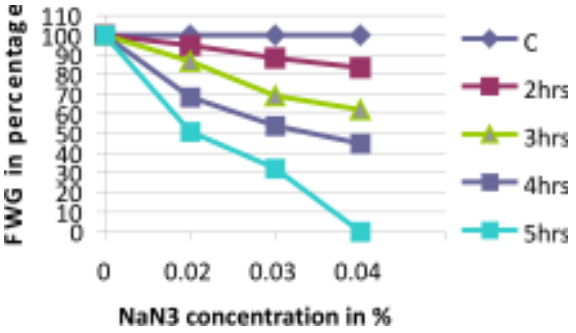


Fig. 13: Effect of sodium azide and treatmental duration on the FWG% of shoot meristems

Proliferating buds

The proliferating buds obtained after second subculture were treated with 0.2, 0.4, 0.6, 0.8 and 1.0 % for ½, 1, 1 ½ and 2 hours in an Incubator shaker at 110 rpm (which is being maintained at 28 ºC). Treated proliferating buds were inoculated in MS medium containing 3.0 mgl^{-1} of BAP and the data on fresh weight gain (FWG%) and number of buds produced were recorded. LD_{50} was determined based on 50% FWG over control. The results indicated that the LD_{50} is fixed as 0.6% for 1 / 2 hours (Table 7).

Fusarium wilt resistance using Fusaric acid

EMS treated shoot buds of Rasthali were inoculated in MS medium containing various concentrations of fusaric acid ranging from 0.5 to 2 mM. But they could not sustain the incorporation of fusaric acid. Hence, their concentration was narrowed down from 0.025 to 0.1mM. Results indicated that 0.025 mM is the optimal dose for screening of shoot meristems for fusarium wilt resistance.

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

Screening of banana germplasm against *P. coffeae.*

Based on nematode root lesion index, nematode population in root, number of healthy as well as infected roots revealed that Karthombiumtham and Calcutta 4 were found to be resistant cultivars and Nendran as highly susceptible cultivar.

Chalcone synthase gene up-regulation studies

Semi-quantitative RT-PCR analysis of chalcone synthase gene (defense gene), which is the first enzyme in the pathway branch for flavonoid biosynthesis, on nematode (*Pratylenchus coffeae)* infected samples of Karthombiumtham (resistance) and Nendran (susceptible) revealed that nematode resistant plants have higher constitutive levels of

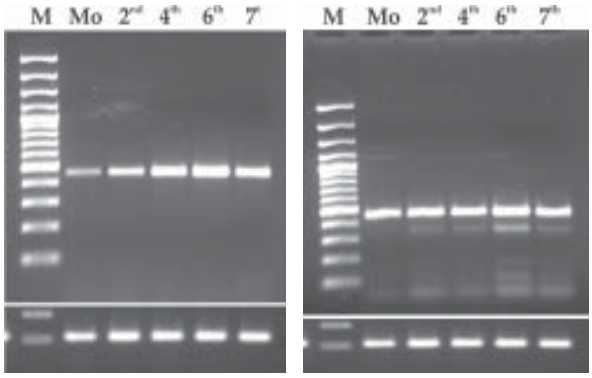


Fig. 14: Semi quantitative RT PCR analysis of Chalcone synthase transcript in A) Nendran and B) Karthombiumtham

Table 7. Effect of EMS on Fresh Weight Gain (FWG) of proliferating buds

TREATMENT	EMS CONCENTRATION 0.2% Initial	0.2% Final	0.2% Weight Gain	0.3% Initial	0.3% Final	0.3% Weight Gain	0.4% Initial	0.4% Final	0.4% Weight Gain	0.6% Initial	0.6% Final	0.6% Weight Gain
C	230.73	233.73	3.00g (100)	229.84	231.84	2.00g (100)	226.32	228.53	2.21g (100.00)	241.08	243.33	2.25g (100)
T1- 2 hrs	237.84	240.89	2.69g (89.66)	267.43	270.33	1.24g (62.00)	245.95	248.70	1.70g (76.93)	228.71	232.55	1.10g (48.88)
T2- 3 hrs	237.26	239.56	2.30g (76.66)	227.43	228.39	0.96g (48.00)	237.30	238.45	1.15g (52.04)	240.43	241.33	0.90g (40.00)
T3- 4 hrs	229.54	231.04	1.50g (50.00)	235.07	235.82	0.75g (37.5)	226.23	227.16	0.93g (42.08)	237.30	237.95	0.65g (28.89)
T4- 5 hrs	230.15	230.90	1.97g (56.28)	246.59	247.00	0.41g (20.5)	239.44	239.95	0.51g (23.08)	226.72	227.02	0.30g (13.33)
SEd			0.0359			0.0579			0.0205			0.0304
CD(0.05)			0.0765			0.1233			0.0437			0.0649

transcripts compared to susceptible plants and the expression of chalcone synthase gene is increasing up to 6th day after nematode inoculation and declining from 7th DAI (Fig. 14). This study revealed that for identifying and isolating differentially expressed genes due to nematode infestation, subtractive library of the interaction of *Musa* with *P. coffeae* should be created by subtracting the cDNA of un-inoculated root samples from cDNA of 6th DAI of nematode in Karthombiumtham.

Resistance Gene Analogue (RGAs) studies

Identification of suitable degenerate primers

Genomic DNA of Karthombiumtham and Nendran were used as template for amplifying the RGAs with two primer combinations namely P6F, P6R as well as P6F & As3R. Out of two primer combinations, combination I (P6F & P6R) amplified at the expected size of ~500bp only in Karthombiumtham, whereas primer combination II did not give expected band size both in cultivars (Fig. 15).

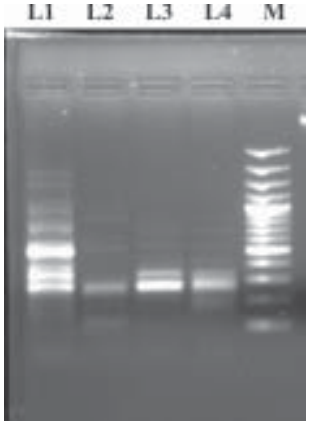


Fig. 15: Identification of suitable degenerate primers for isolation of RGAs from banana.
L1 and L3 Karthombiumtham
L2 and L4 Nendran
L1 and L2 P6 F & R primers
L3 and L4 P6 F and As3 R primer

PCR-RFLP of NBS-LRR region

The 500bp fragment which was obtained by using P6F and P6R primers, was gel purified and used for further analysis. To differentiate individual clones, the PCR product of these clones were digested with *Hae* III, *Hinf* I (Fig. 16) and *Taq* I and the plasmid were digested with *Rsa* I restriction endonucleases. Clones showing different restriction patterns of insert fragments were identified and characterized further by sequencing and sequence analysis. The sequence analysis revealed that the all the three RGAs showed significant homology to the non-TIR-type sequences of R genes.

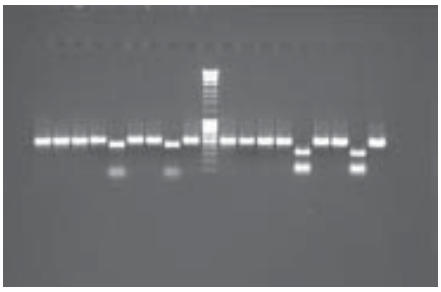


Fig. 16: Identification of differential clones by digesting the PCR product with H*ae* III and H*inf* I

5.2 CROP PRODUCTION

5.2.1 Standardization of nutritional requirements of banana under high density planting

In the plant crop, the data on flowering as influenced by planting density and different levels of fertilizers revealed that the time interval between planting to bunch emergence (shooting) varied significantly among the treatments and the plants under control (T21) took significantly lesser days for shooting (268.4) as against the longest days recorded for flowering in T10 (342.3 days) and T20 (341.3 days) (Fig. 17). The plants at 2X3m spacing and 75% RDF fertigation (T2-S1P2F2) took significantly lesser time (96.1 days) for maturity followed by 2X3m spacing and 100% RDF fertigation (T3-S1P2F3) (Fig. 18).

Among all the treatments, control single plant at 2X2m spacing with 100% RDF fertigation recorded the lowest total crop duration of 370.9 days. While three plants per hill at 1.8X3.6m spacing with 150% RDF fertigation recorded the longest total duration of 445.2 days.

Similarly, the highest bunch weight of 18.5 kg / plant was recorded in the control (T21) and was on par with T2- S1P2F2 (15.5 kg) and T15- S2P2F5 (15.3 kg), while the lowest bunch weight of 10.8 kg was recorded in three plants per pit planted at 2X3m spacing and applied with 50% RDF fertigation (Fig. 19). Data on the total yield revealed that, the yield was the highest in T7-S1P3F2 (62.5t / ha) followed by T8-S1P3S3 (61.5t / ha) while the lowest yield (42.96t / ha) was recorded in T1- S1P2F1 (Fig. 20).

With regard to the fruit quality parameters, significant differences were recorded for fruit TSS, acidity and total sugars among different treatment combinations. The fruit TSS was maximum (22.8 °B) in three suckers per pit planted at 2X3m spacing with 75% RDF fertigation (T7-S1P3F2) followed by T8-S1P3F3 (22.6 °B).

Maximum total sugars (14.7%) was recorded in two suckers per pit at 2X3m spacing and 75% RDF

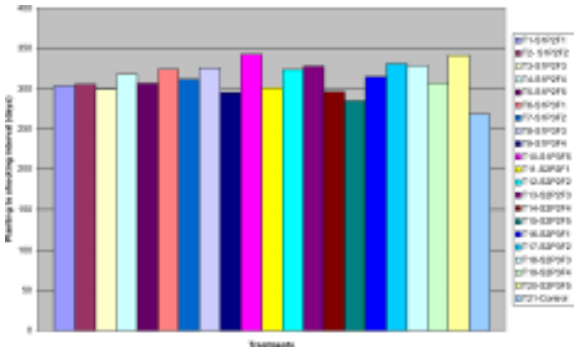


Fig. 17: Effect of different levels of nutrition on time taken for flowering in banana cv. Grand Nain

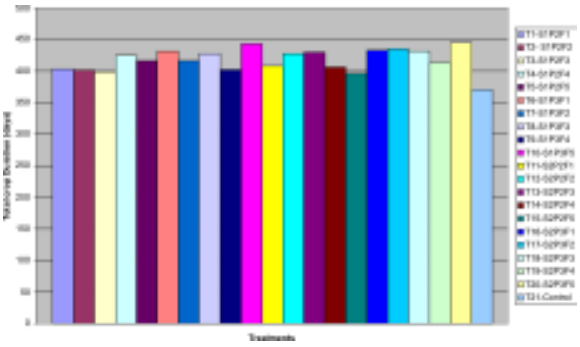


Fig. 18: Effect of plant density and different levels of nutrition on total crop duration in banana cv. Grand Nain

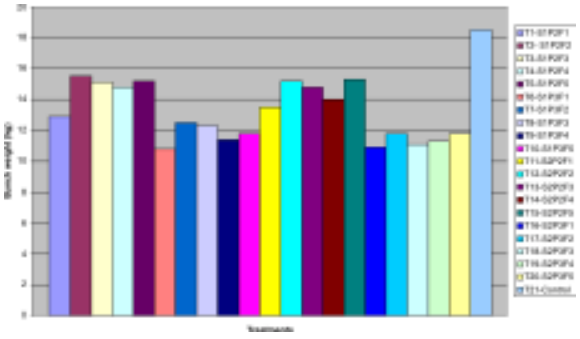


Fig. 19: Effect of plant density and different levels of nutrition on bunch weight in banana cv. Grand Naine

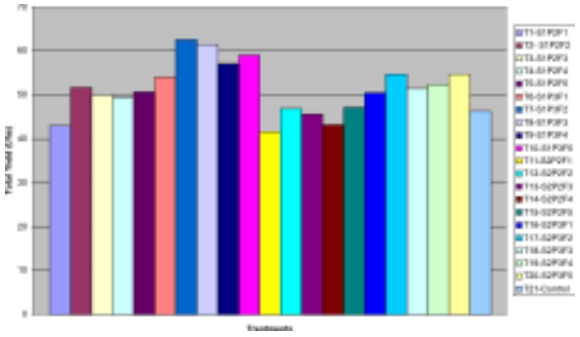


Fig. 20: Effect of plant density and different levels of nutrition on total yield in banana cv. Grand Naine

fertigation (T7) followed by T6 (13.6%). Leaf biochemical analysis revealed that the highest chlorophyll 'a' (1.74 mg / g) and lowest chlorophyll 'b' (0.16 mg / g) contents were recorded in three suckers per pit at 1.8X3.6m spacing with 75% RDF fertigation (T17-S2P3F2). The total chlorophyll content was maximum (1.87mg / g) in T14-S2P2F4 followed by T12-S2P2F2 (1.85 mg / g).

The leaf nutrient analysis revealed that at harvest, planting of three suckers per pit at 2X3m spacing and 100% RDF fertigation recorded the highest leaf N (2.34%) followed by T5- S1P2F5 (2.16%). The highest leaf K content was recorded in two suckers per pit with 100% RDF fertigation followed by the control treatment. While the lowest leaf K was recorded in two plants per pit with 50% RDF fertigation (T11-S2P2F1).

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

A new experiment was laid out to standardize optimum spacing and nutritional requirement for enhancing the yield and fruit quality of banana Udhayam released from the Centre.

At pre flowering stage, significant differences were observed for plant girth, number of healthy leaves, number of suckers per plant, leaf growth parameters and leaf area index whereas the plant height and phyllochron were found nonsignificant among the treatments. The pseudostem circumference was higher (113.00 cm) in 1.8X2.1m spacing with 400g N and 300 K per plant and the lowest 91.8 cm was recorded in the closer spacing of 1.8X1.8m with 200:300g N&K plant^{-1} (Fig. 21). Among the treatments, the number of healthy leaves was maximum (14.85) in plants at 1.8X2.1m spacing and 300:300g N&K fertilizer application.

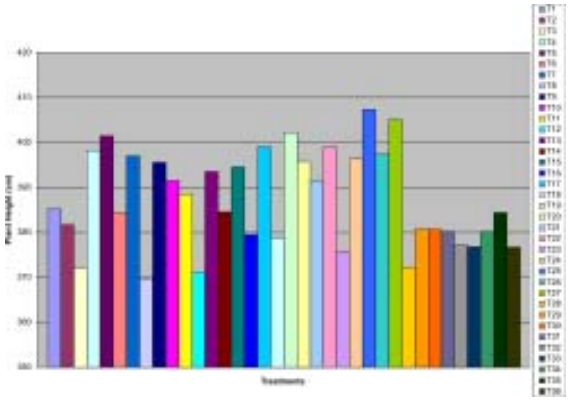


Fig. 21: Effect of spacing and nutrition on plant height in banana cv. Udhayam

The nutritional analysis of the leaf samples at pre flowering stage revealed significant differences for leaf NPK concentration. The highest concentration of both leaf N (2.87%) and K (2.96%) were recorded from plants under T35- S4N8 *i.e.*, 2.1X2.1m spacing with 400:400g N&K plant^{-1}. While T6-S1N6- 1.8X1.8m spacing with 300g N and 500g K plant^{-1} recorded the highest leaf P content of 0.58%.

The biochemical analysis of the leaves revealed that the plants under treatment T18 i.e., 1.8 X 2.1m spacing with 400g N and 500g K plant^{-1} recorded the highest leaf total chlorophyll content (2.86 mg / g) followed by 1.8 X 2.4m and fertilizer dosage of 400g N and 500g K plant^{-1} (2.29 mg / g).

5.2.3 Fertilizer tailoring for targeted banana yield and sustainable soil health

Fertilizer adjustment equations were developed for Poovan and Karpuravalli bananas by following the "Soil Test Crop Response" and 'Targeted yield concept'.

Poovan

Fertilizer requirement of N:P_2O_5:K_2O for producing one tonne of Poovan banana was worked out as14.4:1.74:26.7 kg. In Poovan banana production, 41.0, 35.2 and 61.1% of N, P_2O_5 and K_2O was contributed from soil, 54.0, 48.2 and 63.6% of N, P_2O_5 and K_2O from applied fertilisers and from organic manure 15.7, 18.3 and 31.2%, respectively.

The fertilizer adjustment equations for Poovan are:

FN = (26.7 x T) – (0.76 x SN) – (0.29 x ON)

FP = (3.61 x T) – (0.73 x SP) – (0.38 x OP)

FK = (41.98 x T) – (0.96 x SK) – (0.49 x OK)

Here, FN, FP and FK are nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) requirement (kg / ha) of banana cultivated in one hectare, respectively, through fertilizers. T is the target (tons / ha) of banana yield. SN, SP and SK are quantity (kg / ha) of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) already existing in the soil, before application of fertilizer. ON, OP and OK are quantity (kg / ha) of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) contributed from the recommended dose of organic manures applied to banana crop (Table 8).

Karpuravalli banana

Fertiliser requirement of N:P_2O_5:K_2O for producing one ton of Karpuravalli banana was worked out as 13.6:1.7:16.2 kg for Karpuravalli banana production. 52.3, 40.3 and 42.3% contribution of N, P_2O_5 and K_2O from soil while applied fertilizers contributed 63.1, 52.9 and 72.3% of N, P_2O_5 and K_2O and organic manure 18.3, 11.9 and 23.4%, respectively. The fertilizer adjustment equations for Karpuravalli are given in (Table 9).

FN = (21.6 x T) – (0.83 x SN) – (0.29 x ON)

FP = (3.21 x T) – (0.76 x SP) – (0.22 x OP)

FK = (22.4 x T) – (0.59 x SK) – (0.32 x OK).

Here, FN, FP and FK are nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) requirement (kg / ha) of banana cultivated in one hectare, respectively, through fertilizers. T is the target (tons / ha) of banana yield. SN, SP and SK are quantity (kg / ha) of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) already existing in the soil, before application of fertilizer. ON, OP and OK are quantity (kg / ha) of nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) contributed from the recommended dose of organic manures applied to banana crop.

Table 8: Development of fertilizer adjustment equations for Poovan

	Nutrient Requirement (kg/ton)	Percentage of available nutrient in soil contributed for yield	Percentage of available nutrient in fertilizer contributed for yield	Percentage of available nutrient in organic manure contributed for yield
Nitrogen (N)	14.4	41.0	54.0	15.7
Phosphorus (P_2O_5)	1.74	35.2	48.2	18.3
Potassium (K_2O)	26.7	61.1	63.6	31.2

Table 9. Development of fertilizer adjustment equations for Karpuravalli

	Nutrient Requirement (kg/ton)	Percentage of available nutrient in soil contributed for yield	Percentage of available nutrient in fertilizer contributed for yield	Percentage of available nutrient in organic manure contributed for yield
Nitrogen (N)	13.6	52.3	63.1	18.3
Phosphorus (P_2O_5)	1.7	40.3	52.9	11.9
Potassium (K_2O)	16.2	42.3	72.3	23.4

5.2.4 Studies on micronutrients in banana

The plant growth observations were made in 8 months old Nendran banana under micronutrient trial. The highest plant height of 259 cm was observed at (1,1,1) level – soil application of Fe, Zn and B and it was 10.68% more than control (without micronutrient application). The highest pseudostem girth was observed at (0,1,2) – soil application of Zn and foliar application of B and was 10% more than control (without micronutrient application). The highest number of leaves 27.2 was observed at (0,1,1) level – soil application of Zn and B and it was 20.9% more than that of control. The highest total leaf area of 16 cm^2 was observed at (1,0,0) level - soil application of Fe alone and it was 25.9% more than control. Sulphur application recorded the average plant height of 236.0 cm and it was 3.65% more than that of control (without sulphur application). Sulphur application recorded the average pseudstem girth of 59.3 cm and it was 1.17% less than control the highest. Sulphur application recorded total number of leaves, (23.7) and total leaf area (14.4 cm^2) and it was 28.57% more than that of control (without sulphur application).

5.3. CROP PHYSIOLOGY, BIOCHEMISTRY AND POST-HARVEST TECHNOLOGY

5.3.1 Physiology of flowering and fruit development in banana

Starch, amylose and amylopectin contents in Monthan, Saba and Udhayam varieties

Monthan, Saba and Udhayam banana fruits were harvested at 80-90% maturity. The starch, amylose contents and other quality parameters were analysed. The unripened fruits of Saba and Monthan recorded higher starch (30 -31%) and amylose contents (35-38%) than Udhayam (27.20% starch and 28.26 % amylose). After ripening the Udhayam recorded highest TSS (27.0°B), pulp / peel ratio (2.57) and total sugars but less acidity and starch contents than other two varieties (Table 10). Hence it is more suitable for dessert purpose.

Bunch development studies

The Nendran and Karpuravalli banana bunches were sprayed with potassium sulphate (2%), Brassinolides (20ppm) Benzyl Adenine (25 ppm) and 2,4-D (20ppm) (Na^+ salt commercial grade) after its full bunch opening and 15 days after first spray. The potassium sulphate sprayed bunches increased 1.5kg in both varieties. The finger length (15.12%) and girth (7.26%) increased significantly compared to control. The Brassinolides and Benzyl Adenine sprays increased the bunch weight by 0.75 to 1 kg only in Karpuravalli but not in Nendran and finger girth has increased more.

5.3.2 Drought stress tolerance in banana

Studies on drought tolerance mechanism in banana cultivars

Ten genotypes *viz.*, Saba, Karpuravalli, Poovan, Nendran, Robusta, Ney Poovan, Attu Nendran, Mannan, Ladan and Pisang Berlin were grown in concrete pots (capacity 75 kg) for three months and imposed water stress for 3 weeks by withholding irrigation. After 3 weeks of soil moisture deficit stress, 50% decrease in chlorophyll and 37% reduction in carotenoids pigments in all varieties were observed. In case of Epicuticular wax (ECW) production, the water stressed plants produced 2-3 folds higher in all the varieties. However, Saba, Karpuravalli, Mannan and Nattu Poovan recorded higher ECW

Table 10. Starch, amylose and amylopectin content and quality parameters differences in unripened and ripened banana fruits of Saba, Monthan and Udhayam

	Unripened Banana (Green Banana)							
	% (Dry weight basis) Starch	Amylose	Amylo pectin	Pulp / peel ratio	TSS (°Brix)	Acidity (%)	Total Sugars (%)	% (Fresh weight basis) Starch
Saba	86.72	38.40	61.60	1.16	4.00	0.11	0.21	30.62
Monthan	81.30	35.44	64.56	2.97	5.40	0.20	0.21	31.73
Udhayam	78.21	28.26	71.74	1.56	7.60	0.10	0.43	27.20
	After Ripening							
Saba	_	_	_	1.49	24.60	0.665	15.20	2.35
Monthan	_	_	_	1.45	26.33	0.898	14.93	2.27
Udhayam				2.57	27.00	0.350	18.8	1.12

content (> 0.32 mg / cm^2), while Poovan, Saba and Karpuravalli recorded higher membrane stability index than other varieties. The Relative Water Content (RWC) recorded higher (>45%) in water stressed banana plants of Poovan, Nattu Poovan and Ladan while same varieties recorded higher RWC (>65%) after one week.

Studies on water stress and its alleviation in Grand Nain banana

Water stress induced by PEG 8000 in Grand Nain tissue cultured plants significantly reduced total chlorophyll content with time but water stress increased carotenoid content. The higher level of water stress (32% PEG 8000) and ABA, induced more ascorbic acid production. Under mild water stress (20% PEG 8000), ASA application recorded significantly higher epicuticular wax than control. The POD and SOD activities were less under water stress condition and treatments also did not have any effect on these enzymes (Table 11). The Chlorophyll Stability Index and Membrane Stability Index (MSI) decreased with duration and concentration of the PEG 8000 as compared to control. ABA and BHT treated plants recorded higher MSI than ASA application.

5.3.3 Salt stress tolerance in banana

Field evaluation of banana cultivars in salt affected field

In the salt affected field (EC 1:2.5 = 3.34 and pH 8.1) Saba, *M. balbisiana* Karpuravalli and Ney Poovan recorded normal finger development and fruit filling where as Nendran and Robusta produced small and poorly developed unmarketable fingers. The fruits of Saba, Karpuravalli and Ney Poovan recorded 39-41% starch (fr.wt.) at harvest (100 days after shooting) whereas in Nendran and Robusta, the starch content was only 7-8% at harvest (100 days after shooting). In Saba, delayed senescence of leaves (90-93 days) was observed; where as in susceptible Nendran and Robusta cultivars senescence of leaves were recoded in 78-80 days. Saba (ABB) grown in salt affected field recorded higher chlorophyll content, reducing sugars, ascorbic acid content, Chlorophyll Stability Index, antioxidative enzymes and normal growth with fruit development. Three month old banana sucker plants of Saba, Ney Poovan and Karpuravalli grown in saline soil condition (EC1:2.5 = 3.3.6, pH = 8.1) when treated with ABA (100ppm), Butylated Hydroxy Toluene (BHT) (100ppm), an antioxidant chemical and Acetyl salicylic acid (ASA,100µM) recorded increased photosynthetic pigments, Chlorophyll Stability Index (CSI) and antioxidative enzymes as compared to control. Among the three treatments, the BHT improved the CSI, increased the proline content and reduced the lipid peroxidation. The ASA and ABA increased the antioxidative enzymes and photosynthetic pigments.

Effect of NaCl salt stress and its alleviation by antioxidants and ABA on Grand Nain banana plants

The chlorophyll pigments significantly reduced over the time in all the NaCl treated plants, but in ABA treated plants chlorophyll content significantly increased compared to other treatments. The

Table 11. Effect of antioxidants and ABA on biochemical parameters water stressed banana plants

Treatments	Total chlorophyll (µg/ g)	Carotenoids (µg/ mg)	Ascorbic acid(µg/ g)	Epicuticular wax(µg/ cm^{-2})	Peroxidase (units/mg of protein)	SOD (units/mg of protein)
T1	188.0	27.58	1.00	0.19	11.32	107.69
T2	168.7	30.87	1.02	0.13	9.60	57.67
T3	159.0	31.34	1.33	0.15	8.92	71.79
T4	142.8	28.64	1.35	0.12	8.17	94.02
T5	155.6	30.33	0.97	0.17	10.86	47.48
T6	142.5	26.25	0.97	0.25	8.57	71.47
T7	137.0	27.00	1.15	0.18	9.64	44.41
T8	126.5	31.04	0.97	0.16	9.55	52.27
T9	130.1	22.18	1.03	0.13	10.16	46.92
LSD at 5%	19.42	5.51	0.028	0.012	0.49	2.79

T1- Control T2 – 20% PEG 8000 T3 - 32% PEG 8000
T4- 20% PEG 8000 + ABA T5 – 32% PEG 8000 + ABA T6 – 20% PEG 8000+ ASA
T7- 32% PEG 8000 + ASA T8 – 20% PEG 8000 +BHT T9 – 32% PEG 8000 + BHT

Table 12. Effect of antioxidants and ABA on biochemical parameters of salt stressed banana plants

Treatments	Chlorophyll content (ug/g)	Carotenoids (ug/g)	Malondial-dehyde (nanomoles / mg of protein)	Ascorbic acid (mg/g)	Proline (ug/g)	Epicuticular wax (ug / cm^{-2})
T1	186.5	27.9	497.5	1.00	4.40	0.19
T2	157.6	45.3	547.5	1.08	5.60	0.31
T3	197.3	44.7	508.8	1.04	7.80	0.26
T4	162.3	48.7	487.5	1.03	4.30	0.65
T5	224.2	43.6	475.0	1.06	7.00	0.29
T6	216.9	44.9	458.8	1.08	4.90	0.31
T7	176.7	46.0	513.8	0.97	6.50	0.37
T8	167.4	42.8	587.5	0.97	7.20	0.17
T9	150.0	40.0	513.8	1.18	11.00	0.15
T10	136.8	36.5	442.5	0.92	4.10	0.18
T11	134.3	38.2	375.0	1.04	3.00	0.18
T12	157.1	46.9	491.3	1.00	5.80	0.14
T13	158.3	48.7	422.5	0.99	3.00	0.14
LSD at 5%	20.56	3.72	6.52	0.04	0.06	0.046

T1 - Control
T2 - 100mM NaCl
T3 - 150mM NaCl
T4 - 200mM NaCl
T5 - 100mM+ABA (100ppm)
T6 - 150mM+ABA (100ppm
T7 - 200mM+ABA (100 ppm)
T8 - 100mM+ASA (0.1mM)
T9 - 150mM+ASA (0.1mM)
T10 - 200mM+ASA (0.1mM)
T11 - 100mM+BHT (100 ppm)
T12 - 150mM+BHT (100 ppm)
T13 - 200mM+BHT (100 ppm)

carotenoid pigments were significantly increased in salt stressed and antioxidants and ABA chemicals applied in salt stress treatments compared to control. The Malondialdehyde content decreased in ABA and BHT treated plants. The ABA and ASA treated salt stressed plants recorded higher ascorbic acid and proline content than control. Higher NaCl concentration (200mM) and NaCl stressed with ABA treated plants recorded more epicuticular wax (Table 12). Overall the salt stressed plants applied with ABA is better than other chemicals.

5.3.4 Studies on biochemical mechanism of resistance of bananas to root lesion nematode

The total constitutive phenolic contents before inoculation of *P. coffeae* in roots of Anaikomban, Yangambi Km5, Robusta and Nendran were 0.054, 0.053, 0.043 and 0.048 mg/g fresh tissue respectively. After inoculation of the nematode, the contents of total phenolics were increased at 4 and 7 days and the phenolics contents were the highest at 7 days with 0.224, 0.235, 0.072 and 0.085 mg/g tissue. At 10 and 14 days, the phenolics contents decreased but the levels of phenolics were higher than constitutive levels. The contents of phenolics after 14 days of inoculation were 0.128, 0.209, 0.063 and 0.067 mg/ g fresh weight of tissue. In uninoculated control roots, the phenolics contents were in pre-inoculation levels.

The constitutive activity of peroxidase in the four banana cultivars were more or less in the same level (16, 14, 15 and 15 nanokatals per milligram of protein) in Anaikomban, Yangambi km5, Robusta and Nendran respectively. In post-inoculation, the activity of peroxidase increased to the highest levels of activity at 7 days with 226, 209, 57 and 62 nanokatals per milligram protein in Anaikomban, Yangambi km5, Robusta and Nendran respectively. The peroxidase activity induction levels in nematode-resistant varieties, Anaikomban and Yangambi km5, was four-fold whereas in susceptible varieties it was only around 2-fold. At 10 and 14 days after inoculation of the nematode, the peroxidase activity was found gradually decreasing.

In the case of polyphenol oxidase, the constitutive activities of Anaikomban and Yangambi km5, Robusta and Nendran were 27, 37, 25 and 32 nanokatals per milligram protein respectively. The activity of polyphenol oxidase also increased at 4 and 7 days after inoculation of *P. coffeae*. At 7 days, the activities were 175, 161, 89 and 72 nanokatals per milligram protein. In general, the induction levels of polyphenol oxidase activity were higher in resistant cultivars (Anaikomban and

Yangambi km5) than in susceptible cultivars (Robusta and Nendran).

Polyphenol oxidase isoenzyme profiles in root tissues of Anaikomban, Nendran and Robusta were studied at 7 days after inoculation of the root lesion nematode. The results revealed strong expression of constitutive enzymes and also induction of new isoforms in the *P. coffeae* inoculated roots compared to uninoculated control plant roots.

Estimation of proanthocyanidins in roots of banana varieties revealed that constitutively Anaikomban contained highest quantity of 0.346 (A_{550} nm). In Yangambi km5, Robusta and Nendran, the constitutive content of proanthocyanidins were 0.265, 0.272 and 0.291 (A_{550} nm) repectively. In *P. coffeae* inoculated roots of Yangambi Km5, the condensed tannins increased more than the levels of Nendran and Robusta at 4 and 7 days. At 7 days, the proanthocyanidins contents were 0.428, 0.421, 0.281 and 0.298 (A_{550} nm) in Anaikomban, Yangambi km5, Robusta and Nendran respectively with highest content of condensed tannins in Anaikomban. At 10 and 14 days, the contents of proanthocyanidins decreased but were higher than the pre-inoculation levels. The decrease of contents was higher in susceptible varieties at 10 and 14 days as compared to resistant varieties (Table 13).

Table 13. Contents of proanthocyanidins in roots of resistant and susceptible banana cultivars

Variety	Days After Inoculation / Proanthocyanidins Contents*				
	0	4	7	10	14
Anaikomban	0.346	0.381	0.428	0.425	0.425
YKm5	0.265	0.336	0.421	0.417	0.416
Robusta	0.272	0.279	0.281	0.273	0.260
Nendran	0.291	0.294	0.298	0.271	0.265

*Measured spectrophotmetrically at 550 nm.
Values are the means of six replications.

5.3.5 Post-Harvest Studies

Storage studies in banana

For identifying the critical temperature for storage of NeyPoovan banana, ninety percent mature fruits of NeyPoovan were harvested and bunch were dehanded. The hands were dipped in Bavistin (500 ppm) solution for 10 min and surface moisture was dried under fan. The hands were packed in CFB boxes and stored at 10, 12, and 13.5 °C. Observations were recorded for physical firmness, TSS, acidity, total sugar and activity of amylase enzyme. Organoleptic evaluations were also carried out. The results indicated the critical temperature for storage of NeyPoovan was 13.5 °C. The data on physical and chemical parameters and organoleptic evaluations of the fruits stored at 13.5 °C supported this.

Banana flower based soup

A recipe was standardized for preparation of banana flower based ready to make soup. Karpuravalli flower was used for standardization. Banana flower (6.6g), carrot (1.6g), cabbage (1.6g), garlic (3.3g) pepper (1.6g) cashew nut (3.3g), sugar (16.6g), mustard seed (0.83g), citric acid (0.83g), salt (13.3 g), banana flour (23.3g) and corn flour (23.3g) constituted the ingredients to make one liter soup. In the final soup preparation, 4.2 °B TSS, 0.0405% acidity 0.68% sugar and 0.208% phenols were recorded, which were the acceptable levels in the organoleptic evaluations.

Steeping solution for banana stem

A storage method using steeping solution was developed for storage of banana stem for further product preparation or culinary use. Fresh stems were cut into small pieces and steeped in a solution with 6% salt, 3% acetic acid and 1000 ppm potassium metabisulphite. In this steeping solution, the stems could be stored for one month for further use.

Bulk production of banana wine

The bulk production technique of banana wine was standardized. Juice extracted from ripe Karpuravalli fruits were kept for fermentation, where the fermentation at 10 °C took 13 days for the total sugars to come below 1% and alcohol to 15%. The secondary fermentation process is in progress.

Extraction of pseudostem fibre

The extraction of fibre from pseudostem of Poovan banana using chemical retting process and followed by manual and machine extraction was compared. The results indicated that the yield of fibre was more when chemically retted stems were subjected to manual extraction than machine extraction. The loss due to breakage was more in machine extraction. The yield of fibre was 0.3% in manual extraction compared to 0.17% in machine extraction process. The quality of fibre obtained through chemical retting was superior to physical methods of extraction.

5.4 CROP PROTECTION

5.4.1 Studies on banana nematodes and their management

Survey for nematodes in different banana growing areas in Tamil Nadu

The burrowing nematode, *Radopholus similis*, was the predominant nematode found in most of the root samples of Grand Nain banana in Chinnamanur areas of Theni District followed by the spiral nematode, *Helicotylenchus multicinctus* and root-knot nematode, *Meloidogyne incognita*. The burrowing nematode was also recorded in Ladan / Hill banana grown at Sevrayan hills, Yercaud. These nematodes infestation caused significant reduction in plant growth and yield.

Compatibility of different bio-agents and neem cake

Field trials using biocontrol agents alongwith neem cake laid out on banana revealed that the plant height (85.5, 78.5 and 75.3), girth (65.5, 54.7 and 50.4) and number of leaves (44.8, 40.8 and 39.5) were maximum in the combination of *T. viride* + *P. lilacinus* @ 10g each / plant with 500g of neem cake in cvs. Nendran, Red banana and Robusta repectively and the effect was on par with nematicides. Minimum nematode population of *P. coffeae* (65, 48 and 55 / g root) and *M. incognita* (115, 145 and 88 / g root) was recorded also in the same treatment.

Effect of VAM alone and in combination with biofertilizers and biocontrol agents

Application of VAM, Phosphobacteria, Azospirillum and two biocontrol agents (*P. lilacinus* and *T. viride)* at planting and at 3rd and 6th month after planting in cv. Ney Poovan resulted in significant reduction in nematode population with enhanced plant growth (Table 14). Application of VAM alone recorded the maximum bunch weight with minimum nematode infestation.

Isolation, identification and evaluation of the endophytes

The culture filtrate of twelve endophytic bacteria isolates were tested under *in vitro* condition against the burrowing nematode, *Radopholus similis*. 100 % mortality was observed in two isolates *viz.*, 2C and *P. ceylan* when exposed to 48 h, whereas eight out of twelve bacterial isolates exhibited 100 per cent mortality at 100% concentrations when exposed to 72 h.

Effect of *Bacillus subtilis* against root-knot nematode

In vitro study using 13 isolates of *B. subtilis* isolated from 119 soil samples of banana against the mortality of young juveniles of root-knot nematode revealed that isolates $BSNRCB_{107}$ from Ney Poovan and $BSNRCB_{35}$ from Monthan recorded 100% mortality at 100% concentration when exposed to 24 hrs, while $BSNRCB_{23}$ from Red Banana

Table 14. Effect of VAM alone and in combination with biofertilizers and biocontrol agents for the control of major nematodes in banana

S. No	Treatments	Plant growth parameters			Nematode populations			Weight of bunch (Kg)
		Plant height (m)	Pseudostem girth(cm)	No of leaves	Soil		Root	
					M.i	*Hoplolaimus*	*M.i*	
1.	VAM only	3.48	72.6	8.7	-	4	-	12.85
2.	VAM + *T. viride* + Azospirillum + Phosphobacteria	3.42	70.9	7.8	-	9	-	11.65
3.	*P. lilacinus* + Neem cake	3.39	70.1	7.4	-	10	25	10.9
4.	*P. fluorescens* + Neem cake	3.43	71.9	8.4	94	5	54	10.25
5.	Furadan	3.35	67.8	7	62	-	40	9.9
6.	Untreated Check	3.29	64.9	6	116	-	177	9.45
	SED	0.0716	1.1683	0.2449				2.5567
	CD(.05)	0.1493	2.4371	0.5110				5.1497
	CD(.01)	0.2036	3.3244	0.6970				6.8769
	CV%	3.33	2.65	5.16				5.56

and $BSNRCB_9$ from Nendran recorded 100% mortality at 100% concentration when exposed to 48 hrs followed by $BSNRCB_{72}$ from Saba, which recorded 100% mortality at 75% concentration when exposed to 72 hrs. These five isolates tested at two levels of concentration under pot culture against root-knot nematode on cv. Ney Poovan revealed that 40g / plant of $BSNRCB_{23}$, $BSNRCB_{107}$ and $BSNRCB_{35}$ exhibited maximum plant growth and significant reduction in nematode populations and root-knot indices when compared to control plants.

Screening of core collection of *Musa* germplasm against root-lesion nematode, *P. coffeae* under shade net condition

Sixty core collections of *Musa* germplasms belonging to 12 diploids (AB) and 48 triploids (AAB) were screened against root-lesion nematode, *Pratylenchus coffeae* in pots under shade net condition revealed that diploids *viz*., Kunnan, Gragric sarpara, Narmine and triploids *viz*., Dasaman, Kottavazhai and Sakkar Chyana were resistant to *Pratylenchus coffeae*, whereas diploids Valiya Kunnan and triploids Ladies finger and Cheeni Champa were moderately resistant to root-lesion nematode. It is interesting to note that the triploids Sirumalai, Garomoina, Malaivazhai and Pacha though recorded high root-lesion indices and nematode populations its effect on plant growth parameters was minimal, which indicated that they posses a high degree of tolerance to *P. coffeae*.

5.4.2 Management of Banana Weevils

Survey for insect pests and biocontrol agents

Nine hundred and forty six soil samples were collected from Shevaroy hills, Western ghats (Anamalai hills), Pandrimalai, Kolli hills, Tirunelveli and Karur districts of Tamil Nadu for the isolation of microbial biocontrol agents. The collected soil samples were susbjected to *Galleria* baiting and isolated biocontrol agents like *Beauveria bassiana* (160 isolates) and *Metarhizium anisopliae* (24 isolates). The isolates were evaluated against banana stem weevil, *Odoiporus longicollis* under laboratory conditions and recorded a maximum mortality of 73% and 100% mortality in *Beauveria bassiana* (NRCB-Bb -3-2008) and *Metarhizium anisopliae* (NRCB-Ma-7-2008) respectively. Mealy bug (*Phencoccus solenopsis*) menace was recorded in cvs. Robusta, Poovan ,Ney Poovan , Karpuravalli , Monthan and also on 11 weed plants.

Bioassay and identification of banana leaf sheath volatiles

The banana leaf sheath volatiles of cv. Nendran (collected through air entrainment technique) subjected to GC / MS using carbowax column indicated the presence of 13 terpene components. The molecular weight (Dalton) and RT values (Minutes) ere ranged from 120-136 and 17.0 to 50.6 respectively. Maximum and minimum percentage of different volatile components in the sample includes Geranylnitrile (7.26%) and 2-b-pinene (0.03%), where as GC / MS analysis of the banana leaf sheath volatiles collected from cvs Poovan and Karpuravalli indicated the presence 6 components each.

Evaluation of banana leaf sheath and corm volatiles

Banana corm and leaf sheath volatiles of cv Nendran was collected by air entrapment method and evaluated for corm weevil attraction by Y-tube olfactometer. Maximum weevil attraction was noticed in corm volatiles followed leaf sheath volatiles. Semiochemicals belonging to five groups (fatty acid derivatives, terpenes and N & S containing volatiles, benzene derivatives, cyclic alcohols and ketones) were studied by electroantennography. The following 23 semiochemicals indicated response to banana stem weevil *viz*., hexanol, linalool, a-pinene (r), β-pinene, 2-hexen-1-ol, α-pinene (s), heptanaol, 1-8 cineole, m-anisaldehyde, cyclohexanone, o-anisaldehyde, pyridine, octanone, 2-hepptanone, p-anisaldehyde, r-carvone, methyl jasmonate, farnesyl acetate, carvone-s and 2-heptanone .

Further, the short listed semiochemicals were bioassayed using Y-tube olfactometer. Results indicated that the following chemicals *viz*., hexanal, 1.8-cineole, α-pinene and linalool attracted the virgin male, virgin female, male and female weevils at 60, 60, 80 and 80 % respectively.

Wind tunnel bioassay was conducted for 9 semiochemicals (a-pinene, 1.8- Cineole, heptanol, β-pinene, 2-hexen-1-ol, linalool, hexanol, α-pinene (s) and m-anisaldehyde) against virgin male, virgin female, male and female. Results indicated that weevil attraction of 83.3, 86.6, 86.6% was recorded for virgin male, virgin female and male respectively. Heptanol recorded 90% attraction to female stem weevil.

The selected 23 semiochemicals were evaluated against banana stem weevil, *Odoiporus longicollis* under field conditions in four doses (250, 500, 750 and 1000 ul) using funnel trap. Results revealed that none of the chemicals attracted banana stem weevil.

Screening of semiochemicals against banana corm weevil

Twenty three semiochemicals at four doses (250, 500, 750 and 1000 µl) were screened under field

conditions against banana corm weevil, *Cosmopolites sordidus*, by pit fall trap method. The five chemicals *viz*., y- terpinene, α-bisabolol, b-cedrene, 2-hexan-1-ol, α-pinene, hexanol and cis-3-nonene 1-ol were found attractive to banana corm weevil. Among the chemicals, α-bisabolol was the most attractive semiochemical.

Economic threshold level for Banana corm weevil

Four weevils per longitudinal split banana stem trap is the threshold level of banana corm weevil, *Cosmopolites sordidus*.

IPM strategy for banana weevils

Entomopathogenic nematode

Heterorhabditis indica was evaluated under laboratory conditions with seven treatments ranging from 5 to 25 X 10 IJs. The mortality of corm weevil ranged from 23.3 to 93.3% and the maximum mortality of 93.3 per cent was recorded in the 25 x 10^3 IJ's. Where as in control, no mortality and in standard check (Monocrotophos) 100 percent mortality was recorded.

Evaluation of banana stem traps for the banana corm weevil management

Longitudinal split banana stem traps of different cultivars (Nendran (AAB), Karpuravalli (ABB), Kanthali (ABB) , Monthan (ABB) , Saba (ABB), Poovan (AAB), Ney Poovan (AB), Robusta (AAA), Rasthali (AAB), Red Banana (AAA), Virupakshi (AAB), Ladan (AAB) and Namarai (AA) were evaluated under field conditions. Trap data observation for a period of ten days indicated that maximum and minimum number of weevil was trapped in the cultivars Kanthali (1.8 weevil / trap) and Ladan (0.18 weevil / trap) respectively (Fig. 22).

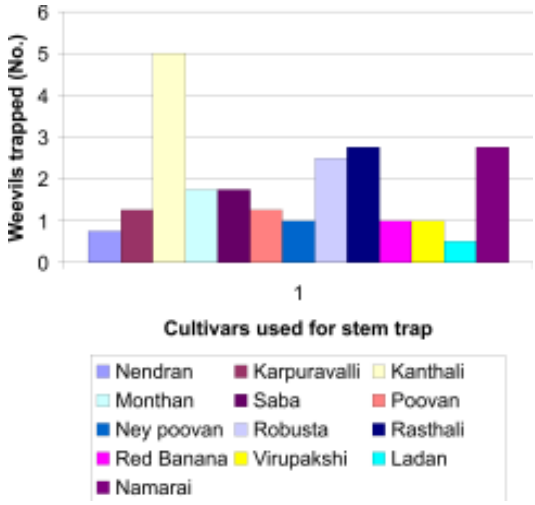


Fig. 22: Corm weevil trap catch inrelation to cultivars

Longitudinal split banana stem traps of different sizes *viz*., 10, 15, 20, 30, 40, 45, 50 and 60 cm were evaluated against banana corm weevil, *Cosmopolites sordidus*. Results indicated that maximum of 8 weevils and minimum of 5 weevils were trapped in the treatments 40 cm and 60 cm respectively (Fig. 23).

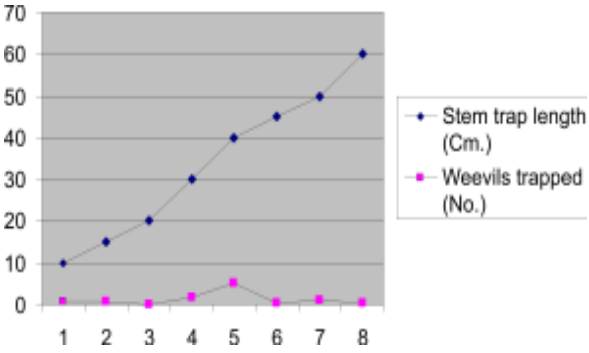


Fig. 23: Evaluation of stem trap size in relation to weevil attraction

Screening of chemicals and biocontrol agents as a sucker treatment and soil application to control banana corm weevil

In order to control banana corm weevil, an experiment was initiated with 18 treatments having 3 biocontrol agents, 3 neem based items and 11 chemicals under net house conditions. Among the treatments maximum weevil mortality of 100 per cent was recorded in Monocrotophos (14ml / litre) followed by Chlorpyrifos (5ml / litre). Minimum mortality was recorded in Phorate, Triazophos (0.05%) and Monocrotophos (0.05%). Among the neem based, Nimbicidine (1.0%) registered 93.33 per cent morality, whereas among the microbial biocontrol agents, maximum weevil mortality of 80 % was recorded in *Beauveria bassiana* and 60% each in *B.brongniartii* and *Metarhizium anisopliae*.

Evaluation of white halo fungus, *Verticillium lecanii* for banana aphid control

Thirty isolates of *Verticillium lecanii* was evaluated against banana aphid, *Pentalonia nigronervosa* under laboratory conditions. Among the four isolates (NRCB VL-2, 5, 7, 4) evaluated, the isolate NRCB VL-7 alone recorded 100% mortality of aphids compared to other isolates. *Verticillium lecanii* (NRCB VL-7) was mass produced in wheat bran and sand- maize flour. The maximum conidial production was recorded in wheat bran (32.3 x 10^7 conidiospores / g). The field evaluation of this isolate at Kanalkadu in lower Pulney hills indicated 80.9% aphid mortality where as the commercial formulation recorded only 31.5 %.

5.4.3 Investigation on fugal and bacterial diseases of banana and their management

Occurrence of race-1 *Foc* isolate infecting Cavendish banana

Fusarium wilt incidence in cv. Cavendish (5 to 25%) was observed in Theni district of Tamil Nadu. The Koch's postulate was proved using tissue culture plants of Robusta. Cross inoculation of this new isolate of Robusta (VCG 0124) in different commercial cultivars of India under pot culture condition revealed that the wilt pathogen caused wilt disease in Karpuravalli (ABB), Rasthali (AAB), Ney Poovan (AB) and Monthan (ABB) varieties. This has proved its versatility in causing the disease in different varieties of banana (Fig. 24).

Fig. 24: Robusta plant with Fusarium wilt disease symptoms

VCG studies conducted for 64 isolates of Fusarium wilt pathogen obtained from Andhra Pradesh, Kerala, Tamil Nadu, Assam and Arunachala Pradesh showed cross reaction among race-1 and race-2 isolates of *Foc*. The *Foc* isolates from var. Rasthali (race-1) of Tamil Nadu reacted with *Foc* isolates of Monthan which belongs to race-2. Similarly, the *Foc* isolates of var. Monthan (race-2) reacted with Ney Poovan and Karpuravalli (race-1).

Isolation and testing the pathogenicity of different isolates of *Erwinia* spp. under pot culture condition

Four different strains of *Erwinia* spp. were isolated from the samples collected from different banana growing regions of Tamil Nadu. The pathogenicity studies carried out under pot culture conditions revealed that only 60% of the plants inoculated showed corm rot symptoms indicating difficulties in carrying out other management studies under pot culture condition (Fig. 25).

Fig. 25: Confirmation of *Erwinia* pathogen obtained from banana by inoculation in potato slices

Fusarium wilt disease in Poovan

Fusarium wilt incidence (5%) was observed in variety Poovan (Mysore–AAB) at Sirugambur of Trichy district. The pathogen was isolated and confirmed as *Foc* by initial microscopic examination.

For the characterization of this *Foc* isolates obtained from var. Poovan, the nit mutants generated were paired with 33 numbers of nit-M testers obtained from Australia. The results indicated that the Poovan *Foc* isolates had formed heterokaryon with the 0124/5 nit-M tester which shows that this Poovan *Foc* isolates belong to 0124/5. The cross infection studies under pot culture condition are in progress (Fig. 26 & 27).

Fig. 26: Fusarium wilt symptoms in var. Poovan with longitudinal splitting of pseudostem

Fig. 27: Vascular discolouration in the corm of Poovan plants

Characterization and evaluation of endophytic bacterial isolates against Fusarium wilt pathogen (*Foc*) of banana

Endophytic bacterial strains (114) obtained from different parts of banana accessions (39 bacterial isolates from roots, 30 from leaf lamina, 28 from corm and 18 from midrib) resistant to Fusarium wilt disease belonged to 10 different groups of bacteria *viz*., *Bacillus, Staphylococcus, Micrococci, Pseudomonas, Actinomycetes, Azotobacter, Klebsilla, Serratia, Enterobacter* and *Citrobacter* based on colony morphology and biochemical analyses. The confirmation of these groups of bacteria by cloning and sequencing of 16s rRNA using universal primer is in progress.

The evaluation of 114 endophytic bacteria against Fusarium wilt pathogen by spore germination method, mycelial inhibition of

pathogen by dual culture plate and volatile production methods indicated that the Actinomycetes strain 17Ra and *Klebsiella* spp. strain 17Rb isolated from Yangambi KM-5 banana accessions recorded maximum inhibition of both mycelial growth and spore germination.

Isolation, characterization and evaluation of endophytic bacterial isolates against *Mycospharella* spp.

Totally 48 endophytic and 35 epiphytic bacterial isolates were obtained from mid rib and leaf lamina of 18 different banana accessions resistant to leaf spot disease complex. The morphological and biochemical tests carried out grouped all the 48 isolates in to six different groups viz. *Staphylococcus, Micrococcus, Serratia, Bacillus, Actinomycetes, Klebsiella* and all the 35 epiphytic isolates in to six groups viz. *Enterobacter, Staphylococcus, Micrococcus, Serratia, Bacillus* and *Klebsiella*. Among these groups, the isolates 6Mb, 2Mb and 14 Mb were found as most effective isolates and were identified as *Klebsiella, Micrococci* and *Actinomycetes* respectively. In the case of epiphytes, an effective isolate 1Eb was identified was *Bacillus* spp.

The evaluation of these endophytic and epiphytic isolates against Sigatoka leaf spot pathogen (*Mycospharella* spp) by spore germination, filter paper disc and volatile production methods indicated that the endophytic isolates *Klebsiella* (6Mb), *Micrococci* (2M), *Actinomycetes* (14 Mb) and epiphytic isolates *Bacillus* spp (1Eb) were found to be highly inhibitory (Fig. 28).

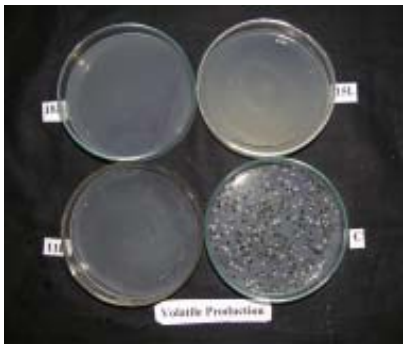


Fig. 28: Volatile production method

Evaluation of native epiphytic fungi against *Mycospharella* spp.

Among the 80 epiphytic fungi isolated from Sigatoka leaf spot resistant banana accessions, the isolate obtained from leaf lamina of cv. *Pisang serribu* recorded 98.1 percent reduction of spore germination of *Mycospharella* spp. This fungus has been identified as *Fusarium* sp. by microscopic examination. This is followed by an isolate obtained from the mid rib of Yangambi Km-5 which recorded 97.5% reduction of spore germination of *Mycospharella* spp. over control. This isolate has been also identified as *Fusarium* sp. (Fig. 29).

Fig. 29: Inhibiton of epiphytic fungi against Mycospha-Vella spp. C- Control, 1 & 2 – Culture filtrate of Staphy-lococcus - epiphytic strain 6E Filter paper disc method

Compatibility of effective antagonistic endo and epiphytic isolates with fungicides

Compatibility studies using four different fungicides showed that all the effective endo and epiphytes were compatible with Carbendazim at all concentrations tested. But in the case of other fungicides tested, all the bacterial antagonists were compatible at 0.01 to 0.05% concentrations.

5.4.4 Studies on viral diseases and their management

Survey for viral diseases

Survey undertaken in Jalgaon district, Maharashtra during Oct., 2008 recorded 29.59 and 19.06 % incidence of infectious chlorosis and bunchy top disease respectively (Table 15). Tissue culture plants grown in Namakkal district were surveyed and CMV incidence ranged from 4.8 to 28.8%.

In general, application of graded dose of fertilizer has increased the bunch weight of virus infected Poovan bananas. The yield reduction due to BBrMV and BSV was more in 50% RDF but with higher doses of application, the bunch weight also increased steadily (Table 16). Application of increased doses of fertilizer has significantly increased the bunch weight in BBrMV infected Nendran bananas. Application of 25% more than the RDF has almost compensated the yield reduction due to BBrMV infection.

Molecular Characterization of banana viruses

A BBTV isolate from Jalgaon had S1 component which putatively related to replication. Cp and rep

Table 15. Survey of BBTV and CMV incidence in Jalgaon district, Maharashtra

Name of place	Per cent incidence of CMV	Name of the places	Per cent incidence of BBTV
Waghoda, 1	12.43	Nimbhora-1	20.44
Waghoda,2	13.3	Nimbhora-2	11.50
Waghoda,3	1.87	Nimbhora-3	32.50
Waghoda,4	20.0	Nimbhora-4	28.57
Waghoda,5	70.5	Nimbhora-5	33.87
Waghoda,6	0.01	Nimbhora-6	21.25
Dasnur-1	31.75	Chinawal-1	24.33
Dasnur-2	48.00	Chinawal-2	24.50
Dasnur-3	31.34	Chinawal-3	4.50
Dasnur-4	17.33	Chinawal -4	9.43
Chinawa1-l	70.00	Dasnur	7.70
Chinawal-2	24.44	Waghoda	15.50
Chinawal-3	31.43	Bhirad	13.67
Chinawal-4	28.50		
Nimbhora-1	28.57		
Nimbhol-1	3.44		
Nimbhol-2	0.03		
Nimbhol-3	35.00		
Dhambhurni Yaval	37.67		
Dhanora,Jalgaon	86.25		

Table 16. Management of banana viral diseases through the application of higher dose of fertilizers in Poovan and Nendran bananas

Variety	Bunch weight (Kg)							
	Cv. Poovan					Cv. Nendran		
Treat ments	BSV infected	BBrMV infected	BSV & BBrMV infected	Healthy	Mean	BBrMV infected	Healthy	Mean
T1	10.00	9.71	8.68	10.30	9.67	7.00	10.03	8.52
T2	12.21	10.63	9.23	13.36	11.36	8.35	10.96	9.66
T3	12.96	12.86	12.06	13.90	12.95	10.91	14.25	12.58
T4	13.36	13.86	12.83	14.01	13.52	13.75	15.55	14.68
T5	13.61	13.58	13.26	16.10	14.14	13.66	14.15	13.91
Mean	12.43	12.13	11.21	13.53	12.33	10.73	12.99	11.86

T1: 50% Recommended dose of fertilizer(RDF); T2:75%RDF; T3:100%RDF; T4:125%RDF; T5:150%RDF

gene of BBTV isolates collected from Karnataka, Andhra Pradesh, Kerala, Bihar, Maharastra and rep gene from Assam, Arunachal Pradesh isolates and cp gene for Andaman BBTV isolate were cloned and sequenced for diversity analysis.

Forty banana streak symptomatic leaf samples were collected from 10 different banana growing places in Karur and Tanjore districts of Tamil Nadu. Partial BSV fragments covering RT / RNase H region were amplified and sequenced. The sequences analysis revealed the existence of high variability among the isolates.

Partial cp gene of CMV from Kannara, Kerala has been cloned and sequenced and found that the isolate belong to CMV subgroup IB.

Expression of recombinant fused CMV viral coat protein in *E. coli*

CMV coat protein gene was cloned into pCOLD and pMal expression vectors and transformed into *E. coli*. The 6X His tagged or MBP+CP CMV fused coat protein was expressed by induction using IPTG. The expressed protein was in insoluble fraction. The expressed cp of CMV was confirmed through SDS-PAGE analysis and western blotting using CMV specific polyclonal antiserum (Fig. 30). Polyclonal antiserum was raised against recombinant coat protein of CMV and the titre tested by DAC-ELISA was 1: 2000 for first bleed and 1: 8000 for second bleed.

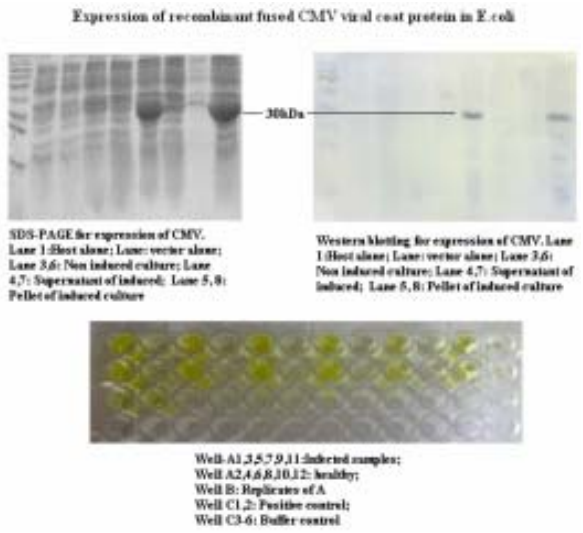


Fig 30. Expression of recombinant fused CMV coat protein in *E. coli*

Expression of recombinant fused BBTV viral coat protein in *E. coli*

BBTV cp gene has been successfully cloned into pCOLD and pMal expression vectors. Presence of the insert has been confirmed by restriction enzyme digestion. The protein expressed after induction showed truncated fusion protein. However the full length transcript could be isolated from the expression vector. Cleavage of fusion protein was confirmed by western blot analysis.

Supply of virus indexed Hill banana mother plants

As per the QRT recommendation, the Hill banana plants indexed for BBTV were supplied to Hill banana growers of Kolli hills and also to the research scholars of Dept. of Biotechnology and tissue culture unit of HC&RI, TNAU, Coimbatore.

Testing apparently healthy Poovan plants against BSMysV and BSOLV

Healthy non-symptomatic Poovan banana plants were planted during 2005. Observation showed that the expression of BSV symptoms had increased gradually. In the third ratoon crop, 4.0% incidence was recorded. Healthy plants selected from third ratoon crop were tested against two sets of primers derived from two BSV species. Total DNA from 200 Poovan plants were isolated and out of which 100 were tested against two of BSV species in PCR only 18 were negative for both BSMysV and BSOLV.

Testing commercial cultivars against six BSV speices

Seventeen commercial banana cultivars including a Bhimkol(BB), a wild banana grown in Assam state were tested with six sets of species specific BSV primers by PCR. Only three varieties were found negative for all the six set of primers. The amplification might be from integrated viral sequences.

Screening of germsplasm against BSV

Fifteen wild *M. babisiana* germsplasm supplied by crop improvement section were tested against BSV species and found that all were positive for either one of the BSV species tested.

Diagnostic techniques for banana viruses

Duplex PCR for CMV and BBrMV has been standardized using new set of primers with similar annealing temperature. Duplex PCR for DNA viruses' *viz*., BBTV and BSV has also been standardized. A sensitive, cost effective simple extraction protocol for template preparation has been developed to detect banana bunchy top virus by PCR. This new protocol has been compared with DNeasy kit and CTAB protocols for detection of the virus by PCR (Fig. 31). No solvents were used in the extraction. The new protocol developed was equally good with other methods available for PCR based detection.

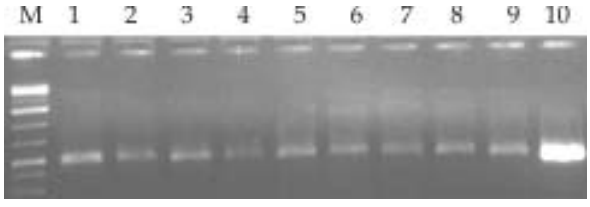


Fig. 31: Comparison of simple extraction protocol with CTAB extraction and commercial kit for detection of banana bunchy top virus infected samples by polymerase chain reaction. Lane M: 1 kb ladder; Lane 1-3: SEP; lane 4-6: phenol extraction; 7-9-Dneasy kit (Quiagen); lane 10: Positive control from clone.

Association of BBTV in other plant species

Association of BBTV in small and large cardamom and coconut has been observed. Different components of this virus were isolated, cloned, sequenced and characterized.

Transmission of viral pathogens

The effective temperature for acquiring the BBTV and BSV were 25-27 °C and 22 °C respectively. Minimum of 6 hrs feeding was required for acquiring the BSV from detached leaf sample kept in moist condition.

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

Developing severity index for BSV

The incidence of BSV has increased in Poovan due to episomal virus expression in the fourth ratoon crop. The severity index based on 0-4 scale has correlated with the yield data. The severity index and the yield significantly correlated in Poovan affected with BSV. The 0-4 scale can be used in diseases assessment after validation in multi-location trials.

Developing multiple virus gene construct for transgenic development resistance to viruses

600bp of BBTV, CMV and BBrMV (of each 200bp) and 400 bp intron of actin gene from *Arabidopsis thaliana* (Columbia) has been cloned in succession and an inverted repeat (600bp) have been added at the end of intron for developing the RNAi construct. The sequencing result has confirmed the sense BBTV, CMV and BBrMV along with intron clone. Agro-infiltration with promoter construct in tobacco has been standardized for transient *gus* gene expression.

A pot culture experiment was laid out during Oct 2008 to study the water stress on episomal expression of BSV in cv. Poovan. Data are being recorded on severity of the diseases in each and every leaf after imposing the water stress treatment. Observation on physiological parameters are recorded.

In order to develop infectious clone of BBTV, the complete components were amplified by rolling circle amplification. BBTV DNA-S was confirmed by component specific enzyme.

5.5 EXTERNALLY FUNDED PROJECTS

5.5.1 Functional Genomics for Sigatoka

Artificial inoculation of *Mycosphaerella musicola* (Yellow Sigatoka) pathogen and cDNA Subtraction

The tissue culture plants of susceptible variety Robusta (AAA) and the resistant variety Manoranjitham (AAA) were grown in a temporary infection chamber, with 80 - 90% relative humidity at 20 to 25 ºC. The plants were sprayed with conidia and samples were collected at 4 hrs interval upto 72 hours. Total RNA was extracted and mRNA from resistant and susceptible cultivars was pooled individually. The mRNA were reverse transcribed (first strand synthesis) using cDNA subtraction hybridization kit.

The susceptible cDNA pool was referred as driver and the resistant referred as tester. Selective Subtractive Hybridization was carried out. More number of colonies obtained and were screened by restriction digestion. Clones having inserts greater than 400bp alone were sequenced (532 clones). Sequence showed similarities with Retrotransposans, Cysteine protease, Rubisco activase, patens predicted protein, putative splicing factor, *M. acuminate* catalase II, Serine threionine kinase and hypothetical protein. More than hundred sequences aligned with *M. acuminata, V. vinifera* metallothionine like protein. Many of the sequence showed rRNA. Functions of anti microbial proteins, metallothionine protein, catalase and serine / threonine kinase functions will be analyzed further to correlate with biotic stress. Among the sequenced fragments analysed, antimicrobial protein showed useful information, which covered 27% anti microbial peptides.

5.5.2 Functional Genomics for Drought

AFLP polymorphism for drought tolerant and susceptible lines of *Musa* germplasm

Based on the phenotyping data for physiological traits by the physiologist, two each of drought tolerant (Poovan & Imbogo) and susceptible (Nendran & Calcutta 4) accessions were chosen to assess the polymorphism between them using advanced marker systems like AFLP. High molecular weight genomic DNA was isolated from the cigar leaf and quantified using UV spectrophotometer and then used for characterization using AFLP markers.

Cigar leaf of the test accessions were collected from the core collection block of NRCB, Trichy and

tested with 64 AFLP primer pair combinations (AFLP kit from M/s Invitrogen from USA) for detecting the polymorphism. Totally 63 primer pairs produced the scorable bands and the remaining one primer pair failed to give amplification in two of the test accessions. AFLP primer combinations amplified bands was size ranged from 20 to 1000 bp.

The average polymorphism registered in the present study was 59.79% indicating that there was substantial variation at the DNA level among the test accessions.

A total of 15 unique bands have been identified using 64 combinations of AFLP markers. Out of 15, seven were specific for tolerance and eight were specific for susceptibility (Table 17). The unique bands identified in the present study are said to be putative diagnostic markers, which could be eluted, cloned, sequenced and then converted into SCAR markers specific for drought tolerance or susceptibility. These markers help in screening the *Musa* germplasm accessions for drought.

Table 17. Putative markers for drought

Primer pairs	Bands specific for drought tolerance (bp)	Bands specificfor drought susceptible (bp)
E-AAC + M-CTT	-	400
E-AAC + M-CAC	-	290, 825
E-AAG + M-CTC	900	-
E-ACA + M-CAG	235	-
E-ACA + M-CTT	410, 691	-
E-ACC + M-CAA	1000	-
E-ACC + M-CAT	-	300
E-ACC + M-CTA	-	470
E-ACT + M-CAT	-	990
E-ACT + M-CTA	325	-
E-ACT + M-CTC	-	745
E-AGC+ M-CTA	-	800
E-AGG + M-CTA	225	-

5.5.3 Induced Mutation-A crop improvement strategy for developing dwarf and Sigatoka leaf spot resistant banana cv. Grand Nain

To develop dwarf and Sigatoka leaf spot resistant cv. Grand Nain through induced mutation, embryogenic cell suspension was used as base material. Disease free immature male flower buds of test cultivar were used for initiation of embryogenic callus, for which modified medium composition, standardised for cv. Robusta (which belongs to the same genomic group) was used. Observation showed that position of floral hands play a major role in formation of embryogenic callus. Ideal calli formed was used to initiate cell suspension culture. ECS developed was further irradiated at a dose ranging from 10 to 50 Gy using a ^{60}Co gamma source. Irradiated ECS was periodically shifted to regeneration and germination medium for the development of plantlets. Parallel study was carried out for mass screening method to reduce the frequency of chimeras among mutants obtained after irradiation. The screening method for tolerance to Sigatoka leaf spot is based on the infiltration of juglone (5-hydroxyl-1, 4 - napthoquinone) a secondary toxic metabolite of *Mycosphaerella fijiensis*. Efficiency of juglone was tested for necrotic induction on leaves in the presence of light after 24 hrs on cvs. Grand Naine, Rasthali (susceptible) and Udhayam (tolerant). Results indicated that juglone failed to induce necrotic spots at lower concentrations (100-750ppm) in cv. Udhayam a known tolerant variety whereas the same concentration was sufficient to induce spots on the leaves of cv. Rasthali and Grand Naine. It also found that time taken for the necrosis depends on various factors like age of plant from which leaf was collected (from net house or from field), nature of leaves (tender or mature) and concentration of the toxin used, etc.

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

Promoter construct from BBTV/BSV intergenic regions

BBTV intergenic regions of components 1 and 5 were cloned in pGEM-T easy vector. BBTV promoter-5 was constructed in pBI121 and transformed in *E.coli* DH5á. This promoter construct is mobilized to *Agrobacterium* and used for promoter assay (Fig. 32).

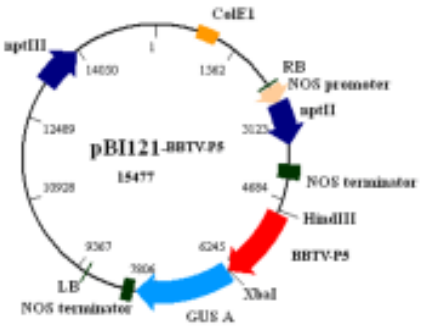


Fig. 32: Diagramatic representation of BBTVP5 derived promoter construct in plant transformation vector (pBI121)

For Poovan ECS, 80 male buds were used as explants for induction of embryogenic cells. Totally 150 calli were obtained and among these only 15 were of embryogenic. Received the BSV binary construct contain 731 bp fragment (5466-6196) of RT/RNaseH region of ORF III instead of coat protein gene from IARI under the ICAR Network Project on transgenic banana. The presence of insert in the binary construct was confirmed and used for co-cultivation.

Out of 907 male buds used as explants for induction of embryogenic calli, 343 callus were obtained and only 10 were of embryogenic in nature. Hill banana cell suspensions were established from the calli and are now kept in modified regeneration media for germination.

Mature embryogenic cell suspensions were cocultivated with *Agrobacterium* containing cp gene construct and plated on regeneration media along with kanamycin selection (54 no glass fibre membrane discs) and kept under dark for further maturation.

Out of 180 shoot tips of Hill banana cocultivatd with *Agrobacterium* harbouring the pBINAR BBTV CP gene only 47 have survived in the selection medium. All the shoot tips were transferred to proliferation media for multiple shoot development.

5.5.5 ICAR Network project on Diagnostics of emerging plant viruses- Developing diagnostic kit for BSV and BBrMV

BBrMV coat protein gene was cloned into pMAL - expression vector and transformed into *E. coli*. The fusion protein was expressed by induction using IPTG. The expressed protein was in insoluble fraction and found in the pellet, which was confirmed through SDS-PAGE analysis. Expressed protein has also been confirmed as "BBrMV-CP" through western blotting using potyvirus specific polyclonal antiserum. Polyclonal antiserum was raised against recombinant coat protein of BBrMV.

A partial fragment of 1115 bp size and 2.5 kb size covering HC-Pro and CI region of BBrMV was cloned into pGEM-T Easy vector sent for sequencing as part of molecular characterization. Nearly 70% of the complete genome has been cloned and sequenced.

5.5.6 Development of transgenic Hill banana resistant to BBTV (replicase mediated)

Developing BSMysV promoters constructs

BSMysV Intergenic regions were amplified and cloned in pGEM-T. Two BSMysV promoters (1209bp and 635bp) were constructed in *Hind*III and *Xba*I restricted *pBI*121 as *pBI*121-*BSP*1(Fig. 33) and *pBI*121-*BP*2 respectively

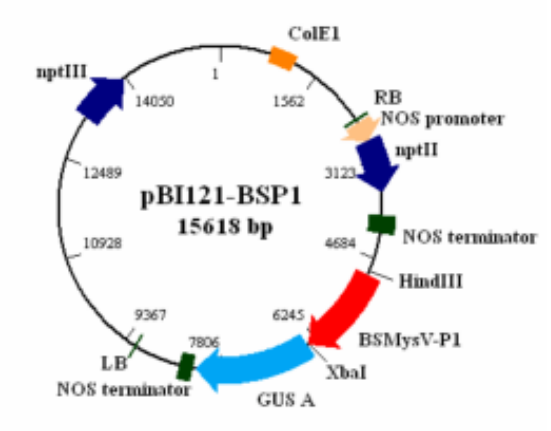


Fig. 33: Diagramatic representation of promoter construct derived from intergenic regions of BSMysV-TRY isolate

Developing ECS for hill banana and Poovan for transformation

Developing ECS for hill banana transgenics research

Out of 2812 male buds, which were used as explants for induction of embryogenic cells, 512 number of callus were obtained and among these only 10 were of embryogenic. Hill banana cell suspensions were established from the calli and are now kept in modified regeneration media for germination. Embryogenic cells are being used for co-cultivation.

Agobacterium mediated transformation

Mature embryogenic cell suspensions were co-cultivated with *Agrobaterium* contain Rep gene construct, and now they are in selection media (Hygromycin).

Out of 300 shoot tips of hill banana co-cultivated with *Agrobacterium* harboring the pCAMBIA BBTV.SR, only five have survived in the selection medium. All the five shoot tips are transferred to proliferation media for multiple shoot development.

5.5.7 ATL scheme for virus indexing

Testing for banana viruses for certified banana tissue culture laboratories in India

The Molecular Virology lab has been recognized by DBT, Govt of India and accredited from Nov 2007. Under this project, equipments such as PCR machine, ELISA reader and high speed refrigerated centrifuge were procured. Testing of tissue culture plants is being done on contract service basis to all the DBT certified tissue culture labs.

6 Technology Assessed and Transferred

Tissue culture technology developed at NRCB was transferred to State Horticultural Officials and knowledge was specially imparted for the selection of good tissue culture planting material.

Rice chaffy grains formulation of entomopathogenic fungus, *Verticillium lecanii* (NRCB VL -7) was released for controlling banana aphid, *Pentalonia nigronervosa* during the Kissan Mela organized at the Centre on 21st August 2008.

Two promising biocontrol agents *viz.*, *Paecilomyces lilacinus* and *Pseudomonas fluorescens* for the management of nematodes in banana were released in the name of NRCB Nemacinus I and Nemacens II during the Kissan Mela organized at the Centre on 21st August, 2008.

Released rice chaffy grain formulation of *Trichoderma viride* (NRCB -1) in the name of "Trichogold" for controlling the Fusarium wilt pathogen of banana present in soil at the Hill Banana Conference held on 29th April, 2008 at Thadiyangudisai, Dindugal dt., Tamil Nadu.

Television Talk

Sl. No.	Topic	Date of Telecast / TV Name	Scientist Name
1.	Integrated management of banana stem weevil	29.05.2008 / *Podhigai-Doordarshan*	B. Padmanaban
2.	Control of banana stem weevil	29.07.2008 / *Makkal* TV	B. Padmanaban
3	About *Beauveria bassiana*	02.02.2009 / *Makkal* TV	B. Padmanaban
4.	Advanced production technologies for banana cultivation	21.01.2009 / *Makkal* TV	V. Kumar

Radio Talk

Sl. No.	Topic	Date of Broadcast / Radio	Scientist Name
1.	Modern methods of controlling banana stem weevil	24.12.2008 / AIR, Trichy	B. Padmanaban
2.	Medicinal properties and uses of banana	27.06.2008 AIR, Trichy	C. K. Narayana
3.	Selection of healthy planting materials, high density planting and their management for achieving higher yields in banana	06.03.2009 AIR, Trichy	V. Kumar

Exhibitions:

NRCB participated in the exhibitions held during the following Seminars, Trainings, Field Days, Kissan Melas, etc

Sl. No.	Title	Organised by/ Place/ State	Date(s)	No. of farmers/ visitors participated
1.	Agricultural Fair	Tamil Nadu State Agricultural Dept & *Dinamalar*, Trichy	08-11.05. 2008	5000
2.	All India Litchi Show	NRC for Litchi, Muzaffarpur, Bihar	08-11.06.2008	4000
3.	One Day Training on Banana Cultivation	State Bank of India and Banana Farmers' Association, Thottiam, T. N.	21.07.2008	500
4.	Workshop on Banana Cultivation	NRC for Banana, and SBI, Trichy	26.07.2008	300
5.	Kissan Mela-cum-Exhibition	NRC for Banana, Trichy	21.08.2008	600
6.	Second Green Revolution Summit & Agro Protech 2008	Govt. of West Bengal, Kolkata	24-26.09.2008	800

Sl. No.	Title	Organised by/ Place/ State	Dates	No. of farmers/ visitors participated
7.	International Conference on Banana	AIPUB and NRCB, Trichy	24-26.10.2008	2000
8.	Seminar on Banana Cultivation	IOB, NABARD, Valliyur, Tirunelveli dt., T. N.	12&13.09.2008	1200
9.	Southern Regional Agricultural Fair- 2008	A.N.G.Ranga Agricultural University, Rajandranagar, Hyderabad	20-23.12.2008	5000
10.	Workshop-cum-Exhibition on Agriculture	*Makkal* TV, Vedasandur, Dindugul dt., T. N.	03&04.02.2009	1500
11.	Seminar on Botanists and Their Future	Bishop Heber College, Trichy	11.02.2009	750
12.	Workshop-cum-Farmers and Scientist Interaction Programme for Banana Growers	IFFCO and NRCB, Sirugampur, T. N.	17.02.2009	600

His excellency Gopalkrishna Gandhi, Governor of West Bengal, visiting NRCB stall at Second Green Revolution Summit and Agro Protech 2008 at Kolkata

Dr. M. M. Mustaffa, Director, NRCB, delivers the inaugural speech at farmers-scientists interaction programme at Sirugampur

7 Education and Training

Guidance of Students

Name of the Guide / Student	Title of the Thesis
Dr. P. Sundararaju, Principal Scientist (Nematology)	
S. Kishwar	Bacterial analysis and nematicidal property of vermiwash against root-lesion nematode (*Pratylenchus coffeae)* infesting banana
B. Sharanya	The effect of *Bacillus subtilis* on root-knot nematode *Meloidogyne incognita* on banana in cv. Ney Poovan
R. Nivetha	Nematicidal activity of *Bacillus cereus* against root-knot nematode, *Meloidogyne incognita* on banana in cv. Robusta
P. Manimangai	Molecular characterization of root-knot nematode *Meloidogyne incognita* isolates infecting banana by RAPD analysis
S. Hemalatha	Isolation of active components of *Tithonia diversifolia* for the management of Banana root lesion nematode, *Pratylenchus coffeae*

Student Name	Title of the Thesis	Guide Name
Dr. B. Padmanaban , Principal Scientist (Entomology)		
M. Sumitha	Isolation and evaluation of Green Muscardine fungus, *Metarhizium anisopliae* against Banana stem weevil, *Odoiporus longicollis*	
Dr. S. Uma, Principal Scientist (Horticulture)		
A. Thanalakshmi Dharini	Macro and microprpagation of musa laterita (section-rhodochlamys) and genetic diversity analysis using RAPD markers	
L. Jaisy Janet	Effect of plant growth promoting rhizosphere microbes and phytohormones on bud proliferation in banana (cv. Rasthali)	
R. Vasanthi	a. *In-vitro* screening of musa spp. (cv. Robusta -AAA) against salt stress using shoot tips and b. cDNA and enzyme expression studies to determine infection time course for *Mycosphaerella musicola* in banana	
S. Lakshmi	a. Embryo rescue and germination studies in wild musa spp. And b. Genetic fidelity in sucker, tissue culture and cell line derived plantlets of cv. Rasthali using RAPD markers	
V. Swaminathan	Studies on polymorphism for drought in diverse diploids (aa) of banana (*Musa* spp.) using AFLP markers	
Jyothilakshmi	Identification of nutrionally rich banana varieties for high carotenoids, macro and micronutrient contents	
S. Chandhru	Preliminary studies on genetic transformation in banana	
Poornima Priyadharshini	*In vitro* studies of differential responses of banana explants for salt stress	
Dr. I. Ravi, Senior Scientist (Physiology)		
M. Savithiri	Effect of exogenous application of Abscisic acid, AcetylSalicylic acid, Butylated Hydroxy Toluene on soil moisture deficit stressed banana plants.	
R. Gomathi	Biochemical studies on abiotic stress protective chemicals on salt stressed banana plants	
M. Rajagopi	Effect of salt stress on Musa AAA (Cavendish sub group) Grand Nain plants.	
Carol Doyana Mary	Effect of soil moisture deficit stress on *Musa* AAA (Cavendish sub group) Grand Nain plants	
Dr. R. Thangavelu, Senior Scientist (Pathology)		
P. Ganga Devi	Isolation, molecular characterization and evaluation of bacterial endophytes for the suppression of Fusarium wilt pathogen *Fusarium oxysporum* f.sp. *cubense*	
R. Baby Shalini	Isolation, molecular characterization and evaluation of bacterial endophytes and epiphytes for the suppression of Sigatoka leaf spot diseases caused *Mycospharella* spp.	
Dr. R. Selvarajan, Senior Scientist (Virology)		
P. Sriramji	Cloning and sequence analysis of partial coat protein gene of *Cucumber Mosaic Virus* affecting banana in Kerala	
R. M. Shyam Sundar	BBTV and its vector *Pentalonia nigronervosa* relationship; molecular detection and confirmation of virus acquisition in vector	

Student Name	Title of the Thesis	Guide Name
S. N. Dhanabalu	Transmission of BSV by mealybug; Molecular confirmation of virus acquisition by vector and transferred to banana	
K. Sivaranjani	Molecular diversity of *banana streak virus* in Karur and Tanjore districts	
M. Tamil Selvi	PCR amplification of different banana streak virus species in the commercial cultivars of banana	
P. Sivaranjani	Molecular screening of BSMysV and BSOLV free planting material in cv. Poovan (AAB)	
Dr. M. Mayil Vaganan, Senior Scientist (Biochemistry)		
P. Preetha	Identification and characterization of differentially regulated proteins in salt resistant and susceptible banana cultivars	
S. Sasirekha	Studies on identification of differentially expressed proteins in cultivar Poovan infected with Banana Streak Virus	
R. Lavanya	Studies on polyphenol oxidase in fruits of Cavendish subgroup bananas in relation to oxidative browning	
Dr. S. Backiyarani, Senior Scientist (Bio-Technology)		
S. Savitha	Cloning and characterization of resistance gene analogues (RGAs) in banana	
D. Joanna Magdalene	Isolation and characterization of resistant gene analogue sequences of the Nucleotide Binding Site (NBS) from *Musa* sp.	
Dr. M. S. Saraswathi, Senior Scientist (Horticulture)		
S. Revathy	*In vitro* studies on induced mutagenesis (Sodium azide) and screening for Fusarium wilt tolerance using fusaric acid in banana cv. Rasthali	
M. Azeera	Studies on polymorphism for drought in diverse triploids (AAB) of banana (*Musa* spp.) using AFLP markers	
V. Sindhuja	Genetic diversity and phylogenetic analyses in core collection clones of banana (*Musa* spp.) using retrotransposan based markers	

8 Awards and Recognitions

The National Research Centre for Banana was presented a **'Plaque of Recognition'** by the Bioversity International, France and the Banana Asia Pacific Network (BAPNET), Philippines, in sincere recognition of NRCB's role as leading partner institution in the framework of BAPNET with the prime goal of advancing banana R&D in India in particular and in Asia-Pacific in general and in appreciation of its gracious and effective hosting of the 6th BAPNET Steering Committee Meeting and the Taxonomy Advisory Group (TAG) meeting.

Dr. M. M. Mustaffa, Director, NRCB was awarded the prestigious international 'Pisang Rajah' award by BIOVERSITY and BAPNET, Philippines for the biennium 2006-08 for his outstanding contribution to banana research and development in India.

Dr. S. Uma received the prestigious international 'Pisang Rajah' award by BIOVERSITY and BAPNET, Philippines for the biennium 2006-08 for the contribution to collect, conserve, characterize *Musa* genetic diversity in India. It also recognizes her significant contribution for the implementation of collaborative projects of BIOVERSITY.

Dr. M.M. Mustaffa, Director, Dr. P. Sundararaju and Dr. R. Selvarajan received the 'Fellow of AIPUB' award for their outstanding contribution to banana research and development in India by the Association for the Improvement in Production and Utilization of Banana (AIPUB) at International Conference on Quality Production of Banana for Domestic and Export Markets during 24-26, October 2008 at Tiruchirapalli, Tamil Nadu.

Dr. P. Sundararaju, received the best poster award for the research paper entitled 'Management of root-knot nematode (*Meloidogyne incognita*) using

Dr. M.M. Mustaffa, Director, NRCB receives the 'Plaque of Recognition, award from Dr. A. Molina, Co-ordinator, BAPNET, Philippines

Dr. M.M. Mustaffa, Director, NRCB receives the '*Pisang Raja'* award from Dr. H.P. Singh

Dr. S. Uma, Pr. Scientist receives '*Pisang Raja'* award

non-pathogenic nematodes' at the National Symposium on Microbial Biodiversity Bioremediation & Biotechnology, organized by Cauvery College for Women and Bharathidasan University at Tiruchirapalli on 28&29, July, 2008.

Dr. R. Selvarajan, received best poster presentation award for paper entitled on 'Evaluation of imazalil (Fungaflor) on post harvest diseases and shelf life of banana cv. Grand Nain' in National Seminar on Advances in plant pathology for sustainable agriculture held during 24&25, November, 2008 at TNAU, Coimbatore, Tamil Nadu.

Dr. B. Padmanaban acted as external examiner and convener for the Ph. D. *viva-voce* of Mr. Sachin P. James at Bharathiar University, Coimbatore on 6, August 2008.

Dr. B. Padmanaban was a Member of the Board of Examiners for the award of Ph. D. degree under the Faculty of Science, University of Kerala, on 5, December 2008.

Dr. S. Uma acted as external examiner for evaluation of two M.Sc. (Hort.) and two Ph.D. (Hort.) thesis from UAS, Bangalore.

Dr. V. Kumar was nominated as a Member, Executive Council of Association for Improvement in Production and Utilization of Banana (AIPUB).

Dr. R. Selvarajan acted as external examiner for evaluation of five M. Sc. (Ag.) theses, by TNAU, Coimbatore and a Ph. D. thesis by Mangalore University, Karnataka.

Dr. R. Selvarajan was nominated as Chief Editor by the Executive Council of 'Association for Improvement in Production and Utilization of Banana (AIPUB)' in the 14th General Body Meeting of AIPUB with effect from Nov., 2008.

Dr. R. Selvarajan acted as external examiner for selection of JRF at ISSR, Calicut under the scheme Accredited Test Laboratory under National Certification System for tissue culture raised plants (NCS-TCP) on 25 April, 2008.

Drs. P. Sundararaju, S. Uma, B. Padmanaban, I. Ravi, R. Thangavelu, R. Selvarajan, M. Mayil Vaganan and S. Backiyarani were recognized as Research Advisers for guiding research work of candidates leading to the degree of Ph. D. by Bharathidasan University, Tiruchirapalli, T. N.

9 Linkages and Collaborations in India and Abroad

A memorandum of understanding was signed on 06.05.2008 between the National Research Centre for Banana and University of Agricultural Sciences, Bangalore on collaborative research programmes, guidance of students of the University by the scientists of the NRCB, training of scientists and technical personnels under human resources development, etc. Also, a MoU for the development of particle boards using pseudostem sheaths of banana was signed between NRCB and IPIRTI, Bangalore. Between the NRCB and Bharathidasan University, Tiruchirapalli, a MoU was inked on recognition of NRCB as one of the Research Centers of the University and recognition of scientists of the Centre for guiding the students for doctoral degree.

Dr. M. M. Mustaffa, Director, NRCB and Dr. P. G. Chengappa, Vice-Chancellor, UAS, Bangalore with MoU documents

New Project

A new project entitled 'Regeneration and safety duplication of priority *Musa* collection' funded by BIOVERSITY, France has been initiated with budget of Rs. 54 lakhs for a period of three years. Dr. S. Uma is project leader.

10 Publications

Research Papers

Kurian, S. P., Sivakumar, G., Josephrajkumar, A., Backiyarani, S., Murugan, M. and Shiva, K. N. 2008. Management of anthracnose disease (Colletotrichum gloeosporioides (Penz) Penz & Sac) of black pepper (*Piper nigrum* L.) in the high ranges of Idukki District, Kerala. *J Spices and Aromatic Crops*, **17**(1):21-23.

Manohari, C., Backiyarani, S., Jebasingh, T., Archana S. and Usha, R. (2008). Efficient plant regeneration in small cardamom (*Elettaria cardamomum* Maton.) through somatic embryogenesis. *Ind. J Biotech.*, **7**:407-409.

Nithya Devi, A., Ponnuswami, V., Sundararaju, P., Soorianathasundaram, K., Sathiamoorthy, S., Uma,S. and Van den Bergh, I. 2007. Mechanism of resistance in banana cultivars against root-lesion nematode, *Pratylenchus coffeae*. *Ind. J Nematol.*, **37**:138-144.

Nithya Devi, A., Ponnuswami, V., Sundararaju, P., Soorianathasundaram, K., Sathiamoorthy, S., Uma, S. and Van den Bergh, I. 2007. Phenylalanine ammonia luase and total phenol content in resistant banana to *Pratylenchus coffeae*. *Ind. J Nematol.*, **37**:149-155.

Nwauzoma, A.B., Uma, S., Mustaffa, M. M. and Durai, P. 2009. Response of banana hybrids to Sigatoka leaf spot disease under tropical conditions in southern India. *Acta Agronomica Nigeriana*, **8**(1):33-42.

Prasuna, A. L., Jyothi, K. N., Prasad, A. R., Yadav, J. S. and Padmanaban, B. 2008. Olfactory responses of banana pseudostem weevil, *Odoiporus longicollis* Olivier (Curculionidae: Coleoptera) to semiochemicals from conspecifics and host plant. *Curr. Sci.*, **94** (7):896-900.

Selvarajan, R., Balasubramanian, V., Kavitha, K., Kavitha, K. S., Sathiamoorthy, S. and Y. S. Ahlawat. 2008. Detection of banana bunchy top virus (BBTV) and banana streak Mysore virus (BSMysV) by PCR: Impact of storing virus infected banana samples. *Ind. J Virol.*, **19** (2):28-33.

Sundararaju, P. N. Swarnakumari, and S. Uma (2008). Evaluation of Banana (*Musa* spp.) germplasm against root-knot nematode (*Meloidogyne incognita*). *Ind. J Ag. Sci.*, **78**(6):563-566.

Sundararaju, P. and Kurinjimalar, S. 2008. Effect of *Meloidogyne incognita* (Kofoid & White) on growth, physiological and biochemical changes in banana. *Pest Management in Hort. Ecosystem*, **14**(2):161-167.

Sundararaju, P. and Thenmozhi, R. 2008. Efficacy of neem based pesticides used for sucker treatment against root-knot nematode infesting banana cv. Robusta. *Pest Management in Hort. Ecosystem*, **14**(2):155-160.

Sundararaju, P. and Sudha, R. 2008. Organic amendments for the management of root-lesion nematode, *Pratylenchus coffeae* Goodey in banana. *Pest Management in Hort. Ecosystem*, **14**(2):148-154.

Thangavelu, R. and Jayanthi, A. 2008. RFLP analysis of rDNA-ITS regions of native non- pathogenic *Fusarium oxysporum* isolates and their field evaluation for the suppression of Fusarium wilt disease of banana. *Aust. Pl. Pathol.*, **38**(1):13-21.

Popular Articles

Kumar, V. and Jeyabaskaran K. J. 2008. Advanced production technologies for enhancing the production and productivity of bananas and plantains. *Souvenir: International Conference on Quality Production of Banana for Domestic and Export Market*, 24-26 Oct., NRCB, Tiruchirapalli, pp. 29-37.

Kumar, V. 2008. Producing quality banana through improved technology. *Ind. Hort.*, **53**(3):22-24 .

Mustaffa, M. M. and Kumar, V. 2008. Feasibility and potential of organic farming in banana *Souvenir: National Conference on Organic Farming in Horticultural Crops with Special Reference to Plantation Crops*. CPCRI, Kasaragod, 15-18 Oct.

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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 different TC industries, such as SPIC-ABC, Coimbatore; Godrej Agrovet, Ranga Reddy Dist, AP; Ramco Biotech, Bengaluru; Reliance Bio, Mumbai; Jain Irrigation System Ltd, Jalgaon; Gugle Biotech, Pune; Arcadia Agro, Vadodara; Rise'n Shine biotech, Pune; Indrayani Biotech, Pune; Brookfield Biotech, AP; Ace AgroTtechnologies, Secundrabad, AP; Seema Biotech, Maharashtra; Beej Biotech, Pune; Sarjan Biotech, Bhuj, Gujarat; Thiruvensun Biobotanica, Chennai; Hari Biotech, Pune, Sai Lara Biotechnologies, Hyderabad; and Nirmitee Biotech Pune and S&S Agro biotech Pvt Limited, Secunderabad, AP were indexed with ELISA, PCR and NASH technologies. This financial year 6,291 samples have been tested for BBTV (3385), BBrMV (248), BSV (1538) and CMV (1120). An amount of Rs.12 lakhs was generated through these contract services.

Resource generation through sales

Sales of farm produces - Rs. 7.5 lakhs.

12 RAC, IMC and IRC

RAC Meeting

The 10th Research Advisory Committee meeting commenced with the field visit to Research Farm in the morning of 23rd December, 2008. The Chairman and all the members reviewed the ongoing experiments in the field. The Director and Scientists explained the research activities. All the experiments under various projects were explained to the RAC Chairman and members. The Chairman and members of the RAC appreciated the well maintenance of research farm and the research work under different programmes. After the field visit, the RAC visited the laboratories, seen the infrastructure facilities available at each laboratory and also were explained the research activities by the respective scientists. In the afternoon of 23rd December, 2008, the 10th Research Advisory Committee Meeting was held at the committee room of NRCB, wherein, Dr. S. J. Singh, chaired the session and conducted the proceedings. Two minute silence was observed for the demise of Dr.R.M. Pandey, Chairman, RAC.

Dr. M. M. Mustaffa, Director, National Research Centre for Banana, Trichy, while welcoming the Chairman and members of RAC, gave a brief account of the salient research achievements made by the NRCB during the last one year. The Action Taken Report on the recommendations of 9th RAC was presented by Dr. P. Sundararaju, Member Secretary. The Chairman and Members were fully satisfied on the action taken on the recommendations of the previous RAC Meeting and confirmed the minutes of 9th RAC. This was followed by presentations of Head of Sections on the various research activities on banana. After detailed discussions on the research progress of the ongoing projects, the RAC suggested the future programmes to be carried out in various areas of research in banana. The Chairman and other RAC Members appreciated the work carried out by the Scientists and also the infrastructure facilities developed at the Centre.

Dr. S.J. Singh chairing the RAC meeting

RAC Members

1.	Dr. S. J. Singh	Chairman
2.	Dr. N. Kumar	Member
3.	Dr. B. Bandyopadhyay	Member
4.	Dr. R. C.Tiwari	Member
5.	Dr. Lalitha Anand	Member
6.	Dr. M. M. Mustaffa	Member
7.	ADG (Hort.)	Member
8.	Dr. P. Sundararaju	Member Secretary

The significant decisions of RAC are:

1. Works on DNA finger printing of germplasms may be initiated and DNA bar-coding may be done for important and unique germplasms and help of NRC on DNA Finger Printing may be taken for this.

2. More sensitive molecular markers need to be developed to assess genetic stability of cryo-preserved germplasm.

3. Nutritional trial on fixed plots at road side for crop exhibition with 1000 m^2 large plot with one most promising cultivar of banana and recommended dose of fertilizers may be taken up.

4. Confirmation of the *Foc* race-1 affecting Cavendish is required and proper care must be taken to see that this race does not spread to other places.

IMC Meeting

The twelfth meeting of the Institute Management Committee was held on 29.07.2008 and 22.12.08 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: 2008-'09; Recognition of Authorized Medical Attendants for the benefit of staff and family

Dr. M. M. Mustaffa, Director, chairing the twelfth IMC meeting

members; Post-facto approval for dropping of some equipments; Distribution honorarium to scientists and staff for testing of viruses.

IMC Members

Chairman

Dr. M. M. Mustaffa
Director, NRC for Banana, Trichy

Members

Dr. Robert Vincent
Deputy Director of Horticulture,
Trichy

Dr. E. R. Suresh
Principal Scientist, IIHR, Bengaluru

Dr. P. Sundararaju
Principle Scientist, NRC for Banana, Trichy

Shri. K.K. Hamza
FAO, SBI, Coimbatore

Non- Official Member

Prof. S. Sivaramakrishnan,
Chairman
M/s. Sankara Group of Institution, Trichy

Member Secretary

Shri. B. Vijayakumar
AAO, NRC for Banana, Trichy

IRC Meetings

Twelfth Institute Research Council Meeting was held on 1st and 7th May, 2008 and 13th IRC was held on 4th and 5th, February and 11th March, 2009. Project-wise presentations were made by respective scientists. The salient achievements along with the activities to be taken up for next year were presented. The Director, Chairman of IRC, gave critical inputs for the experiments to be conducted in the field as well as in laboratory. He asked the scientists to propose new projects for external funding in the identified area of research in banana. Two new institute projects were proposed, which were approved by the house. The member secretary proposed a vote of thanks at the end of meeting.

Dr. M.M. Mustaffa, Director, chairing the XIII IRC meeting

13 Trainings/ Workshops/ Seminars/ Conferences/ Winter & Summer Courses/ Meetings Attended by Scientists

Scientist	Title of the Programme/ Venue	Date(s)
M. M. Mustaffa	TNAU Research Council Meeting, TNAU, Coimbatore	04.04.2008
	Banana Seminar – organized by Rashtria Chemicals, Trichy	07.04.2008
	Horticulture Subject Core Group Committee Meeting, TNAU, Coimbatore	25&26.04.2008
	Review Meeting called by DDG (Hort.), ICAR, IIHR, Bengaluru	02.05.2008
	MoU signing between UAS, Bangalore and NRCB, Trichy, UAS, Bengaluru	06.05.2008
	Annual Workshop on AICRP on Tropical Fruits, TNAU, Coimbatore	09-11.05.2008
	DAP-NADP Meeting, Trichy	24.05.2008
	Group Discussion Meeting for Trainings, SRS, Sirugamani	28.05.2008
	Interaction meeting on nutritional dynamics in Horticultural Crops, IIHR, Bengaluru	14&15.06.2008
	NAIP Consortium Advisory Committee Meeting, Navsari Agril. University, Navsari, Gujarat	21.06.2008
	Hort. Institutes – Review Meeting called by DDG (Hort.), ICAR, IIHR, Bengaluru	23&24.06.2008

	State Level NHM Meeting at Secretariat, Chennai	15.07.2008
	EUREGAP – Cold Storage Certification Meeting, Trichy	19.07.2008
	Farmers' Meet, Thottiam, TN	23.07.2008
	Chief Guest – Microbiology Association – Inaugural Function, Jamal Mohd. College, Trichy	01.08.2008
	Chief Guest – Workshop on Molecular Diagnostic, Vivekananda College of Arts and Science, Namakkal, TN	18.08.2008
	Workshop on Post Harvest Technology, IIHR, Bengaluru	23&24.08.2008
	Brain Storming Session on Climate Change in Horticultural Crops, CPRI, Shimla	06&07.09.2008
	International Workshop on Natural Fibre-Technical Committee Preliminary Meeting at ASRB, New Delhi	06.10.2008
	MoU Signed between IFTRI, Bangalore and NRCB, Trichy, IFTRI, Bengaluru	07.10.2008
	EFC of 11th FYP Finalization Meeting, ICAR, New Delhi	14&15.10.2008
	ASRB Foundation Day Celebration – Technical Workshop, ASRB, New Delhi	04.11.2008
	International Workshop on Natural Fibre – Technical Committee Programme Finalization Meeting – CIRCOT, Mumbai	05.11.2008
	Natural Fibre – Preliminary Meeting, ICAR, New Delhi	16.12.2008
	ICAR Institutes Directors' Conference, New Delhi	14&15.01.2009
	National Conference on Banana, Pune	17.01.2009
	Seminar on Natural Fibre, CRIJAF, Kolkatta	25.01.2009
	Annual Workshop – AICRP on Vegetable Crops. TNAU, Coimbatore	11&12.02.2009
	Scientific Advisory Committee Meeting, KVK, Sirugamani	19.02.2009
	Special Lecture in NLT on Natural Fibres of India, CRIJAF, Kolkatta	27&28.02.2009
	TNAU Research Council Meeting, TNAU, Coimbatore	02.03.2009
	NHM-SLEC Meeting, Secretariat, Chennai	04.03.2009
P. Sundararaju	Nematode management strategies and challenges in banana, HC&RI, Periyakulam, TN	04.04.2008
	Biennial Group Discussion on AICRP (Tropical fruits), TNAU, Coimbatore	9-11.05.2008
	Brainstorming Session on use of Innovative Extension Methodologies in TOT in Horticulture, IIHR, Hessarghatta, Bengaluru	24.06.2008
	Interactive Meeting on Post Harvest Management of Horticultural Crops, IIHR, Hessarghatta, Bengaluru	23&24.08.2008
	National Symposium on Organic Farming in Horticultural Crops with Special Reference to Plantation Crops, CPCRI, Kasaragod, Kerala	15-18.10.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	National Conference on Banana, Pune	16&17.01.2009
B. Padmanaban	Delivered lecture on the anagement of Insect Pests of Banana at the Hill banana conference organized by the hill banana growers association at Thandikudi, TN	29.04.2008

	Farmers Training, NRCB, Trichy	27.05.2008
	Delivered a special lecture on Integrated Pest Management in Banana to the III Year B. Sc. (Ag.) students of Anbil Dharmalingam Agricutlural College & Research Institue, TNAU, Tiruchirapallion	13.08.2009
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	Farmers Meeting, Vanoli Uhavar Sangam, Tiruchirapalli	15.11.2008
	Delivered 7 lectures and one practical class to participants of eight days model training course on Integrated Pests and Disease Management in Banana	17-24.11.2008
C. K. Narayana	Biennial Group Workers meeting of AICRP on Tropical Fruits, TNAU, Coimbatore	08-10.05.2008
	Workshop on banana marketing issues, Cuddapah, Andhra Pradesh	05.07.2008
	Meeting on EUROGAP certification for banana, Trichy	19.07.2008
	Seminar on Banana Cultivation and PHM, Thottiyam, TN	21.07.2008
	Interactive Meeting on Post Harvest Technology of Horticultural Crops, IIHR, Bengaluru	23&24.08.2008
	NAIP sponsored Workshop on Web design methodologies, protocols and content management strategies, NAARM , Hyderabad	09&10.09.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
S. Uma	Orientation meeting for the project on Accreditated Test Laboratory under National Certification System for Tissue culture Raised plants, DBT, New Delhi	28.04.2008
	Meeting on BIOVERSITY work plan for the biennium, ICAR, New Delhi	16.06.2008
	Institute Biosafety Committee, NRCB, Trichy	18.06.2008
	Group meeting on Commercialization Plant varieties of Vegetatively Propagated and Perennial Crops, SBI, Coimbatore	28.07.2008 & 23.09.2008
	Brainstorming session on Post harvest technology for Horticulture crops, IIHR, Bengaluru	14.08.2008
	International Taxonomic Advisory committee meeting, Trichy	20-25.10.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	Meeting on developing DUS procedure for Agri, Horti and Grass crop species, New Delhi	23.03.2009
	BRNS- TDPM meeting on BARC funded projects, Mumbai	03&04.02.2009
	Annual Review meeting of the Networking project on Transgenics crops in crop plants, NRC for Plant Biotechnology, New Delhi	04&05.03.2009
I. Ravi	Training-cum-Workshop on IP and Technology Management, NAARM, Hyderabad	29-31.05.2008
	Training course on Integrated Pest and Disease Management in Banana, NRCB, Trichy	17-24.11.2008
	Winter school on Advances in design and Analysis of Agricultural Experiments, IASRI, New Delhi	14.01-03.02.2009

	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	Golden Jubilee Conference on Challenges and Emerging Strategies for Improving Plant Productivity, IARI, New Delhi	12-14.10.2008
	Brainstorming session on Impact of Climate Change for Research Priority Planning in Horticulture Crops, CPRI, Shimla	06&07.09.2008
	Interactive meeting on Postharvest Technology of Horticultural Crops, IIHR, Bengaluru	23&24.08.2008
R. Thangavelu	International Conference on Banana, Trichy	24-26.10.2008
	Sixth BAPNET Meeting, Trichy	22-24.10.2008
	Banana Farmers Seminar, Thottiam, TN	21.07.2008
	Banana Farmers Seminar, Sirugambur, TN	17.02.2009
	Banana Seminar on Advanced Production Technologies for Enhancing the Production and Productivity of Banana, Valliyur, TN	12&13.09.2008
	Banana Farmer's meet, Chinnamanur, TN	03.09.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
R. Selvarajan	One day operational level training programme for incharge of ATL under NCP, IARI, New Delhi	28.04.2008
	Biennial workshop of AICRP- tropical fruits, TNAU, Coimbatore	09-11.05.2008
	Selection committee meeting as external expert for selection of JRF, IISR, Calicut	25.04.2008
	A review meeting of ICAR Network project on transgenic in crops, New Delhi	02.06.2008
	DBT project review meeting on Development of virus resistant transgenic in crops, M.D.U, Rhothak	06&07.07.2009
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	International training programme on virus indexing in banana, NRCB, Trichy	28.10-01.11.2008
	National Seminar on Advances in plant pathology for sustainable agriculture, TNAU, Coimbatore	24&25.11.2008
	National Conference on Banana, Pune, Maharashtra	16&17.01.2009
	Workshop for DBT nominees and IBSC members for strengthening regulatory compliance by IBSC's, MSSRF, Chennai.	02.02.2009
	15th AICRP biennial workshop on tropical fruits, HC&RI, TNAU, Coimbatore	09-12.05.2008
	ICAR project review meeting on network project on transgenic in crops- transgenic component, NRCPB, New Delhi.	05.03.2009
	DBT project review meeting and task force meeting on Development of transgenic Hill banana, TNAU, Coimbatore	18.03.2009
V. Kumar	Banana Farmers Meet, Thottiam, TN	21.07.2008
	Banana Growers' Meet, Chinnamanur, TN	03.09.2008

	Banana Seminar on Advanced Production Technologies for Enhancing the Production and Productivity of Banana, Valliyur, TN	12&13.11.2008
	Horticultural Workshop, Vedasandhur, TN	04.01.2009
	Banana Growers Workshop, Sirugambur, TN	17.02.2009
	XV Biennial Workshop of AICRP (TF), TNAU, Coimbatore	09-11.05.2008
	Brain Storming Session on Use of Innovative Extension Methodologies in Horticulture, IIHR, Bangaluru	24.06.2008
	Second Green Revolution Summit & Agro Protech 2008, Kolkata, West Bengal	24-26.09.2008
	National Conference on Organic farming in Horticultural Crops with Special Reference to Plantation Crops, CPCRI, Kasaragod	15-18.10.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
M. Mayil Vaganan	Training–cum-workshop on IP and Technology Management in ICAR System, NAARM, Hyderabad.	29-31.05.2008
	DPC meeting as member for technical personnel of NRCB, Trichy	28.06.2008
	International Conference on Quality Production of Banana for Domestic and Export Market, NRCB, Trichy	24-26.10.2008
	Integrated Pests and Diseases Management in Banana, NRCB, Trichy	17-24.11.2008
	National Conference on Eco-Friendly Approaches in Sustainable Agriculture and Horticulture Production, Amity University, Lucknow	28-30.11.2008
K. J. Jeyabaskaran	Group meeting of the AICRP and ICAR Ad-hoc schemes on Tropical Fruits, TNAU, Coimbatore.	09-12.05.2008
	Interactive Meeting on Nutrient Dynamics in Horticultural Crops Chaired by the DDG (Hort.), IIHR, Bengaluru	14&15.06.2008
	Training-cum-workshop on IP and technology management-Theme: Procedural requirements of patenting, NAARM, Hyderabad	29-31.05.2008
	2nd Research Advisory Committee Meeting for KVK, Dindivanam, TN	06-09.2008
	Second Green Revolution Summit and Agro Protech-2008, Kolkata	24-26.09.2008
	Banana Farmers Meeting, Thottiyam, TN	20.11.2008
	Farmers Meeting, Allur, TN	25.11.2008
	State Level Ecological Sanitory Workshop, Trichy, TN	05.02.2009
	Farmers Meeting, Sirugampur, TN	28.02.2009
	Farmers Trainings, NRCB, Trichy	27.05-03.06.2009 05.08-16.09.2009
S. Backiayarani	Group meeting on Commercialization of ICAR Plant varieties of Vegetatively Propagated and Perennial Crops and Low Volume varieties, SBI, Coimbatore	28.07.2008& 23.09.2008
	International Taxonomic Advisory committee meeting, Trichy	20-25.10.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008

	Training–cum-workshop on IP and Technology Management in ICAR System, NAARM, Hyderabad.	29-31.05.2008
	Training on Integrated pest and disease management in banana, NRCB, Trichy	17-24.11.2008
	Annual Review meeting of the Networking project on Transgenics crops in crop plants, NRC for Plant Biotechnology, New Delhi	04&05.03.2009
M. S. Saraswathi	Training on Marker Assisted Selection in Rice at DRR, Hyderabad	07-11.07.2008
	DPC meeting as Member Secretary for consideration of the promotion cases of Administrative personnel of NRCB	28.06.2008
	International Taxonomic Advisory committee meeting, Trichy	20-25.10.2008
	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	Training on Integrated pest and disease management in banana, NRCB, Trichy	17-24.11.2008
	Training on Genome Assisted Breeding, TNAU, Coimbatore	03.02-05.03.2009
R. Natarajan	International Conference on Quality Production of Banana for Domestic and Export Markets, NRCB, Trichy	24-26.10.2008
	International training on *In vitro* and cryopreservation techniques for conservation of plant genetic resources, NBPGR, New Delhi	17-29.11.2008

14 Seminars/ Meetings/ Workshops/ Conferences/ Summer Institutes and Farmers Training Organized at the Centre

An international training programme on '*Musa* virus indexing' was held at Molecular Virology Lab., NRC for Banana, Tiruchirapalli from 28th Oct. to1st Nov., 2008. This training was conducted by Dr. J. E. Thomas, Senior Principal Plant Virologist, QDPI, Australia. The training programme was coordinated and sponsored by Bioversity International, France in collaboration with NRC for Banana, ICAR.

A Model Training Course on 'Integrated pest and disease management in banana' sponsored by Central Directorate of Extension Ministry of Agriculture, Govt. of India, New Delhi was held during 17-24, Nov. 2008.

The following farmers training programme were held at the Centre organized by NRCB with the financial assistance of National Horticultural Board, Gurgaon.

Kissan Mela

The National Research Centre for Banana, Tiruchirapalli, organized a Kissan Mela on 21st August 2008 at its Research Farm located at Podavur village. The Mela was organised to celebrate the 15th Foundation Day of the Centre and to disseminate the improved technologies developed by the NRCB on production, protection and post-harvest aspects of banana. Over 400 banana farmers from Tamil Nadu, Kerala and Andhra Pradesh and agriculture extension workers from banana-growing districts of Tamil Nadu participated in the Mela.

In inaugural function, Dr. M. M.Mustaffa, Director, NRC for Banana welcomed the Chief Guest, other dignitaries, farmers and extension workers participating in the Mela. He spoke about the improved production, protection and post-harvest technologies developed by the Centre and exhorted the farmers to adopt such technologies to obtain higher income from banana cultivation. Thiru K. N. Ramajeyam, Chairman, Saraswathi Krishi Vigyan Kendra (KVK), Pulutheri, Karur district, was the Chief Guest, who declared open the exhibition and delivered chief guest address. During the Kissan Mela, two technologies were released for the benefit of the farmers by the chief guest. On the occasion, 10 banana farmers and entrepreneurs were honoured as 'progressive farmers'. Thiru B. Sivaramakrishanan, Chairman, Sankara group of institutions, Tiruchirapalli, presided over the function and delivered the presidential address. Dr. S. Ramanathan, Head, KVK (TNAU), Sirugamani; Dr. N. Barathi, MD, Growmore Biotech., Hosur; Mr.

Dr. M. M. Mustaffa, Director, NRCB releases rice chaffy grain formulation of EPF in Kissan Mela

Interaction between Farmers and Scientists during Kissan Mela at NRCB Research Farm

Thukili C. Subramaniam, President, All India Radio Farmers Association, Tiruchi; Thiru G. Ajeethan, Secretary, Tamil Nadu Banana Growers Federation and Thiru R. Narayanaswamy, Theni District Banana Growers Association, spoke and felicitated the banana farmers. Finally, Dr. P. Sundararaju, Principal Scientist of the Centre proposed a vote of thanks.

In the technical session, scientists of the Centre made presentations on improved technologies developed on production, protection and management of pests, diseases and nematodes and various post-harvest products. An interaction session between scientists and farmers was also held and farmers clarified their various dogbts on banal1a productiol1' For the benefit of farmers from Andhra Pradesh, Dr. C. K. Narayana, Principal Scientist, clarified their doubts in Telugu.

An exhibition was arranged on the occasion and was participated by various fertilizers, pesticide and tissue culture companies and post-harvest entrepreneurs. The farmers visited the exhibition stalls earnestly. The farmers were taken to the fields of experimental farm and scientists explained on-field the different technologies and demonstrated practically the high-density planting, organic farming, drip-irrigation and fertigation in banana cultivation and integrated management techniques of pests, diseases and nematodes and other aspects of banana cultivation.

At end of the day, the farmers were given a kit consisting of booklets and pamphlets on technologies of banana cultivation, various banana value added products and tissue cultured banana seedlings of Udhayam variety released by the Centre.

BAPNET Meeting

National Research Centre for Banana (NRCB) hosted sixth Banana Asia-Pacific Network (BAPNET) Steering Committee Meeting held at Tiruchirapalli, Tamil Nadu during 22-24, October 2008. The meeting was attended by 21 committee members / representatives, including four observers from Guangdong Academy of Agricultural Sciences (GDAAS), China. Dr. H. P. Singh, DDG (Hort.), ICAR was the General Chairman of the meeting and Dr. M. M. Mustaffa, Director, NRCB also participated in the meeting.

The inaugural session of the 6th BAPNET meeting on 22.10.2008 was chaired by Dr.H.P.Singh, DDG (Hort.), ICAR, New Delhi and the participants were welcomed by Dr.M.M.Mustaffa, Director, NRC for Banana, Trichy. Dr. A.Molina, Regional Coordinator-BAPNET, Philippines gave a talk on the role of BAPNET in banana improvement in South East Asia and Dr.Nicolas Roux, Bioversity spoke about Bioversity's role in banana. Dr.P.Sundararaju, Principal Scientist, NRCB proposed a vote of thanks. In addition to the BAPNET members, the TAG participants also participated in the inaugural session.

Dr. H. P. Singh, DDG (Hort.), ICAR, New Delhi delivering the inaugural address in the sixth BAPNET meeting

Taxonomy Advisory Group Meeting

The second Taxonomy Advisory Group (TAG) meeting was held at Tiruchirapalli, Tamil Nadu during 20-25, October 2008. Dr. M. M. Mustaffa, Director, and Dr. S. Uma, Senior Scientist, NRCB participated in the Group Meeting.

Dr. John Britto delivers chief guest address in TAG meeting

The inaugural session on 20.10.2008 was presided over by Dr.Nicolas Roux and Dr. John Britto delivered the Chief Guest address of the inaugural function. Dr. M.M.Mustaffa, Director, NRCB, Trichy welcomed the gathering and Dr.S.Uma proposed a vote of thanks. During the deliberations of the TAG meeting, two major theme areas emerged were viz., taxonomic issues, germplasm management and conservation of banana. Also discussed about the Asia-Pacific implementation of the project funded by the Global Crop Diversity Trust while aims to strengthen the global network of priority collections.

International Conference on Banana

The Association for the Improvement in Production and Utilization of Banana (AIPUB) and the National Research Centre for Banana (NRCB), Tiruchirapalli organized an 'International Conference on Quality Production of Banana for Domestic and Export Markets' during 24-26, October 2008 at Tiruchirapalli, Tamil Nadu. Researchers from Australia, China, Papua New Guinea, Philippines, Taiwan and Thailand participated in the conference besides 300 researchers, farmers and entrepreneurs of banana from Tamil Nadu, Kerala, Andhra Pradesh and Maharashtra.

In the opening ceremony, Dr. M. M. Mustaffa, Director, NRCB welcomed the gathering and Dr. H. P. Singh, DDG (Hort.), ICAR, New Delhi presided over the function and released the 'Conference Souvenir' brought out on the occasion and conferred the *Kadali Purashkar* award of AIPUB on Dr. Agustin B. Molina, Regional Coordinator for Asia-Pacific Bioversity International and Executive Secretary, BAPNET, Philippines in recognition of his leadership in setting the *Musa* research agenda in the Asia Pacific region, particularly in the area of *Musa* germplasm conservation and use. In his presidential address, Dr. Singh reviewed the production technology for banana in India and emphasized the need to produce quality production of banana for local and export trade. Research attempts made in the quality production of banana was highlighted and asked the farmers, experts to follow the technologies to the maximum.

Dr. Molina and Dr. Nicolas Roux, Bioversity International, France also spoke. Shri Bijay Kumar, Managing Director, National Horticulture Board, Gurgaon declared open the exhibition and also Banana Show where different varieties of Banana Bunches and products were arranged for the event. The exhibition was participated by ICAR institutes, banana growers and entrepreneurs, private and tissue culture companies and developmental agencies. There were seven technical sessions held in the conference *viz*., 1. National and international scenario of quality management; 2. Banana varieties for export and domestic market; 3. Production system management; 4. Plant health management; 5. Marketing and trade; 6.Postharvest management and value addition for export market and 7. Production of quality planting materials. A total of 25 presentations were made in the various technical sessions. Scientists of the NRCB and several expert members from South East Asia regions presented technical papers during the conference. The open session of Buyer-Sellers meet was chaired by Shri. S. S. Mehta, Secretary, CIH which was held on 25th, Thiru A. P. Karuppaiah, Shri Jai Oberai and Thiru B. Shivaramakrishnan acted as panelists, wherein many problems encountered by the growers and marketers of banana produce and products were discussed threadbare.

The plenary session was chaired by Dr. H. P. Singh and Dr. M. M. Mustaffa acted as Convenor. In the session, the chairman gave away the best paper presentation, best banana bunch, best banana product and best farmers' stall awards to the speakers, growers and entrepreneurs.

Dr. H. P. Singh, DDG (Hort.), ICAR, New Delhi lighting the ceremonial lamp to inaugurate International Conference on Banana

List of Trainings offered

Sl. No.	Title of the training	Date	Farmers from
01	Improved production technology including post harvest management and value addition in banana	26-30.05.2008	Kerala
02	Improved production technology including post harvest management and value addition in banana	04-08.08.2008	Madhya Pradesh
03	Improved production technology including post harvest management and value addition in banana	15-19.09.2008	West Bengal
04	Improved production technology including post harvest management and value addition in banana	29.12.2008 03.01.2009	Assam
05	Improved production technology including post harvest management and value addition in banana	16-20.02.2009	Mizoram

15 Distinguished Visitors

List of VIP and other Dignitary-Visitors

Sl. No.	Date	Name& Address
01.	12.05.2008	Dr. S. N. Pandey, ADG (Hort), ICAR, New Delhi
02.	02.09.2008	Shri. Bijaykumar, Managing Director, NHB, Gurgoan, Haryana
03.	02.09.2008	Shri. K. Natarajan, President, Flower Growers Association of India & Vice president - CIH
04.	22.10.2008	Dr. Anuradha Agarawal, NBPGR, New Delhi
05.	22.10.2008	Dr. Jeff Daniells, South Johnstone, Australia
06.	22.10.2008	Dr. Felipe S. DelaCruz, Institute of Plant Breeding, UPLB, Laguna, Philippines
07.	22.10.2008	Dr. Deborah Karamura, Bioversity International, Kampala, Uganda
08.	22.10.2008	Dr. Prem Mathur, Bioversity International-India, New Delhi
09.	22.10.2008	Dr. N. M. Nayar, Kerala Agril. University, Thrissur
10.	22.10.2008	Dr. Nicolas Roux, Bioversity International, France
11..	22.10.2008	Dr. Agus Sutanto, Indonesian Fruit Research Institute, Indonesia
12.	22.10.2008	Dr. Hugo Volkaert, Kasetsart University, Thailand
13.	22.10.2008	Dr. Inge Van den Berg, Bioversity International, France
14.	22.10.2008	Dr. Van den Houwe Ines, Leuven, Belgium
15.	22.10.2008	Dr. Vezina Anne, Bioversity International, France
16.	26.10.2008	Dr. H. P. Singh, DDG (Hort), ICAR, New Delhi
17.	26.10.2008	Dr. Gopalji Trivedth, Former VC, RAU, Pusa
18.	17.11.2008	Prof. S. Kannaiyan, Former VC, TNAU
19.	22.12.2008	Dr. Robert Vincent, IMC-Member
20.	22.12.2008	Dr. E. R.Suresh, IMC-Member
21.	23.12.2008	Dr. S. J.Singh RAC- Chairman
22.	23.12.2008	Dr .B. Bandyopadhyay, RAC -Member
23.	23.12.2008	Dr. N. Kumar, RAC -Member
24.	23.12.2008	Dr. R. C. Tiwari, RAC -Member

Dr. H. P. Singh, DDG (Hort.) ICAR, New Delhi, inaugurates the new glass house at the premise of NRCB on 26.10.08

Dr. S. N. Pandey, ADG (Hort.), ICAR, New Delhi visits the NRCB research farm

Dr. M. M. Mustaffa, Director, explains the research activities of NRCB to Prof. S. Kannaiyan, Former VC, TNAU

Banana farmers from Madurai district, Tamil Nadu on an exposure visit

More than 3000 banana farmers, agricultural & Horticultural officers, self help groups and students visited for the training and studies.

16 Empowerment of Women

An exhibition-cum-demonstration on value added products of banana was organized for the women students of the Bishop Heber College, Tiruchirapalli on 11. 02. 2009 on the sidelines of Seminar on Botanists and their Future. In the programme, the scope and opportunities available on preparation of various value added products from banana fruits, stem flower, corm and pseudostem sheath were explained and the students were encouraged to take up enterprises related to banana industry. Around 200 students of the college visited the exhibition and participated in the demonstration.

Around 400 women belonging to various Self-Help Groups, Teacher Training Institutes and Colleges visited the Centre during the year. The scientists of the Centre explained the technologies and research activities to the visiting personnels.

Exhibition of value added products at Bishop Heber College, Tiruchirapalli

17 Personnel

Transfer

Dr. C. K. Narayana, Princiapal Scientist (Hort.), transferred to IIHR, Bengaluru on selection as Head, Division of Post-Harvest Technology on 10.02.2009.

Promotion

Mr. R. Krishnamurthy, UDC to Assistant w.e.f. 01.07.2008

Mrs. S.Durgavathy, LDC to UDC w.e.f. 01.07.2008

Mrs. C. Sagayam Jacqueline, T-3 to T-4 w.e.f. 01.01.2008.

Mr. R. Pitchaimuthu, Technician T-2 to T-3 w.e.f. 01.01.2008.

Mr. N. Marimuthu, Technician, T-2 toT-3 w.e.f. 01.01.2008.

Mr. V. Selvaraj, Technician,T-2 to T-3 w.e.f. 05.03.2007.

Mr. K. Kamaraju, Technician, T-2 to T-3 w.e.f. 10.03 .2007.

Mr. T. Sekar, Technician, T-2 to T-3 w.e.f. 10.03.2007.

Retirement

Mr. M. Balu, Assistant, retired on superannuation from Council's service on 30.06.2008.

Mr. M. Balu. Asst. receives a momento from Dr.M.M. Mustaffa during his superannuation; (left) Dr. I. Ravi, Sr. Sci. and Secretary, NRCB Recreation Club

Scientific Staff

Name	Designation
Dr. M.M. Mustaffa	Director
Dr. P. Sundararaju	Principal Scientist
Dr. B. Padmanaban	Principal Scientist
Dr. C. K. Narayana	Principal Scientist (upto 10.02.2009)
Dr. S. Uma	Principal Scientist
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

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, Audits & Acounts and Supporting Staff

Name	Designation
Administrative, Audits and Acounts	
Mr. B. Vijayakumar	Assistant Administrative Officer
Mrs. C.Gomathi	Asst. Finance & Accounts Officer
Mr. M. Balu	Assistant (upto 30.06.2008)
Mr. M. Krishnamoorthy	Personal Assistant 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 Day

The Hindi Day was celebrated at NRCB on 20.11.2008. Mr. Raja Lingam, Post Master General, Central Regional Post Office, Tiruchirapalli was the Chief Guest and Dr. M. M. Mustaffa, Director, NRCB presided over the function. In his speech, Mr. Raja Lingam observed that Hindi language did not reach the common man in Tamil Nadu and highlighted the importance of learining Hindi. Finally, the Chief Guest distributed the prices to the winners of various competitions conducted in Hindi.

Mr. Raja Lingam gives away prize to a winner, Dr.M.S. Saraswathi, of Hindi competition

ANNEXURE - I

List of On-going Institute Projects

I. Crop Improvement

1. 2000711002: Crop improvement of banana through conventional breeding

   Project Leader: : **M. M. Mustaffa**

   Project Associate(s) : S. Uma, S. Backiyarani and R. Natarajan

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

   Project Leader : **S.Uma**

   Project Associate(s) : M. S. Saraswathi

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

   Project Leader : **S.Uma**

   Project Associate(s) : M. S. Saraswathi and R. Natarajan

4. 2000711005: Identification and characterization of nematode resistance gene(s) in banana

   Project Leader : **S. Backiyarani**

   Project Associate(s) : S. Uma, M. S. Saraswathi, P. Sundararaju and M. Mayil Vaganan

5. 2000711006: Improvement of Rasthali through induced mutagenesis

   Project Leader : **M. S. Saraswathi**

   Project Associate(s) : S. Uma, S. Backiyarani, R.Thangavelu

II. Crop Production and Post-Harvest Technology

6. 2000713001: Standardisation of agro-techniques for banana production and productivity

   Project Leradee : **V. Kumar**

   Project Associate(s) : M. M. Mustaffa and K. J. Jeyabaskaran

7. 2000713004: Studies on micronutrients in banana

   Project Leader : **K. J. Jeyabaskaran**

   Project Associate(s) : V. Kumar

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

   Project Leader : **K. J. Jeyabaskaran**

   Project Associte(s) : V. Kumar

9. 2000717001: Studies on handling, storage and processing of banana

   Project Leader : **C. K. Narayana**

   Project Associate(s) : M. M. Mustaffa

10. 2000717002: Standardization of storage conditions for banana

    Project Leader : **C. K. Narayana**

    Project Associate(s) : I. Ravi

11. 2000716001: Studies on physiology of flowering and fruit development in banana

    Project Leader : **I. Ravi**

    Project Associate(s) : C. K. Narayana and K. J. Jeyabaskaran

12. 2000716002: Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance

Project Leader : **I. Ravi**

Project Associate(s) : M. M. Mustaffa, C. K. Narayana, M. Mayil Vaganan and S.Uma

13. 2000716003: Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance

Project Leader : **I. Ravi**

Project Associate(s) : M. M. Mustaffa, C .K. Narayana, M. M. Mayil Vaganan and K. J. Jeyabaskaran

14. 2000716004: Physiological and biochemical mechanism of nematodes and pseudostem weevil resistance and identification of 'biomarker metabolites' in banana

Project Leader : **M. Mayil Vaganan**

Project Associate(s) : M. M. Mustaffa, I. Ravi, P. Sundararaju and B. Padmanaban

III. Crop Protection

15. 2000715002: Studies on banana nematodes and their management

Project Leader : **P. Sundararaju**

Project Associate(s) : B. Padmanaban and R.Thangavelu

16. 2000715003: Investigation on fungal and bacterial diseases of banana and their management

Project Leader : **R.Thangavelu**

Project Associate(s) : P. Sundararaju

17. 2000715005: Studies on viral diseases of banana and their management

Project Leader : **R. Selvarajan**

Project Associate(s) : S. Backiyarani

18. 2000715006: Management of banana weevils

Project Leader : **B.Padmanaban**

Project Associate(s) : P. Sundararaju and R.Thangavelu

19. 2000715007: Host-virus interactions in Banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's

Project Leader : **R. Selvarajan**

Project Associate(s) : I. Ravi, M. Mayil Vaganan, S. Backiyarani and S. Uma

ANNEXURE – II

Meteorological Data

Month	Max. Temp. (°C)	Min. Temp.(°C)	Relative Humidity (%)	Rain Fall (mm)
April 2007	36.3	25.5	83.6	-
May 2007	36.0	26.3	75.7	19.5
June 2007	36.2	26.4	73.4	-
July 2007	36.5	26.2	79.6	63.3
August 2007	35.7	25.2	81.8	2.0
September 2007	34.9	24.6	78.8	6.8
October 2007	34.0	24.4	88.6	46.9
November 2007	30.37	23.5	89.1	63.2
December 2007	28.1	22.0	94.8	13.8
January 2008	30.4	20.8	89.4	-
February 2008	33.5	20.1	85.6	-
March 2008	35.4	23.5	84.3	-