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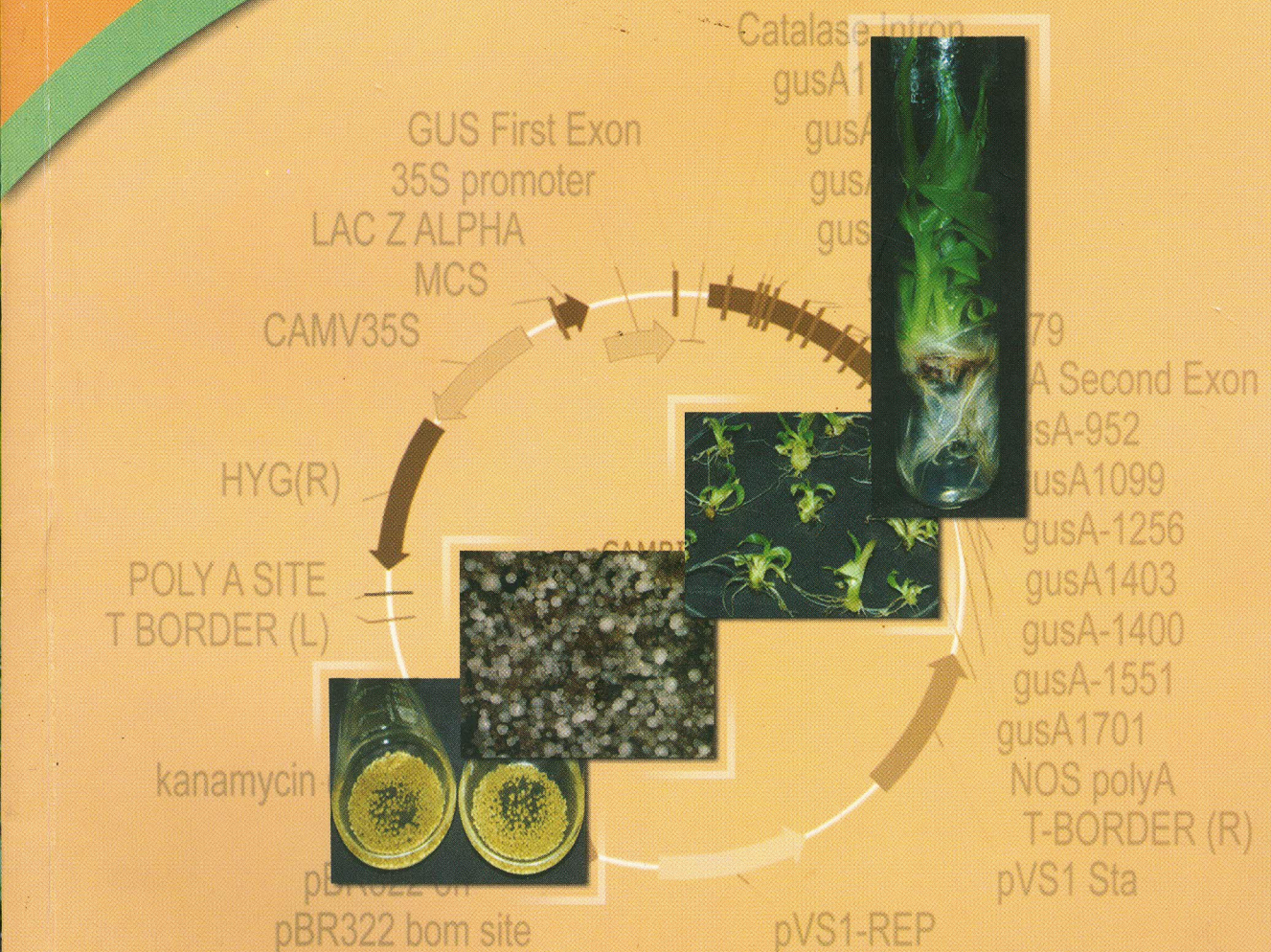
# NRC BANANA

## वार्षिक प्रतिवेदन २००६ - ०७
## ANNUAL REPORT 2006 - 07




राष्ट्रीय केला अनुसंधान केंद्र
(भारतीय कृषि अनुसंधान परिषद),
तोगमलै रोड, तायनूर पोस्ट, तिरुच्चिरापल्लि - ६२० १०२, तमिल नाडु

भा कृअनु प
ICAR

**NATIONAL RESEARCH CENTRE FOR BANANA**
**(Indian Council of Agricultural Research)**
**Thogamalai Road, Thayanur (P.O.)**
**Tiruchirapalli - 620 102, Tamil Nadu**

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NATIONAL RESEARCH CENTRE FOR BANANA
(Indian Council of Agricultural Research)
Thogamalai Road, Thayanur Post
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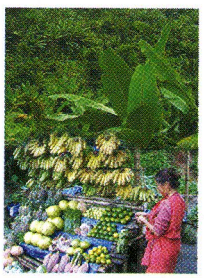
Front Cover Page : Different stages of somatic embryogenesis and regeneration in banana, Backround : Physical map of a binary vector

Back Cover Page : Top : A view of wild bananas in hills of Arunachal Pradesh
Bottom : Banana fruits and flower are sold in a road side shop in Meghalaya



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# CONTENTS

# 1. PREFACE

It is my privilege to present the annual report for the year 2006-07 of the Centre. This year, many developments in the research front have taken place. The research priorities are constantly being modified to suit the present need of the banana growers and other stakeholders, as per the recommendations of RAC meetings and also the outcome of brainstorming meetings on various researchable issues on banana. The efforts of scientists have yielded major breakthrough like ECS development, gene constructs, viral genomics, VCG analysis etc.

As a part of collection, a well known resistant genotype for many biotic agents, *Musa acuminata* ssp *burmannica* has been added to the existing field gene bank. Regeneration of ECS is an important event in somatic embryogenesis, which has been achieved in two important banana varieties viz., Rasthali and Nendran. Breeding has yielded a promising hybrid, which belongs to Pisang Awak subgroup, with resistance to Sigatoka leaf spot diseases.

As a part of organic banana production, use of VAM, phosphobacteria, Azospirillum, rice husk ash and poultry manure has shown promising results. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, had increased the bunch weight resulting in an additional profit of Rs 38,000 per ha. Soil moisture stress accelerated the leaf senescence in cv. Robusta. The peel pickle developed has good promise and had a good storage life of eight months. Juice blends such as banana and Jamun found the best with high antioxidant content.

The integrated pest and disease management research has resulted in many salient output. Pseudostem split traps found better for trapping weevils and killing them *in situ* when bioagents like *Beauveria bassiana* and EPN's (*H.indica*) are used. Combined application of *P.lilacinus* and neem cake or *Tagetus* or *S.torvum* are effective in the management of root-knot nematodes. Nine different VCG's have been identified in India. Cross reaction of FOC race 1 and race 2 has been confirmed under pot culture. A PCR based technique has been developed to differentiate the EPRV's from episomal BSV's. The complete genome of BSV infecting Poovan has been cloned and sequenced for the first time in India. BBTV free Hill banana plants were supplied to the needy hill banana growers to assess its performance in the field.

The Centre has participated in many exhibitions and farmers' mela to disseminate the developed technologies. Tissue culture plants produced by different companies are tested for viruses under contractual service which has improved the quality concerns of TC bananas.

I acknowledge Dr.R.Selvarajan and other publication committee members involved in bringing out the annual report of the Centre. I also thank Dr. S.K. Singh, IARI New Delhi for translating the executive summary in Hindi.

Tiruchirapalli
Jan, 2008

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

# 2 कार्यकारी सारांश

राष्ट्रीय केला अनुसंधान केन्द्र ने केला उगाने वाले किसानों तथा अन्य केला व्यापारियों की सामाजिक एवं आर्थिक स्थिति के सुधार के लिए चार अनुसंधान कार्यक्रम फसल सुधार, उत्पादन तकनीकी, कटाई उपरांत प्रबंधन तथा फसल सुरक्षा चिन्हित किए है। आधुनिक विकास के लिए अनुसंधान और केला व्यापारियों की आवश्यकता के आधार पर पारिदृश्यक योजना विजन 2025 अनुसंधान केन्द्र द्वारा तैयार किया गया था, जो आर.एन.ए.आई. और ट्रान्सजैनिक को नवीनतम अनुसंधान के रूप में अग्रदूत/अग्रणी पहचान किया है। केला का कम लागत और अच्छा/उत्तम उत्पादन और उत्पादकता इस अनुसंधान/शोध के मुख्य बिन्दु है। केन्द्र की गौण उपलब्धियां निम्नवत हैं:-

## फसल सुधार

दो जंगली केला प्रजातियां अण्डमान और निकोबार द्वीप समूह से और एक जंगली क्लोन मुसा एक्युमिनाटा उपजाति बरमैनिका टी.बि. जी.आर.आई. केरल द्वारा जर्मप्लाज्म एकत्रीकरण के रूप में एकत्रीकरण केन्द्र में जोड़ दिया गया है (बी.आर.एस. कोव्वूर से) 49 देशी एक्सेसन और राष्ट्रीय पादप आनुवांशिकी संसाधन ब्यूरो, दिल्ली से। 47 विदेशी एक्सेसन केन्द्र के जीन बैंक में एकत्रित किया गया है। पूर्वोत्तर राज्यों के लिए 12 एक्सेसन का बाह्यवर्गीकरण और 148 एक्सेसन का ए. बी.बी. जीनोमिक समूहीकरण पूरा किया जा चुका है।

दो आर.ए.पी.डी. मार्कर क्वेंडिश प्रजाति के उप-समूहों को अलग-अलग कर रहे थे। आर.ए.पी.डी. प्राइमर प्रयोग करने से थेला चक्रकेली और अन्य ए.ए.ए. क्लोन अलग-अलग चिन्हित किए जा सकते है। तीस एस. एस. आर. प्राइमर ऐसे मिले जो ए.बी.बी. समूह के बाह्यवर्गीकरण के लक्षणों के लिए लाभदायक थे।

इन्टर रीट्रो ट्रांसपोसान एम्पलीफाइड पालीमार्फिज मार्कर द्वारा 57 मुसा एक्सेसन को जीनोमिक और उप-समूह स्तर पर अलग-अलग किया गया। अगेती संतति की स्क्रीनिंग/छटनी के लिए एक प्यूटेटिव डायग्नास्टिक आई.पी.जे. मार्कर को सिगाटोगा रोधिता से जोड़ दिया गया है। सूत्रकृमि रोधिता के लिए भी प्यूटेटिव डायग्नोस्टिक आर.ए. पी.डी. मार्कर का पहचान किया जा चुका है।

एफ.एच.आई.ए.-23 की मल्टीलोकेशन/बहुस्तरीय स्तर पर स्यूडो-तना सूड़ी के प्रति ग्रसित पाई गई थी। कैरोटिनाइड का स्तर (भिन्न-भिन्न केलों में) 86-1626 मिग्रा/100 ग्राम गूदा पाया गया था और सबसे अधिक तिरूवनन्तपुरम में रिकार्ड किया गया था।

## फसल उत्पादन

फसल उत्पादन तकनीक के अन्तर्गत केला की तीन प्रजातियों को मानकीकृत किया गया है जो है:- रोबस्टा, ग्राण्डनेने तथा लाल केला है। जोड़ पंक्ति रोपाई पद्धति लाल केला प्रजाति की उत्पादकता को बढ़ाती है जबकि पौधे की ऊंचाई, फसल अवधि , पत्ती अंकुरणदर तथा प्रथक गुच्छे की उपज कम घनत्व रोपाई पद्धति से बढ़ती है। साधारणत: उर्वरक प्रयोग विधि की तुलना में नई उर्वरक प्रयोग तकनीक (फर्टीगेसन) प्रकाश संश्लेषण को अधिक बढ़ाती है। पहले वर्ष रोबस्टा तथा ग्राण्डनेने प्रजाति में जोड़ पंक्ति रोपाई की तुलना में कम घनत्व रोपाई पद्धति फसल की बढ़वार तथा उपज को बढ़ाते है।

एजोस्पाइरिलिम कवक की तुलना में वैम (वैस्कुलर माइकोराइजा) (ट।ड) तथा फास्फो बैक्टीरिया (जीवाणु) केले की बढ़वार तथा उपज को अधिक बढ़ाता है। धान की भूसी की राख, वर्मीकम्पोस्ट एवं पोल्ट्री खाद रस्थली किस्म के लिए उपयोगी पाया गया। पन्द्रह किलो धान की भूसी की राख + 25 किग्रा. वैम + एन.पी.के. की 80 प्रतिशत अनुमोदित उर्वरकों की मात्रा के उपयोग से प्रति हैक्टेयर रूपये 32,500 अधिक मुनाफा प्राप्त हुआ। मृदा में लौह एवं बोरॉन मिलाकर एवं जिंक का छिड़काव कर केले के गुच्छों में 53.5 प्रतिशत की वृद्धि पाई गई। सूक्ष्म तत्वों का छिड़काव कर करीब रूपए 38,000 प्रति हैक्टेयर अधिक प्राप्त हुए।

मृदा प्रणाली से पोषक तत्वों का उपयोग कर-स्थली किस्म में अच्छा उत्पादन लिया जा सका। मृदा में नमी की छलास से रस्थली किस्म में प्रकाश संस्लेषण एवं पत्तियों के सूखने की प्रक्रिया अधिक पाई गई, परन्तु नेन्द्रन व नईपूवन इससे कम प्रभावित हुए।

## मूल्य संवर्धन

केले के छिलके से निर्मित नया उत्पाद पील पिकिल तैयार किया गया जो केले के फूल से तैयार अचार की तुलना में श्रेष्ठ था। केला एवं जामुन के रस के मिश्रण (1:1) से तैयार पेय अन्य अनुपातों से बेहतर पाए गए। इस पेय में अधिक पौष्टिक एवं एन्टीऑक्सीडेन्ट गुण पाए गए। पूर्व किस्म का रस चुकन्दर के रस में मिलाने (1:1) पर अधिक उपयोगी सिद्ध हुआ।

## पौध संरक्षण

केले के तना सूड़ियों के लिए कृत्रिम खुराक तैयार की गई। केले के पत्ते से प्राप्त वोलाटाईल अधिक ई.ए.जी. प्राप्त हुए। केले



के तना के फटने के स्थान में ब्यूवैरिया बैसियाना युक्त खुराक से उपचार कर अधिक तना एवं कन्द भेदक सूड़ियों का नाश किया जा सका। केले के तना फटने पर 25 मिली. ई.पी. एन. हेटरोरहाबडिविस इन्डिका, स्टेनेरेमा ग्लासरी व स्टेनेरेमा अब्बसी करीब 63.12 एवं 36.8 प्रतिशत तना एवं कन्द वीविल का नियंत्रण किया जा सका। ब्यूवेरिया बैसियाना की आइसोलेट न. 5 के प्रयोग से करीब 83.8 प्रतिशत विविलो को मारा जा सका।

कूर्ग एवं वाइनाद जनपदों के सर्वेक्षण में इन क्षेत्रों में बरौड़िंग सूत्रकृमि का प्रकोप अधिक पाया गया। टी. वीरडे एवं पी. फ्लूरेन्स के प्रयोग से केले में लगने वाले सूत्रकृमियों से निवारण पाया जा सका। पी. लीलासिनस व नीम की खली के संयुक्त प्रयोग से भी गेंदे या सोलानम टोरवम के सूत्रकृमियों का सफलतापूर्वक नियंत्रण किया जा सका। कनाई बन्सी, मूसा बल्बेबिसियाना, अधियाकोल, भीमकोल एवं अधिकोला बरोड़िंग सूत्रकृमि के प्रति अवरोधी पाये गये।

*फ्यूजेरियम ऑक्सीस्पोरम क्यूबेन्स की म्यूटेन्ट* 141 एफ.ओ. सी. 100 आइसोलेट के रिमाक्सन की गई। गमलों में किए गए प्रयोग से एफ.ओ.सी. के रेस-1 व रेस-2 में क्रास रियाक्सन का अध्ययन किगया गया। फोक के भिन्न आइसोलेटों को आर.ए.पी. डी. व पी.सी.आर, आर.एफ.एल.पी के प्रयोग से उन्हें 13 भिन्न प्रजातियों में वर्गीकृत किया जा सका। आई.टी.एस. क्षेत्र के ऐम्पलिफिकेशन एवं सिक्वेन्ससड करने पर उन्हें 50 आइसोलेटों व 9 समूहों में बांटा जा सका।

गठबंधन, अनुबंधन व मानव संसाधन विकास केन्द्र ने विभिन्न शोध संसाधन जैसे भाभा आणविक अनुसंधान केन्द्र, मुम्बई, तमिलनाडु कृषि विश्व विद्यालय, कोयमबटूर व नई दिल्ली के साथ मिलाकर कई क्षेत्रों में कार्य किया है। केन्द्र के कई वैज्ञानिक उच्च प्रशिक्षण एवं शिक्षा प्राप्त करने हेतु विभिन्न संस्थानों में भेजे गए। साथ ही कई तकनीकी वर्ग के कर्मचारियों को भी प्रशिक्षण के लिए भेजा गया। विभिन्न विश्व विद्यालयों से करीब 31 विद्यार्थियों ने अपने शोधकार्य केन्द्र के सहयोग से पूर्ण किए।

## संसाधन उपार्जन

वर्ष 2007, में केन्द्र ने करीब रूपए 3.60 लाख मात्र विषाणु-इन्डैसिंग (सूक्षम प्रवर्धित पौधों) से अर्जित किए। व्यावसायिक परामर्श द्वारा केन्द्र ने करीब रूपए 31,000 अर्जित किये। इसके अन्तर्गत केले के रस व कृत्रिम तरीके से फल पकाने की विधि शामिल है। विभिन्न उत्पादों के बिक्री से रूपए 3.52 लाख व तकनीकी स्थानान्तरण के माध्यम से रूपए 1.35 लाख प्राप्त किए गए।

# 3 Executive summary

The National Research Centre for Banana (NRCB) is working to increase the productivity and to uplift socio-economic status of the banana growers and other stakeholders through intensive research on identified areas under four different programmes *viz.*, crop improvement, production technology, post harvest management and crop protection. The vision 2020 drafted in 1998 has been modified as perspective plan-Vision - 2025 based on the recent developments in research and requirements of banana stakeholders. The main research remain focused on minimizing the cost of inputs for better output in banana production and productivity. The salient achievements of the Centre for the period of 2006-07 are furnished in brief hereunder.

## Crop improvement

As part of germplasm collection, two wild banana species from Andaman and Nicobar islands and a wild clone, *viz., Musa accuminata* ssp *burmannica* from TBGRI, Kerala have been added to the Center's collection. 49 indigenous and 47 exotic accessions from BRS, Kovvur and NBPGR, New Delhi respectively were added to the NRCB gene bank. Morphotaxonomic characterization for 12 accessions of NEH states and 148 accessions belonging to ABB genomic group has been done.

Duplex RAPD markers were used to distinguish different cultivars of Cavendish sub group. Thella Chakerakeli (AAA) could be differentiated from other AAA clones with a set of RAPD primers. Thirty SSR primer pairs were useful for supporting the data obtained from morphotaxonomic characterization for accessions of ABB group. The Inter Retro transposan Amplified Polymorphism(IRAP) markers differentiated 57 *Musa* accessions at both genomic and sub group level. A putative diagnostic RAPD marker linked to Sigatoka leaf spot resistance has been identified for early screening of progenies obtained in breeding. Putative diagnostic RAPD marker has also been identified for nematode resistance.

FHIA-23 found susceptible for pseudostem weevil in all the multilocation field trials. The carotenoid content in different bananas ranged from 86 to 1626 mg per 100gm pulp and the highest was recorded in Thiruvananthapuram (AAB).Totally 47 progenies obtained from crossing were planted in the field for evaluation for different agronomic traits. Crossing work undertaken in the second half of the reporting period produced 5582 hybrid seeds and only 82 of them successfully germinated. A new Pisang Awak hybrid resistant to Sigatoka leaf spot has been developed. Duration of this hybrid was lesser than the ruling Pisang Awak cultivars and the yield was 28kg per bunch. ECS has been successfully established for five cultivars namely Rasthali, Nendran, Ney Poovan, Robusta and Grand Nain. Regeneration of plants from ECS was achieved in Nendran and Rasthali.

## Crop production

Agrotechniques have been standardized for three banana varieties *viz.*, Robusta, Grand Nain and Red Banana. Paired row system increased the productivity of Red Banana. But the plant height, crop duration, leaf emergence rate and individual bunch yield were more in conventional system of planting. Fertigation had influence on photosynthetic activity than the conventional fertilization. In case of ratoon, in cvs Robusta and Grand Nain, the growth and yield parameters were significantly higher in conventional system than paired row planting.

Application of VAM and phosphobacteria was superior to Azospirillum for increasing the banana growth and yield parameters. Rice husk ash was superior to vermicompost and poultry manure in increasing the bunch weight of cultivar Rasthali in its ratoon crop. Application of 15kg rice husk ash + 25gm of VAM + 80% recommended NPK could generate an additional profit of Rs 32,500 per ha. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, had increased the bunch weight to 43.5% over control. An additional net profit of Rs 38,000 per ha could be obtained with micronutrient application. Research on soil test based nutrient tailoring for banana, has resulted in developing fertilizer adjustment equations for Rasthali. Farmers friendly software has been developed for decision making for obtaining the expected yield based on their soil nutrient test status. The exact requirment of nutrients to be applied will be automatically deduced if the target yield is fixed. Photosynthesis was more at flowering in Rasthali than other banana commercial cultivars. Soil moisture stress accelerated the leaf senescence in cv. Robusta. The leaf longevity was more in Robusta than Nendran, Rasthali and Ney Poovan.

## Value addition in banana

Peel pickle, a new value added product from waste peels of Nendran having equivalent quality as that of flower pickle has been prepared and it could be stored for 8 months. Banana and Jamun juice blend was the best among the blends made with other fruits juices and it was good because of





added antioxidants. Poovan juice blended in 1:1 ratio with beet root juice found more acceptable.

## Crop Protection

Artificial diet has been prepared for banana stem weevil. Banana leaf sheath volatiles eluted with hexane and methanol gave EAG response. Pseudostem split trap swabbed with chaffy grain formulation of *Beauveria bassiana,* trapped stem and corm weevils which was better than maize flour formulation. Banana pseudostem split traps swabbed with 25 ml solution containing EPN's such as *Heterorhabditis indica, Stenernema glaseri* and *S.abbasi* trapped 63.12 % and 36.8 % stem and corm weevils respectively and mortality due to *H.indica* was 44.14%. Isolate No. 5 of *B.bassiana* collected during survey gave 83.3 % mortality of weevils.

Survey for nematodes taken up in Coorg and Wynad districts revealed the presence of burrowing nematode in all the cultivars. *T.viride* and *P.fluorescens* were superior in controlling the nematodes and increased the plant growth parameters of cv Robusta. Integration of *P.lilacinus* with either neem cake or Tagetus or *Solanum torvum* can be effectively used in the management of root-knot nematodes. Kanai Bansi, *Musa balbsiana*, Athiakol, Bhimkol and Aittakola were identified as resistant to burrowing nematode and root lesion nematode.

141 nit mutants of FOC were developed from 100 FOC isolates and 9 different VCG's were identified. Cross reaction between race 1 and race 2 has been observed in VCG analysis which was confirmed with pot culture experiment. FOC isolates have been characterized using RAPD. PCR-RFLP analysis of IGS region has grouped the FOC isolates into 13 genotypes. The ITS region was amplified, sequenced and the phylogenetic analysis revealed 9 groups among the 50 FOC isolates. 19 endophytic NPF's have been assessed for their effect on spore germination of FOC. Different isolates of *Colletotrichum musae* have been characterized both morphologically and also based on amplicon of rDNA-ITS region. The population of *T.viride* mass multiplied in rice chaffy grain was stable even after 6 months of storage.

Survey revealed widespread occurrence of BBTV and BBrMV in Coorg and Wynad districts. A quick PCR based technique has been developed to detect the EPRV's present in the host genome. Increased dose of fertilizer i.e. 125 to 150 % of RDF compensated the yield of BBrMV affected plants of cvs. Ney Poovan and Robusta in the main crop as that of healthy plants. 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. BSV infection in *Musa.acc.* ssp *zebrina* has been confirmed with PCR. Coat protein genes of BBTV and CMV have been cloned into expression vector. Hill banana plants free of BBTV were supplied to the hill banana growers. Both sense and antisense BBTV cp gene constructs and a BBTV replicase construct have been prepared in pBINAR / pCAMBIA 2301 vectors respectively for transformation. Embryogenic calli has been obtained for Hill banana and Poovan for transgenic research. Dig-labeled RNA probes have been prepared and assessed for detection of BBrMV by NASH.

## Transfer of technology

Value added products technologies have been transferred to two clients. Short term trainings were offered on value added products and also on tissue culture multiplication technology. Three radio talks were broadcasted and 22 video programmes were recorded by Department of agribusiness management, Ministry of Agriculture, New Delhi. The Centre participated in many exhibitions to disseminate the technologies to the stakeholders.

## Linkages, collaboration and HRD

The centre has collaboration with BARC, TNAU and NBPGR for various research activities. A commercial tissue culture facility has been created to supply virus free quality planting materials to farmers and industries. The scientists have been deputed to undergo training and pursue higher studies to update the recent developments in their respective field of research. The technical personnel and other staff were also deputed for various training to enhance their capability. Under education and training, more than 31 students belonging to different universities have been guided for their project work in various aspects in banana.

## Revenue generation

As part of resource generation an amount of Rs 3.60 lakhs has been generated through virus indexing of tissue culture plants of commercial companies. An amount of Rs 31,000 has been received for advisory consultancy on banana juice preparation and ripening of banana under controlled conditions. An amount of Rs. 3.52 lakhs has been generated from the farm produce and Rs. 1.35 lakhs has been earned through training on PHT in Banana.

# 4 Introduction

To increase the production and productivity of banana and plantains through mission mode basic and strategic research approaches, the National Research Centre for Banana was established on 21st August, 1993 at Tiruchirapalli, Tamil Nadu by the ICAR, New Delhi. This centre is located at 11.50° N latitude and 74.50° E longitude, 90m above msl, and receives 800mm rain a year. The climate is warm humid and the average min and max temperature are 25°C and 35°C respectively. In Tiruchirapalli district, nearly 10 commercial bananas belonging to different genomic group are being grown. The Centre has approximately 90 acres research farm and has good ground water resources as well as canal water from Kavery river. Infrastructural facilities like library, ARIS Cell, exhibition hall, green houses, quarantine lab and net houses are also established in the Centre. The Centre's laboratory and administrative building is situated in an eight acre land just near to research farm and staff quarters have been constructed both in the office premises and also in the city.

The Centre works on four major areas of research *viz.*, Crop Improvement, Crop Production, Post Harvest Management and Crop Protection. With the funding during 8th, 9th and 10th five year plans and also through externally funded projects, the Centre 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 early nineties, the Centre was more focused to collect and conserve the banana germplasm sourced from primary and secondary Centers of diversity and has established a field gene bank. The genetic resources team has explored 9 times to collect the wild banana germplasm from the NEH states, Western Ghats and Andaman and Nicobar Islands. At regular intervals, exotic banana accessions were also received from International Transit Centre (ITC), Belgium through NBPGR, New Delhi. Now, the Centre has reoriented its research priorities based on the QRT and different RAC recommendations. The centre has executed 7 in-house research projects and 10 are being pursued in the 11th Five year plan. In addition to Centre's in-house projects, 23 external projects funded by AP-Cess fund of ICAR, NATP, DBT, NHB and INIBAP were carried out. The perspective plan and vision 2025 based on the research priorities and also inputs from QRT and RAC was 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 plantain to meet the growing need in India.

The mandate of the Centre are :

- To undertake the basic and strategic research for developing the technology 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

Till date more than 1000 accessions have been collected from both indigenous and exotic sources which are maintained in the field gene banks at Tiruchirapalli and Agali. Banana field gene bank of the Centre is the "National Reportary" for banana in India. Collections were made through 9 explorations from all the regions of India. The genomic status of collected accessions has been assigned based on the morphotaxonomic characterization using score card devloped by Stover and Simmonds. The collections include AA, AB, BB diploids, AAA, ABB, AAB triploids, AAAA, AAAB, AABB, ABBB, AAAh tetraploid accessions and Fe'i bananas Among the accessions, 92 accessions are rated highly resistant and 25 are resistant to Sigatoka leaf spot disease. The collected germplasm has been narrowed down to 310 by eliminating the synonyms using both morphotaxonamic and molecular markers *viz.*, RAPD, IRAP and SSR. Three promising selections have been identified and being evaluated. NRCB-selection 1 has been released as UDHAYAM for cultivation. It is a high yielder, tolerant to Sigatoka leaf spot and nematodes and belongs to Pisang Awak sub group. Under IMTP trials, wilt, Sigatoka and nematode resistant clones were identified. 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*. More than 12 hybrids have been developed through breeding, which are being evaluated under field condition. Embryogenic cell suspensions (ECS) for five different commercial varieties have been developed and regeneration protocol from ECS for Nendran and Rasthali has been developed. In addition to NRCB gene bank, a satellite gene bank for breeding purpose has been established at Agali, Kerala. This helps in maintaining temperature sensitive wild bananas and also highly suited for successful breeding. A Pisang Awak hybrid resistant to Sigatoka leaf spot has been identified. This year, a well known wild banana, *viz.*, *Musa accuminata* ssp *burmannica* has been added to the Centre's collection. The Inter Retro transposan Amplified Polymorphism (IRAP) markers differentiated 57 accessions at both genomic and sub group level. A putative diagnostic RAPD marker linked to Sigatoka resistance has been identified for early screening of progenies obtained in breeding. Putative diagnostic RAPD marker has also been identified for nematode resistance. 47 hybrid progenies were planted in the field for evaluation for different agronomic traits.

## Crop Production

The achievements on the crop production research are highlighted hereunder. 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. Application of organic manures, reduced the time taken for flowering, maturity and total crop duration in all cultivars. Weed free conditions in Karpuravalli banana up to 6 months after planting was critical for growth and yield. Weed free condition up to 9 months gave an additional income of Rs.26600/- in Karpuravalli banana. Poovan plants supplied with 20 litre water/day/plant and 75% N (150g N/pl) as fertigation recorded 20% increase in yield 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. This combination has also significantly suppressed the population of root lesion, root knot and spiral nematodes. The organic manure applied plants had less incidence of Sigatoka leaf spot disease while the inorganic treatment had severe incidence of leaf spot diseases. Application of gypsum @2kg/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 15kg rice husk ash or 15kg 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 accomodates 4500 plants/ha increased the productivity and fruit quality with 75 per cent recommended fertilizers dose as fertigation in Robusta, Grand Nain and Red Banana. Fertigation had positive influence on photosynthetic activity than soil application. In first ratoon crop of Robusta and Grand Nain, the growth and yield parameters were significantly higher in conventional system than paired row planting. Application of VAM and phosphobacteria was found superior to Azospirillum for increasing the banana growth and yield parameters. Rice husk ash was superior to vermicompost and poultry manure in increasing the bunch weight of Rasthali in its ratoon crop. Application of 15kg rice husk ash + 25g VAM + 80% recommended NPK gave an additional profit of Rs 32,500 per 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 per ha. Research on soil test based nutrient tailoring for banana, has resulted in developing fertilizer adjustment equations for Rasthali. 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.

## Post Harvest Technology

Pre-packaging in 400 gauge LDPE bags, low temperature storage, use of ethylene absorbents and pre-storage treatments has resulted in extension of shelf life upto 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 beaverages and functional fruits like chapaathi, bread and health drink have been developed. Many of these technologies have been commercialized. Banana and Jamun juice blend was the best among the blends made with other fruit juices rich in and antioxidants. Poovan juice blended in 1:1 ratio with beet root was found more acceptable.

## Crop Protection

Root-lesion nematode (*Pratylenchus coffeae*) and root-knot nematode (*Meloidogyne incognita*) were present in all banana growing states. The burrowing nematode (*Radopholus similis*) was present in few pockets of Tamil Nadu, Maharashtra, Gujarat, Karnataka and Kerala. 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 method for *Paecilomyces lilacinus*, (an egg parasite of root-knot nematode) using banana petiole and pseudostem, has been developed. Flower extracts of *Tagetus erecta* was highly effective against nematode. 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. Kanai Bansi, *Musa balbsiana*, Athiakol, Bhimkol and Aittakola were identified as resistant to burrowing and root lesion nematodes.

Bhimkol (BB), Athiakol (BB), Elavazhai (BB) Sapkal(ABB), Dudhsagar (AAA), Pisang Lilin (AA) and Pisang Jari Buaya (AA) were resistant while Nendran was highly susceptible to pseudostem weevil (BSW). Use of longitudinal split traps in the field at seventh month after planting eliminated the weevil population. Swabbing 0.06 % Chlorpyrifos 20 EC on the pseudostem to a height of 1.2 m during 5$^{th}$ and 8$^{th}$ months completely controlled BSW. Treating suckers with Monocrotophos 36 EC (14 ml / litre ) followed by soil application of Carbofuran 3G, at the rate of 60 g per plant at 4$^{th}$ and 7$^{th}$ months after planting found effective against corm weevil. Pseudostem traps swabbed with entomopathogenic fungus recorded 90 per cent mortality. Pseudostem split trap swabbed with chaffy grain formulation of *Beauveria bassiana* trapped, stem and corm weevils better than traps swabbed with maize flour formulation. Banana pseudostem split traps swabbed with 25 ml solution containing EPN's such as *Heterorhabditis indica, Stenernema glaseri* and *S.abbasi* trapped 63.12 % and 36.8 % stem and corm weevils respectively and the mortality due to *H.indica* was 44.14 %. *B.bassiana* (Isolate 5) collected during survey gave 83.3 % mortality of weevils.

Diseases such as wilt, *Erwinia* rot, Sigatoka leaf spot, peduncle rot (5 to 25 %) were prevalent in all banana growing states. Septoria leaf spot (*Septoria eumusae = Mycosphaerella eumusae)*, eye spot (*Drechslera sp*) and pitting disease were recorded for the first time in India. A new wilt disease caused by Triclomataceae fungus of Basidiomycetes has been identified. 141 nit mutants of FOC were developed from 100 FOC isolates and 9 different VCG were identified. Cross reaction between race 1 and race 2 of FOC has been observed in VCG analysis which was confirmed in pot culture experiment. 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 both morphologically and also based on amplicon size of rDNA-ITS region. Screening of germplasm and entries from International *Musa* Testing Programme revealed 17 accessions as highly resistant to Sigatoka leaf spot disease. A fusaric acid detoxifying strain of *Pseudomonas fluorescens* was isolated. 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 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 percent) spray were also effective in controlling the disease anthracnose. Three applications of *T.harzianum*, *P. fluorescens* and *B.subtilis* each 10 g per plant at the time of planting, 3$^{rd}$ and 5$^{th}$ month after planting significantly reduced the wilt incidence. *P. aerogonosa* and *P.viridiflavus* were effective in controlling crown rot disease. Population of *T.viride* mass multiplied in rice chaffy grain was stable even after 6 months of storage.

Viral diseases *viz.*, Banana Bunchy Top (BBTV), Streak (BSV) and Infectious Chlorosis (CMV) were present in the entire banana growing areas, while Bract Mosaic (BBrMV) was restricted to South India. The yield loss due to BBrMV in Nendran, Robusta and Ney Poovan was assessed. A yield loss of 49 per cent due to BSV was recorded in Poovan. Three aphid vectors including *Pentalonia nigronervosa* transmitted BBrMV and mealy bug vector *Ferrisia virgata* transmitted BSV. 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 and are routinely used for testing the viruses on commercial basis. A multiplex PCR technique has been developed for detecting three banana viruses simultaneously. 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. Both sense and antisense BBTV cp gene constructs and a BBTV replicase construct have been prepared in pBINAR / pCAMBIA 2301 vectors respectively for transformation. Embryogenic calli has been obtained for Hill banana and Poovan for transgenic research. Increased dose of fertilizer i.e. 125 to 150 % of RDF compensated the yield of BBrMV affected plants of Ney Poovan and Robusta in the main crop as that of healthy plants.





## Transfer of Technology

"Udhayam" variety released from the Centre is becoming popular among farmers. Suckers and tissue culture plants have been supplied to the progressive growers and tissue culture companies. Bunchy top virus indexed Hill banana plants have been supplied to the hill banana growers of lower Pulney hills. A virus testing lab was developed based on NRCB technology at BTC, Dept of Horticulture, Govt. of AP, Hyderabad. Virus testing of mother plants and tissue cultured plants from different tissue culture industries is done on contract service mode. Technologies on value added products were transferred to many clients. Virus indexing training was imparted to technical personnel of many tissue culture companies, scientists, assistant professors and students involved in banana research. Banana value added products training were offered to 'Mahabanana' personnel, Maharashtra, to farmers and others beneficiaries. The Centre has participated in many exhibitions to disseminate the technologies to the stakeholders. Radio talks on different production technologies of banana were broadcasted and 22 video programmes were recorded by Department of Agribusiness Management, Ministry of Agriculture, New Delhi for dissemination of the technology at national level.

## HRD and Education

The scientists have been deputed regularly to undergo training and pursued higher studies to update the recent developments in their respective field of research. The technical personnel and other staff members were also deputed for various training to enhance their capability. Under education and training, more than 250 students belonging to different universities have been guided for their project work in various aspects of banana. The science day is regularly celebrated and many school children have been invited on that occasion to show cause the research on banana.

## Linkages and Collaboration

The Centre has developed good linkages with international institutes *viz.*, INIBAP, 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, CIRCOT, Mumbai; IICT, Hyderabad; IIHR, Bangalore; NHB, 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 developmental activities. NRCB also co-ordinates with AICRP(Tropical Fruits) centres working on banana as co-operating unit. The new technical programmes for banana under AICRP-TF were made in consultation with NRCB scientists.

## Revenue Generation

A gross revenue of Rs.8.77 lakhs was generated from consultancy, contract research projects, contract services, technology transfer services, training and also from sale of farm produce. This year an amount Rs. 31,000/- was received from two clients for advisory consultancy on juice preparation and ripening of banana under controlled conditions and Rs 3.60 lakhs have been received for virus indexing of tissue culture plants.

**BUDGET FOR 2006-07 UNDER NON-PLAN**

| S.No | Head | Budget |
|---|---|---|
| 1 | Establishment Changes | 9808000 |
| 2 | TA | 200000 |
| 3 | Other charges | 4790000 |
| 4 | Works | 300000 |
| 5 | OTA | 200 |
| | **Total** | **15100000** |

**BUDGET FOR 2006-07 UNDER PLAN**

| S.No | Head | Budget |
|---|---|---|
| 1 | Establishment charges | 0 |
| 2 | TA | 300000 |
| 3 | Other charges | 4385000 |
| 4 | HRD | 200000 |
| 5 | Equipment | 4746000 |
| 6 | works | 1199000 |
| 7 | Furniture Fixtures | 300000 |
| 8 | Library | 300000 |
| | **Total** | **11430000** |

# 5 Research Achivements

## CROP IMPROVEMENT

### 5.1 Genetic Resource Management

#### 5.1.1 Exploration and collection

During the reporting period, two wild accessions namely Nicobari Kela and *Musa andamanica* were received from Andaman Islands and *Musa ac.* ssp. *burmannica* was collected from TBGRI, Thiruvananthapuram, Kerala

**Secondary source of collection**

Forty nine accessions belonging to various genomic groups and few wild species have been collected from a secondary center, BRS, ANGRAU, Kovvur, Andhra Pradesh for conservation and evaluation. The details of accessions collected during the reporting period is presented in Table 1. Also, 47 exotic accessions have been received from NBPGR, New Delhi.

**Table 1. List of accessions received during 2006-2007**

**Andaman and Nicobar Islands**

Nicobari Kela, *Musa andamanica*

**Western Ghats of Kerala (TBGRI)**

*M.ac.* ssp. *burmannica*

**BRS, ANGRAU, Kovvur, AP**

Namarai (AA), Mitli(AB), Kappu Kadali(AB), Agniswar(AB), T atilla Kunnan(AB), Yelakkibale (AB), MC 94-02 (AB), Attikol (BB), Gros Michel (AAA), KBS-4 (AAA), Amritsagar (AAA), Robusta (AAA), Dwarf Cavendish(AAA), Grand Nain (AAA), Valery (AAA), Williams(AAA), Srimanthi(AAA), Red Banana (AAA), Manoranjitham(AAA), Poyo(AAA), KBS-8(AAA), Sugandham(AAA), Eleswaram Bukkisa(AAA), Mortmon(AAA), Sonkela(AAA), Wather(AAA), Kallar(AAA), Nendra Padathi(AAA), Rajapuri(AAA),Pisang Rajah (AAA), Manjira Nendran(AAA), Kovvur Bontha(ABB), KBS-5 (ABB), Simla(ABB), KBS-2(ABB), Chinia(ABB), Bharata Ratnavali(ABB), Komarada Bukkisa(ABB), KBS-9 (Kanchi Kela)-(ABB), KBS-3 (MC 92-02) (ABB), Jillegudem Collection(ABB), MC 93-02 (ABB), Uthiran (AAB), Sri Sailam Collection(ABB), Jurmony(ABB), Assam wild, *Musa laterita*, PA-03-22, Calcutta-4 (AA).

**Exotic accessions received from NBPGR, New Delhi**

Safed Velchi, Pisang Mas Ayer, Kluai Lep Mu Nang, Namwa Khom, Bata Bata, Saba, *M.ac.* ssp. *malaccensis* type *malaccensis*, Cachaco, Ney Poovan, Amas (South Johnstone), Vietnam no.5, *Musa maclayi* ssp. *maclayi* varmaclayi, Sar, *Musa maclayi* ssp. *ailulvai*, Long Tavoy, *M.ac.* ssp. *truncata*, *Schizocarpa* no.1, Hawain 2, Hawain 3, Dwarf Cavendish, Robusta (Poyo), Pisang Nanga, Ice cream, Williams, Sabra, Giant Parafitt, T6, Taybut, Nkono wa Tembo, GCTCV-215, Yangambi no.2, GCTCV-119, Pisang Berangan, FHIA- 25, Pisang Jari Bauya, PV-42-320, TMP2 x 2829-62, TMP2 x 9128-3, Kamaramasenge, Prata, Guyod, GCTCV-106, GCTCV-247, 2390-2, B7925, TMP 2x 1297-3

#### 5.1.2 Conservation

A core collection with 310 accessions has been conserved at NRCB field genebank and a duplicate of rare and unique collections are maintained at the Satellite Genebank, Agali, Kerala. Apart from these, 52 exotic accessions are maintained for evaluation.

Six wild bananas belonging to AA and BB genomic group collected from North Eastern states have been multiplied *in-vitro* and proliferating cultures were sent to NFTCR, NBPGR, New Delhi for medium and long term conservation. Emphasis has been on conservation of fragrant landraces of *Musa* and three important fragrant landraces have been supplied for long term conservation through cryopreservation.

#### 5.1.3 Characterization

##### 5.1.3.1 Morphotaxonomic characterization

Twelve accessions belonging to sections Eumusa and Rhodochlamys collected from North Eastern states have been morphologically characterized for 117 traits. Twenty three hybrid progenies with varied ploidy and genomic status developed under the hybridization programme have also been morphotaxonomically characterized and documented.

##### 5.1.3.2 Molecular characterization of wild species

Two new species collected during the last exploration in Arunachal Pradesh were





characterized using morphological traits and confirmed their separate species status using SSR and STMS markers. They were named as *M. kuppiana* and *M.saddlensis*, after their place of collection.

### 5.1.3.3 Molecular characterization of 'Cavendish' bananas

28 accessions belonging to Cavendish sub group (AAA genome) were subjected to duplex RAPD marker analysis (OPA 12+18 and OPK 09+14) to identify possible differences. The competence between the two random primers in a single reaction showed some discrimination between the test accessions. Unique accession like Thella Chakkarakeli exhibited specific bands, which could be successfully employed in clonal identification (Fig. 1).

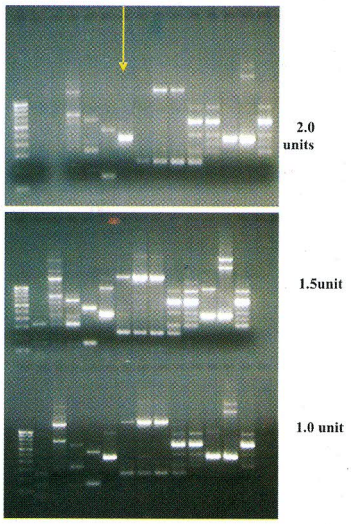



Fig 1. Duplex RAPD marker analysis

### 5.1.3.4 Morpho-taxonomic characterization of *Musa* ABB germplasm

Genetic diversity among ABB germplasm (cooking types) was analyzed using morphotaxonomic traits and microsatellite markers. The morphotaxonomic data for 131 traits of 148 accessions were subjected to HCA and PCA using NTSYS pc. The morphotaxonomic characterization was studied in 126 ABB, 4AA and 18 BB accessions. Two major clusters were recognized from the dendrogram. Cluster 1 was comprised of only AA accessions. Cluster 2 consisted of both BB and ABB. Cluster 2, which shared 20 per cent similarities, had nine subclusters (a-i) and each had 2-5 microclusters. Two dimensional scatter plot obtained as a result of PCA also depicted a clear cut demarcation between AA, BB and ABB types confirming the diversity patterns brought out by HCA. The results indicated that only 69 accessions were distinct.

### 5.1.3.5 Molecular characterization of cooking type bananas

Forty five ABB (cooking types) accessions which were doubtful for their identity based on morphotaxonomic characterization were further characterised along with an unique control (AA, BB and ABB) using microsatellite markers (SSR). Among the 36 primer pairs tested, 30 primer pairs (83.33 per cent) produced discrete, repeatable amplicons which were considered for genetic diversity analysis. PIC value of above 0.5 was registered (30 per cent). Twelve micro satellite (40 per cent) primer pairs failed to amplify products in some of the test accessions. Alleles specific for genomes namely Calcutta-4 (AA), Elavazhai (BB) and ABB (Sagarkol, Pidi Monthan, Boothibale, Bluggoe and Nuchan-I) were identified with the primer pairs used for genetic diversity analysis. The consensus tree obtained based on the results of 30 primer pairs exhibited two major clusters. Cluster 1 with Calcutta-4 and Cluster 2 with BB and ABB accessions. Cluster 2 had 4 subclusters (a-d). Cluster 1 was distinctly away from cluster 2 sharing only 15 per cent similarities. BB shared more than 30 per cent similarities with ABB indicating the possibility of involvement of BB accessions in evolutionary pathway of cooking bananas. The co-phenetic correlation co-efficient estimates were 0.9849 and 0.9858 for morphological and molecular characterization respectively indicating a good fit of the dendrogram with the similarity matrix. Mandel T-test of significance used to compare the two matrices produced a linear model indicating that the results of morphotaxonomic characterization are in agreement with those of molecular characterization (Fig. 2 ).

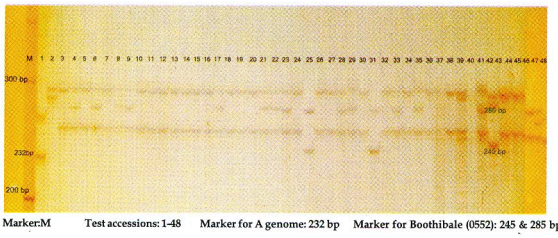



Fig 2. Diversity of ABB germplasm using SSR Markers

### 5.1.3.6 Diversity analysis in Core collection of *Musa* using IRAP markers

Comprehensive analysis of diversity within the *Musa* core collection was studied using IRAP (Inter Retro transposan Amplified Polymorphism) markers. Fifty-seven accessions of different genomic groups were characterized using IRAP markers. The maximum numbers of polymorphic bands were produced by Nikita + LTR 6150 followed by Sukkula + 5' LTR 2, LTR 6149 + Nikita and Sukkula + LTR 6149. The genetic similarities of the tested 57 accessions ranged from 63-96% and they clustered into three

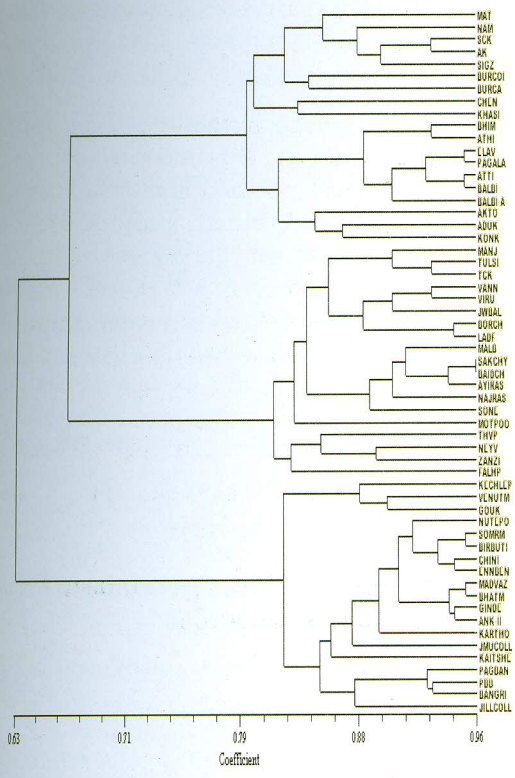



Fig 3. Dendogram showing the clusters obtained using IRAP markers

major groups with 63% similarities. The results indicated that though IRAP is a dominant marker like those of RAPDs, it could be successfully employed to differentiate *Musa* accessions at both genomic and subgroup levels (Fig. 3)

### 5.1.4 Development of markers for specific traits

#### 5.1.4.1 Sigatoka leaf spot resistance

Susceptible varieties namely Robusta (AAA) and Anaikomban (AA) and resistant varieties namely

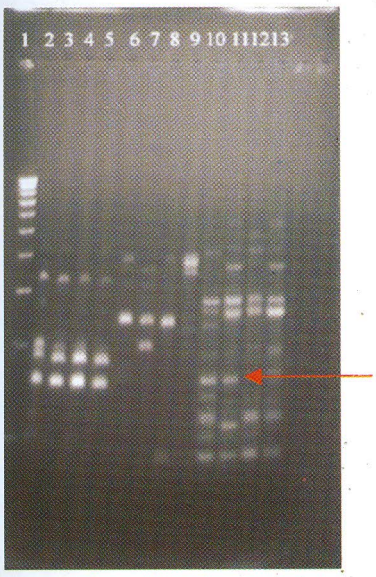



Fig 4. Arrow showing informative bands (777 bp) of OPC-20 primer for resistance cultivars

Manoranjitham (AAA) and Sannachenkadali (AA) were studied using RAPD in screening banana germplasm for Sigatoka resistance and to identify the genomic markers linked to Sigatoka resistance.

Out of 104 primers screened, forty primers produced polymorphic bands, but only five primers produced consistent, reproducible and informative bands. Of the five primers, four primers corresponded to the resistant varieties and one to the susceptible varieties. Four primers namely OPA 01 (620bp), OPA 05 (1363 bp), OPC 20 (777bp) and OPD 07 (1309 bp) amplified a band which was present in both the resistant varieties but absent in the susceptible varieties (Table 2) (Fig. 4). Similarly, one primer OPD-2 amplified a band of approximately 741 bp only in the susceptible varieties. The discrete bands identified could be possible putative diagnostic markers which could be converted into a SCAR marker that is more robust and reliable for early detection.

**Table 2. Products of primers and discrete bands for Sigatoka leaf spot resistance**

| Primers | Amplified fragment weight(bp) | Resistant varieties | | Susceptible varieties | |
|---|---|---|---|---|---|
| | | Mano ranjitham (AAA) | Sanna chenkadali (AA) | Robusta (AAA) | Anai komban (AA) |
| OPA-1 | 620 | √ | √ | x | x |
| OPA 5 | 1363 | √ | √ | x | x |
| OPC 20 | 777 | √ | √ | x | x |
| OPD 5 | 635, 908 | √ | √ | x | x |
| OPD 7 | 1309 | √ | √ | x | x |

#### 5.1.4.2 Nematode resistance

Similar strategy was attempted to develop a diagnostic marker for nematode resistance which could be useful in the early screening of progenies. Resistant and susceptible cultivar used for the study were Yangambi KM5 and Nendran respectively.

The selected cultivars were tested with 104 random primers. Of which, 27 primers produced polymorphic bands, but only 11 primers produced consistent, reproducible and informative bands. Seven primers correspond to the resistant Yangambi KM5 were OPA1, OPC 10, OPD 12, OPD 13, OPR 11, OPB 13 and OPC 14. Each primer produced one unique band except OPC 14, which produced two unique bands. Four primers corresponding to the susceptible Nendran were OPC 1 and OPC 9 which produced one unique band while OPD 11 and OPV 9 produced two unique bands (Table 3). Those putative diagnostic markers above 1000 bp could be converted into a SCAR marker.





**Table 3.Primers and discrete bands produced for nematode resistance**

| S. No. | Primers | Molecular weight (bp) of amplified fragment | Presence (√) or absence (X) of product | |
|---|---|---|---|---|
| | | | Resistant cv Yangambi KM5 | Susceptible cv Nendran |
| 1 | OPA 1 | 3233.87 | √ | X |
| 2 | OPC 10 | 1266.72 | √ | X |
| 3 | OPC 14 | 407.50 | √ | X |
| 4 | OPD 12 | 1098.67 | √ | X |
| 5 | OPD 13 | 617.21 | v | X |
| 6 | OPR 11 | 1677.89 | √ | X |
| 7 | OPB 13 | 398.47 | √ | X |
| 8 | OPC 1 | 1846.52 | X | √ |
| 9 | OPC 9 | 903.37 | X | √ |
| 10 | OPD 11 | 1406.69 | X | √ |
| 11 | OPV 9 | 528.91 | X | √ |

## 5.1.5 Evaluation

### 5.1.5.1 Multi-location testing of FHIA-23

An introduction FHIA-23 from FHIA, Honduras was evaluated at three locations under global hybrids evaluation programme and was found unsuitable for Trichy district due to long duration, high susceptibility to pseudostem weevil and improper bunch filling.

FHIA-23, a Cavendish type hybrid was tested in Tamil Nadu, Kerala and Bihar states under AICRP. Except for pulp:peel ratio and number of hands per bunch, growth and bunch parameters were statistically significant in all the locations tested. Plant height varied from 2.69 m to 3.91 m and was highly significant (Table 4). Similarly bunch weight also showed significant difference and it ranged from 22.70 kg and 27.50kg. Yield / ha varied from 45.5 to 55.5 tonnes. The crop duration was maximum (466 days) at Pusa and minimum (385 days) at Kannara.

In all locations, FHIA-23 was found highly susceptible to pseudostem weevil.

### 5.1.5.2 Screening of *Musa* germplasm for rich in minerals and carotenoids

Banana is a rich source of minerals and vitamins, of which potassium, magnesium and vitamin C are most important. As a preliminary study, 31 accessions were evaluated for various minerals (sodium, potassium, calcium, magnesium, phosphorous, iron and manganese) and carotenoid contents. The land race, Bhimkol (BB) exhibited highest source for mineral contents except carotenoid. Among cultivated varieties, Chengalikodan (AAB) and Thiruvananthapuram (AAB) registered the highest. The carotenoid content ranged from 86 to 1626 mg per 100 g of pulp and the highest was recorded in cv Chengalikodan while the lowest in

**Table 4. Performance of FHIA-23 for quantitative and qualitative traits under different agro-ecological conditions**

| Traits | NRCB Trichy, TN | Kannara Trissur, Kerala | Pusa 2005 Hajipur, Bihar | CD 5% | CV % |
|---|---|---|---|---|---|
| Plant height (cm) | 269.33 | 288.00 | 341.87 | 10.65 | 1.65 |
| Days to flower | 292.00 | 282.60 | 355.33 | 7.08 | 1.07 |
| Days to bunch harvest | 127.67 | 102.40 | 107.33 | 4.89 | 2.22 |
| Crop duration (days) | 419.67 | 385.00 | 466.00 | 8.29 | 0.94 |
| Bunch weight (kg) | 27.50 | 25.63 | 26.37 | 0.76 | 1.48 |
| Yield (t/ha) | 55.45 | 51.67 | 53.13 | 1.69 | 1.64 |
| Hands / bunch | 10.33 | 9.27 | 9.50 | NS | 4.18 |
| Fingers / bunch | 159.33 | 147.10 | 211.63 | 6.56 | 1.92 |
| Pulp : Peel ratio | 2.90 | 2.96 | 2.82 | NS | 1.65 |
| TSS (°Brix) | 29.10 | 29.20 | 23.67 | 0.64 | 1.12 |

NS : Non significant

ellapalayankodan. The potential of *acuminata* diploids with high carotenoid content are explored for use in gene pyramiding programme.

### 5.1.6 Collaborative Programmes

Stability evaluation study on cv. Rajeli *in-vitro* plants derived from meristem culture and embryogenic cell suspensions has been initiated with the colloboration with BARC.

#### 5.1.6.1 Improvement of cv. Giant Cavendish through induced mutation

Shoot tips were irradiated with 5,10 and 30 Gy and were developed into plants, to study the effect of induced *in-vitro* mutation for the improvement of Grand Nain especially for its duration. Plants treated with 30 Gy failed to establish. The other treatments were planted in field along with control and are in vegetative phase of development.

#### 5.1.6.2 Standardization of regeneration protocol

Three Indian ABB genotypes were cryopreserved and evaluated with various regeneration protocols.

Medium without auxin (BAP, NAA and IBA ) could regenerate cryopreserved germplasm successfully. The plants are being field evaluated for its trueness to its mother type.

### 5.1.7 Classical breeding

#### 5.1.7.1 Progeny development

Diploids and culinary bananas were planted in "Breeding Block" for crossing purposes. Forty seven progenies were developed during last year and field planted for evaluation. They have also been initiated by *in-vitro* for faster multiplication, for simultaneous evaluation against various biotic and abiotic stresses.

#### Progeny evaluation

5582 hybrid seeds were produced during September 2006 to February 2007. Of which only 1.5% germinated which included both diploid (2n x 2n) and triploid combinations (3n x 2n) (Table 5). Progenies of various parental combinations were evaluated for agronomic traits and the details are presented (Table 6).

Of the 23 progenies developed, 12 were parthenocarpic and useful in eventual selection, 4 were seeded and male fertile while 2 were aneuploids without any bunch formation. 4 inter specific progenies involving *Rhodochlamys* x *Eumusa* exhibited poor fruit filling and seed formation.

A Pisang Awak hybrid Hybrid, 2/5-05 (Fig.5) has been identified. Which is highly resistant to Sigatoka leaf spot under field conditions. It exhibits very short crop duration and flowered in 9-10 months as against 12 months with a 28 kg bunch. This hybrid is further evaluated against biotic stresses and yield stability.

### 5.1.8 Non-conventional approaches

#### 5.1.8.1 Development of Embryogenic Cell Suspension (ECS)

ECS has been successfully established in five cultivars namely Rasthali (AAB), Nendran (AAB),

**Table 5. Details of successful crosses yielding seeds and per cent germination achieved**

| Parents used | No. of seed obtained | No. of seed germinated | Per cent germination |
|---|---|---|---|
| Anaikomban X Matti | 39 | - | 0 |
| Anaikomban X Chengdawt | 15 | - | 0 |
| Matti X Cv. Rose | 16 | 1 | 6.3 |
| Matti X Calcutta 4 | 100 | - | 0 |
| Matti X Cv. Rose | 100 | - | 0 |
| Matti X *M. laterita* | 100 | - | 0 |
| Matti X P. Jajee | 15 | - | 0 |
| Matti X Calcutta 4 | 15 | - | 0 |
| 3-02/05 X Anai Komban | 10 | 3 | 30 |
| Lairawk X Anai Komban | 30 | 2 | 6.7 |
| Lairawk X Namarai | 30 | 10 | 33.3 |
| Manorinjitham X Kanai bansi | 24 | - | 0 |
| Manoranjitham X *M.laterita* | 45 | - | 0 |





| Parents used | No. of seed obtained | No. of seed germinated | Percent germination |
|---|---|---|---|
| Sannachenkadali X Matti | 10 | - | 0 |
| Sannachenkadali X Pisang Jajee | 15 | - | 0 |
| P.Jajee X Cv. Rose | 30 | 3 | 10 |
| P.Jajee X Anai Komban | 30 | - | 0 |
| P.Jajee X Lairawk | 30 | 3 | 10 |
| P. Jajee X Lairawk | 100 | 30 | 30 |
| P. Jajee X Calcutta 4 | 45 | - | 0 |
| Cv. Rose X *M. laterita* | 30 | 1 | 3.3 |
| Namarai X P. Mas | 30 | - | 0 |
| Udhayam X P.Jajee | 6 | - | 0 |
| Udhayam X Calcutta 4 | 15 | - | 0 |
| Udhayam X P.Lilin | 1 | - | 0 |
| Udhayam X P. Lilin | 30 | - | 0 |
| Udhayam X P.Jajee | 10 | - | 0 |
| Udhayam X P. Jajee | 15 | - | 0 |
| Udhayam X Chengdawt | 15 | - | 0 |
| Udhayam X Chengdwat | 80 | 1 | 1.3 |
| Kanai bansi X Calcutta 4 | 7 | - | 0 |
| *M.ac.burmanica* | 50 | 1 | 2 |
| M.ac. Arunachalpradesh | 10 | - | 0 |
| *M.laterita* X Chengdawt | 15 | 2 | 13.3 |
| *M.laterita* X P.Jajee | 15 | - | 0 |
| *M.laterita* X Chengdawt | 15 | - | 0 |
| *M.laterita* X P. Jajee | 30 | 2 | 6.7 |
| 13-01/05 X Calcutta 4 | 15 | 1 | 6.7 |
| Saba X P. Jajee | 15 | - | 0 |
| Saba X Chengdawt | 15 | - | 0 5 |
| Saba X P. Lilin | 2 | - | 0 |
| H201X P. Jajee | 15 | 3 | 20 |
| Lairawk X Udhayam | 75 | - | 0 |
| Lairawk X Calcutta 4 | 775 | - | 0 |
| Lairawk X Matti | 275 | - | 0 |
| *M.balbisiana* (Andaman) X Chengdwat | 15 | - | 0 |
| Pagalaphad (BB) X Calcutta 4 | 50 | 4 | 8 |
| *M. velutina* X P.Jajee | 15 | - | 0 |
| *M. velutina* X P Lilin | 45 | 13 | 28.9 |
| Calcutta 4 X *M. laterita* | 60 | - | 0 |
| Calcutta 4 X Calcutta 4 | 155 | 1 | 0.6 |
| Calcutta 4 X Lairawk | 107 | 1 | 0.9 |
| Ankur II X Lairawk | 2775 | - | 0 |
| **Total** | **5582** | **82** | **1.5 (Average)** |

**Table: 6. Field evaluation of hybrid progenies obtained in crossing**

| Sl. No. | Progeny Number | Progeny type | Tentative genomic group | Height (cm) | Girth (cm) | Petiole length(cm) | No. of leaves at harvest | Leaf area (sq cm) | Crop duration (days) | Bunch weight (kg) | No. of hands |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 01/05 | Seeded | AA | 190 | 42 | 40 | 7 | 41832.0 | 372 | 4.0 | 6 |
| 2 | 02-1/05 | Seeded | AA | 160 | 40 | 40 | 6 | 22310.0 | 355 | 2.0 | 4 |
| 3 | 02-2/05 | Parthinocarpic | ABBB | 420 | 120 | 90 | 10 | 124160.0 | 412 | 10.5 | 7 |
| 4 | 02-3/05 | Parthinocarpic | ABBB | 380 | 98 | 88 | 11 | 135580.0 | 418 | 11.5 | 9 |
| 5 | 02-4/05 | Parthinocarpic | ABBB | 450 | 110 | 85 | 12 | 149001.0 | 414 | 10.0 | 9 |
| 6 | 02-5/05 | Parthinocarpic | ABBB | 450 | 92 | 92 | 11 | 133352.0 | 345 | 8.5 | 7 |
| 7 | 02-6/05 | Parthinocarpic | ABBB | 440 | 96 | 90 | 10 | 118358.0 | 375 | 9.0 | 8 |
| 8 | 03-1/05 | Parthinocarpic | AA | 220 | 64 | 44 | 8 | 57402.0 | 281 | 4.5 | 5 |
| 9 | 03-2/05 | Parthinocarpic | AA | 210 | 52 | 64 | 7 | 51244.0 | 294 | 3.0 | 4 |
| 10 | 03-3/05 | Parthinocarpic | AA | 230 | 48 | 50 | 8 | 49481.0 | 381 | 5.0 | 6 |
| 11 | 04/05 | Seeded | AA | 220 | 60 | 62 | 8 | 61330.3 | 272 | 2.5 | 4 |
| 12 | 05/05 | Irregular Fruiting | AA | 220 | 46 | 45 | 7 | 46480.0 | 380 | 2.0 | 4 |
| 13 | 06/05 | Irregular Fruiting | AA | 230 | 66 | 64 | 8 | 81273.0 | 291 | 2.5 | 5 |
| 14 | 07/05 | Aneuploid | - | - | - | - | - | - | - | - | - |
| 15 | 08/05 | Parthinocarpic | AA | 410 | 68 | 88 | 8 | 94952.0 | 411 | 6.0 | 8 |
| 16 | 09/05 | Parthinocarpic | AA | 225 | 75 | 62 | 6 | 77887.2 | 386 | 5.0 | 4 |
| 17 | 10/05 | Parthinocarpic | AA | 225 | 70 | 64 | 6 | 67309.6 | 390 | 4.5 | 4 |
| 18 | 11/05 | Parthinocarpic | - | 300 | 75 | 46 | 8 | 83664.0 | 396 | 8.0 | 6 |
| 19 | 12/05 | Aneuploid | - | - | - | - | - | - | - | - | - |
| 20 | 13-1/05 | Irregular Fruiting | - | 206 | 32 | 64 | 10 | 53784.0 | 221 | 2.0 | 6 |
| 21 | 13-2/05 | Irregular Fruiting | - | 196 | 30 | 62 | 10 | 49667.2 | 220 | 2.0 | 6 |
| 22 | 14-1/05 | Irregular Fruiting | - | 210 | 34 | 62 | 10 | 56440.0 | 238 | 1.5 | 6 |
| 23 | 14-2/05 | Irregular Fruiting | - | 212 | 36 | 60 | 11 | 64384.7 | 238 | 2.0 | 6 |

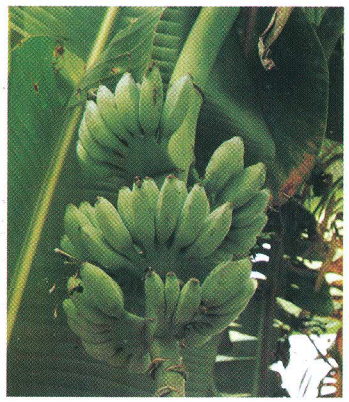


Fig. 5. A new Pisang Awak hybrid

NeyPoovan(AB), Robusta (AAA) and Grand Nain (AAA) by adopting the protocol of INIBAP with modifications. However, successful regeneration into plantlets has been achieved only in Nendran and Rasthali (Fig. 6). Use of antioxidants could not effectively control the phenolic exudation and browning which was encountered during the development of ECS.

#### 5.1.8.2 Standardization of tissue culture protocols for trait specific (fragrant) bananas

Programmes have been initiated to conserve Indian fragrant landraces *viz.*, Manoranjitham(AAA), Hilll Banana (AAB) and Ladan (AAB) through development of specific tissue culture protocol for mass multiplication and for their eventual reintroduction into the natural habitat *viz.*, Kolli Hills and Sirumalai hills of Tamil Nadu.

## 5.2 Crop Production

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

In Red Banana plant crop, conventional planting system recorded significantly taller plants (215.9 cm), enhanced leaf emergence rate (7.63 days), advance ment in flowering and also reduction in the total crop duration by 15.9 days and 24.9 days respectively as compared to paired row planting system. Though conventional planting (2.0m x 2.0m) recorded significantly more bunch weight (8.30 kg), but the highest yield (28.45 t/ha) was recorded in paired row planting as against 20.76 t/ha obtained in conventional planting. The quality analysis revealed that plants grown under paired row planting recorded high TSS (23.5 °B), total sugars (20.96 %), reducing sugars (3.09 %) and ascorbic acid (12.53 mg/100g) with low pulp: peel ratio and acidity of fruits.

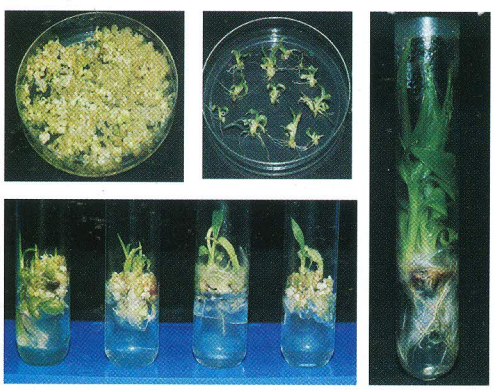


Fig. 6. Different stages of ECS development in banana

Among the fertigation levels, application of 100% recommended NK dose recorded the highest bunch weight with an estimated yield of 25.80 t/ha. The lowest bunch weight and yield were recorded in plants with 50% recommended N&K fertigation. Similarly 100% fertigation recorded better fruit quality *viz.*, TSS (23.0 °B), total sugars (20.56 %), reducing sugars (3.05%), ascorbic acid (12.01mg/100g) with low acidity as compared to other fertigation treatments.

Analysis of the plant samples revealed that, the leaf nutrient concentration was high in plants grown under conventional planting and among the fertigation levels, 75% RDF recorded the highest nutrient levels followed by 100% RDF. The physiological and biochemical analyses revealed that the photosynthetic rate, chlorophyll contents, protein and polyphenol oxidase activity were highest in plants grown under conventional planting system and among the fertigation levels, 100 % RDF recorded the highest values for all these parameters.

In the first ratoon crop of Robusta banana, the plants under conventional planting system (P1) recorded significantly more plant height, pseudostem circumference, number of leaves, mean leaf area, no of suckers and less phyllochron as compared to paired row planting. In Grand Nain banana, the plants under conventional planting system recorded significantly more plant circumference, number of healthy leaves and suckers than paired row planting. Fertigation with 75% recommended dose of N&K recorded early leaf emergence with a phyllochron of 7.7 days leaf $^{-1}$ as against 8.5 and 8.2 days recorded under 100% and 50% RDF respectively.

In Red Banana, the plants under paired row planting system recorded significantly more Leaf Area Index (LAI) i.e 2.37 as compared to conventional planting (1.69). Among the fertigation levels, 75 % RDF recorded significantly more number of healthy leaves (8.37), mean leaf area (0.80m) and LAI (2.36) than the other levels of fertigation.

The physiological and biochemical analyses revealed that the chlorophyll contents, photosynthetic activity, protein and polyphenol oxidase activity were

the highest in plants grown under conventional planting and among the fertigation levels, 100 % RDF recorded the highest values for all these parameters. The treatment combination of conventional planting with 100% RDF fertigation recorded the highest photosynthetic activity of 12.28, 14.57 and 10.96 µmol $CO_2$ $m^{-2}$ $second^{-1}$ in Robusta, Grand Nain and Red banana first ratoon plants respectively.

### 5.2.2 Studies on integrated nutrient management in banana

In the II[nd] ratoon (Rasthali), the leaf nutrient concentration ranged *viz.*, N:1.9-2.9%, P:0.17-0.36% K:2.4-3.8%, (Fig.7b, 7c and 7d), Ca:0.22-0.59%, Mg:0.12-0.35%, Fe:198-301ppm, Cu:2-8ppm, Mn:148-220ppm and Zn:10-43ppm at flowering stage. The post harvest soil nutrient concentration were N:183-246, P:6-11, K:254-335, Ca:1050-2100, Mg:534-750 kg/ha. The highest and optimum leaf nutrient concentrations were observed in the treatment having 80%rec.NPK + VAM + rice husk ash or vermicompost application. These treatments also recorded the highest bunch weight, which was 30 per cent more than that of treatment with 100% inorganic-NPK fertilizers only (Fig.7a). Irrespective of organic manures application, the performance of VAM and *Phosphobacteria* was superior over *Azospirillum*.

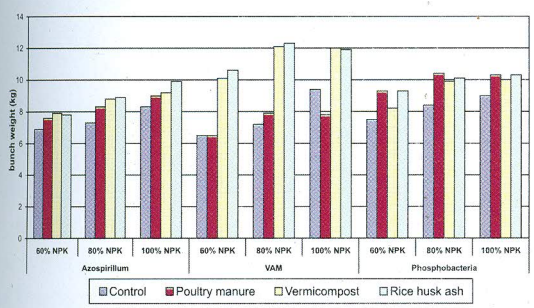



Fig 7a. Effect of organic manure and bio-fertilisers with graded levels of NPK on bunch weight of Rasthali ratoon-II

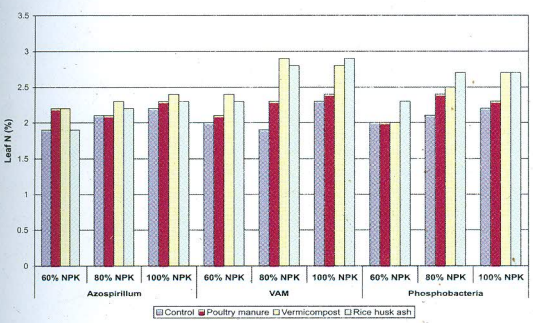



Fig. 7b. Effect of organic manures and bio-fertiliser with graded levels of NPK on leaf N concentration of Rasthali ratoon-II

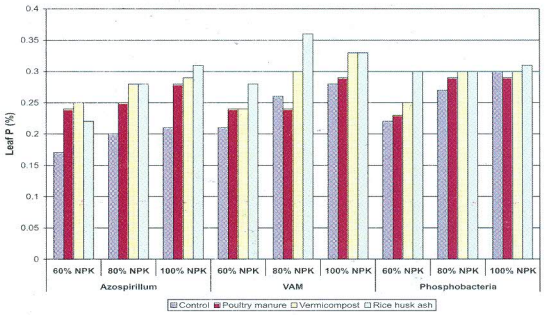



Fig. 7c. Effect of organic manures and bio-fertiliser with graded levels of NPK on leaf P concentration of Rasthali ratoon-II

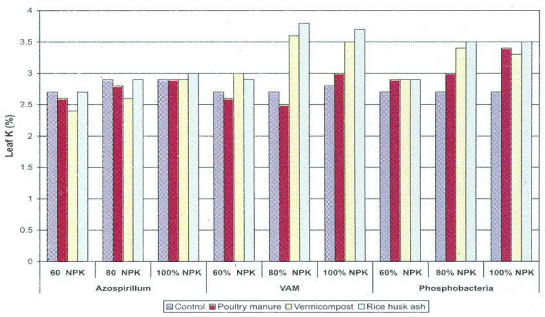



Fig. 7d. Effect of organic manures and bio-fertiliser with graded levels of NPK on leaf K concentration of Rasthali ratoon-II

Irrespective of bio-fertilizer used , the performance of rice husk ash was superior to vermicompost and poultry manure, in increasing the bunch weight. Thus, application of 15 kg rice husk ash + 25 g VAM+ 80% rec. NPK/plant could generate an additional net profit of Rs. 32,500/- per hectare.

### 5.2.3 Studies on micronutrients in banana

The highest plant height and pseudostem girth were observed in the treatment ($Fe_{soil}$, $Zn_{foliar}$, $B_{soil}$). The highest total number of leaves and number of fingers per bunch were observed in $Fe_{control}$, $Zn_{foliar}$, $B_{foliar}$. Application of micronutrients significantly influenced the chemical composition of the leaf tissues. The treatment ($Fe_{soil}$, $Zn_{foliar}$, $B_{soil}$) recorded the highest bunch weight, which was 43.5 per cent more than that of the control (Fig. 8a). The correlation coefficients between bunch weight and nutrient concentrations in the leaf tissues were significant, except for Fe and Cu (Bunch weight Vs N=0.81**; P=0.23*; K=0.97**; Fe=0.05$^{NS}$; Zn=0.40**; B=0.20*; Mn=0.22* and Cu=0.19$^{NS}$). Wherever Zn was applied to the soil, the P concentration in the leaf tissues was drastically reduced due to precipitation of P as Zinc phosphate, which is an insoluble compound (Fig. 8b). Soil application of Fe and B along with foliar spray of Zn under high





pH soil condition, increased the bunch weight to the tune of 43.5 per cent and produced an additional net profit of Rs. 38,000/ha over control.

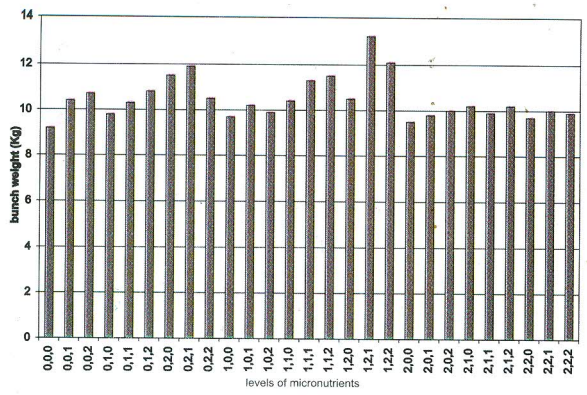



Fig. 8a. Effect of micronutrients on banana yield

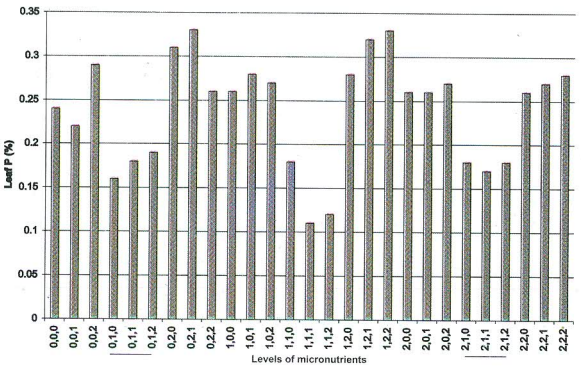



Fig. 8b. Effect of micronutrients on leaf P (%)

## 5.2.4 Physiology and Biochemistry

Source-sink relationship in banana, pre-anthesis storage of starch in the corm and its contribution to the fruit development was studied. In Karpuravalli, stored starch in corm during pre-anthesis period has contributed 83.52% followed by Robusta (82.05%), Ney Poovan (82.64%), Pachanadan (79.14%) and Rasthali (73.81%).

The starch, amylose and amylopectin contents varied among the banana cultivars. The fresh green banana fruit pulp (90% maturity) contains 80-85% of starch on dry weight basis. The amylose content recorded were 35% in Nendran (AAB) and cooking bananas *viz.*, Saba (ABB) and Monthan (ABB) while dessert cultivars (Robusta, Rasthali, Poovan and NeyPoovan) recorded 25-29 %.

At 3rd and 5th month of planting, the number of roots produced by Nendran were 37 and 92 respectively which was lesser than the other cultivars *viz.*, Robusta, Ney Poovan, Poovan, Rasthali, Saba, Karpuravalli and Red Banana. In a three month old Robusta banana corm, the total sugars in outer core was higher (10.23 mg/g) than inner core of corm (5.35 mg/g). Similar trend was observed in reducing and non- reducing sugars.

The corm tissues were analysed for sugar and starch content. After three months of planting in the field, genotypic variations in the accumulation of starch and sugar contents in corm was observed. The starch content (dry weight basis) of Red banana recorded the highest followed by Rasthali, Nendran, Poovan, Robusta, NeyPoovan and Karpuravalli. The sugar content also varied from 0.22% to 2.3% (dry weight basis). Nendran recorded the highest sugar content followed by NeyPoovan and Robusta, Rasthali, Poovan and Karpuravalli while Red banana recorded the lowest content.

After 3rd month, the cultivars were observed for different growth parameters. Poovan recorded the maximum height than other varieties while Karpuravalli recorded the maximum circumference. The no. of roots was the highest in Ney Poovan and the least in Nendran.

The photosynthesis was recorded at 3rd, 5th, 7th months after planting and at flowering. At flowering, Rasthali recorded the highest Pn (21.01 $\mu mol\ m^{-2}\ s^{-1}$) than all other varieties.

Under pot culture studies, the soil moisture stress was imposed on three month old plants for three weeks to reach the available soil moisture at 53% (leaf osmotic potential -0.685Mpa) and in irrigated (-0.375Mpa). At the end of stress period, three lower leaves became yellow but no new leaves were produced. Where as in control, two new leaves were produced and no leaf senescence was observed. In Robusta, the soil moisture stress accelerated the leaf senescence with reduced leaf growth and development. The antioxidative enzymes like catalase and ascorbate peroxidase contents increased at 21 days after treatment.

Genotypic variations in the leaf longevity and senescence were observed. A fully expanded first leaf of three month old Robusta plant senesce after 108 days, where as in Nendran, Rasthali and NeyPoovan leaves senesces after 66.66, 65.00 and 67 days after full development.

When Robusta banana plant was imposed for soil moisture stress for three weeks to reach 53% of available soil moisture, the osmotic potential of plant sap reached -0.671MPa in stressed plants as compared to irrigated control -0.379MPa. The increase in decreasing osmotic potential after 7 days to 21 DAI in water stressed treatment was not significant.

During water stress treatment, leaf production has decreased as compared to control, where normal leaf formation was observed. Besides, the water stress induced faster senescence of lower leaves as compared to zero senescence in control.

## 5.3 Postharvest Technology

### 5.3.1 Development of value added products from banana peel

In Nendran banana the peel constitute about 35-40% as waste in chips making industries. A new product *viz.*, banana peel pickle (Fig 9), was developed, receipe standardized and storage studies were carried out. Its quality was comparable to that of banana flower pickle and had a storage life of 8 months under ambient conditions.

Fig 9. Peel Pickle

### 5.3.2 Storage of banana flower as pulp for subsequent use in pickle industry

The availability banana flower is seasonal and varies in different banana growing regions. Non-availability of flowers during the lean season is a handicap to banana flower pickle manufacturers. A study was conducted to store the banana flowers in the form of pulp after acidification under ambient conditions. The product was stable for 6 months and the pickle prepared from the stored pulp was acceptable for another six months.

### 5.3.3 Studies on storage and nutritional qualities of banana blended juices

Blended beverages were prepared using banana juice as base with varying quantities of tomato, orange and jamun. The results revealed that the blend of banana and jamun was the best followed by banana and tomato. It was nutritionally rich with more anthocyanins and lycopene which are potent antioxidants (Fig. 10).


Fig 10. Blended Juice

### 5.3.4 Growth and development studies in Nendran banana

Growth and development studies in Nendran banana indicated that it took 90 days from flowering to full maturity of fruits and at full maturity, it had 17.58 cm length, 11.36 cm girth, 4.6°Brix TSS, 1.97 pulp to peel ratio, 32.5% starch and 0.31% total sugars.

### 5.3.5 Development of spiced and blended wines from banana and other vegetables

Spiced wine was prepared from banana with cinnamon in different combinations and blended wine was developed from banana and beet root. Among the different blends, beetroot and Poovan juice blended in 1:1 ratio and fermented, was the most acceptable wine with a score of 6.92 out of 9 points on hedonic scale.

### Amelioration of chilling injury in banana using different techniques

Studies on amelioration of chilling injury using different techniques like cold adaptation, intermittent warming and modified atmosphere storage were tried in Nendran banana which indicated that cold adaptation and intermittent warming could not control the chilling injury at temperatures below 12°C while modified atmosphere packaging could keep the fruits with out chilling injury up to 44 days at 10°C.

## 5.4 Crop Protection

### 5.4.1 Management of Banana weevils

#### 5.4.1.1 Standardisation of methodology for screening of *Musa* germplasm against banana corm weevil *(Cosmopolites sordidus)*

Studies to standardize the screening methodology /material for banana corm weevil resistance using, the corm cube, banana leaf sheath and corm (sucker planted in a pot) as a material for corm weevil feeding. Corm (sucker planted in a pot ) was found to be suitable for quantifying the feeding damage and progeny development.

#### 5.4.1.2 Development of artificial diet for banana stem weevil *(Odoiporus longicollis)*

**i) Survival (days)**

Among the three artificial diets evaluated, maximum survival was recorded in diet -II (18.5 days) while a minimum (13.4 days) in diet-I, where as in control (banana leaf sheath), 58 days survival was recorded. The survival was maximum in potato tubers (51.7 days ) and minimum in pineapple (7.9 days).





### ii) Feeding

Among the diets, maximum feeding (55.4 mg) was observed in diet –II followed by diet-I (47.5mg) and the lowest (41.1mg) in diet-III. In banana leaf sheath (control), 73.9mg feeding was observed. In potato and pineapple, it was 43.9 and 23.2 mg respectively.

### iii) Eggs laid

In general, the egg laying was very poor in all the diets evaluated .The egg laying ranged from 0.4 to 1.5 eggs. In pineapple, egg laying was not recorded while in potato, it was 0.4 egg. In banana leaf sheath, 6.8 eggs were recorded. Results revealed that for oviposition, original leaf sheath is required, other wise the oviposition is not possible.

### 5.4.1.3 Biochemical profiles of banana leaf sheath

The biochemical profiles such as protein, pectin, total phenol, total sugars, peroxidase and polyphenol oxidase activities were studied in Poovan, Ney Poovan, Karpuravalli, Monthan, Nendran, Robusta, Rasthali, Red banana, Pachanadan, Saba and Bhimkol.

The total phenol content ranged from 0.70 mg/g (Robusta ) to 2.0mg/g (Bhimkol). Protein content was maximum in Monthan (2.48mg/g) and the least in cv Ney Poovan (0.96mg/g). Pectin content was maximum in (2.96 %) Karpuravalli and minimum (1.28%) in Rasthali. Minimum sugar was recorded in Bhimkol (0.26 %) and maximum in Ney Poovan (1.14%). Bhimkol and Ney Poovan recorded the minimum peroxidase activity of 0.008 and 0.018 activity /min /g respectively. Polyphenol oxidase activity was maximum in Rasthali (0.074 /min/g) and minimum in Bhimkol (0.008/min/g.) (Table 7 ).

### 5.4.1.3.1 Bioassay of semiochemicals and banana leaf sheath volatiles against banana stem weevil,

13 Semiochemicals were tested against male, female, virgin male and virgin female of banana stem weevil, using electroantennogram and the response was recorded in milli volts (mv).

### i) Response of male weevil

m-anisaldehyde evoked the highest response of 1.415 mV followed by 2-Heptanone (1.176 mV ).The response of 13 semiochemicals ranged from 0.437 to 1.415 mV.

### ii) Response of female weevil

The response of 13 semiochemicals ranged from 0.419-1.140 mV. Maximum response was recorded in 2-anisaldehyde (1.140 mV) followed by Octanone (1.046mV)and Farnasyl acetate (0.808mV ) and minimum response was recorded in Carvone -S .

### iii) Response of virgin male weevil

The response ranged from 0.310 -1.255mV. m-anisaldehyde,o-anisaldehyde, Pyridine Farnasyl mixture, the responses were 0.725 ,0.743 and 0.738 mV respectively.

### iv) Response of virgin female weevil

Maximum response of 1.586 mV in p-anisaldehyde followed by 1.410mV in farnasyl acetate and 0.865 mV in Pyridine was recorded. The range was 0.305mV (Cyclohexanone ) to 1.410 mV (Farnasyl acetate) (Fig. 11).

**Table 7. Biochemical profiles of banana leaf sheath of different cultivars.**

| Cultivar | Peroxidase (Unit activity/min./g) min./g) | Polyphenol activity (Unit activity/ | Total sugar(%) | Protein (mg/g) | Total phenol (mg/g) | Pectin content (%) |
|---|---|---|---|---|---|---|
| Red Banana | 0.015 | 0.100 | 0.42 | 1.76 | 1.56 | 1.62 |
| Poovan | 0.017 | 0.026 | 0.54 | 2.00 | 1.22 | 2.18 |
| Rsathali | 0.014 | 0.074 | 0.56 | 1.58 | 1.38 | 1.28 |
| Robusta | 0.014 | 0.040 | 0.50 | 1.22 | 0.70 | 1.62 |
| Pachanadan | 0.019 | 0.011 | 0.72 | 1.34 | 1.92 | 2.00 |
| Nendran | 0.014 | 0.017 | 0.58 | 1.92 | 1.22 | 4.60 |
| Ney Poovan | 0.018 | 0.017 | 1.14 | 0.96 | 1.56 | 3.08 |
| Monthan | 0.011 | 0.010 | 0.98 | 2.48 | 0.94 | 1.92 |
| Saba | 0.012 | 0.014 | 1.00 | 2.00 | 0.94 | 1.88 |
| Karpuravalli | 0.015 | 0.014 | 0.46 | 1.80 | 1.72 | 2.96 |
| Bhimkol | 0.008 | 0.008 | 0.26 | 1.74 | 2.00 | 1.90 |

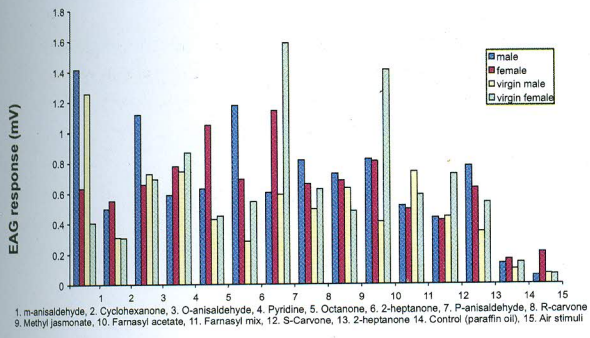



Fig. 11 Screening of semiochemicals against banana stem weevil,

### 5.4.1.4 Response of Banana leaf sheath volatiles against banana stem weevil, *Odoiporus longicollis* by Electroantennography

In Poovan and Karpuravalli bananas, by air entrainment method (72 hours), volatiles were trapped using Tenax adsorbent and eluted sequentially using Hexane, Dichloromethane, Ethyl acetate and Methanol. The eluted volatile was diluted at 25, 50,75 and 100 per cent concentrations and the EAG response was recorded against male, female and virgin male and female weevils. Results indicated that the volatiles eluted with hexane and methanol only gave EAG response irrespective of concentration. Virgin female and male indicated weevil response at 25 %concentration of hexane and methanol extracted leaf sheath volatile (Table 8 ).

### 5.4.1.5 Olfactometry studies on banana leaf sheath volatiles in Karpuravalli and Poovan

Banana leaf sheath volatiles (Karpuravalli and Poovan) were collected by air-entrainment method and eluted with dichloromethane solvent. The eluted sample was tested in 3 doses ie., 2.5, 5.0 and 7.5 µl. In Karpuravalli, maximum weevil response of 20% and 30% was recorded in dose 10 µl in male and female weevils respectively. In control (Karpuravalli leaf sheath) weevil response was 20 and 50 % respectively by male and female weevils.

In Poovan, maximum weevil response (10% and 20%) was recorded in dose 10 µl in male and female weevils respectively. In control (Poovan leaf sheath), the weevil response was 2 0 and 30 % respectively by male and female weevils (Table 9a & b).

**Table 8. Electroantennogram response of Banana stem weevil, *Odoiporus longicollis* against banana leaf sheath volatiles of cvs. Poovan and Karpuravalli eluted and diluted in different solvents at four concentrations.**

| Cultivars | Male | | Female | | Virgin male | | Virgin female | |
|---|---|---|---|---|---|---|---|---|
| | Max. | Min. | Max. | Min. | Max. | Min. | Max. | Min |
| Poovan | 0.182 | 0.036 | 0.172 | 0.031 | 0.230 | 0.030 | 0.256 | 0.056 |
| Concentration | 75% He | 75% Me OH | 100% He | 50% Me OH | 100 % He | 75 % Me OH | 25% He | 25% Me OH |
| Karpuravalli | 0.342 | 0.066 | 0.320 | 0.066 | 0.688 | 0.044 | 0.591 | 0.052 |
| Concentration | 25% He | 50% Me OH | 100% He | 75% Me OH | 100% He | 50% Me OH | 100% He | 75% Me OH |

He : Hexane MeOH : Methanol

**Table 9(a). Olfactometer response of banana stem weevil, to leaf sheath volatiles of cv.Karpuravalli.**

| Dose (ul) | No.of weevils released. | | No.of weevils attracted | | Time taken to reach the sample (Minutes) | | Weevil response (Per cent) | |
|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female |
| Control | 10 | 10 | 2 | 5 | 30 | 15 | 20 | 50 |
| 5 | 10 | 10 | 1 | 1 | 25 | 15 | 10 | 10 |
| 7.5 | 10 | 10 | 1 | 2 | 15 | 20 | 10 | 20 |
| 10.0 | 10 | 10 | 3 | 2 | 10 | 15 | 20 | 30 |





Table 9(b). Olfactometer response of banana stem weevil, to leaf sheath volatiles of cv. Poovan.

| Dose (ul) | No.of weevils released | | No.of weevils attracted | | Time taken to reach the sample (Minutes) | | Weevil response (Per cent) | |
|---|---|---|---|---|---|---|---|---|
| | Male | Female | Male | Female | Male | Female | Male | Female |
| Control | 10 | 10 | 2 | 3 | 10 | 5 | 20 | 30 |
| 5 | 10 | 10 | 0 | 1 | 0 | 14 | 0 | 10 |
| 7.5 | 10 | 10 | 1 | 1 | 8 | 9 | 10 | 10 |
| 10.0 | 10 | 10 | 1 | 2 | 6 | 10 | 10 | 20 |

Table. 10. Collection of volatiles from the dry banana leaf sheath by air entrainment method.

| Cultivar | Solvent | Indicator | No.of bands | Remarks | Colour |
|---|---|---|---|---|---|
| Karpuravalli | Hexane | Anisaldehyde:Sulphuric acid:Glacial acetic acid | 1 | Clear band | Yellow |
| | Ethyl acetate | | 1 | - | Yellow |
| | Dichloromethane | | 4 | Clear bands | Yellow, Violet, Dark yellow, Light pink. |
| | Methanol | | 1 | - | Yellow |
| Poovan | Hexane | Anisaldehyde:Sulphuric acid:Glacial acetic acid | 1 | Clear band | |
| | Ethyl acetate | | 1 | | |
| | Dichloromethane | | 5 | Clear bands | Ash colour, Yellow, Violet, Dark yellow, Light pink. |
| | Methanol | | 1 | | Yellow |

Table 11. Collection of volatiles from the banana leaf sheath by hydrodistillation method.

| Cultivar | Solvent | Indicator | No.of bands | BandColour |
|---|---|---|---|---|
| Karpuravalli | Diethyl ether | Anisaldehyde:Sulphuric acid:Glacial acetic acid | 7 | 1. Light Orange<br>2.Green<br>3.Indigo<br>4.Indigo<br>5.Light violet<br>6.Blue<br>7.Light orange |
| Poovan | Diethyl ether | Anisaldehyde:Sulphuric acid:Glacial acetic acid | 7 | 1. Light Orange<br>2.Green<br>3.Indigo<br>4.Indigo<br>5.Light violet<br>6.Blue<br>7.Light orange |

Table 12. Collection of volatiles from the dry banana leaf sheath by shaker method.

| Cultivar | Solvent | Indicator | No.of bands | Remarks |
|---|---|---|---|---|
| Karpuravalli | Hexane | Anisaldehyde: Sulphuric acid: Glacial acetic acid | 6 | Clear bands |
| | Ethyl acetate | -Do- | 6 | - |
| | Dichloromethane | -Do- | 6 | Clear bands |
| | Methanol | -Do- | 6 | - |
| Poovan | Hexane | -Do- | 6 | Clear bands |
| | Ethyl acetate | -Do- | 6 | - |
| | Dichloromethane | -Do- | 6 | Clear bands |
| | Methanol | -Do- | 6 | - |

### 5.4.1.6 Separation of banana leaf sheath volatiles by thin layer chromatography

Leaf sheath volatiles were collected from Karpuravalli and Poovan banana by solvent extraction method and the volatiles was sequentially eluted with hexane, dichloromethane, ethylacetate and methanol. In both the cultivars, six bands were separated by thin layer chromatography.

In Karpuravalli, 4 bands were separated when eluted with Dichloromethane, while one band was separated using other solvents. In Poovan, 5 different bands were separated when eluted with dichloromethane. Whereas, one band each was separated by other solvents. Leaf sheath volatiles collected from cvs. Karpuravalli and Poovan by air-entrainment method and the volatiles were eluted with Diethylether. 7 bands were separated by thin layer chromatography (Table 10,11 and 12 (Fig. 12).

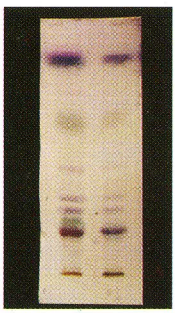


Fig. 12 Separation of banana leafsheath volatiles by Solvent Extraction Method

### 5.4.1.7 Preliminary identification of banana leaf sheath volatiles

GC-MS analysis of banana leaf sheath volatile of Karpuravalli collected by hydrodistillation method indicated the presence of Ethyl benzene $C_8H_{10}$ (m.wt 106) and 3-Hexanal, $C_6H_4O$ (m.wt 102) with Carbowax column. GC-MS analysis of banana leaf sheath volatile of Karpuravalli collected by Air-entrainment method using Porapak S indicated the presence four components with molecular weight at 136 (2) and 148 (2) with HP5 column.

### 5.4.1.8 Banana pseudostem traps as a delivery system for biocontrol agents

#### 5.4.1.8.1 Entomopathogenic fungus, *(Beauveria bassiana)*

Field studies were conducted in Virupakshi banana under high land production system in Lower Pulney hills using maize flour and chaffy grains formulations. These formulation were swabbed on split stem traps which resulted in trapping of both corm and stem weevil. Maximum trapping of both the weevils was recorded in traps swabbed with rice chaffy grains formulation and lowest in the maize flour formulation. Similarly, the per cent mortality of both the weevils was also higher in rice chaffy grains formulation (77.23 %) than the maize flour formulation (72.47%).

The observations recorded on the infestation level for the stem weevil using 0-6 scale scoring method indicated that the use of rice chaffy grains formulation in split stem traps recorded 62.5% reduction in infestation and maize flour formulation recorded 55% reduction in infestation. However, the maximum reduction of infestation (81.25%) was achieved in the garden, where the plants injected with Monocrotophos 36 EC .

#### 5.4.1.8.2 Entomopathogenic nematodes (EPN) *Heterorhabditis indica ,Steinernema glaseri* and *S.abbasi*

Banana split traps were swabbed with 25 ml (solution containing $1x10^8$ IJ's/ml) entomopathogenic nematodes such as *Heterorhabditis indica, Steinernema glaseri* and *S.abbasi* and kept near the banana plant. 63.12 and 36.8% stem weevil and corm weevil were trapped respectively. Among trapped weavils female population was more than the male.

The stem weevil mortality due to EPN was ranged from 9.64 to 44.14%. Mortality due to *H.indica* was higher (44.14 %) than the other two nematodes *(S.abbasi* and *S.glaseri)* which registered a weevil mortality of 9.64 and 21.22 per cent respectively. Stem weevil mortality due to EPN ranged from 9.0 to 27.54 per cent and among the nematodes the maximum mortality was recorded by *H.indica* (27.54%) where as *S.abbasi* and *S.glaseri* registrered a mortality of 9.0 and 22.80 per cent respectively. Corm weevil mortality due to EPN ranged from 7.0 to 20.34 per cent while 20.34 per cent mortality was recorded by *H.indica.*





### 5.4.1.9 Mass production of bio-control agents for banana weevil management

#### Entomopathogenic fungus

*i) Beauveria bassiana*

Among 7 substrates, maximum conidial production was recorded in rice chaffy grains ($1x10^{10}$ cfu /g) and minimum in rice bran ($3.6x10^{7}$ cfu/g). Among the banana based substrates, maximum production was recorded in banana inflorescence ($4x10^{7}$ cfu/g ) and minimum in banana bract ($5x10^{6}$ cfu/g) .

*ii) Metarhizium anisopliae*

Among the 8 substrates, maximum conidial population was recorded in rice chaffy grains ($1x10^{11}$ cfu /g ) and minimum in wheat bran ($5.0x10^{5}$ cfu/g). Among the banana based substrates, maximum production was recorded in Robusta banana peel ($2.5 x10^{9}$ cfu/g) and minimum in banana corm ($1x10^{5}$ cfu/g).

*iii) Verticillium lecanii*

Among the 8 substrates , maximum conidial population was recorded in maize flour ($2x10^{9}$ cfu /g ) and minimum in groundnut shell ($1.3.x10^{5}$ cfu/g). Among the banana based substrates, maximum production of was recorded in Poovan banana dried peel ($3.0 x10^{11}$ cfu/g) and minimum in banana inflorescence ($1x10^{6}$ cfu/g) ( Fig. 13).

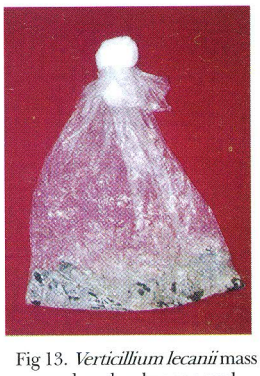


Fig 13. *Verticillium lecanii* mass produced on banana peel

iv) Non-pathogenic *Fusarium oxysporum*

Among the 8 substrates, maximum conidial population was recorded in sand maize media ($2x10^{9}$ cfu /g ) and minimum in paddy straw ($1.0.x10^{5}$ cfu/g). Among the banana based substrates, maximum production was recorded in Poovan banana dried peel ($1.0 x10^{9}$ cfu/g) and minimum in banana inflorescence ($2.3x10^{5}$ cfu/g).

v) *Bacillus thuringiensis*

Among the 12 substrates, maximum spore production was recorded in rice clarified grains ($12.6x10^{11}$cfu /g ) and a minimum production was noticed in ragi flour ($6.0.x10^{5}$ cfu/g). Among the banana based substrates, maximum production was recorded in banana inflorescence( $5.3. x10^{7}$ cfu/g ) and minimum in banana peduncle ( $40x10^{5}$ cfu/g).

### 5.4.1.10 Compatibility of commonly used insecticides against biological control agents

The commercial formulations of nineteen commonly used pesticides of banana (9 insecticides, 6 fungicides, 1 weedicide ,3 botanicals and bleaching powder) were evaluated against microbial biocontrol agents like *Beauveria bassiana ,Metarhizium anisopliae, Verticillum lecanii ,Non-pathogenic Fusarium oxysporum* and *Bacillus thuringiensis* under laboratory conditions using poison food technique on PDA medium.

*i) B. bassiana*

Among the insecticides evaluated against *B.bassiana,* maximum inhibition of 72.5% was recorded in Carbofuran and minimum of 10 %) in recommended dose of Monocrotophos. In half the dose of recommended, the maximum inhibition (62.5%) was recorded in Imidacloprid and minimum inhibition was noticed in Phorate (5 %). Among the fungicides, maximum inhibition was recorded in Calixin (70 %) and minimum inhibition in Carbendazim( 22.5% ) in recommended dose. In half recommended dose maximum inhibition was recorded in tilt (69.76%) and minimum inhibition was noticed in Mancozeb (52.5%).Growth inhibition was observed in Companion and Emissan. In Weedicide (Round up), 57.5 per cent growth inhibition was recorded; where as in half recommended dose, growth inhibition was not recorded. 22.5 per cent growth inhibition was recorded in recommended dose of bleaching powder where as exhibiting in half recommended dose, 5 %inhibition was recorded. In recommended dose, maximum inhibition of 27.5% was recorded in Nimbicidine, where as in half recommended dose both Neemazal and Nimbicidine did not inhibit the growth (Fig. 14).

*ii) Metarhizium anisopliae*

Among the insecticides evaluated against *Metarhizium anisopliae,* maximum inhibition was recorded in Carbofuran (75%) in recommended dose. Minimum inhibition was recorded in Cartap hydrochloride ( 36.36%) . In the half recommended dose, maximum inhibition was recorded in Dimethoate (34%). Where as, complete growth inhibition was recorded in Carbofuran, Monocrotophos and Triazophos. Among 6 fungicides tested inhibition was recorded only in Calixin (43.1 %) in recommended dose. A complete growth inhibition was recorded in the following chemicals , Tilt, Carbendazim Companion ,Mancozeb and Emisan. In half recommended dose, growth inhibition was recorded in all the 6 fungicides tested. 59.0 per cent growth inhibition was recorded in the recommended dose of Roundup weedicide. In half recommended dose, 11.36 % growth inhibition was recorded. At recommended dose of bleaching powder, 43.18 per cent growth

inhibition was recorded. In half recommended dose 27.2 per cent growth inhibition was recorded. Neemal at recommended dose, inhibited growth to an extent of 54.5%.Where as Nimbicidine at both recommended and half recommended dose completely inhibited the growth (Fig. 15).

### *iii) Verticillum lecanii*

Among the 9 insecticides evaluated against *Verticillum lecanii* maximum inhibition was recorded in Phorate (74.3 %) and minimum in Chlorpyrifos (50%) of recommended dose. In half recommended dose, maximum inhibition (53.48%) was recorded in Riazophos and minimum inhibition was noticed in Cartap hydrochloride (18.6%). Complete inhibition was recorded in Carbofuran, Phorate, Chlorpyriphos and Dimethoate in half recommended dose .Where as in recommended dose, growth inhibition was recorded in Triazophos and Cartap hydrochloride. Among the 6 fungicides tested, maximum inhibition (74.04%) was recorded in Mancozeb and minimum inhibition was exhibited by Companion (58.1) in recommended dose. Tilt and Emissan completely inhibited the growth. In half recommended dose maximum inhibition was recorded in Carbendazim (69.76%).Tilt, Calixin, Companion, Mancozeb and Emissan completely inhibited the growth even at half recommended dose. Weedicide (Round up) exhibited a growth inhibiton of 51.16 % in half recommended dose. In recommended dose complete growth inhibition was recorded. In recommended dose of Neemazal and Nimbicidine complete growth inhibition was recorded (Fig. 16).

### *iv) Non-pathogenic Fusarium oxysporum*

Among the 9 insecticides evaluated against non - pathogenic *Fusarium oxysporum,* maximum inhibition was recorded in Phorate (50%) and minimum in Triazophos (22.5%) in recommended dose. In half recommended dose, maximum inhibition was recorded in Phorate (27.5%) and minimum inhibition was noticed in Cartap hydrochloride (10%). In half recommended dose, complete growth inhibition was recorded in Chlorpyrifos and Dimethoate. Among the 6 fungicides tested, complete growth inhibition was recorded in recommended and half recommended dose .In half recommended dose, Mancozeb inhibited 10 per cent growth. At recommended dose, weeedicide (Round up) exhibited a growth inhibition of 60 per cent, where as at half recommended dose 41.7 %inhibition was recorded. 55 per cent growth inhibition was recorded in bleaching powder at recommended dose. Botanicals tested ( Neemazal and Nimbicidine) were highly incompatible at recommended dose ,where as at half recommended dose 22.5 % and 10.% growth inhibition was observed by Nimbicidine and Neemazal respectively (Fig. 17).

Fig. 14 *Beauveria bassiana* incompatible with Monocrotophos at HRD

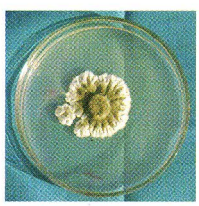


Fig. 15 *Metarhizium anisopliae* compatible with Cartap hydrochloride at HRD

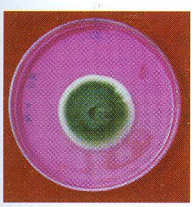


Fig. 16 *Verticillium lecanii* compatible with Chlorpyrifos at HRD

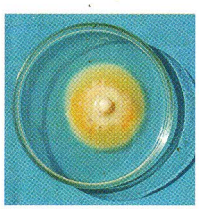


Fig. 17 Non pathogenic *Fusarium oxysporum* compatible with Triazophos at HR Dose

### *v) Bacillus thuringiensis*

All the pesticides, botanicals and chemicals evaluated for growth inhibition were compatible except the weedicide, Roundup.

### 5.4.1.10.1 Compatibility of entomopathogenic nematodes with pesticides

The commercial formulations of twelve common pesticides used in banana (6 insecticides, 5 fungicides and 1 chemical) were evaluated against entomopathogenic nematodes viz., *Heterorhabditis indica ,Steinernema carpocapsae,S.masoodi* under laboratory conditions.

### *i) H.indica*

Maximum nematode mortality was recorded in Triazophos (18.25%) at recommended dose,and minimum mortality was recorded in Monocrotophos (3.50%). At half recommended dose maximum nematode mortality was recorded in Triazophos (14.5%)and minimum was recored in Phorate (6.35%).

Among the fungicides, maximum mortality was recorded in Emisan (16.5%). Minimum mortality was recorded in Mancozeb (4.25%). At half recommended dose; maximum mortality was recorded in Calixin (11.25 %) minimum mortality was recorded and (3.25%) in Mancozeb.

Bleaching powder tested at recommended and half recommended dose completely killed the nematodes indicating its incompatibility.

### *ii) Steinernema carpocapsae*

Maximum mortality (54.25 %)was recorded in Chlorpyrifos at recommended dose and minimum





mortality (8.50 %) was recorded in Triazophos .Where as at half recommended dose, maximum mortality was recorded in Chloropyrifos (49.50 %) and minimum in Triazophos (6.0%). Among the fungicides, at recommended dose a maximum mortality was recorded in Mancozeb (46.50%) and minimum mortality (8.50 per cent) was recorded in Saff .At half recommended dose maximimum and minimum mortality of 38.5 and 7.25 per cent was recorded in Emisan and Saff respectively.

Bleaching powder tested at recommended and half recommended dose completely killed the nematodes revealing its incompatibility.

### *iii) Steinernema masoodi*

Among the insecticides tested, maximum mortality of 100 % in Monocrotophos and minimum of 0.25% in Carbofuran was observed at recommended dose.At half recommended dose, maximum and minimum mortality was 88.75 and 31.0 per cent respectively in Triazophos and Phorate. Calixin and Carbendazim recorded a maximum and minimum mortality of 70.25 and 28.0 per cent respectively at recommended dose. At half recommended dose, a maximum and minimum mortality of 49.5 and 15.5 per cent was recorded in Emisan and Mancozeb respectively. Bleaching powder tested at recommended and half recommended dose completely killed the nematodes indicating its incompatibility.

### 5.4.1.11 Isolation and evaluation of biocontrol agents from endemic areas

Microbial bio-control agents were isolated from the soil samples /weevils collected from endemic areas and were evaluated against three banana pests.

### i) Banana stem weevil, *(Odoiporus longicollis)*

Five isolates of *Beauveria bassiana* were tested *in vitro* against banana stem weevil, with a single dose of $1x10^8$ conidiospores / ml. Among the five isolates screened, the weevil mortality ranged from 30.0 to 83.3 per cent and the isolate No.5 registered a maximum weevil mortality of 83.3 %.

### ii) Banana aphid, *(Pentalonia nigronervosa)*

Green muscardine fungus ,*Metarhizium anisopliae* and White halo fungus, *Verticillum lecanii* harvested from PDA plate were tested against banana aphid, *Pentalonia nigronervosa* by detached leaf bioassay technique. The treatments ranged from $1x10^5$ to $1x10^9$ conidiospores. The *M.anisopliae* treatment recorded the maximum aphid mortality of 95 %.

### iii) Banana stem weevil, *(Odoiporus longicollis )*

Non-pathogenic *Fusarium oxysporum* was tested against banana stem weevil, 10 isolates of Non-pathogenic *Fusarium oxysporum* were mass produced in different substrates. An isolate mass produced on sugarcane baggase was evaluated against banana stem weevil, and mortality (60 %) was recorded.

### iv) Biological control of banana stem weevil, (AICRP Trial)

Insecticide (Chlorpyrifos ) and biocontrol agents (*Beauveria bassiana, Metarhizium anisopliae ,Heterorhabditis indica* and *Steinernema glaseri*) applied at 3rd ,5th and 7th months after planting at Thadiankudisai under high land banana production system which is endemic to banana weevils. Observations on growth and other parameters are being recorded.

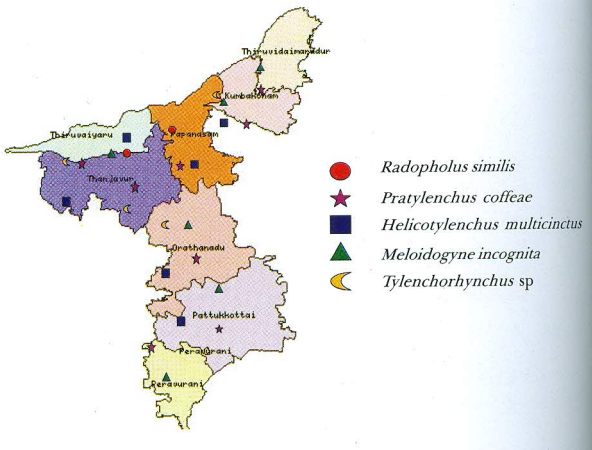
## 5.4.2 Studies on banana nematodes and their management

### i) Survey for nematodes

Survey for nematodes was undertaken in banana areas of Coorg district of Karnataka, Wyanad district of Kerala, Nilgiris and Dindigul districts of Tamil Nadu. The burrowing nematode, *Radopholus similis* was the most common and predominant nematode present in most of the samples collected from Ney Poovan, Marabale (hill banana), Nendran and Robusta in Coorg and Wyanad districts, where as root-lesion nematode, *Pratylenchus coffeae,* root-knot nematode, *Meloidogyne incognita* and spiral nematode, *Helicotylenchus multicinctus* were the most common and predominant nematodes present in all varieties of banana grown in Tamil Nadu followed by Kerala and Karnataka. None of the varieties were found free from nematode infestation. Entomopathogenic nematode, *Heterorhabditis indica* was recorded in large number from Robusta grown in Dindigul district of Tamil Nadu. The collected EPN was multiplied in Mass Wout's medium.

### ii) Nematodes associated with banana in Thanjavur district of Tamil Nadu

Widespread occurrence of root- lesion and root-knot nematodes in cultivars Poovan, Robusta and



Elavazhai in eight taluks of Thanjavur district of Tamil Nadu were recorded. Yield loss due to nematode infestation was estimated around 15 to 20%.

**iii) Effect of biocontrol agents against root-lesion and root-knot nematodes**

The promising biocontrol agents *viz. Pseudomonas fluorescens, Bacillus subtilis, Trichoderma viride* and *Paecilomyces lilacinus* collected from the nematode infested and non-infested soils of banana plantations were mass multiplied and tested for their efficacy either alone or in different combinations against root-lesion nematode, *in* cv.Robusta.

Significant increase in plant growth was recorded in all the treatments as compared to control plants. Plants with *T.viride* and *P.fluorescens* have recorded the maximum plant growth with significant reduction in nematode population.

**iv) Compatibility of botanicals with bioagents and organic amendments against root-knot nematode**

Individual effect of *P. lilacinus*, *Tagetus* spp. (leaf and flower extracts) and combination of *P. lilacinus* + *Tagetus* spp. (flower extracts), *P. lilacinus* + *Tagetus* spp. (leaf extracts), *P. lilacinus* + neem cake, *Tagetus* spp. (flower extracts) + *S. torvum* were found effective in increasing plant growth with significant reduction in nematode population. The present investigations have clearly indicated that integration of *P. lilacinus* with neem cake or any one of the botanicals namely *Tagetus* spp., (leaf or flower extracts) or *S. torvum* can be effectively used in the management of root-knot nematode in banana.

**v) Effect of leaf extracts on the juveniles of root-knot nematode**

Fresh leaves of twenty eight plants were tested for their nematicidal activity against the root-lesion and root-knot nematodes infesting banana. The results indicated that all plant extracts exhibited cent per cent mortality when exposed to 72hrs. *Tithonia diversifolia, Prosopis juliflora, Abutilon indicum, Azadirachta indica, Solanum tarvum* and *Acalypha indica* recorded 100 per cent mortality at 24hrs exhibiting their highest nematicidal properties.

**vi) Screening of *Musa* Germplasm against major nematode pathogens**

Based on the plant growth parameters, root-lesion, root-gall indices and nematode populations from soil and roots, the following diploids *viz.*, Kanai Bansi, *Musa balbisiana*, Athiakol, Bhimkol, and Aittakola were identified as resistant to burrowing nematode, *Radopholus similis* and root-lesion nematode, *Pratylenchus coffeae* while the triploid Ankur showed moderately resistant reaction to root-knot nematode, *Meloidogyne incognita.*

Soil and root samples collected from 31 accessions at Agali were assessed for nematode estimations. Results indicated that cvs.Matti, Dudh Sagar, Namarai, Peyan, Udhayam and Manoranjitham were free from nematode infestation, whereas the remaining accessions were infested with either one or more nematodes. The root-knot nematode, *M.incognita* was the predominant nematode infecting all the remaining accessions at different intensities. The root-lesion nematode, *P.coffeae* infestation was seen only in accessions Gros Michael and Nendran. The spiral nematode, *H.multicinctus* and reniform nematode, *Rotylenchulus reniformis* were the other dominant nematodes recorded in all accessions.

## 5.4.3 Studies on fungal and bacterial diseases of banana and their management

### 5.4.3.1 Characterization of anthracnose pathogen *Colletotrichum musae* isolates

**i) Morphological characterization**

21 isolates of *C. musae* isolated from commercial cultivars such as Poovan, NeyPoovan, Karpuravalli, Robusta, Rasthali and Hill banana(Virupakshi) from different locations of Tamil Nadu. All the isolates were measured for the size of the spores. The size of the spores differed significantly among each group of *C.musae* isolates. Among the isolates, the size of the spore was larger in 1a isolate of Poovan group (6.4 X 2.8), which was collected from Viruthachalam area and the size was smaller in 7b isolate of Monthan group (4.6 X 2.2) which was collected from Attur of Salem district.

**ii) Molecular characterization of *C.musae* isolates by rDNA- ITS region**

21 isolates of *C.musae* isolated from different varieties of banana were subjected to PCR amplification of Internal Transcribed Spacer (ITS) of 5.8S ribosomal RNA gene by using the PCR specific primer ITS-1and ITS 4 which was developed by White et al. (1990). The molecular weight of ITS region of rDNA amplified was ranged from 471 to 656 bp. The maximum uw 656 was observed in *C.musae* isolate of Matti, Virupakshi and Karpuravalli. The size amplified of rDNA- ITS region for the Poovan group of *C.musae* isolates was 502 – 644 ; for Karpuravalli ( 471– 656) ; for Monthan group ( 571 – 618); for Robusta and Ney Poovan groups (527); for Rasthali group (553 to 645) and for Matti and Virupakshi group (656 bp).

**iii) Cross infection potential of different isolates of *C. musae*.**

From each group of *C. musae* isolates, the representative cultures was selected and





inoculated in 5 different commercial cultivars of banana.The disease severity result indicated that all the group of isolate infected all the commercial cultivars of banana, but differed in severity of the disease. In general, the isolate of a particular group had caused maximum severity in that particular or respective group of banana. *C.musae* isolated from Poovan group isolate caused maximum disease severity of 3.0 in Poovan variety as compared to other varieties. Similarly, other isolates except Karpuravalli isolate which caused the maximum disease severity in Poovan variety followed by Rasthali and Ney Poovan as compared to Karpuravalli. However, among the varieties, Poovan was found to be highly susceptible followed by Rasthali and Ney Poovan.

### iv) Population dynamics of *Trichoderma viride* in rice chaffy grain formulation

The population dynamics of rice chaffy grain inoculums of *T. viride* studied in different soils for a period of 6 months indicated that the rice chaffy grain formulation maintained $10^{15}$cfu/g of soil up to 3 months and then decreased gradually to $10^{10}$ at 6 months after application. But in talc powder formulation, it was $10^{10}$ at 3 month after application and decreased to $10^{5}$ at 6 months after application. Among different soils, the black soil recorded the maximum population of *T. viride* ($10^{15}$ cfu/g) compared to other soils.

### v) *In vivo* evaluation of endophytic bacteria isolated from different banana accessions against FOC

In the pot culture experiment, among 39 endophytic bacteria evaluated, Lfr1 isolated from Lady's Finger, Kvr4 from Krishnavazhai, Pcr2 from Pisang Ceylon, Ner1 from Nendran, Sac1from Saba, Mbc2 from *Musa balbisiana* and Pbs1 from Pisang Berlin recorded a wilt score of 1 as against the score of 6 in *FOC* inoculated TC plants of Rasthali after 6 months of planting.

### vi) Screening germplasm against FOC under sick plot condition

Among the 22 IMTP wilt accessions evaluated for their reaction to *Fusarium* disease, except Rasthali (Score 5), all showed no symptom under sick plot condition. Besides, out of 13 diploid accessions evaluated Pisang Lilin alone showed internal wilt symptom (Score -2) under sick plot conditions.

### vii) Pot culture evaluation of different bio-agents and botanicals against *Fusarium* disease

Out of different fungal and bacterial bio-agents and botanicals evaluated for the suppression of *Fusarium* disease under pot culture condition, the NPF-3 recorded the maximum reduction of 71.86% followed by *T. viride* (69.19%), NPF-2 (54.02), *Bacillus* sp (45.36%) as compared to pathogen alone inoculated control plants.

## 5.4.4 Studies on Viral diseases of banana and their management

### Survey for viral diseases

Surveys were conducted in parts of TN, Karnataka, Puducherry and Kerala for banana viruses. BBTV has re-emerged and spread in high proportion in Lower Pulney hills of TN. BSV incidence in the Hill banana and BBrMV incidence in Cavendish clones (grown in backyards) were recorded for the first time in Lower Pulney Hills. BBTV and BBrMV were present in all surveyed areas in Coorg region, Wayanad district (Karnataka) and Gudalur, Nilgiri district (TN); which was confirmed with PCR and RT-PCR (Fig. 18 a&b). One of the isolates of BBTV did not get amplified probably due to variation in sequence. A wild diploid banana (locally *Melugu Thiri*) resembling Pisang Lilin, had infection of BBTV. BBrMV infection was recorded in the Hill banana grown in tea estates of Gudalur region of TN. Survey was also conducted in Puducherry, Madurai and Kanyakumari districts of TN, and Thiruvanthapuram district of Kerala for banana viruses which indicated the presence of BBTV, BBrMV and BSV in many varieties. CP gene of BBTV-Puducherry isolate and CP gene of BBrMV Coorg isolate have been cloned. BBTV and BBrMV samples were also collected from Calicut and confirmed by PCR for studying the diversity of the viruses.

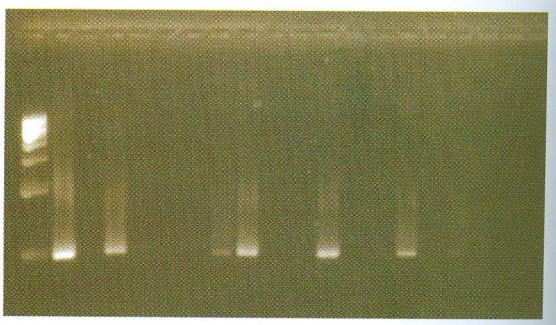


Fig. 18a Detection of BBTV in surveyed samples

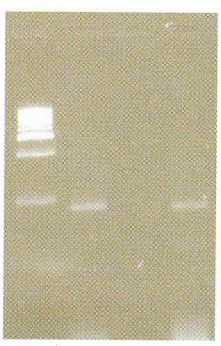


Fig. 18b Detection of BBrMV in surveyed samples

### Diagnostic techniques for banana viruses

A quick PCR based technique has been developed to detect EPRV's of BSV without the use of radioactive or non radioactive probes. Designed primers for full length cp genes of BBrMV, CMV and the complete cp genes were amplified and cloned in p-GEM-T vector.

### Effect of fertilization on BBrMV infected Ney Poovan and Robusta bananas

Yield loss due to BBrMV in Ney Poovan ranged from 3.5 to 22.1% where as in Robusta, maximum (13.1%) loss was recorded in the plant crop. In the plant crop of Robusta, increased fertilizers dose proportionately increased the bunch weight in healthy and BBrMV infected plants. But in the case of Ney Poovan, as fertilizers dose increased, the yield increment in bunch weight of healthy and BBrMV infected plants decreased. The yield loss due to BBrMV could be compensated with increased dose of fertilizer i.e. 125 to 150 per cent of recommended dose (Table 13).

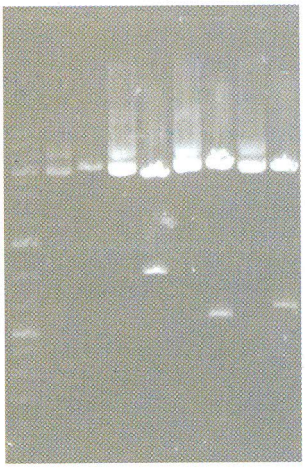


Fig. 19 Confirmation of BSV genomic clones by restriction analysis

transcriptase and RNaseH. The genome was 450 bp shorter than the BSV-OL sequence. In addition to BSOLV infection, a full length genome of BSMysV was also been cloned into five parts in p-GEM-T easy vector. The clones have been confirmed for the presence of fragment through restriction analysis(Fig. 19). The intergenic region of BSOLV approximately 900bp has been cloned into p-GEM -T vector for developing promoter construct and to study and compare the promoter activity.

**Table 13. Effect of fertilizers stress on the yield parameters in cultivar Ney Poovan & Robusta (Ist crop)**

| Treatments | Ney Poovan | | | Robusta | | |
|---|---|---|---|---|---|---|
| | Disease | Healthy | Mean | Disease | Healthy | Mean |
| T1 | 10.33 | 11.84 | 11.08 | 10.9 | 10.83 | 10.86 |
| T2 | 10.91 | 13.1 | 12 | 11.26 | 11.83 | 11.54 |
| T3 | 13.68 | 14.08 | 13.88 | 10.87 | 12.08 | 11.47 |
| T4 | 13.82 | 14.49 | 14.15 | 11.09 | 12.4 | 11.74 |
| T5 | 16.02 | 16.37 | 16.19 | 13.22 | 12.73 | 12.97 |
| MEAN | 12.95 | 13.97 | 12.95 | 11.47 | 11.97 | 11.72 |

### Developing severity index for BBrMV and BSV

To develop severity score and disease severity index for assessing the damage due to BBrMV and BSV in germplasm, a field trial was conducted. Based on symptoms expressed in Ney Poovan, BBrMV was scored into four categories i.e. mild, severe, very severe and no symptom with rating as 1, 2, 3 and 0. Similarly, BSV infection in Poovan was grouped into 0 to 3 scales. Where 0: no visible symptom, 1= very few streaks (less than 10% leaf area) or chlorotic flecks on the leaf lamina, 2= streaks or chlorotic flecks covering a moderate portion (10 to 50%) of leaves, 3 = most of the leaf lamina (more than 50%) covered with streaks or chlorotic flecks.

### Molecular characterization of banana viruses

Complete genome of BSV infecting Poovan was cloned and sequenced. It is more similar to BSV-OL and GD sequences. It had three ORF's and ORF 3 encodes a polyprotein which includes aspartic protease, putative coat protein gene, reverse

The episomal expression of BSV in Rasthali has been recorded for the first time. Mysore, RSR, RD, OL primer pairs of two different BSV species amplified expected product from BSV infected Rasthali banana. BSV-GF and BSV-IM primers did not amplify any product from Rasthali. BSV related sequences were amplified from *M.acuminata* ssp *Zebrina*, collected from Bangalore (Fig 20).

Partial cp gene along with NIb region of BBrMV was amplified and cloned in vector for sequencing. Cloned and sequenced partial BBrMV coat protein gene from cultivar Palayankodan from Kerala.

Replicase gene of BBTV from large cardamom having Foorkey disease has been amplified and cloned.





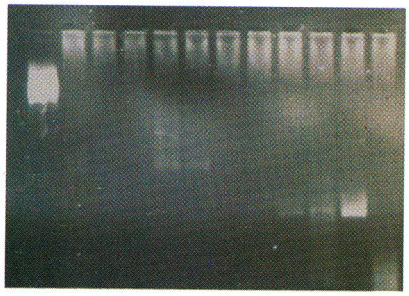


Fig. 20: Detection BSV in *M.accuminata spp* zebrina

### Expression of viral cp genes in *E.coli*

The coat protein gene of BBTV was amplified using *pfu* polymerase and added an A base with Qiagen-A addition kit and cloned into UA expression vector for expressing the CP of BBTV. But the expressed proteins of BBTV could not be purified owing to its insoluble form. BSV-ORF 2 was also cloned in the Qiagen expression vector.

cp gene of CMV infecting banana has been cloned into T vector and recloned into Qiagen expression vector and mobilized the plasmid to M15 *E.coli* cells and the 'cp' has been over expressed with IPTG induction which has been confirmed with SDS-PAGE.

### Purification of viruses

In order to purify the CMV, it was transferred to *Nicotiana glutinosa* by mechanical transfer and sufficient infected leaf material has been obtained for purification.

### Symptomatology

Preliminary study on host - pathogen interactions revealed that simultaneous infection of BSV and BBrMV infection lead to the expression of very severe symptoms. Fruits of infected plants were necrotic (on peel) in cultivar Poovan. However, the quality of pulp does not have any significant change as compared to healthy Poovan.

### Screening the germplasm for BSV

Wild *Musa* collections collected during survey to NEH states in 2005 were tested for BSV. 4 out of 16 germplasm accesions were positive for BSV. Some clones expressed visible symptoms typical to BSV.

## 5.5 EXTERNALLY FUNDED PROJECTS

### 1) Network Project on transgenic in crops

#### i) Functional Genomics

#### a) Sigatoka leaf spot

720 *Musa* germplasm accessions were screened for *Mycosphaerella* spp the resistant and susceptible sources for sigatoka disease were identified. The cultivars resistant and highly susceptible to sigatoka disease were micro propagated and transferred to glass house.

The fungal spores from *Mycosphaerella* have been isolated, diluted in water and sprayed on young leaves of the tissue cultured plants. The plants were maintained in 90% humidity for 3 days. The leaves from the both resistant and susceptible cultivars were collected from 24 hours, 48 hours and 72 hours from the time of spray. The total RNA has been isolated from leaf samples of both resistant and susceptible cultivars by lithium chloride precipitation method. The mRNA was separated from total RNA. mRNA isolated from the susceptible and resistant cultivars were pooled and used as driver and tester for subtractive hybridization. The subtraction hybridization was carried out by the PCR select subtractive hybridization kit (Clonetech, USA). DNA received after subtraction hybridization were cloned into TOPO$^R$ cloning vector and the library has been screened.

Differential screening of the subtracted library resulted in 200 colonies. These colonies were patched on LB (Luria Bertani) medium containing 50 µg / ml ampicilin. Out of 200 colonies, only 86 colonies grown upon patching. DNA was extracted from these colonies and subjected to restriction analysis. Among 86 colonies, only 40 colonies had insert. Despite 40 colonies having insert, only 16 colonies carried greater than 200bp insert. DNA from these 16 colonies, was sequenced.

#### b) Drought

Study of DNA polymorphism was carried out using published microsatellite markers. Focus on one set of crosses, namely SCK X Lairawk yielded good seed set. But more than 90% of seeds were floating seeds. Good seeds were germinated. Three progenies could be successfully established in the field and are being evaluated for physiological traits indicating drought.

The progenies have been initiated *in-vitro* for mass multiplication and large scale field testing for drought. At present they are being evaluated at hardening stage under net house conditions.

### 2) ICAR– Adhoc scheme – Soil test based integrated nutrient tailoring for optimum banana production and sustainable soil health.

Fertilizer adjustment equations were developed for Rasthali banana by following the 'Targeted yield concept'. The important factors used in development of fertilizer adjustment equations for Rasthali are given in the table 14. The (Fig. 21 a) depicts the variation in Rasthali bunch size due to variation in NPK levels.

Table 14. Important factors used in development of fertilizer adjustment equations for Rasthali

| | Nutrient Requirement (NR) (kg/ton) | Contribution from soil in control plot (CS) (%) | Contribution from fertilizer in treatment plot (CF) (%) | Contribution from organic fertilizer in treatment plot (CO) (%) |
|---|---|---|---|---|
| Nitrogen (N) | 13.9(486/35) | 69.6 | 75.7 | 22.1 |
| Phosphorus ($P_2O_5$) | 1.7(58/35) | 44.2 | 59.9 | 16.7 |
| Potassium ($K_2O$) | 28.2(986/35) | 55.4 | 70.7 | 29.8 |

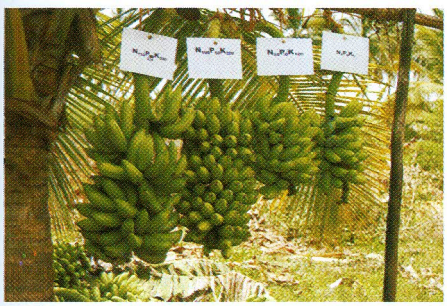


Fig. 21a. Effect of different levels of NPK on Rasthali bunch

### Fertiliser adjustment equations for Rasthali

FN = (18.34 x T) – (0.92 x SN) – (0.29 x ON)

FP = (2.77 x T) – (0.74 x SP) – (0.63 x OP)

FK = (39.85 x T) – (0.78 x SK) – (0.51 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.

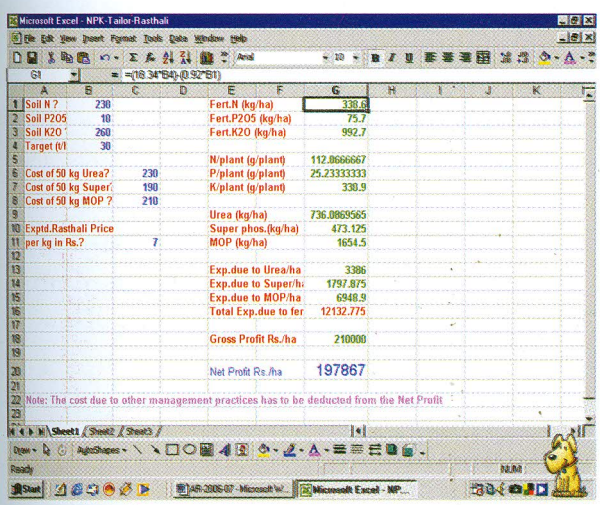



Fig. 21b. Computer screen showing the fertilizer tailoring software

A software has been developed which is very useful in decision making of banana farmers in fixing the target of banana yield based on their initial soil fertility status, with respect to NPK. A computer screen capturing output is given in Fig. 21b, where the soil fertility status is of 230 kg N/ha, 10 kg $P_2O_5$/ha and 260 kg $K_2O$/ha, the yield target fixed is 30 t/ha and the expected price at harvest is Rs. 7/kg.

## 3) ICAR Network Project: Wilts of crops with special reference to cultural, morphological, pathogenic and molecular Characterization of isolates in India

### Characterization of *Fusarium* wilt isolates by Vegetative Compatibility Grouping (VCG)

A total of 141 nit mutants were developed out of 100 representative isolates of *Foc* and among these, 9 were nit –M testers, 75 were nit- 1 mutants and remaining were nit-3. When these entire 75 nit -1 were allowed to mate with 9 nit-M testers using minimal medium, 9 different VCG groups have been observed. The cross-reaction between race-1 and race-2 were also observed in many cases. The Monthan *Foc* isolates (44 MT, 45MT, 181MT) isolated from Tamil Nadu, which belong to race-2, have reacted with nit-M testers of Rasthali *Foc* isolate (19b) which belongs to race-1. Similarly, the race-1 *Foc* isolates such as 14 RT, 107RT, 132 RA 127 Rka, 188RN obtained from Tamil Nadu, Andra Pradesh, Karnataka and North Eastern states of India respectively have reacted with Monthan isolates which belong to race-2. The *Foc* isolates of hill banana reacted with both race- 1 and race-2 isolates.

### Studies on validation of cross infection potential of different isolates of *Foc* under glass house condition

The cross reaction between race-1 and race-2 which has been observed in VCG studies have been tested/validated under pot culture condition using respective banana varieties. The results confirmed the cross reaction between the members of race-1 and race-2.





## Molecular characterization of *Fusarium* wilt pathogenic isolates

### RAPD-PCR

Out of 20 primers screened against 100 representative isolates of *Foc*, only 3 primers OPB-01, 07 and 17 have produced polymorphic bands. OPB –07 was very useful for characterization of *Foc* isolates (Fig. 22).

The results of RAPD banding pattern indicated that OPB –07 primer has grouped Rasthali-Foc isolates of India in to 10 major groups, Karpuravalli Foc isolates in to 2 major groups, Neypoovan-*Foc* isolates in to 7 major groups and Monthan *Foc* isolates in to 4 major

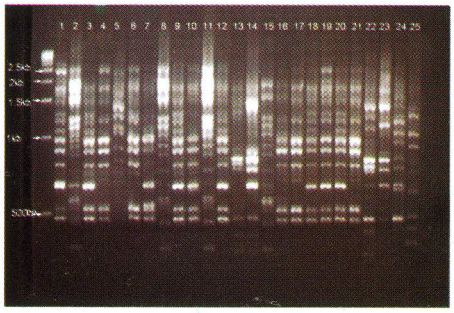



Fig. 22 RAPD of PCR of FOC isolates by primer OPB-07 (Rasthali)

groups. The hill banana Foc isolates (which have reacted with both Rasthali and Monthan *Foc* isolates in VCG studies) have been grouped with both Rasthali (Race-1) and Monthan (Race-2) *Foc* isolates.

*Colletotrichum musae*, *Lasiodiplodia theobromae* and NPF were included in RAPD analysis along with Foc isolates for comparison purpose which were differentiated well by the primer OPB-07.

### PCR –RFLP analysis of Intergenic spacer region of ribosomal DNA (IGS)

The size of the amplified band was ranged from1391bp to 2306bp. The PCR products of the IGS amplified region were digested with 9 restriction enzymes. Among these, six enzymes namely HaeIII, RsaI, HhaI, HinfI, TaqI and MspI had restriction sites and each produced unique banding patterns. Totally 18 IGS genotypes were observed and all these could be distinguished by a six-letter code designated to each isolates IGS genotype. For pathogenic *Fusarium* wilt isolate alone, 13 IGS genotypes were observed and AAAAAA (group 1) was the most common and consisted of 44 isolates of pathogenic *Fusarium*. Each of the other isolates of pathogens of banana, castor and non-pathogenic Fusarium isolates were grouped as separate IGS genotype.

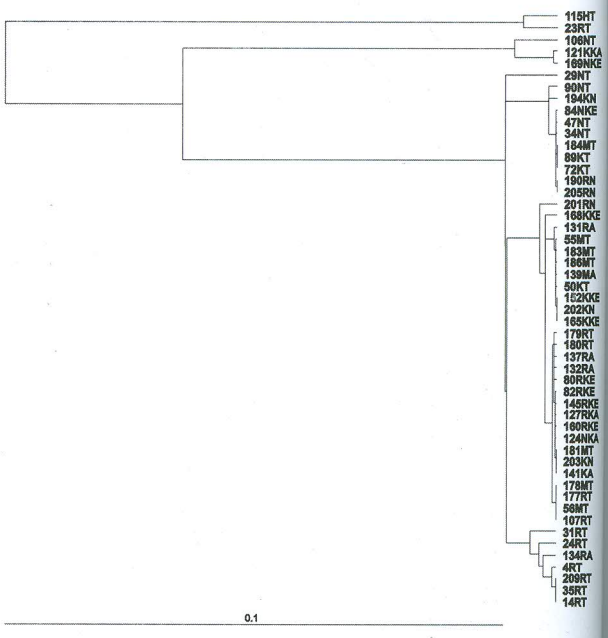



Fig. 23 Phylogram of *Foc* isolates based on the sequence of rDNA-ITS region

### Sequence analysis of internal transcribed spacer (ITS) region of ribosomal DNA

The DNA extracted from 50 representative isolates of *Foc* have been subjected for the amplification of rDNA –ITS region using the specific primer of ITS-1 and ITS-4. The result indicated that the primers have amplified rDNA –ITS region having the molecular weight of 500 to 600 bp. These amplified products were sequenced. The phylogram drawn for these sequences revealed the presence of 9 major groups in 50 Foc isolates (Fig. 23). It was also found that the possible origin of all the *Foc* isolates would be from Hill banana isolated from Tamil Nadu, which have reacted with both race –1 and 2 of *Foc* in VCG studies and also in RAPD analysis.

### Designing molecular marker for the identification and differentiation of pathogenic *Fusarium* from non-pathogenic *Fusarium* spp.

To design a molecular marker for the specific identification of pathogenic isolates of *Fusarium* wilt

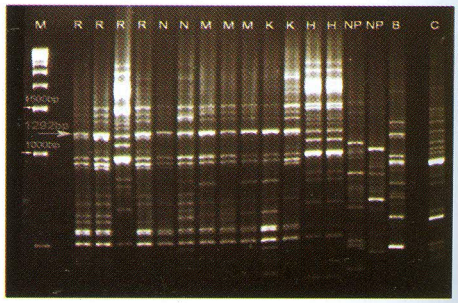



Fig. 24 RAPD - PCR for FOC isolates infecting cvs. Rasthali (R), Ney Poovan (N), Monthan (M), Karpuravalli (K), Hill Banana (H), Non Pathogenic Fusarium (NP), Botryodiplodia (B) and *Colletotrichum musae* (C). An arrow mark shows 1292 bp product precent only in FOC isolates

of banana, representative isolates of *Foc* from different groups were subjected for the RAPD –PCR using the primer OPB-17. Besides, non- pathogenic *Fusarium* isolates, other pathogens of banana viz., *Botryodiplodia theobromae* and *Colletotrichum musae* were also included in the analysis.

The study has resulted in the successful identification of an unique amplicon of 1292 bp which is present only in pathogenic isolates of *Fusarium* but absent in other banana pathogens and also in non-pathogenic *Fusarium* (Fig. 24). This band will be utilized to develop SCAR markers specific to panama Wilt pathogen.

### Isolation and characterization of non-pathogenic *Fusarium* (native and endophytic) spp. and their *in vivo* evaluation against *Fusarium* wilt disease of banana

#### *In vitro* screening of non-pathogenic Fusarium (NPF) isolates against FOC

Isolates of non-pathogenic *Fusarium* were collected from both rhizosphere soil and roots of different banana cultivars of diploid and triploids. These NPF isolates were tested to assess their inhibition potential to mycelial growth and spore germination of pathogenic *Foc* race-1 under *in vitro* condition

#### Evaluation of endophytic NPF isolates

19 endophytic NPF isolates have recorded about 74% reduction of mycelial growth of the pathogen and rest have recorded about 62 % reduction as compared to control. However an isolate ScR-2 which was isolated from Sanna Chenkadali recorded a maximum reduction of 99.5 per cent spore germination followed by Plr-1 (isolated from the Pisang Lilin) which recorded 98.4% reduction of spore germination over control. The other isolates which recorded more than 95% reduction in spore germinations were NaR, MaR, and F23R.

#### Native NPF isolates from rhizosphere soil of banana

Among of 13 NPF isolates from soil rhizosphere of banana, the maximum reduction over control was

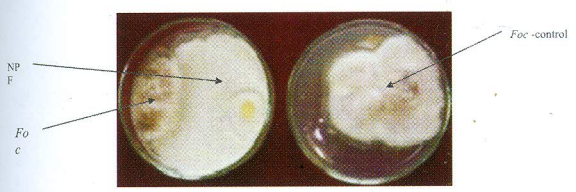



Fig. 25 Inhibition of FOC by NPF in dual culture plate technique

recorded by the isolate Pn2 (86.87%) followed by RoS and AS1 which recorded 74.37 % reduction of mycelial growth of the pathogen as compared to control. When the culture filtrate of NPF isolates was tested, the isolate T2 from. Tongat recorded the maximum of (94.14%) reduction of spore germination of the pathogen followed by the isolate KJS2 from cv. Kanai Bansi which recorded 80.5% reduction over control.

#### *In vivo* evaluation of non-pathogenic Fusarium isolates for the suppression of *Fusarium* wilt disease

The pot culture evaluation of NPF isolates against race-1 isolate of Foc infection on Rasthali indicated that among 40 NPF isolates, the isolates *viz*, 130 a, 137, T1, T2, PN-2 recorded 100 per cent reduction in disease severity as compared to control plants.

#### Molecular identification of non-pathogenic *Fusarium* (NPF)

The DNA isolated from all the NPF isolates were subjected for PCR using *Fusarium oxysporum* specific primer for confirmation. The primer set FOF1 and FOR1 permitted the amplification of a single DNA fragment of 325 bp in size. This primer set has amplified all the isolates, which have been identified morphologically as *F.oxysporum.*

#### PCR –RFLP of rDNA –IGS region

The universal primer set specific for the amplification of IGS region had amplified IGS region of the NPF isolates and also the other pathogens for the comparison purposes. The size of the amplified band was ranged from 1144bp to 1875bp. The PCR products of the IGS amplified region were digested with 9 restriction enzymes. Among these, five enzymes namely RsaI, HhaI, HinfI, TaqI, and MspI only had restriction sites and each produced unique banding patterns. A total of 16 IGS genotypes were observed which included the pathogens of *Fusarium* wilt, anthracnose and crown rot diseases of banana and also the *Fusarium* wilt of castor and nonpathogenic *Fusarium*. For non-pathogenic *Fusarium* alone, 11 IGS genotypes were observed and BBCCC (group 2) was the most common and consisted of 7 isolates of nonpathogenic *Fusarium*. Each of the other isolates of pathogens of banana (other than Foc) and castor were grouped as separate IGS genotype.

#### Induction of systemic resistance due to NPF isolates against *Fusarium* wilt disease in cv. Rasthali

The application of NPF and also the challenge inoculation with FOC increased the PO and PAL activities and also the total phenolic content significantly as compared to control plants in all the days of sampling (Fig. 26, 27, 28). Among the NPF isolates, NPF-3 recorded the maximum level of PO and PAL activities and also the total phenolic content followed by T1 and 137a. The increase in enzyme activities and also the total phenolic



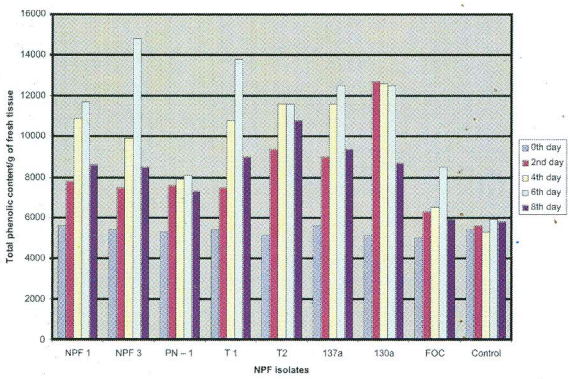



Fig. 26 Total phenolic content in NPF and pathogen challenge inoculated plants

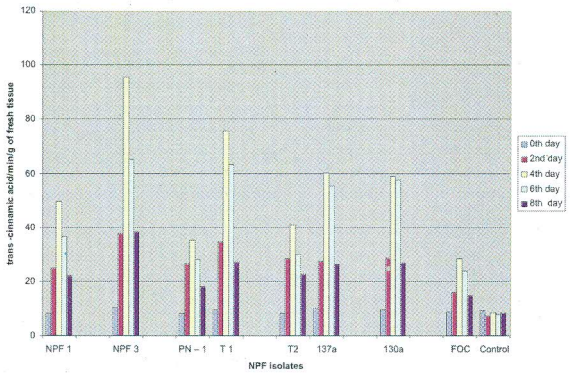



Fig. 27 Changes in PAL activity in NPF+Pathogen challenge inoculated plants

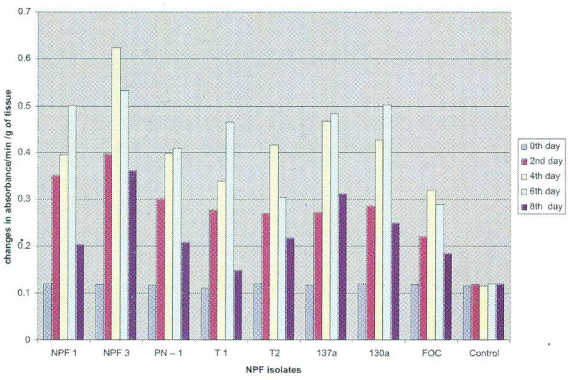



Fig. 28 Changes in peroxidase activity in NPF and Foc applied plants

content was two to five folds higher in NPF applied plants and challenge inoculated plants as compared to control.

## Network Project on transgenic in crops - Transgenic component (3042)

### Developing Transgenic Banana Resistant to BSV and BBTV

#### Genome characterization of BBTV

All six components of BBTV were cloned and four of them were sequenced. *In silco* analysis was done which revealed their homology was above 94% with published sequences.

#### Developing gene constructs with BBTV cp gene

The BBTV -cp gene cloned in pGEM-T easy vector was re-amplified with appropriate restriction enzymes and cloned in pBinAR vector restricted with same restriction enzymes and cp gene presence has been confirmed using restriction analysis (Fig. 29). In another approach, cp gene was cloned in 'antisense' direction in pBinAR vector. Binary constructs of cp gene were mobilized from *E.coli* to *Agrobacterium tumefasciens* LBA4404 strain by triparental mating using helper plasmid pRK2013 and also through electroporation.

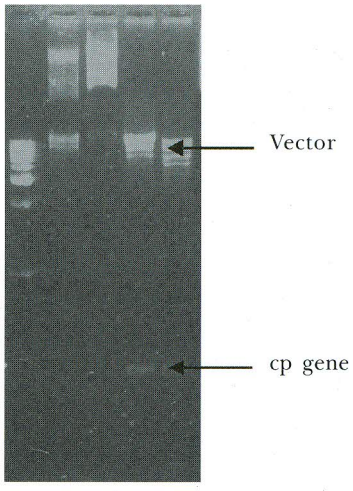



Fig. 29 Restriction digestion analysis of pBinAR having BBTV cp gene

#### Development of promoter constructs from BBTV intergenic sequences

Intergenic regions of BBTV components 1 and 5 were cloned and sequenced. *In silico* analysis has been done for their promoter activity. A promoter construct has been developed in pBI121.

## ICAR Net Work Project: Diagnostics of emerging plant viruses

### Developing diagnostic kit for BSV and BBrMV

Pure cultures of the viruses are being maintained in the insect proof glass house in banana cultivars. From viral genomic RNA, cDNA was synthesized by AMV reverse transcriptase using oligo dT primer. Using cDNA as template, 600bp BBrMV fragment was amplified and cloned into p-GEM-T Easy vector and sequenced. The BBrMV specific primers could detect Sugarcane Mosaic Virus and also PRSV.

Complete genome of BSV was cloned, sequenced and deposited in the genbank. The complete genome comprised of 6950 bases and 439 bases shorter than BSOL virus (Part of the work is from in-house project). Detection of episomal BSV through PCR based approach has been developed.

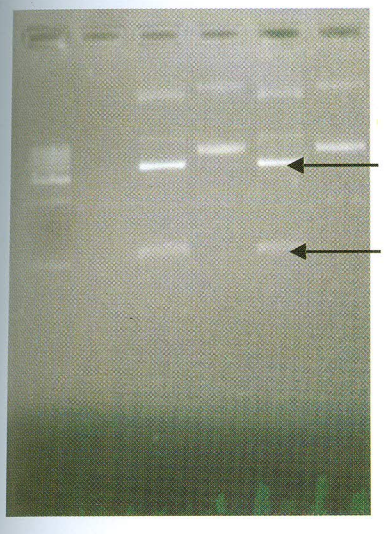



Fig. 30 Confirmation of BBrMV cp gene clones through restriction digestion analysis.

A dig-oxigenin labeled non-radioactive probe has been made from 600 cp clone of BBrMV using DIG-high prime labeling kit. This was used to detect BBrMV, SCMV and PRSV samples. The probe could able to detect SCMV, BBrMV and PRSV. DIG labeled probe for complete genome of BSV has been developed.

Complete cp gene of BBrMV (900bp) has been cloned into expression vector pQ30 through directional cloning approach and the insert has been confirmed through restriction analysis (Fig. 30). ORF-2 of BSOLV cloned in Qiagen U/A expression vector but expression of the putative protein could not be achieved.

## DBT-Development of transgenic Hill banana resistant to BBTV (replicase gene mediated)

### Developing replicase gene construct of BBTV

Replicase gene of BBTV has been cloned into pGEM-T easy vector and which was re-amplified with appropriate RE and cloned into pBINAR. The putative construct was checked for rep gene insert by colony PCR and an expected sized amplicon obtained in the colony PCR.

### Developing ECS for Hill banana for transformation

600 Hill banana plants indexed twice for BBTV using PCR and virus free TC plants were planted in April'06 (Fig. 31). The male buds are used for developing ECS for transformation. ECS for Hill banana using MA-1 media were initiated. Around 2000 immature male flowers were used to initiate ECS. Very few of immature male flowers have produced calli. Different media compositions have been used to induce embryogenic calli from immature male flowers. In order to induce ECS from scalp, virus indexed hill banana plants are transfered to proliferation media.

Fig. 31 Virus indexed hill banana plantation established at the centre for supplying to the hill banana growers.





# 6 Technology Assessed and transferred

## Training

- Technology for 'Mass multiplication of commercial banana varieties' was transferred to KVK, Indian Institute of Vegetable Research, Varanasi. One Scientist and two technicians were trained for one week (11-17th March, 2007).
- A short term training course on production of value added products of banana was conducted to 10 prospective entrepreneurs between 24th to 28th April 2006 and 6 entrepreneurs from Mahabanana between 17th to 24th July 2006.
- A short term training course on production of value added products of banana was conducted for 11 entrepreneurs between 20th to 27th September 2006.
- Trained 500 farmers and self help group women on post harvest handling and value addition in banana under the aegis of Tamil Nadu Agricultural Marketing and Sales Department, Govt. of Tamil Nadu from 20-23rd February 2007.

## Supply of BBTV free hill banana mother plants

Virus indexed BBTV free Virupakshi (Hill Banana) plants were planted at NRCB research field during 2005. The Virupakshi BBTV free plants were supplied to hill banana growers, private companies HC& RI, Periakulam and TNAU, Coimbatore. The plant supplied to the hill banana growers are being assessed for performance in lower pulney hills with respect to disease incidence and yield parameters.

## Video films

22 titles/ clippings on banana related activities were filmed by Department of Agribusiness Management, Ministry of Agriculture, New Delhi to make a full document about NRCB, Trichy.

**Radio Talk**

| Sl.No. | Topic | Name of the Scientist | Date of broadcast |
|---|---|---|---|
| 1 | Top dressing in banana | Dr. K.J. Jeyabaskaran | 30-05-2006 |
| 2 | Integrated nematode management | Dr. P.Sundararaju | 24-02-2007 |
| 3 | Sucker selection in banana | Dr.V.Kumar | 12.01.2007 |

**Exhibitions : NRCB participated in the following exhibitions to disseminate the technologies**

| Sl.No. | Title | Organised by | No. farmers participated | Date |
|---|---|---|---|---|
| 1 | Rashtriya Bhagwani Kissan Mela cum Exhibition | IIHR, Bangalore Karnataka. | 6000 | 3.4.06 to 4.4.06 |
| 2 | Farmer's field visit (Front line Demonstration) | Tamil Nadu banana growers association, Kulithalai, T.N. | 250 | 5.1.07 |
| 3 | Farmers Mela for Banana production technology | State Agril. & Horticultural departments, Trichy, T.N. | 850 | 13.2.07 |
| 4 | 8th Agril. Science Congress -2007 | TNAU , Coimbatore, Tamil Nadu ; NAAS, New Delhi | 8000 | 15.2.07 to 18.2.07 |
| 5 | Training programme on Banana cultivation and Value addition. | State Horticultural & Export departments, Trichy, T.N. | 500 | 20.2.07to 23.2.07 |
| 6 | TN AGRICON 2007 (Seminar on Banana) | Confederation of Indian Industry, Trichy, T.N. | 450 | 23.2.07 to 24.2.07 |
| 7 | Exhibition cum workshop on organic farming | Junior Chamber international, Erode, Tamilnadu. | 5500 | 17.3.07 to 18.3.07 |

# 7 Education and Training

| Name of the student | Title of the thesis | Name of the guide |
|---|---|---|
| S. Mohana | Molecular characterisation of Poovan banana having BSV genome integration | Dr. R. Selvarajan |
| S. Indumathi | Molecular analysis of BSV infected banana for viral integrants | Dr. R. Selvarajan |
| S. Subha | Molecular detection of banana viruses in vector and host | Dr. R. Selvarajan |
| S. Sailakshmi | Molecular characterization of non pathogenic *Fusarium* isolates collected from banana rhizosphere using rDNA - ITS - RFLP and rDNA - IGS - RFLP technique | Dr. R. Selvarajan |
| R. Kumudha | Molecular characterization of pathogenic *Fusarium* Wilt isolates of India by ISSR analysis | Dr. R. Selvarajan |
| T.R. Annapurni | Studies on biochemical changes in cv. Poovan (AAB) green banana fruit stored under low temperature. | Dr.I. Ravi |
| P. Devika | Low temperature storage effect on banana ripening: Studies on carbohydrate content variation and antioxidative enzymes of banana cv. Poovan (AAB) | Dr.I. Ravi |
| M. Punithavathi | Studies on starch, amylose and amylopectin content variation in different banana cultivars. | Dr.I. Ravi |
| R. Sheela | Isolation, mass production and evaluation of green muscardine fungus, *Metarhizium anisopliae* against banana stem weevil, *Odoiporus longicollis.* | Dr.B. Padmanaban |
| B. Lavanya | Isolation, mass production and evaluation of *Steinernemas glaseri* against banana stem weevil, *Odoiporus longicollis.* | Dr.B. Padmanaban |
| P. Hema Maheswari | *In vitro* evaluation of conidial germination and growth of muscardine fungi and their compatibility with pesticides to develop eco-friendly pest management | Dr.B. Padmanaban |
| V. Gayathri | Studies on entomopathogenic bacteria, *Xenorhabdus bovienii* associated with entomopathogenic nematode, *Steinernema masoodi* and compatibility of commonly used pesticides. | Dr.B. Padmanaban |
| P. Esther | *In vitro* evaluation of *Heterorhabditis indica* associated with endosymbiont, *Photorhabdus luminescens* for the management of banana corm weevil, *Cosmoploites sordidus.* | Dr.B. Padmanaban |
| M. Suja | Emergence of *Beauveria bassiana* from the cadavers, screening of non-pathogenic *Fusarium oxysporum* against banana stem weevil, *Odoiporus longicollis.* | Dr.B. Padmanaban |
| S. Sathiya Praba | Laboratory bioassay to assess the pathogenicity of "white-halo" fungus *Verticillium lecanii* (Zimmerman.) and *Metarhizium anisopliae* (Metchinikoff.) to control banana aphid, *Pentalonia nigronervosa.* | Dr.B. Padmanaban |
| I. Jenita Pauline | Screening of substrates for sporulation and mass mulitiplication of white muscardine fungus, *Beauveria bassiana* to control banana corm weevil, *Cosmopolites sordidus.* | Dr.B. Padmanaban |





| | | |
|---|---|---|
| R. Jayabagavathi | Isolation, identification, mass production and evaluation of *Bacillus thuringiensis* against banana corm weevil, *Cosmopolites sordidus*. | Dr.B. Padmanaban |
| C. Kalaioviya | Isolation, identification, mass production and Evaluation of green muscardine fungus, *Metarhizium anisopliae* to control banana corm weevil, *Cosmopolites sordidus* | Dr.B. Padmanaban |
| V. Sumathi | Studies on symbiotic bacteria, *Xenorhabdus nematophilus* associated with entomopathogenic nematode ,*Steinernema carpocapsae* against banana stem weevil, *Odoiporus longicollis* | Dr.B. Padmanaban |
| P. Latha | Isolation, identification and genetic variability of non-pathogenic *Fusarium oxysporum to* control banana stem weevil, *Odoiporus longicollis.* | Dr.B. Padmanaban |
| P. Gokila | Separation of plant volatiles from the banana leaf sheath for the management of banana stem weevil, *Odoiporus longicollis.* | Dr.B. Padmanaban |
| P. Kiruthika | Effect of *Paecilomyces lilacinus* and botanicals against root –knot nematode, *Meloidogyne incognita* on banana cv.Robusta. | Dr. P. Sundararaju |
| V. Madhula | Leaf extracts of certain plants and their effects on the juveniles of root-knot nematode, *Meloidogyne incognita.* | Dr. P. Sundararaju |
| R. Srinivasan | Biodiversity of plant parasitic nematodes associated with banana in Thanjavur district of Tamil Nadu. | Dr. P. Sundararaju |
| M. Anitha | Standardization of processes for production of spiced and blended banana wine using *Saccharamyces cerevisiae* var.*ellipsoideus* | Dr. C.K. Narayana |
| J. Muneeswaran | Studies on blending of various fruits and herbs for production of blended Banana. | Dr. C.K. Narayana |
| R. Sridhar | Production, optimization and purification of amylase enzyme from *Aspergillus niger* under soiled substrate formation using banana starch | Dr. C.K. Narayana |
| S. Ramaraj | Comprehensive diversity analysis in banana (*Musa* sp.) core collection using IRAP markers. | Dr. S. Uma |
| N. Sujatha | Preliminary studies on the development of markers for nematode (*Pratylenchus coffeae*) resistance in banana | Dr. S. Uma |
| S. Bharathi | "Identification of nutritious bananas among indigenous and exotic varieties for high carotenoids and minerals" | Dr. S. Uma |
| A. S. Saravana Kumar | Identification of molecular markers for sigatoka disease resistance in Banana (*Musa* sp.) | Dr. S. Uma |
| M. Dinesh Anto | Long term conservation of wild banana genetic resources using Seed DNA and confirmation through molecular markers | Dr. S. Uma |
| M.S. Saraswathi | 'Morpho-molecular characteization and marker based screening for BSV integrants in B-genome rich *Musa* germplasm. | Dr. S. Uma (Member in advisory committee) |

# 8 Awards and Recognitions

Dr. B.Padmanaban, Senior Scientist has acted as the external examiner for the evaluation of Ph.D., thesis of Mr.Amitava Banerjee entitled "Studies on some bio-ecological aspects of *Aphis craccivora* Koch.(Hemiptera:Aphididae),Bidhan Chandra Krishi Viswavidyalaya , Mohanpur, West Bengal.

Dr. P.Sundararaju, Principal Scientist has received the Best Poster Presentation Award for the research paper entitled "Efficacy of neem based pesticides used as sucker treatment against root-knot nematode infesting banana cv.Robusta" in the Technical Session-I Pest and disease management in fruit crops during the III[rd] National symposium on Plant protection in horticulture: Emerging trend and challenges, organized by Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE) at IIHR, Bangalore during 7-9, March,2007.

Dr.S.Uma, Senior Scientist has been recognized as a member of Global *Musa* Taxonomic Advisory Group (TAG) by INIBAP / FAO.

# 9 Linkages and Collaboration in India and Abroad

- Two collaborations have been developed with BARC, Mumbai. A collaborative project entitled 'Induced mutation -A crop improvement strategy for developing dwarf and Sigatoka leaf spot resistant banana cv. Grand Nain' has been implemented with the support of DAE.
- Stability analysis of regenerated cryopreserved *Musa* germplasm is being done with the collaboration of NBPGR, New Delhi.

# 10 Publications

## Books Chapter

Sathiamoorthy,S., Uma,S. and Selvarajan,R. 2006. Certification Standards: Tissue cultured Bananas. *In* Seed: A Global Perspective (eds. G.Kalloo, S.K.Jain, Alice K.Vari and Umesh Srivastava. Associated Publishing Company, New Delhi,pp.312.

## Research papers

Narayana, C.K. and M.M.Mustaffa. 2006. Influence of maturity on shelf life and quality changes in banana during storage under ambient condition. *Indian Journal of Horticulture* Vol. 64(1).

Selvarajan, R. and Jeyabaskaran. K.J. 2006. Effect of banana bract mosaic virus (BBrMV) on growth and yield of cultivar Nendran (Plantain, AAB). *Indian Phytopathology*, 59 (4) : 496-500.

Sundararaju, P.2005. Effect of marigold, *(Tagetus erecta)* intercropped with banana cv. Nendran against root-lesion nematode, *Pratylenchus coffeae. Indian J.Nematol.* 35:123-26

Sundararaju, P and V.Saritha, 2006. Effect of leaf extracts of *Acalypha indica, Cassia fistula and Solanum torvum* on *Pratylenchus coffeae. Indian Journal of Nematology* 36(1): 144- 145

Sundararaju, P. 2005. Biodiversity of plant parasitic nematodes associated with banana in Northern parts of Tamil Nadu, India. *Current Nematol.* 16 (1,2): 27-33.

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Padmanaban, B. 2006. Semiochemicals in banana weevil management (Abstract pp 28 ) Annual discussion meeting in Entomology –Semiochemicals in Crop Protection :On going technologies ,2 ,December 2006 held at COSTED ,Chennai.

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**Technical Bulletins**

| S.No | Technical Bulletin No. | Title of the Publication | Author | Year |
|---|---|---|---|---|
| 1 | 13 | Commercial Value added Products | C.K. Narayana<br>S.Sathiamoorthy<br>M.M. Mustaffa | 2006 |
| 2 | 14 | Vazhayil Madhipootapatta Upaporutkkal (Tamil) | C.K. Narayana<br>M.M. Mustaffa | 2006 |
| 3 | 15 | Improved Post Harvest Handling Technology in Banana. | C.K. Narayana<br>M.M. Mustaffa | 2006 |
| 4 | 16 | Kele Ka Thudai Upranth Praudhyogiki (Hindi) | C.K. Narayana<br>S.Sathiamoorthy<br>M.M. Mustaffa | 2006 |

# 11 Consultancy services and Commercilization of Technologies

## Resource generation through contract services

The Centre has a consultancy processing cell to effectively transfer technologies on commercial basis as per the Johl's committee recommendations

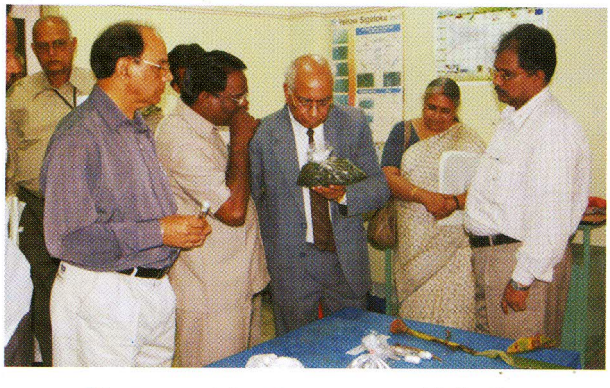
Tissue culture banana plants and mother plant suckers from different TC industries, such as SPIC-ABC, Coimbatore, Godrej Agrovet, Ranga Reddy Dist, AP, Ramco Biotech, Bangalore, Reliance Bio, Mumbai, etc., were indexed with PCR and NASH based technology developed in virology lab. 4044 samples have been tested for BBTV, BBrMV, BSV and CMV and an amount of Rs3,58,000 (Three lakhs fifty eight thousand rupees only) has been earned under contract service in virology lab.

| Name of the consultancy project | Period | Estimated cost | Scientist involved |
|---|---|---|---|
| Providing technical advisory consultancy for Banana juice preparation | 2006-2007 | Rs.37,940.00 | Dr.C.K. Narayana |
| Providing technical advisory consultancy for banana ripening under controlled temperature | 2006-2007 | Rs.10,330.00 | Dr.C.K. Narayana |

# 12 RAC, IMC and IRC with significant decisions

## 8th RAC Meeting

The eighth RAC Meeting was held on 29.12.2006. Dr. R.M.Pandey, chaired the session and conducted the proceedings. Dr.M.M.Mustaffa, Director, NRCB welcomed the Chairman and the RAC members. He briefed the research activities and salient achievements of NRCB. Dr.P.Sundararaju, Member Secretary, RAC presented the Action Taken Report of last RAC. The Chairman and the members were satisfied about the action taken on the recommendation of previous RAC meeting and approved the minutes of 7th RAC. This was followed by a brainstorming session in which heads of sections presented the various research activities on banana. After detail discussion on the research progress of the on going projects, the Chairman and RAC members suggested the future programmes to be carried out in various new areas of research in banana. The Chairman in his concluding remarks appreciated the Director and the team of scientists of for effectively carrying out the research programmes.



Director explains about mass multiplication of *Trichoderma viride* to the Chairman, RAC


## 9th IMC

Institute Management Committee (IMC) met on 29.12.2006. Dr. M.M. Mustaffa, Director chaired the meeting. Approval for purchases of imported instruments were taken up. Mr. V.L. Mahajan requested the Director to depute the scientists to Jalgaon district in Maharashtra to assess the outbreak of BBTV and Erwinia head rot diseases.

## 11th IRC

Institute Research Council (IRC) meeting was held on 31st Jan 07 and 21st Feb 07. 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






**IMC Committee members**

the experiments to be conducted in the field as well as in lab. He asked the scientists to propose new projects for external funding in the identified area of research in banana. Two new institute projects *viz.*, "Abiotic stress tolerance in banana: Investigation of the physiological, biochemical and molecular responses to drought and salt stresses" and "Host virus interaction in Banana: Molecular mechanism of resistance and susceptibility, latency, intergration and episomal expression of EPRV's" were proposed. Both the projects have been approved by the house. The member secretary proposed a vote of thanks at the end of meeting.

| S.No. | Name and address | Position |
|---|---|---|
| 01. | Dr.M.M.Mustaffa<br>Director, NRC for Banana, Trichy. | Chairman |
| 02. | Asst.Director General (Hort.-I)<br>Indian Council of Agril. Research, KAB - II<br>Pusa, New Delhi – 110 012. | Member |
| 03. | Director of Horticultural & Plantation Crops, Govt. of Tamil Nadu, Chennai. | Member |
| 04. | Dean, Horticultural College & Research Institute,<br>Tamil Nadu Agril. University, Coimbatore. | Member |
| 05. | Additional Director of Agriculture, Dept. of Agriculture,<br>Govt. of Pondicherry, Pondicherry. | Member |
| 06. | Dr.Ram Kishan, Principal Scientist, Central Institute for Sub-tropical Horticulture, Lucknow. | Member |
| 07. | Dr.G.S.Prakash, Head, Fruit Crops Division, Indian Institute of Horticultural Research, Bangalore. | Member |
| 08. | Dr.E.R.Suresh, Principal Scientist, Indian Institute of Horticultural Research, Bangalore. | Member |
| 09. | Dr.P.Sundararaju, Principal Scientist, NRC for Banana, Trichy. | Member |
| 10. | Finance & Accounts Officer, Sugarcane Breeding Institute, Coimbatore. | Member |
| 11. | Shri V.L.Mahajan, Secretary, Banana Growers Association of India, Jalgaon, Maharastra. | Non-Official Member |
| 12. | Shri Subash Shamrao Kadam, Nanded, Maharastra. | Non-Official Member |
| 13. | Shri G.Ajeethan, Mohanur, Namakkal, Tamil Nadu. | Special Invitee |
| 14. | Shri B.Vijaykumar, Asst. Admn. Officer, NRC for Banana, Trichy. | Member Secretary |

RAC Committee

| S.No. | Name & Address | Position |
|---|---|---|
| 1 | Dr. R.M.Pandey<br>E-29, E-DDA (MIG) Flats, Mayapuri, New Delhi – 110 064. | Chairman |
| 2 | Dr.S.J.Singh<br>Flat No.23, 5th Floor, Prachy Residency, Bower Road, Pune – 411 045. | Member |
| 3 | Dr.N.Kumar<br>Professor,HC & RI, TNAU, Periyakulam – 625 604 | Member |
| 4 | Dr.B.Bandyopadhyay<br>OIC – AICRP on TF,Dir. of Research,<br>BCKV, Kalyani, Nadia – 741 235. WB | Member |
| 5 | Dr.R.C.Tiwari<br>B-4, Maa Bhagirathi Nagar, Sundarpur, Varanasi – 221 005 | Member |
| 6 | Dr. Lalitha Anand<br>114, 2nd Main,208 SFS, Yelahanka New town, Bangalore – 560 064 | Member |
| 7 | The Asst. Director General (Hort - I),<br>Indian Council of Agril. Research, KAB-II,<br>Pusa, New Delhi – 110012 | Member |
| 8 | The Director-NRCB, Trichy | Member |
| 9 | Shri V.L.Mahajan<br>At. PO – Chinawal, Tal.Raver, Jalgaon – 425 505 | IMC Member |
| 10 | Shri S.S.Kadam<br>House No.1/2/1414, Shivaji Nagar, Nanded – 431 602, Maharashtra | IMC Member |
| 11 | Dr.P.Sundararaju,<br>Principal Scientist, NRC Banana, Trichy | Member Sec. |

# 13 Trainings/ Workshops/ Seminars/ Conferences/ Winter/ Summer courses/ Meetings attended by Scientists.

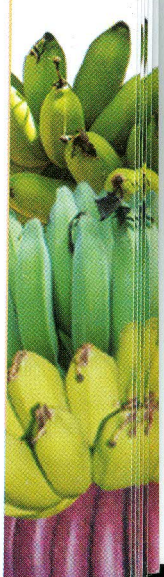
## Training

K.J. Jeyabaskaran, participated in the short course on "Advanced Irrigation Systems for Intensive Crop Production" held from 15-3-2007 to 25-3-2007 at the Water Technology Centre, Indian Agricultural Research Institute, New Delhi.

V. Kumar, attended an International Training Course on "Agricultural Water Management For Enhancing Water Productivity" Jointly organized by WTC, ANGRAU and Alterra- ILRI, The Netherlands, at Hyderabad from Jan.22 to Feb. 11, 2007.







| Name of the Scientist | Name of the Seminars/ Meetings/ Workshops / Conference/Symposium | Date |
|---|---|---|
| Mustaffa, M.M. | Botany association inauguration meeting, Bishop Heber College, Trichy | 9th October, 2006 |
| | 11th FYP - Sub-Group Committee meeting on Hort., Bangalore | 19th October,2006 |
| | NRCB, Vision 2025 – Draft report preparation meeting, ICAR, N.Delhi | 23rd October, 2006 |
| | State level National Hort. Mission meeting – Secretariat, Chennai | 25th October, 2006 |
| | ICAR Institute Director's Meeting, ICAR, New Delhi | 3-4th November, 2006 |
| | IPR Patent guidelines preparation meeting, NBPGR, N.Delhi | 5th November 2006 |
| | Tamil Nadu State KVK's review meeting , TNAU, Coimbatore | 7th November, 2006 |
| | ISTRC Symposium, CTCRI, Thiruvananthapuram | 20th November 2006 |
| | District level NHM meeting, Collectorate, Trichy | 20th November 2006 |
| | Scientific advisory committee meeting, KVK, Namakkal | 8th December, 2006 |
| | Flower, lemon, and banana growers meeting, Collectorate, Trichy | 12th December, 2006 |
| | BAPNET Steering committee meeting, Cambodia | 22-26th January, 2007 |
| | State level NHM meeting, Secretariat, Chennai | 1st February., 2007 |
| | Banana seminar at Kulithalai, organized by Hort. Dept., Karur | 13th February, 2007 |
| | 8th Africultural science Exhbition, TNAU, Coimbatore | 15th February, 2007 |
| | TNAGRICON- Banana Seminar organised by CII, Trichy | 23rd February, 2007 |
| | Dist. level NHM meeting, Collectorate, Trichy | 2nd March, 2007 |
| | 3rd Intl. conference on linking markets and farmers – Special Invitee – organised by IFPA, New Delhi | 12-13th March, 2007 |
| | Seed certification / varietal release committee meeting, ICAR, N.Delhi | 20th March, 2007 |
| Padmanaban, B. | Farmers meeting on banana cultivation held at Thanneerpalli organised by banana farmers of Kulithalai | 4th January, 2007 |
| | IIIrd National symposium on "Plant protection in Horticulture : Emerging trends & challenges, held at IIHR, Bangalore | 7-9th March, 2007 |
| | National conference on "Organic waste utilization and eco-friendly technologies for crop protection", held at ANGRAU, Rajendra nagar, Hyderabad, Organised by PPAI, Hyderabad | 15-17th March, 2007 |
| | Annual discussion meeting in entomology on Semiochemicals in Crop Protection: On going technologies ,held at COSTED , Chennai. | 2nd December, 2006 |
| Kumar, V. | Scientific advisory committee meeting, KVK, Sirugamani, Trichy | 24th December 2006 |

| | | |
|---|---|---|
| Narayana, C.K. | Talk on "Appropriate post harvest technology for quality banana production" in the TN Agricon 2007, at hotel Sangam, Trichy, organized by CII-Trichy | 24th February, 2007 |
| Selvarajan, R. | "National Seminar on Gene Constructs" held at Division of biotechnology, IIHR, Bangalore | 17-18th,May 2006 |
| | Project review meeting on Network project " Diagnostics of emerging plant viruses" at Division of Plant Pathology, IARI, New Delhi | 25th August, 2006 |
| | 2nd/3rd Project review meetings of the ICAR-Network Project on Transgenic in Crops at NRCPB, Pusa Campus, IARI, New Delhi | 23-24th, June, 2006 & February 2007 |
| | Coordination committee meeting of TN precision farming project at RRS, TNAU, Payur | 3rd July 2006 |
| | A Brainstorming Session on "Revival of Hill banana cultivation" conducted by TNAU, at HRS, Thadiyankudisai | 27-28th , July 2006 |
| | 8th Agricultural Science Congress, at TNAU, Coimbatore | 15-17th, February 2007 |
| | A seminar on "Banana cultivation and production of banana byproducts" at Kulithalai, Tamilnadu | 13th February 2007 |
| | Review meeting of DBT- Net work project on transgenic for virus resistance in crops at Plant Virology Unit, Dept of Plant Pathology, IARI, New Delhi | 20th December 2006 |
| | A special invited lecture on "Genetic engineering for plant virus resistance" at a one day seminar on "Thrust areas of biotechnology" at Bishop Heber College, Tiruchirapalli, Tamil nadu | 19th September, 2006 |
| | Invited lead talk on"Genetic engineering of plant for virus resistance :RNAi approach for virus resistance" at National Conference on "Microbial technology for second green revolution (MTSGR)" held at Dept. of Microbiology, Annamalai University | 28&29th March 2007 |
| Sundararaju, P. | Banana Seminar organized by the Banana Farmers at Thiruvaiyaru | 1st January .2007 |
| | Participated in the inaugural meeting of "Tamil Nadu Hill Banana Growers' Federation " launched by the Hill banana farmers group at Thadiyankudisai | 19th January 2007 |
| | Banana Seminar organized by the Dept. of Horticulture and Agriculture, Govt. of Tamil Nadu at Kulithalai | 13th February 2007 |
| | Workshop for Kisan call centre level I and level II operators organized by Coconut Development Board at Guindy,Chennai | 6th March 2007 |
| | IIIrd National Symposium on Plant Protection in Horticulture: Emerging trend and challenges" organized by Association for Advancement of Pest Management in Horticultural Ecosystems (AAPMHE) at IIHR, Bangalore | 7-9th , March, 2007 |





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|---|---|---|
| Uma, S. | International meeting on 'Molecular tools for quality improvement in vegetative propagated crops including banana and cassava' held at CTCRI, Thirvunanthapuram, Kerala organized by IAEA, Vienna, Austria | 5-9th February, 2007 |
| | Review meeting on ICAR network project on Transgenics in Crops - Functional genomics IARI, New Delhi | 21-23rd February, 2007 |
| | DBT Brain storming session on 'Biodiversity conservation through biotechnological interventions' at Tropical Botanic Garden and Research Institute, Thiruvananthapuram, Kerala | 10-11th January, 2007 |

# 14 Seminars/ Meetings/ workshops/ Conference/ Summer institutes and Farmers training organized at the centre.

Four days training was provided for 500 farmers and self help group members of Trichy district on improved methods of post harvest handling, and processing of banana under the aegis of Tamil Nadu State Agricultural Marketing and Sales Department from 20-23rd February 2007.

Short term training courses on production of value added products of banana were conducted for 10 prospective entrepreneurs between 24th to 28th April 2006, 6 prospective entrepreneurs from Mahabanana between 17th to 24th July 2006 and for 11 prospective entrepreneurs between 20th to 27th September 2006.

During the period under report banana growers and other farming groups from different parts of Tamil Nadu visited to NRCB (Table) . The activities of NRCB and technologies generated were explained to the visitors by specialised scientists.

**Table : List of farmers group and the agency arranged the visit to NRCB during 2006-07**

| Sl. No | | Name & Address | Purpose of visit | No. of farmers visited |
|---|---|---|---|---|
| 1. | 19.05.2006 | Village Development Centre, Mannachanallor | Training on Banana cultivation | 6 |
| 2. | 01.07.2006 | Uzhaikkum Uzhavar Mandram,Trichy | Training on Banana cultivation | 17 |
| 3. | 24.08.2006 | Banana Grower Association, Erode | Training on Advance technologies in Banana cultivation | 7 |
| 4. | 12.09.2006 | RSVY Farmers, State Agricultural Department, Tiruvanamalai | Training on Advance technologies in Banana cultivation | 50 |
| 5. | 26.09.2006 | Banana growers, Vedapuri K.V.K, ICAR, Tiruvananamalai | Training on Banana cultivation | 53 |
| 6. | 03.10.2006 | RSVY Farmers, State Agricultural Department, Tiruvanamalai | Exposure visit | 51 |
| 7. | 05.10.2006 | Banana farmers, State Agricultural Department (PPM), Tiruvanamalai | Exposure visit/ Training | 55 |
| 8. | 31.10.2006 | Banana growers, Vedapuri KVK, Kancheepuram | Exposure visit/ Training | 53 |
| 9. | 05.12.2006 | Banana growers and Scientists of KVK, Sirugamani, Trichy | Training on value added product in banana | 26 |

| | | | |
|---|---|---|---|
| 10. 07.12.2006 | RSVY farmers, Vedapuri KVK, Tiruvanamalai | Training on value added product in banana | 44 |
| 11. 20.12.2006 | Banana Growers, Assistant Director of Agriculture, Pudukkotai | Training on banana cultivation | 28 |
| 12. 25.01.2007 | Members of Banana Growers Association, Anibil Dharmalingam Agricultural College, Trichy | Awareness tour on banana | 74 |
| 13. 02.02.2007 | Banana farmers, Vedapuri KVK, Tiruvanamalai | Educational visit | 53 |
| 14. 05.02.2007 | Banana farmers, State Horticultural Deparment | Training on banana cultivation | 52 |
| 15. 27.02.2007 | Farmers, Agriculture Engineering Training Centre, Trichy | Field & exhibition visit | 27 |
| 16. 28.02.2007 | Farmer Tour Centre, Tindivanam. | To know about NRCB | 62 |
| 17. 02.03.2007 | Farmers association, Tirunelveli. | Exposure visit | 23 |
| 18. 15.03.2007 | Farmers, KVK, Tirunelveli | Exposure visit | 38 |
| 19. 15.03.2007 | Members of Banana growers association, Asst. Director of Agriculture (FTC) Karur. | To know about banana cultivation | 52 |
| 20. 24.03.2007 | Banana farmers, Saraswathi KVK, Plutheri, Karur | Exposure visit | 32 |

# 15 Distinguished Visitors

## DDG (Hort.) visits NRCB

Dr. H.P. Singh, Deputy Director General (Hort.) visited the NRCB on 11th March 2007. He reviewed the field experiments being conducted and gave critical inputs for better experimentation. Asked the scientist to reorient research activities to meet the challenges to increase the productivity in banana. He said that efforts for waste utilization through vermicomposting, organic farming, germplasm enhancement through biotechnological intervention and effective diagnostic kits for viral and sucker borne pathogens are the need of the hour in banana research in India. He also visited all the labs, exhibition hall and had a brain storming session with the scientists in which IIHR scientists also participated. He asked to prioritize the research needs for increasing the productivity in banana.

DDG reviewing the field experiments with scientists

**List of important dignitories visited the centre during 2006-07**

| Sl.No. | Date of visit | Name & Address |
|---|---|---|
| 1 | 07.12.2006 | Dr. Parvatha Reddy, Ex. Director, IIHR, Bangalore. |
| 2 | 07.12.2006 | Dr. S. Maiti, Director, NRCMAP, Anand, Gujarat. |
| 3 | 07.12.2006 | Dr. N.K. Mohan, Reg. Co-ordinator, SFABC, Guwahati, Assam. |
| 4 | 03.02.2007 | Dr. Nicholas Roux, Bioversity International, France. |
| 5 | 03.02.2007 | Dr. Jaroslav Dolezel, Institute of Experimental Biology, Czech Republic. |





| Sl. No. | Date of visit | Name & Address |
|---|---|---|
| 6 | 16.02.2007 | Dr. Andy James, CICY, Mexico |
| 7 | 22.02.2007 | Dr. Anupam Varma, Ex-National Proferssor IARI/Vice - Presedent INSA, New Delhi |
| 8 | 22.02.2007 | Dr. O.P. Reddy, Retd. Jt. Director, (PQ), Deptt. of Plant Production Quarantine and Storage, MoA, Chennai |
| 9 | 22.02.2007 | Shri Shiv Kant Shukla, Dy. Manager, BCIL, New Delhi |
| 7 | 22.02.2007 | Dr. M. Kochu Babu, Director, NRC-Oil Palm, Pedavegi, A.P. |
| 8 | 22.02.2007 | Dr. Gurumurthi, Retd. Director, IFGTB, Coimbatore |
| 8 | 27.02.2007 | Dr. Krishnakanth, Sr. Director, Ministry of Communication & Information Technology, Govt. of India, New-Delhi. |
| 9 | 11.03.2007 | Dr.H.P.Singh, D.D.G. (Hort), ICAR, New-Delhi. |
| 10 | 22.03.2007 | Dr. R.P.Kachru, AICRP on Tropical Fruits. |
| 11 | 22.03.2007 | Dr. Singh, AICRP on Tropical Fruits. |
| 12 | 22.03.2007 | Dr. G.S. Prakash, Head, Dept. of Fruit Crops, IIHR, Bangalore. |

## 16 Empowerment of Women

Trained 500 self help group women on post harvest handling and value addition of banana under the aegis of Tamil Nadu Agricultural Marketing and Sales Department, Govt. of Tamil Nadu from 20-23rd February 2007.

## 17 Personnel

- Mrs.M.S.Saraswathi, Scientist (Sr.Scale) of Crop Improvement has resumed duty on 26.12.06 after completion of her Ph.D by availing study leave.
- Dr. R. Thangavelu, Sr. Scientist, Plant Pathology, has been deputed to Department of Primary industries and fisheries, Indooroopilly, Brisbane, Australia by availing long term Research Overseas Associateship sponsored by DBT, to carry out research work on "Developing diagnostic kit for early detection of Fusarium wilt of Banana" from 01.02.07 to 31.01.08.

**Scientific staffs**

| Name | Designation |
|---|---|
| Dr.M.M.Mustaffa | Director |
| Dr.P.Sundararaju | Principal Scientist (Nema.) |
| Dr.B.Padmanaban | Senior Scientist (Ent.) |
| Dr.C.K.Narayana | Senior Scientist (Hort.) |
| Dr.S.Uma | Senior Scientist (Hort.) |
| Dr.I.Ravi | Senior Scientist (Pl.Phy.) |
| Dr.R.Thangavelu | Senior Scientist (Pl.Path.) |
| Dr.R.Selvarajan | Senior Scientist (Pl.Path.) |
| Dr.V.Kumar | Senior Scientist (Hort.) |
| Dr.K.J.Jeyabaskaran | Senior Scientist (Soil Sci.) |
| Dr.M.S.Saraswathi | Scientist (Sr.Scale) (Hort.) |
| Mr.R.Natarajan | Scientist (Eco.Bot.) |

**Technical staffs**

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

**Administrative, Audits & Accounts and Supporting staffs**

| Name | Designation |
|---|---|
| **ADMINISTRATION** | |
| Mr.B.Vijaykumar | AAO |
| Mr.M.Krishnamoorthy | PA to Director |
| Mr.R.Krishnamurthy | Upper Division Clerk |
| Mrs.S.Durgavathy | Lower Division Clerk |
| Mr.R.Sridhar | Stenographer Gr.III |
| Mr.M.Devarajan | Lower Division Clerk |
| **AUDIT AND ACCOUNTS** | |
| Smt.C.Gomathi | AFAO |
| Mr.M.Balu | Assistant |
| Mr.R.N.M.S. Kannan | Stenographer Gr.III |
| **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

## New Project on transgenics launched

Implemented a new DBT funded project on "Development of Transgenic hill banana resistant to banana bunchy top virus(replicase gene mediated)" which was sanctioned on 29th September, 2006 at a cost of Rs.48.25 lakhs.

## Hindi Week Celebrated

Hindi week was celebrated at NRCB during September, 2006. On this occasion various events *viz.*, Hindi dictation, essay, recitation, singing and quiz were conducted. All staff participated actively. Deputy Director, Central Hindi Teaching Scheme, Tiruchirapalli, distributed the prizes to the winners in the valedictory function.

## Institute Biosafety committee (IBSC)

As per the DBT guidelines, an Institute Biosafety committee has been constituted at the centre. One of the member has been nominated by DBT. The IBSC is chaired by the Director, NRCB and the members are Dr. Vivekanandan, Head, Dept of Biotechnology, Bharathidasan University , Trichy; Dr. L. Uma , Director, National Facility for Marine Cyanobacteria, Bharathidasan University; (DBT, nominee); Dr. S. Uma and Dr. I. Ravi, Sr. Scientists (NRCB) are internal members and Dr. R. Selvarajan, is the member secretary. The committee will look after the safetly guidelines to be followed in projects dealing on trangenics and recombinant DNA technology, genetically modified organisms etc. The committee will meet twice in a year.

## ANNEXURE - I

### List of approved on-going projects

**I Crop Improvement**

1. Management of genetic resources of banana
   Project Leader : **S.Uma**
   Project Associate : M.S.Saraswathi
2. Crop improvement of banana through conventional breeding
   Project Leader : **M.M. Mustaffa**
   Project Associate : S.Uma
3. Crop improvement of banana through non-conventional breeding
   Project Leader : **S.Uma**
   Project Associate : M.S.Saraswathi

**II.Crop production and Postharvest technology**

4. Standardisation of agrotechniques for banana production and productivity
   Project Leader : **V. Kumar**
   Project Associates : M.M.Mustaffa, K.J.Jeyabaskaran
5. Integrated nutrient management in banana
   Project Leader : **K.J. Jeyabaskaran**
   Project Associate : M.M.Mustaffa
6. Studies on micronutrients in banana
   Project Leader : **K.J. Jeyabaskaran**
   Project Associate : V.Kumar
7. Standardization of technology for organic banana production
   Project Leader : **M.M. Mustaffa**
   Project Associates : V.Kumar, K.J.Jeyabaskaran
8. Standardization of nutritional requirements of banana using soluble fertilizers
   Project Leader : **V. Kumar**
   Project Associates : M.M. Mustaffa, K.J.Jeyabaskaran
9. Studies on physiology of flowering and fruit development in banana
   Project Leader : **I. Ravi**
   Project Associates : C.K.Narayana, K.J.Jeyabaskaran
10. Studies on handling, storage and processing of banana
    Project Leader : **C.K.Narayana**
    Project Associate : M.M.Mustaffa
11. Standardization of storage conditions for banana
    Project Leader : **C.K.Narayana**
    Project Associate : I.Ravi
12. Abiotic stress tolerance in banana: Investigation of the physiological, biochemical and molecular responses to drought and salt stresses
    Project Leader : **I.Ravi**
    Project Associate : C.K.Narayana, M.M. Mustaffa, S. Uma, K.J. Jeyabaskaran





## III. Crop Protection

13. Insect pest management in banana

    Project Leader : **B.Padmanaban**

    Project Associates : P.Sundararaju, R.Thangavelu

14. Studies on banana nematodes and their management

    Project Leader : **P.Sundararaju**

    Project Associates : B.Padmanaban, R.Thangavelu

15. Investigation on fungal and bacterial diseases of banana and their management

    Project Leader : **R.Thangavelu**, upto 31st Jan 2007 ; **R.Selvarajan**, from 1st Feb 2007

    Project Associate : R.Selvarajan

16. Studies on viral diseases of banana and their management

    Project Leader : **R.Selvarajan**

    Project Associate : R.Thangavelu

17. Host virus interaction in Banana: Molecular mechanism of resistance and susceptibility, latency, intergration and episomal expression of EPRV's

    Project Leader : **R.Selvarajan**

    Project Associate : S.Uma, I. Ravi

## List of on - going externally funded projects

1. Network project on Transgenic in Crops – Banana Functional Genomics (Sigatoka and Drought)

   P.I. : **S.Uma**

   Co. P.I : I.Ravi, R.Thangavelu & R.Selvarajan

2. Network project on Diagnostics of emerging plant viruses - Funding source ICAR AP Cess fund

   P.I.: : **R.Selvarajan**

3. Network project on Wilts of crops with special reference to cultural pathogenic and molecular characterization of isolates in India - Funding source ICAR AP Cess fund

   P.I. : **R.Thangavelu**

4. Soil test based integrated nutrient tailoring for optimum banana production and sustainable soil health - Funding source ICAR AP Cess fund

   P.I. : **K.J.Jeyabaskaran**

5. Net work Project on Transgenic in Crops - Transgenic Development: Development of streak virus and bunchy top virus resistant transgenic banana

   P.I. : **R.Selvarajan**

   Co.P.I : S.Uma

6. Development of transgenic Hill banana resistant to BBTV (replicase gene mediated)

   Funding source : DBT

   P.I. : **R.Selvarajan**

   Co.P.I : S.Uma

## ANNEXURE - II

### Meteorological Data

| Month | Maximum Temp($^0$C) | Minimum Temp($^0$C) | Rain Fall (mm) | Relative Humidity (%) |
|---|---|---|---|---|
| April, 2006 | 36.36 | 25.86 | 3.5 | 83.13 |
| May, 2006 | 37.26 | 26.23 | 4.5 | 77.74 |
| June, 2006 | 36.70 | 26.21 | 9.9 | 74.53 |
| July, 2006 | 37.74 | 26.96 | 0 | 70.52 |
| August, 2006 | 36.92 | 25.14 | 86.4 | 77.50 |
| September, 2006 | 34.03 | 24.62 | 38.0 | 86.70 |
| October, 2006 | 32.24 | 24.91 | 192.2 | 94.72 |
| November, 2006 | 29.13 | 23.30 | 114.1 | 95.31 |
| December, 2006 | 29.42 | 22.26 | 12.0 | 90.8 |
| January, 2007 | 28.90 | 20.64 | 0 | 87.97 |
| February, 2007 | 33.14 | 22.25 | 0 | 90.52 |
| March, 2007 | 36.20 | 24.64 | 0 | 88.84 |