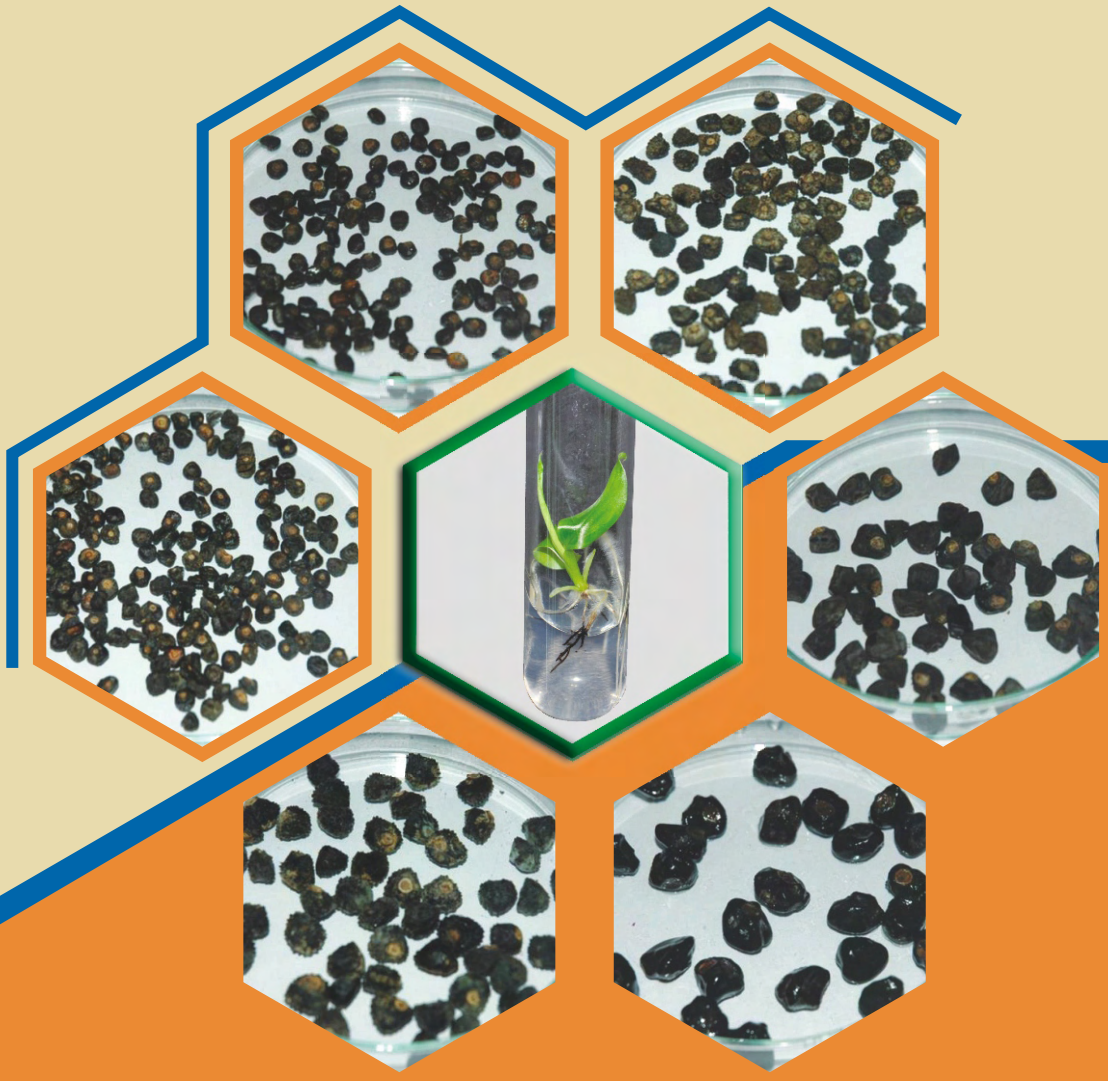
ICAR NRC BANANA

ANNUAL REPORT 2014 - '15

वार्षिक प्रतिवेदन २०१४ - '१५



ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

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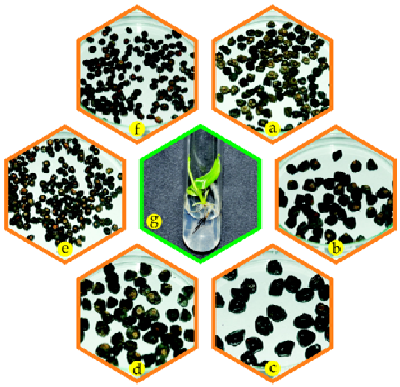

a. *Musa rosaceae*
b. *Musa sikkimensis*
c. *Musa saddlensis*
d. *Musa nagensium*
e. *Musa velutina hybrid*
f. *Musa aurantica*
g. Seedling produced from embryo

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PREFACE

The ICAR-National Research Center for Banana, Tiruchirapalli, continued to play a major role in research and extension activities related to bananas and plantains. It gives me great pleasure to present the Annual Report of ICAR- NRCB for the period of 2014-15.

During the research year 2014-15, the Institute has made two selections in scented near extinct 'Manoranjitham' banana for its bunch weight, which was five times more than local. Exploration made in Arunachal Pradesh resulted in collection of nine *Musa* species and four land races. Ramkela, a Tripura wild collection has been characterized and was identified as *Musa flaviflora.* Genomic status was assigned to ITC new introductions *viz.,* Mizo Cavendish (AAA), Ash Monthan (ABB), Behula (ABB) and Batheesa Cheriya (ABB). Ten species-specific ISSR markers were validated to identify *Musa* wild species and it may help to prevent bio-piracy. In bioinformatics, MusatransSSRDB - *Musa* Transcriptome SSR database was developed and hosted at ICAR-NRCB Website. Screening of *Musa* germplasm accessions against banana weevils showed that Adukkan (AB), Dinamalakol (ABB), Norman (AB), KNR mutant (AB) and Jurmony (BB) as promising resistant accessions.

In production section, which includes production, soil science, physiology, biochemistry and post-harvest technology, significant achievements were made during this reporting period. The negative effects of soil moistures deficit stress in cv. Grand Naine, was alleviated through foliar priming of plants at 5th month stage, the most critical stage for moisture stress, with 0.1mM acetyl salicylic acid (ASA) which prevented bunch malformation and yield reduction. Banana plants primed with ASA and butylated hydroxyl toluene under moisture stress retained the photosynthesis machinery to sustain the leaf function. The salt tolerant banana genotype 'Saba' produced higher total dry matter and recorded less susceptibility index under 100 mM NaCl stress compared to other banana cultivars. Biochemical mechanism of 'ripe green' in Cavendish bananas indicated lower activity of *Mg-dechelatase* and impairment of *pheophorphide a oxygenase* responsible for de-greening at elevated temperature (>31^{o}C). Green life was enhanced in Grand Naine and Poovan using 1-MCP. The shelf-life of banana leaves of commercial cultivars increased up to 30 days by storing at 10^{o}C. Prevention of enzymatic browning in central core stem of banana was standardized for commercially grown banana cultivars. Banana central core stem juice based products such as RTS stem juice and Jelly were developed.

Foliar spray of *Bacillus* spp. (1e2 and 12acy) at shooting stage reduced *eumusae* leaf spot disease. Multivirus resistant transgenic plants were generated using RNAi construct from 8 embryonic cell suspension (ECS) lines.

In the HRD area, two staff from administration, four technical staffs and four scientists received training on capacity building and leadership development respectively during the period. A total of 16 research papers (10 national and 6 international) have been published from the Centre and another 18 research abstracts were presented in various national and international seminars/ conferences/ symposia etc.,

The Centre has organized an international *Musa* programme during 6th December 2014 in which, trainees from 11 Taxonomic Reference Collection Project (TRCP) partners from Burundi, Cameroon, Costa Rica, Indonesia, Nigeria, Philippines, Tahiti, Uganda, USA, Vietnam and India participated, in collaboration with Bioversity International ,France .Also two trainings in Kerala and two in Seemandhra were organized for the tribal banana farmers under TSP programme.

I congratulate and also thank Dr. B. Padmanaban, Chairman and Drs. I. Ravi, S. Backiyarani, P. Giribabu and P. Ravichamy, members of the Publication Committee for their good work in compiling, editing and bringing out this report of the Centre in time.

I express my sincere gratitude to Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR for his valuable guidance and Dr. N.K. Krishna Kumar, Deputy Director General (Hortl. Sci.), ICAR for his constant inspiration and encouragement.

(M.M. Mustaffa)
Director

2 EXECUTIVE SUMMARY

Improvement

Exploration in Arunachal Pradesh has resulted in collection of nine *Musa* species and four land races. Two high yielding plants of Manoranjitham (which yielded five times higher bunch weight than the parent) were selected from Kolli Hills for further evaluation. Ramkela a Tripura wild banana was characterized and found to be *Musa flaviflora.* Genomic status was assigned to the new ITC introductions such as Mizo Cavendish (AAA), Ash Monthan (ABB), Behula (ABB), and Batheesa Cheriya (ABB). Principal coordinates analysis of DArt marker results of 91 mini core collections suggested close proximity between AA with *Rhodochlamus*; AB with AAB; ABB with BB. More number of unique bands were observed in *Rhodoclamus* species which indicated the genetic difference from other genomic groups of *Musa.* Identified ten ISSR markers producing species-specific unique bands for ten *Musa* species, which can be used in identification of *Musa* wild species and protection from bio-piracy. Phenolic exudation in cv. Neypoovan shoot multiplication was solved by changing the sub-culture medium. The optimum period of cell proliferation and effective regeneration of cells was 12 months after the initiation of suspension later the regeneration percentage of the cell started to decline. Eight putative *Fusarium* wilt resistant Rasthali mutants were identified through pot screening against *Foc* (VCG 0124).

Multi location testing (MLT) of selection-10 (NamwaKhom) ratoon crop has proved its superiority with respect to dwarf stature and earliness. Similarly MLT of selection 08 ratoon crop has proved its superiority in yield by 37% than local check. The highest germination was recorded in ABB x AA cross combination, and the highest germination percentage was recorded in the Kothia based crosses followed by Saba and Bangrier. Seed set was observed for the first time in plantain group (Ginde-AAB) and 250 sunken seeds were obtained from 338 total seeds and Ginde X Pisang Lilin hybrid plants have been developed.

MusatransSSRDB - *Musa* Transcriptome SSR database was developed and hosted at ICAR-NRCB Website. URL: http://nrcb.res.in/nrcbbio/. Involvement of lignin biosynthesis pathway in *Pratylenchus coffeae* resistance mechanism of banana was proved through transcriptome studies. qRT-PCR analysis reconfirmed induced expression of MusaWRKY95 in *P. coffeae* challenged resistant cultivar and indicated the important role of transcription factor in resistant mechanism. The transcriptome and qRT-PCR analysis revealed the confirmation of phenylpropanoid, shikimate, isoprenoid pathways in *eumusae* leaf spot resistance mechanism.

Screening of *Musa* germplasm accessions against banana weevils showed that Adukkan (AB), Dinamalakol (ABB), Norman (AB), KNR mutant (AB) and Jurmony (BB) were tolerant to weevil.

Production

Under nutrient dynamic studies, cvs. Ney Poovan and Rasthali, recorded highest total dry matter (TDM) production and nutrient accumulation in pseudostem and lowest in flower bud at shooting stage. The TDM increased at shooting stage with fertilizer application in cvs. Ney Poovan and Rasthali and was maximum at 150% recommended NPK followed 125% NPK.

The major abiotic factors which affect production and productivity of bananas are drought and salt stresses and studies were carried out to alleviate the effect of drought and salt stresses in banana. The negative effects of soil moistures deficit stress in cv. Grand Naine was alleviated through foliar priming of plants at 5th month stage which is the most

critical stage for moisture stress. Foliar spraying with 0.1mM ASA which prevented the bunch malformation and yield reduction. The banana plants primed with acetyl salicylic acid (ASA) and butylated hydroxyl toluene under moisture stress indicated the sustainability of the photosynthesis machinery. In salt stress management studies, Grand Naine plants primed with Glycine betaine (20 mM) and subsequent imposition of salt stress with 50mM NaCl increased two and five fold dry matter production compared with unprimed salt stressed plants of 50 mM and 100 mM NaCl respectively. Foliar priming of three month old banana cv. Grand Naine with 200µM beta amino butyric acid before imposition of salt stress (50mM NaCl) recorded significantly less Na^+(0.03%) accumulation in leaves than non-primed plants (0.18%) and increased K^+ accumulation (3.45%) than non-primed plant leaves (1.82%). Salt tolerance mechanism in banana revealed, salt tolerant banana genotype 'Saba' produced higher total dry matter and recorded less susceptibility index under 100 mM NaCl stress compared to common banana cultivars. Besides under salt stress, leaf became more succulent due to increased intercellular space.

The biochemical mechanism of resistance of banana to root lesion nematode revealed that, the transcript levels of highly differentially expressed enzymes/proteins *viz*., glutamine reductase, â-galactosidase and cinnamyl alcohol dehydrogenase were higher in banana roots infected with the root-lesion nematode which was confirmed by the over-expression/upregulation of these enzymes are due to infection of the nematode. Biochemical mechanism of 'ripe green' in Cavendish bananas revealed that at elevated temperature (>31 °C), lower activity of Mg-dechelatase and impairment of pheophorphide a oxygenase contributed for de-greening in Cavendish banana.

A significant achievement was made to enhance green life of bananas by treating the fruits with an ethylene synthesis blocker, 1-MCP, which prolonged the green life by 44 and 20 days at 13.5 and 21°C respectively of full three quarter (90%) mature Grand Naine banana. Similarly, in Poovan banana, 1-MCP enhanced the green life by 30 and 20 days at 13.5 and 21 °C respectively. The physiological parameters, biochemical characteristics and qualitative parameters (TSS and acidity) of 1-MCP treated bananas during ripening were similar to untreated control fruits.

The shelf-life of banana leaves of commercial cultivars increased up to 30 days at 10°C. Under improved postharvest packing and storage technique, 'Saba' (100% maturity), Poovan (90% maturity) and Nendran (75% maturity) harvested green banana recorded 28, 35 and 68 days of shelf life under active modified atmosphere packaging (MAP) at 13.5°C. Prevention of enzymatic browning in central core stem of banana was standardized for commercially grown six banana cultivars. Banana central core stem juice based products such as RTS stem juice and Jelly was developed.

Protection

Studies on persistence of endophytic *Beauveria bassiana* and *Metarhizium anisopliae* on tissues of banana cv. Grand Naine by root dip and soil drenching methods indicated their persistence in plants and corm weevil mortality. Effect of aqueous and hexane extracts of zimmu were tested against banana weevils showed that by insect dip method, maximum stem weevil mortality (100%) was recorded at 100% concentration of aqueous extract on 10th day, while banana corm weevil showed no mortality. The solvent extract tested against banana corm weevil indicated 100% mortality at 100% concentration on 6th day. Studies on amylase Inhibitor bioassay against 3rd instar stem weevil grub showed 100% mortality with

75mg/20ml concentration at 10th day after treatment.

Zimmu planting was found to reduce the soil inoculum load of *Fusarium* wilt from 5.60 x 10^5 to 6.6 x 10^2. Foliar spray of *Bacillus* spp. (1e2 and 12acy) at shooting stage reduced *eumusae* leaf spot disease by 56.8% and 54.3% respectively. Among the six biocontrol agents tested against root-knot nematode, (*Meloidogyne incognita*) soil application of wild endophytic *Trichoderma asperellum* was found effective. Bio-control agents, *Trichoderma asperellum* and *T. longibrachiatum* were found effective in inhibiting mycelial colonies of post harvest pathogens (*Colletotrichum musae* and *Lasiodiplodia theobromae*). *T. asperellum* (prr2) was also found effective in extending shelf life of banana fruits by 28 days at 23°C and 55 days at 13°C from post harvest diseases.

Three complete genome (7.6 Kbp) of Banana Streak Virus (BSV) species infecting cvs. Rasthali and Poovan were amplified by RCA and cloned. A solvent free simple extraction protocol was developed and validated for the detection of banana bunchy top virus (BBTV). Studies showed that streak virus severity and yield loss were significantly higher in TC plants than healthy and banana streak mysore virus (BSMYV) infected sucker grown plants. Complete genomes of BSMYV and BBTV were obtained in dually infected Poovan sample. Transgenic banana plants resistant to BBTV were generated using BBTV-rep gene construct and the resultant 52 plants tested negative to BBTV inoculation through banana aphid (*Pentalonia nigronervosa*). Multivirus resistant transgenic plants were generated using RNAi construct from 8 embryonic cell suspension (ECS) lines. These plants were inoculated with BBTV through banana aphid, *P. nigronervosa* and symptom expression was absent in three lines.

Phloem proteomics studies of banana cv. Nendran revealed the presence of > 30 reproducible spots (from leaf, bract and pseudostem) with up and down regulation. These protein spots were found to be involved in defense, signal transduction, cell structure and function, photosynthesis and energy, plant growth, protein designation/storage and transcription/translation. Oxidative stress studies in BBTV-infected cvs. Nendran and Poovan revealed quantifiable changes in physiological and biochemical parameters such as proteins, phenolic compounds, polyphenol oxidase (PPO), peroxidase (POX), ascorbate peroxidase (APX), guaiacol peroxidase (GPX), catalase (CAT) and superoxide dismutase (SOD) activities were observed between BBrMV infected and healthy leaves of banana cultivars. Phenols, total proteins, SOD and GPX activities were significantly higher in leaves of BBrMV infected plants of both the cultivars than in healthy plants, whereas catalase, APX, PPO and POX activities showed a reverse trend. Under DBT QUT project on biofortification, >100 transformed transgenic plants of Grand Naine and Rasthali generated for iron fortification of banana using construct *p*BMGF-53.

Transfer of Technology

In this year, two radio talks (All India Radio) and two television talks (DD - Podhigai and Puthiya Thalaimurai) and twenty five press notes in various dailies and magazines were published by the faculty of ICAR-NRCB, Tiruchirapalli. Totally 65 seminars/ conferences/ symposia/ workshops/ meetings were attended by the scientists at regional/ national/ international. Participated/ organized eight exhibitions at regional/ national levels. On-campus and off-campus trainings (nine each) were conducted to farmers and other people working on banana.

Technologies on post harvest handling, packing and storage were transferred to four entrepreneurs. Mother cultures of tissue cultuture banana plants received from DBT recognised tissue culture production units were tested for banana viral diseases and fidelity.

Eight VIPs and about 5800 people including farmers, Agricultural & Horticultural officers, self help group personals and students visited.

Linkages and Collaboration

The Centre has developed good linkages with international institutes *viz*., Bioversity International, France and QUT, Australia. Collaborated with different national research institutions for different activities *viz*., NBPGR, New Delhi; BARC and CIRCOT, Mumbai; IIHR, Bangalore; Coffee Board, Bengaluru; NHB, DST and DBT New Delhi; NCL Pune, all SAUs and Bharathidasan University, Tiruchirapalli, Tamil Nadu. Tissue culture industries involved in banana mass propagation, farmers, exporters, banana federations, State Horticulture and Agriculture departments and self-help groups are linked with the Centre for various research and developmental activities. ICAR-NRCB also co-ordinates with AICRP (Tropical Fruits) Centres working on banana. The Centre has collaborated with CTCRI, Thiruvananthapuram and CPRI, Shimla for development of extruded product by blending banana, cassava and potato flours and with CIAE, Regional Station, and Coimbatore for developing banana central core stem slicer, juice extractor and developing postharvest mechanization package for banana central core.

HRD and Education

Four scientists, four technical staffs and two administrative staff of the Centre have undergone training on capacity building and a leadership development. Management development programme on leadership development. A total of 16 research papers (10 national and 6 international) have been published from the Centre and another 18 research papers abstracts were presented in various national and international seminars/ conferences/ symposia, *etc*. Eleven M. Sc. and B. Tech. (Biochemistry, Biotechnology and Microbiology) students of various colleges/ universities of Tamil Nadu were guided by the scientists for project/thesis works on different aspects of banana.

Revenue Generation

A total of Rs.63.65lakhs was generated as revenue by the Centre during the year 2014-2015.

3 INTRODUCTION

The ICAR-National Research Centre for Banana was established on 21st August 1993 at Tiruchirapalli, Tamil Nadu by the ICAR, New Delhi with an aim to increase the production and productivity of bananas and plantains through mission mode basic and strategic research approaches. This Centre is located at 11.50° N latitude and 74.50° E longitude, 90 m above MSL and receives 800 mm rain annually. The climate is warm and humid and the average minimum and maximum temperature are 25 and 35 °C respectively. The Centre has a research farm of 36 ha with laboratory complex in 3 ha.

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

The ICAR-NRC banana has been identified as the National Repository for banana. It has a field gene bank consisting of 566 banana germplasm of indigenous collections from North - Eastern region, Western Ghats and Andaman and Nicobar Islands and also exotic banana accessions from International Transit Centre (ITC), Belgium through NBPGR, New Delhi. The Centre has completed nine in-house research projects and 18 are in progress. In addition to Centre's in-house projects, 23 externally funded projects funded by NATP, DBT, NHB and INIBAP were completed. The Perspective Plan and 'Vision 2050' document on the research priorities and also reports by QRT and RAC were published. The Centre conducts two meetings of Institute Research Council to review the on-going research projects and also monitor the progress made on the of RAC and QRT recommendations. The vision of the Centre is to be the world leader in production and productivity of bananas and plantains thereby to meet the growing need in India. The research advisory committee, under the Chairmanship of Dr.G.L.Kaul reviewed the research activities of the Centre and recommended future research activities for the progress of banana industry in India.

Mandate of the Centre are

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

Salient Achievements

Improvement

A field gene bank with 566 core accessions (478 indigenous and 88 exotic) have been assembled and maintained in the field gene bank repository at Tiruchirapalli. Among the collections, 92 accessions are highly resistant and 25 are resistant to Sigatoka leaf spot disease. ICAR-NRCB released variety Udhayam, which belongs to *Pisang Awak* sub group, is a higher yielder than the local Karpuravalli. Embryogenic cell suspensions

(ECS) for five different commercial varieties *viz*., Rasthali, Nendran, Ney Poovan, Robusta and Grand Naine have been developed and regeneration protocol from ECS for Nendran and Rasthali has been standardized. ICAR-NRCB has developed a DNA Bank for *Musa* germplasm with 225 accessions. A farmers' friendly mass production method by 'Macro propagation' technique was developed to meet the local need of small and marginal farmers, in multiplication of disease free traditional varieties of banana. An introduction viz., Formosona (a high yielding Cavendish banana resistant to *Fusarium* wilt (race-4) from Taiwan Banana Research Institute (TBRI), Taiwan was added. NRCB selection - 08 proved its superiority for high yield and less duration in all the AICRP Centers tested. Cultivar Saba based progeny (No.183) was found promising in terms of fruit qualities like firm pulp, good cooking quality and suitability to chips making. Namwa khom (Pisang Awak, ABB) a dwarf exotic introduction was found promising and was suitable for high density planting. Screening of *Musa* germplasms against major nematodes resulted in the identification of 5 diploids and 8 triploids resistant to both root-lesion and root-knot nematodes. Screening of *Musa* germplasm accessions against banana weevils showed that Adukkan (AB), Dinamalakol (ABB), Norman (AB), KNR mutant (AB) and Jurmony (BB) as promising resistant the donors.

Explorations in Arunachal Pradesh yielded nine *Musa* species and four land races. Species specific ISSR markers for those nine species were also developed. Two high yielding plants of cv. Manoranjitham were selected in Kolli Hills, Tamil Nadu and mass multiplied. Multi-location testing of Selection - 10 (NamwaKhom) and NRCB Selection - 08 has proved its superiority with respect to yield, dwarf stature and earliness. MusatransSSRDB - *Musa*Transcriptome SSR database was developed and hosted at ICAR-NRCB Website. URL: http://nrcb.res.in/nrcbbio/ This database provides information on *Musa* SSRs namely type of SSRs, primer details, annealing temperature, product size, putative function and metabolic pathways of the SSR containing genes and their expression profiles under specific stresses.

Production

Poovan plants with 20 litre water/day/plant at 75% N (150 g N/plant) as fertigation increased the yield by 20% and recorded maximum net profit with a benefit ratio of 1.96. A combination of distillery sludge 2.5 kg + 1 kg vermicompost + 1 kg neem cake + 2.5 kg poultry manure per plant recorded the maximum growth and yield parameters in Rasthali and Karpuravalli bananas. Application of gypsum 2 kg/ plant + FYM 15 kg/ plant + 120% recommended K in saline sodic soil increased the yield by 51 % over control in Nendran and Rasthali bananas. Paired row planting system with 4,500 - 5,200 plants/ha, increased the productivity and fruit quality with 75% of recommended fertilizers dose as fertigation in Robusta, Grand Naine and Red Banana. In the second ratoon crop, application of 20kg FYM, 0.9 kg Neem cake, 2.0kg vermicompost and 0.9kg groundnut cake recorded the highest bunch weight of 15.9 kg with more number of hands (12.1) and fingers/bunch (188.5). Application of 20 kg FYM + 0.9 kg Neem cake + 2.0 kg vermicompost + 0.9 kg groundnut cake as well as other organic treatments significantly improved the porosity (45.5 %) as well as particle density (44.3%) as against a porosity of 40.2% with 100% inorganic that was on par with 125% inorganic fertilization.

Application of 15 kg rice husk ash + 25g VAM + 80% recommended NPK recorded an additional profit of Rs. 32,500/ha. Soil application of Fe and B along with foliar spray of Zn under high pH soil condition, increased the bunch weight of Ney Poovan banana by 43.5% over control, resulting in an additional net profit of Rs. 38,000/ha. In cv. Ney Poovan

under high pH soil condition indicated application of sulphur 20g/plant reduced the soil pH from 8.6 to 7.8 in the rhizosphere and increased the plant growth (up to 12.5 %) and yield parameters (up to 14%) significantly over the control. In the first ratoon crop of Udhayam banana, application of recommended dose of 300:400g N&K plant^{1} in ratio of 7:2:1 N and 4:3:3 K_2O at vegetative, flowering and bunch development stages recorded the earliest fruit maturity. Fertilizer adjustment equations for Poovan and Karpuravalli bananas were developed. The fertilizer adjustment equations developed at ICAR-NRCB were validated at different banana growing areas in Tamil Nadu, West Bengal, Kerala and Karnataka through AICRP Centres. Impact of source reduction (leaf pruning) on flowering and fruit yield studies indicated in cvs. Poovan, Ney Poovan and Karpuravalli, reduction in source area increased more photosynthesis as a compensation mechanism. Eight drought tolerant accessions were identified based on leaf water retention capacity. The leaf longevity was more in Robusta than Nendran, Rasthali and Ney Poovan bananas. Saba, Karpuravalli and Ney Poovan have been identified as tolerant cultivars to salt stress. Drought tolerant Saba and Karpuravalli cultivars maintained higher (>200) K/Na ratio in leaf (lamina and midrib) than susceptible Ney Poovan, Nendran and Robusta cultivars (4.52 to 17.56) at shooting and fruit maturity.

Foliar priming of 5 month old banana cv. Grand Naine with 0.1mM acetyl salicylic acid (ASA) prevent bunch malformation and yield reduction due to soil moisture deficit. Foliar priming banana cv. Grand Naine with 20 mM Glycine betaine and subsequent imposition of salt stress with 50mM NaCl increased two and five fold dry matter production compared with unprimed salt stressed plants. Similarly, foliar priming of three month old banana cv. Grand Naine with 200µM beta amino butyric acid and subsequent imposition of salt stress (50mM NaCl) recorded significantly less Na+(0.03%) accumulation in leaves than non-primed plants (0.18%) and increased K+ accumulation (3.45%) than non-primed plant leaves(1.82%). Salt tolerant 'Saba' produced higher total dry matter and recorded less susceptibility index under 100 mM NaCl stress compared to other banana cultivars.

A study on biochemical mechanism of resistance of bananas to *Pratylenchus coffeae* generally indicated that the activity of phenol oxidizing enzymes, stress related enzymes and the level of total phenols, lignin and tannins were higher even at 30 days in resistant than in susceptible cultivars. The induction of these above said enzymes were more in the nematode challenge inoculated plants than in the unchallenged plants. The phenol-ammonium acetate protocol yielded the highest protein concentration than other protocols tested for protein extraction from root tissues for proteomics study.

Biochemical mechanism of resistance of banana to root lesion nematode, *Pratylenchus coffeae* revealed that, the transcript levels of enzymes/proteins *viz.,* glutamine reductase, â-galactosidase and cinnamyl alcohol dehydrogenase were higher in banana roots infected with root-lesion nematode. Biochemical mechanism of 'ripe green' in Cavendish banana revealed that at elevated temperature (> 31°C), lower activity of Mg-dechelatase and impairment of *pheophorphide a oxygenase* contributed for de-greening of Cavendish banana. Enhancing green life of banana was achieved by treating with 1-MCP (an ethylene synthesis blocker) which resulted in prolonging green life by 44 and 20 days at 13.5 and 21 °C respectively.

Postharvest Technology

Pre-packaging in 400 gauge LDPE bags, low temperature storage, use of ethylene absorbents and pre-storage treatments have resulted in extension of shelf life up to 3 months in Robusta, Grand Naine, Rasthali and Ney Poovan bananas. Several value added

products like flower *thokku*, peel *thokku*, fruit pickle, fig, biscuits, jam, ready to serve beverages and functional foods like *chapathi*, bread and health drink have been developed. Banana and Jamun juice blend was the best among the blends made with other fruit juices rich in antioxidants. A recipe for banana flower based ready to make soup has been standardized. A new product, banana pulp based 'Sip-up' was prepared without pasteurization. The product can be stored up to 15 days at 0°.

An improved postharvest packing and storage technique, modified atmosphere packaging (MAP) of harvested green banana at 13.5°C, recorded 28, 35 and 68 days of shelf life of 'Saba' (100% maturity), Poovan (90% maturity) and Nendran (75% maturity) respectively. Prevention of enzymatic browning in central core stem of banana was standardized for commercially grown banana cultivars namely, Poovan, Karpuravalli, Ney Poovan, Pachanadan, Saba and Mortman (Andhra Rasthali). Banana central core stem juice based products (RTS stem juice and Jelly) were developed.

Protection

Mass production technique for *Paecilomyces lilacinus,* (an egg parasite of root-knot nematode) using banana petiole and pseudostem has been developed. Combined application of *Bacillus subtilis* and *B. cereus* in cv. Ney Poovan resulted in 60% increase in plant growth with 90% reduction of root lesion nematode populations than individual treatments. Maximum reduction of 90% nematode population with 50% increase in plant growth and bunch weight was recorded in plants treated with *P. linacinus* + *P. flourescens* + Neem cake + Marigold as intercrop. Swabbing 0.06% Chlorpyrifos on the pseudostem upto 1.2 m height during 5 to 8 month stage completely controlled banana stem weevil incidence. Treating suckers with Monocrotophos (14 ml/litre) followed by soil application of Carbofuran 30g per plant at 4th and 7th month after planting found effective against corm weevil. Pseudostem split trap swabbed with chaffy grain formulation of *Beauveria bassiana* trapped the stem and corm weevils better than traps swabbed with maize flour formulation. Among 37 semiochemicals tested. Maximum olfactory response by corm weevil was recorded to bisabol-ol, which was found effective for banana corm weevil monitoring under field conditions. Field evaluation conducted using funnel trap in weevil (*O. longicollis)* endemic areas of Theni and Dindigul districts of Tamil Nadu showed that weevil attraction was maximum (80%) in the treatment semiochemical No. 1 + host plant volatile extract obtained from cv. Nendran.

Root dipping of soil endophyte, *Beauveria bassiana* on cv. Grand Naine was found promising as it recorded 100% weevil mortality, whereas soil drenching of *M. anisopliae* recorded 75 % mortality. By insect dip method, aqueous and hexane extracts of zimmu showed 100% stem weevil mortality at 100% concentration on 10th day. The solvent extract of zimmu tested against banana corm weevil resulted in 100% mortality at 100% concentration on 6th day. Studies on amylase Inhibitor bioassay against 3rd instar stem weevil grub showed 100% mortality with 75mg/20ml concentration at 10th day after treatment.

Cross reaction between race 1 and race 2 of *Foc* has been observed in VCG analysis. Diversity of *Foc* isolates has been studied using RAPD, PCR-RFLP analysis of IGS region and sequence analysis of rDNA-ITS region. Carbendazim (0.1 %) dipping the suckers before planting followed by soil drenching in root zone 1-2 lit at 2,4 & 6 month after planting) and stem injection 2ml at 2,4 & 6 MAP effectively controlled the *Fusarium* wilt disease in Ney Poovan under field conditions. The combined application of rhizospheric and endophytic fungal antagonists with or without fungicide application under

field condition significantly increased the bunch weight (up to 74.8%) and suppressed the *Fusarium* wilt disease. The biopriming of banana plants with the combined application of *Pseudomonas putida* + Alpinia, *Pseudomonas putida* + *Hibiscus* sp., *Pseudomonas putida* + zimmu, *Bacillus* sp. + zimmu combinations resulted in complete control (100 %) and significantly increased the plant growth parameters. Zimmu planting was found to reduce the soil inoculum load of *Fusarium* wilt from 5.60 x 10^5 to 6.6 x 10^2. Microscopic examination and molecular analysis of 96 isolates of *Mycospharella* spp. isolated from different cultivars of banana grown in different regions of India revealed the presence of *M. eumusae* indicating that the leaf spot in India is caused by *M. eumusae.* Foliar spray of *Bacillus* spp. (1e2 and 12acy) at shooting stage reduced eumusae leaf spot disease by 56.8% and 54.3% respectively. Bio-control agents, *Trichoderma asperellum* and *T. longibrachiatum* were found better in inhibiting mycelial colonies of post harvest pathogens, *Colletotrichum musae* and *Lasiodiplodia theobromae*. *T. asperellum* (prr2) was also found effective in extended shelf life of banana fruits by 28 days at 23°C and 55 days at 13°C from post harvest pathogens.

Soil application of increased dose of fertilizer (150% of RDF) in cv. Poovan has compensated the yield loss due to BBrMV. Polyclonal antiserum to BBTV was produced and ELISA technique has been standardized for detection. NA probe and PCR based diagnostic techniques have been developed for all banana viruses. A multiplex PCR technique has been developed for detecting three banana viruses simultaneously. Complete genome of BSV infecting Poovan has been cloned and sequenced. Promoter sequences from BBTV were cloned and sequenced. Duplex PCR for all the four viruses CMV, BBrMV, BBTV and BSV has been standardized. Real Time-PCR technique for simultaneous detection of banana viruses was standardized. Rolling circle amplification (RCA) approach which uses bacteriophage Phi29 DNA polymerase has been standardized to detect episomal virus of BSMysV in Poovan and BBTV in Hill banana. Primers and probe have been designed for rep gene of BBTV and assessed the quantity of its transcripts in latent and severely infected plants using real time-PCR.

Three complete genomes (7.6 Kbp) of Banana Streak Virus (BSV) species infecting cvs. Rasthali and Poovan were amplified by RCA and cloned. A solvent free simple extraction protocol was developed and validated for the detection of banana bunchy top virus (BBTV). Studies showed that streak virus severity and yield loss were significantly higher in TC plants than healthy and banana streak mysore virus (BSMYV) infected sucker grown plants. Complete genomes of BSMYV and BBTV were obtained in dually infected Poovan sample. Transgenic banana plants resistant to BBTV were generated using BBTV-rep gene construct and the resultant 52 plants tested negative to BBTV inoculation through banana aphid (*Pentalonia nigronervosa*). Multivirus resistant transgenic plants were generated using RNAi construct from 8 embryonic cell suspension (ECS) lines. These plants were inoculated with BBTV through banana aphid, *P. nigronervosa* and symptom expression was absent in three lines.

Standard phloem protein isolation was developed using acetone - HCl extraction method. Phloem proteomics studies of banana cv. Nendran revealed more than 30 reproducible spots from leaf, bract and pseudostem with up and down regulation. These protein spots were found to be involved in defense, signal transduction, cell structure and function, photosynthesis and energy, plant growth, protein designation/storage and transcription/translation. Oxidative stress studies in BBTV-infected cvs. Nendran and Poovan revealed quantifiable changes in physiological and biochemical parameters such as proteins, phenolic compounds, polyphenol oxidase (PPO), peroxidase (POX), ascorbate

peroxidase (APX), guaiacol peroxidase (GPX), catalase (CAT) and superoxide dismutase (SOD) activities were observed between BBrMV infected and healthy leaves of banana cultivars. Phenols, total proteins, SOD and GPX activities were significantly higher in leaves of BBrMV infected plants of both the cultivars than in healthy plants, whereas catalase, APX, PPO and POX activities showed a reverse trend.

Transfer of Technology

Technology dissemination through mass media comprising two radio talks (All India Radio), two television talks (DD - Podhigai and Puthiya Thalaimurai) and twenty five press notes in various popular dailies and magazines were published in different aspects of banana cultivation including postharvest management. Totally 65 seminars/ conferences/ symposia/ workshops/ meetings were attended by the scientists at regional/ national/ international. Participated/ organized eight exhibitions at regional/ national levels. Ten off-campus trainings on production and postharvest technology of banana were conducted.

Visitors comprising 16 VIPs and about 4800 banana farmers, Agricultural & Horticultural officers, self help groups and students have visited ICAR-NRCB. Technologies on post harvest handling, packing and storage were transferred to four entrepreneurs. Mother cultures of tissue cultuture banana plants received from DBT recognised tissue culture production units were tested for banana viral diseases and fidelity.

Linkages and Collaboration

The Centre has developed good linkages with the following international institutes *viz*., Bioversity International, France and QUT, Australia. Collaborated with different national research institutions for different activities *viz*., NBPGR, New Delhi; BARC and CIRCOT, Mumbai; IIHR, Bangalore; Coffee Board, Bengaluru; NHB, DST and DBT New Delhi; NCL Pune, all SAUs and Bharathidasan University, Tiruchirapalli, Tamil Nadu. NRCB also co-ordinates with AICRP (Tropical Fruits) Centres working on banana and ICAR institutes like CTCRI, CPRI and CIAE.

Revenue Generation

A total of Rs.63.65lakhs was realized as revenue by the Centre during the year 2014 - 15.

Budget details (Revised Estimate) for the year 2014-15 (Rs. in lakhs)

S.No.	Head of account	Plan (Including TSP & NEH)	Non-Plan
1	Estt. Charges	0.00	390.97
2	Overtime Allowance	0.00	0.04
3	Travelling Allowance	7.39	5.00
4	Contingencies	88.49	127.80
5	HRD	2.87	0.00
6	Equipments	63.62	3.79
7	Furniture & Fixtures	3.39	0.00
8	L:ibrary & Journals	0.16	0.00
9	Information Technology	1.07	0.00
10	Pension & Retirement Benefits	0.00	30.42
	Total	**166.99**	**558.02**

4 | RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

4.1.1 Genetic Resource Management

Improvement and management of banana genetic resources in the Indian subcontinent

Collection

Exploration in Arunachal Pradesh and secondary resource centers *viz.*, BRS, Kannara, Kerala and BCKVV, Kalyani, West Bengal resulted in collection of thirty banana accessions. Arunachal Pradesh districts namely West Kameng, East Kameng, Papumpare, Lower Subansiri and Upper Subansiri habited nine *Musa* species *viz., M. cheesmani* (Kulu), *M. cheesmani* (Kurmi), *M. itinerans, M. sikkimensis, M. velutina, M. velutina* variant, *M. rosaceae, M. aurantiaca,* and *M. saddlensis* (Fig. 1) and four landraces, *viz.,* Pakthe, Bhat Manohar, Monthan (Arunachal) and Kechulepa.

High yielding two plants of cv. Manoranjitham were collected from Vellarikaattupatti (Kolli Hills) with a bunch weight of 50 and 48 kg respectively. (Table 1, Fig. 2 a&b) which is five times higher than parent crop. Autotetraploids of *M. balbisiana* (Sasrabale) was developed for the first time and planted.

Fig. 1. Flower, emerging bud, bunch and hands of *Musa* sp.

a - *M. rosaceae*; b - *M. rosaceae*; c - *M. velutina*; d - *M. saddelensis*; e - *M. aurantiaca*; f - *M.itinerans*; g - *M.cheesmani*; h - Pakthe

Fig. 2a. High Yielding Manoranjitham (bunch)

Table 1. Fruit traits of banana high yielding Manoranjitham clones

Parameter	Normal Manoranjitham	High Yielding Manoranjitham	
		Plant 1	Plant 2
Fruit length (cm)	10.2	14.2	13.8
Fruit girth (cm)	4.5	9	8
Fruit weight (g)	176.9	211.2	209.8
Pulp weight (g)	166.6	195.8	189.6
Peel weight (g)	10.35	15	13
TSS (Brix)	24.6º	24.72º	23.82º
Acidity (%)	0.27	0.319	0.280
Total sugar (%)	-	22.26	21.61
Hand weight (kg)	2.5	4.5	3.9
No. of hands per bunch	5-7	12-14	12-14
No. of fingers per hand	14	21	20
Bunch weight (kg)	15	50	48


Normal Manoranjitham


Variant Manoranjitham

Fig. 2b. Bunch and hands of variant Manoranjitham

Conservation

A total of 566 accessions of which 478 indigenous and 88 exotic accessions are being conserved in the field gene bank.

Characterization

Morpho-taxonomic description using IPGRI *Musa* descriptor for seven ITC accessions were completed (Table 2). Cocos and Gu Nin Chio, ITC accessions were confirmed for their identity and genetic trueness. Genomic status has been assigned to new introductions such as Mizo Cavendish, Ash Monthan, Behula, and Batheesa Cheriya using Simmond and Shepherd's score card. Characterization of Ramkela, one of the wild collections from Tripura, found to be *Musa flaviflora* (Fig. 3).

Fig. 3. Characterization of Ramkela

Table 2. Assigning of genomic status for newly collected germplasm accessions

Acc.No	Name	Assigned genomic group / Species
2221	Cocos	AAA
2201	Gu Nin Chio	AA
2244	Mizo Cavendish	AAA
2254	Ash Monthan	ABB
2256	Behula	ABB
2257	BatheesaCheriya	ABB
2258	Ramkela	*Musa flaviflora*

Phylogenetic analysis of indigenous accessions using DArT markers

The DArT marker analysis of 91 mini core collections grouped into 9 populations. Genetic variability studies of the nine populations indicated 48% and 52 % of variation among the populations and within the populations, respectively. The lowest genetic variation was recorded with wild *M. balbisiana* types and the highest among wild and cultivated type AA genotypes. Genetic diversity parameters indicated greater diversity within AA genome and within *Rhodoclamus* species. More number of unique bands observed in *Rhodoclamus* species suggested it is highly different from other genomic groups of *Musa*. Principal coordinates analysis suggested close proximity between AA with *Rhodoclamus*; AB with AAB; ABB with BB.

Evaluation of elite clones of cv. Neypoovan

Based on the bunch weight (18-21 kgs) and shorter crop duration (< 310 days), suckers of seven superior clones of Neypoovan were collected from various farmers' fields of Tamil Nadu and evaluated in a farmer's field at Malliyampathu, Tiruchirapalli, Tamil Nadu. All the seven clones showed significant variations for important traits like plant height, days taken for shooting, number of fingers, number of hands, bunch weight and crop

Fig. 4. Superior clone of cv. Neypoovan at harvesting stage in farmer's field

duration and performed uniformly as compared to control (Table 3, Fig. 4).

Evaluation of NRCB selections

NRCB selection - 10

Multilocation testing of Selection-10 (NamwaKhom) at ICAR-NRCB,

Fig. 5. NamwaKhom Bunch

Table 3. Vegetative and reproductive parameters recorded in the elite clones of cv. Neypoovan in farmer's field

Clone No.	Height (cm)	Shooting (days)	Bunch Weight (kg)	No. of hands	No. of fingers	Crop Duration (days)
1	312ab	192.5a	25.0a	12.5a	215.5a	306.0a
4	311.5abc	192.5a	26.0a	12.5a	213.0a	307.5ab
8	320a	194.0a	26.0a	13.0a	210.0a	307.5ab
22	312.5a	193.5a	26.5a	12.5a	212.5a	309.0abc
26	315bc	199.5a	27.2a	13.0a	222.5a	312.0c
27	310.5ab	198.0a	26.2a	12.5a	218.5a	310.5bc
29	315.5a	192.5a	26.7a	12.5a	220.5a	307.5ab
Control	295c	259.0b	18.2b	9.0b	160.5b	340.0d
CD (0.05)	16.64	10.66	2.34	1.28	15.70	3.45
Significance	*	**	**	**	**	**

Table 4. Evaluation of Ratoon crop of NRCB selection-10 with local Karpuravalli (ABB) at different locations

Traits	NRCB, Trichy			Level of Signi ficance	BRS, Kannara			Level of Signi ficance
	NRCB selection	Local Karpura valli	t-test value		NRCB selection	Local Karpura valli	t-test value	
Height (cm)	248.4	448.6	8.11	**	274.7	409.7	4.29	**
Girth (cm)	95.4	87.4	0.00075	NS	84.7	74.6	0.000027	NS
Bunch weight (kg)	24.8	20.3	6.85	**	18.3	19.4	0.03754	NS
Hand/ Bunch	13.7	14.8	0.0087	NS	13.2	12.9	0.139436	NS
No of fruits/hand	17.9	16.6	0.0031	NS	19.1	16.5	0.00062	NS
Duration (days)	355.4	463	7.93	**	320.5	382.5	7.5	**
Pulp TSS (brix)	27.8	27.1	0.0553	NS	25.2	25.6	0.266	NS
Acidity (%)	0.274	0.279	0.1364	NS	0.306	0.311	0.232	NS
Fruit weight (g)	120.1	114.9	4.57	**	111.8	109.9	0.077	NS

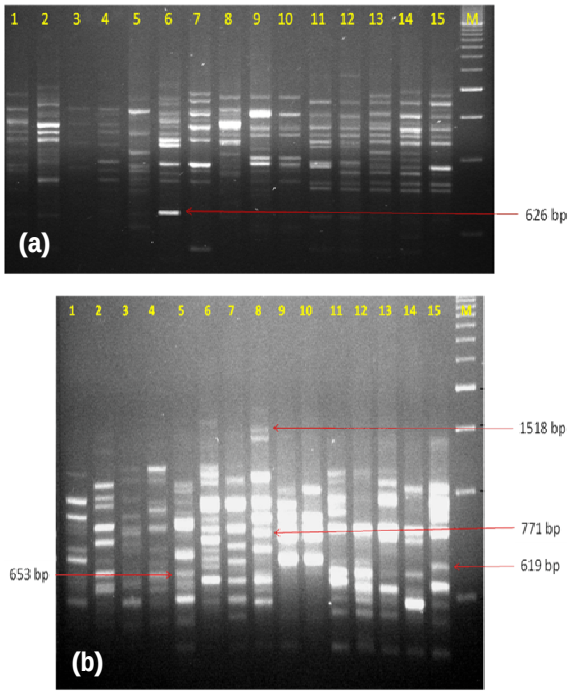
Tiruchirapalli, Tamil Nadu and BRS, Kannara, Kerala along with local check (Karpuravalli) has proved its superiority with respect to dwarf stature and earliness. The results of MLT are provided in Table 4 and Fig. 5.

NRCB Selection 08

Evaluation of NRCB Selection 08 with local check (Monthan) at three different places, *viz*., ICAR-NRCB Tiruchirapalli; TNAU, Coimbatore and BRS, Kannara under MLT programme has proved its superiority over the local check in terms of yield (Table 5). Average bunch weight of Selection 08 is 27.8kg, whereas the local check recorded 20.2kg as average weight.

Molecular characterization of the collections from Arunachal Pradesh using ISSR markers

Ten ISSR markers were used for DNA profiling of 10 *Musa* wild species collected from Arunachal Pradesh. Species-specific unique bands were identified for ten species, the DNA fingerprints developed are presented in Table 6 and Fig. 6. This will have application in identification of wild species and protect them from bio-piracy.



Lane Nos. 1 – *M. flaviflora*; 2- *M. ochracea*; 3- *Bhimkol*; 4- *Athiakol*; 5- *M. itinerans*; 6- *M. laterita*; 7- *M. sikkimensis*; 8- *M. cheesmani-I*; 9- *M. cheesmani-II*; 10- *New species*; 11- *M. velutina-I*; 12- *M. velutina-II*; 13- *M. rosaceae*; 14- *M. aurantiaca*; 15- NISH

Fig. 6. Species specific bands produced by ISSR primers UBC 868 (a) and 812 (b)

Table 5. Evaluation of ratoon crop of NRCB selection-8 with local Monthan (ABB) at different locations

Traits	Location								
	Trichy			Coimbatore			Coimbatore		
	Sel-8	Local Monthan	t test	Sel-8	Local Monthan	t test	Sel-8	Local Monthan	t test
Plant height (cm)	385.33	374.83	NS	365.50	376.33	NS	351.17	351.33	NS
Girth (cm)	88.83	75.83	3.06**	81.33	86.50	2.89**	81.50	63.50	1.86**
Bunch weight (kgs)	28.50	22.00	7.46**	27.00	22.17	5.61**	28.17	15.92	2.07**
No of hands	9.83	7.00	NS	12.50	7.33	4.39**	12.33	6.17	4.22**
No of fruits/ hand	14.67	13.00	7.37**	13.33	12.33	NS	13.67	12.67	NS
Duration (days)	350.33	424.83	2.79**	425.67	416.00	NS	371.00	335.00	7.29**
Pulp TSS (Brix)	19.33	23.50	4.32**	22.00	23.33	NS	23.43	23.33	NS
Acidity (%)	0.27	0.42	NS	0.23	0.32	2.35**	0.27	0.30	NS
Fruit weight (g)*	268.83	288.00	NS	117.67	215.17	2.60**	189.17	232.58	8.53**

*Data pertains to the third hand

Table 6. Species specific bands produced by different ISSR markers used for DNA fingerprinting

Musa spp.	Primer	Product size
M. flaviflora	UBC811	1131
	UBC841	586
M. ochracea	UBC807	2144
	UBC811	2361
	UBC834	691
	UBC840	660
M. balbisiana type Athiakol	UBC840	307
M. itinerans	UBC811	362
	UBC812	653
	UBC834	480
	UBC842	514
M. laterita	UBC868	626
M. sikkimensis	UBC807	545
	UBC811	335, 1413, 1527
UBC840	574	
	UBC842	823
M. cheesmani -I	UBC811	437, 749
	UBC812	771, 1518
	UBC818	242
	UBC840	1120, 1336
M. cheesmani –II	UBC818	313
New species	UBC811	1088
Natural International	UBC807	1554 hybrid
	UBC812	619

Musa germplasm screening for weevil resistance

Musa germplasm accessions screened against banana stem weevil (nine accessions) and corm weevil (seven) under *in vitro*. Adukkan (AB) indicated 100 and 93.75 % stem weevil mortality in Dinamalakol (ABB), Norman (AB), KNR mutant (AB) and Jurmony (BB) indicated 100 per cent mortality. In Nendra Kunnan (AB) and Agniswar, 81 % corm weevil mortality was recorded. 75.0 % mortality was recorded in Dinamalakol (ABB), 68.75% and 56.25 % mortality was recorded in Adukkan (AB) and Poovila chundan (AB). Birbutia (ABB) and Norman (AB) registered corm weevil mortality of 43.76 and 37.50 % respectively.

Studies on different regeneration systems in banana

Immature male flower buds

The position of floral hands influenced direct regeneration in three commercial varieties namely, Udhayam (16-20), Rasthali (14-18) and Neypoovan (16-19). Among the three varieties tested, initially direct regeneration of shoots using male floral hands as explant was successful only in Rasthali and Udhayam. Now direct regeneration of shoots has also been achieved from male floral hands of cv. Neypoovan which is quite often recalcitrant for shoot tip culture. Results of the trial indicated that only greening and meristem clump formation was achieved in MS + BAP + TDZ at higher concentration while shoot regeneration was achieved in MS+BAP+TDZ at lower concentration. Further shoot development is in progress (Fig. 7).

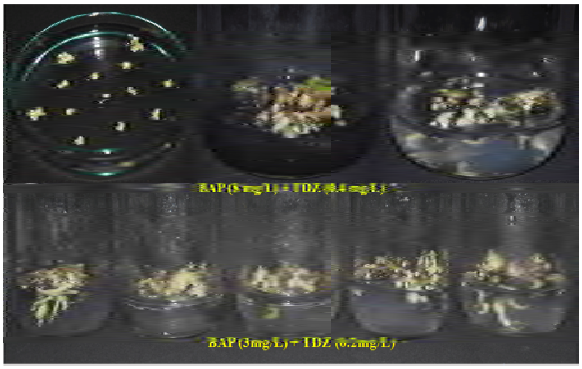


Fig. 7. Direct shoot regeneration in cv. Neypoovan from male floral hands

Cormlets

Cormlets obtained during the primary decortication in the process of macropropagation were used as explants for direct regeneration in cv.Udhayam. Results showed that MS medium with PP333+TDZ+ BAP+IAA was optimum for shoot proliferation. Cormlets produced 12.4 shoots

as against the maximum of 6.30 shoots in case of shoot tips of cv.Udhayam (Fig. 8).

Fig. 8. Shoot proliferation of cormlets of cv.Udhayam in MS medium with various growth regulator combinations

Development of tissue culture protocol for cv. Neypoovan

Phenolic exudation is the major problem often hindering shoot multiplication in cv. Neypoovan. Addition of antioxidants like ascorbic acid, citric acid and cysteine through filter sterilization to the initiation MS medium containing BAP and IAA significantly reduced the phenolic exudation and induced multiple shoots right from second subculture onwards.

Growth regulator combinations were tried to obtain maximum shoot proliferation in cv. Neypoovan. Four types of cytokinins, namely, BAP, TDZ, PP333 inclusive of the natural cytokinin source *i.e.,* coconut water and an auxin IAA in different combinations were supplemented in the MS medium. Ascorbic acid 30 mg l^{-1} was added in all the treatments to overcome the problem of phenolic exudation. MS medium with PP333+TDZ+ BAP+IAA was found optimum for shoot proliferation.

Development of macropropagation protocol for cv. Udhayam

Macropropagation of cv. Udhayam was attempted using an African protocol. Accordingly, 4-5 months old suckers were extracted. After paring and pralinage, the suckers were kept in shade overnight. Next day, primary decortication was done for suckers and were steam sterilized at 100^{0}C for

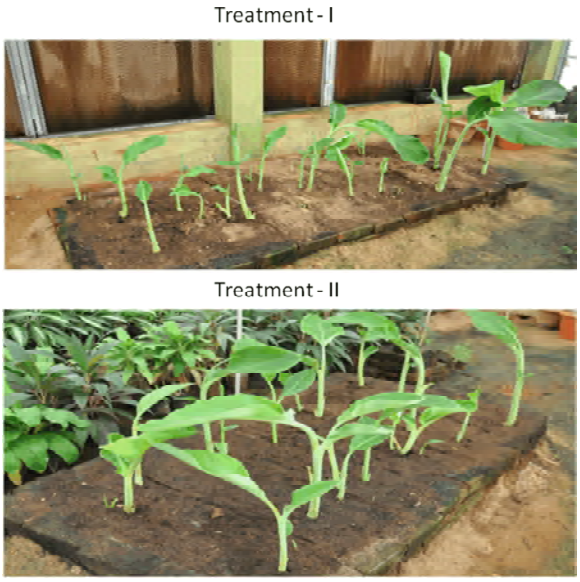
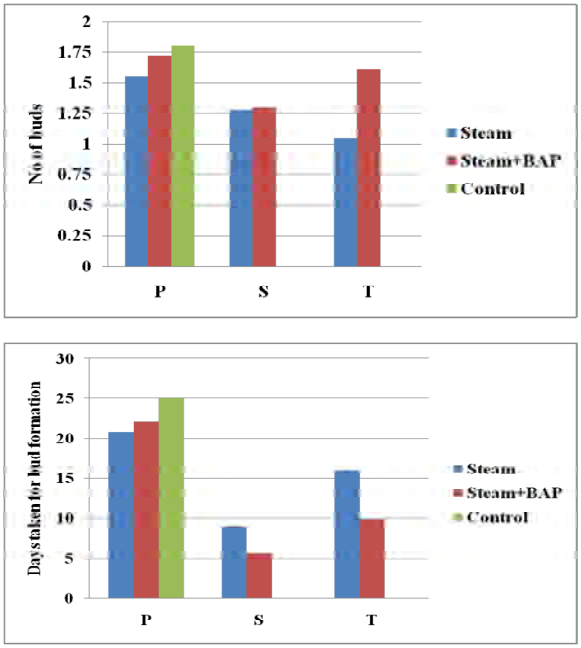


Fig. 9. Bud formation observed in the treatments after fourth decortications



(P, S and T are the primary, secondary and tertiary decortications respectively)

Fig. 10. Effect of steam sterilization and BAP on macropropagation of cv.Udhayam

5 min and dipped in Bavistin 0.1% for 10 min before planting in the saw dust medium. Regular watering was done. After secondary and tertiary decortication, BAP was added into the disturbed meristem and covered with saw

dust. Though greater number of plants was produced in control during the primary decortication, no plant production was observed during further decortications. But in the treatments, sprouting of new shoots was observed even after fourth decortications (Fig. 9). This resulted in the production of 3.90 plants per corm as against 1.8 plants per corm in control without steam sterilization. The repetition trials with BAP enhanced the number of plants to 4.62 plants per corm. The treatments were significantly different for two traits, namely, no. of buds formed and days taken for bud formation except for the number of buds formed during the primary decortication (Fig. 10).

Proteomic analysis of somatic embryo development in banana

Grouping of identified proteins based on gene ontology

All the differentially expressed proteins were subjected to Mass Spectrometric analysis and grouped based on gene ontology. Most of the differentially expressed protein spots were found in chloroplast location followed by mitochondria and nucleus region of the plant cell. Differentially expressed proteins were mainly found to be metal ion (23%) and ATP binding (18%) proteins (Fig. 11). Interestingly it was observed that defense and stress response proteins were highly expressed during early embryogenic induction (i.e., embryogenic callus formation).

Functional classification of identified proteins revealed that most of the identified proteins correspond to enzymes that are involved in various processes which include defense and stress related process, metabolic process, signal transduction, protein synthesis and degradation, hormone responsive and others.

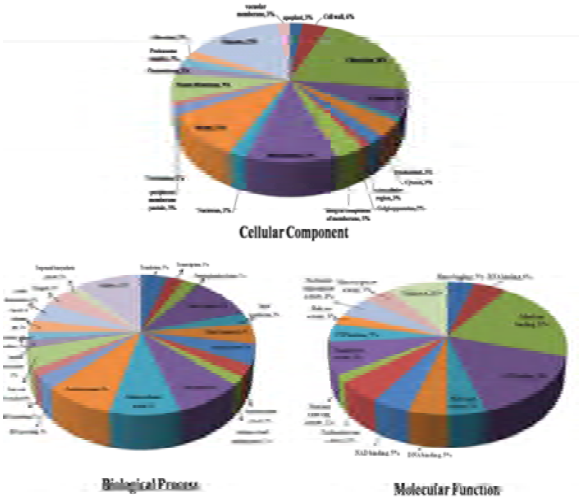


Fig. 11. Gene ontology of differentially expressed proteins between explant, NEC and EC of cv. Grand Naine

Validation of proteomic results with respect to transcripts through semi-quantitative RT-PCR

Semi-quantitative RT-PCR indicated that the mRNA levels of cationic peroxidase, mitochondrial dicarboxylate carrier protein and adenylate isopentenyl transferase were well correlated with the relative volume of protein level in the 2D-gel (Fig. 12). Though mRNA expression of nudix hydrolase, MYB transcription factor, glyceraldehydes 3-phosphate dehydrogenase and indole-3-pyruvate mono oxygenase genes was observed in floral hand, NEC and EC, expression of the respective proteins was observed only in EC.

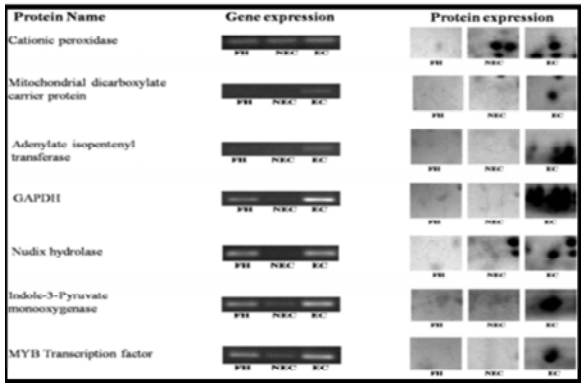


Fig. 12. Comparison of gene expression at transcript and protein level

It was also observed that the transcript level of these genes was high in EC when compared to FH and NEC. Thus, non-expression of these proteins in FH and NEC might be due to variations in mRNA stability, translatability and also due to post-translational modification of the proteins.

4.1.2 Improvement through conventional breeding

A total of 419 bunches were crossed with various combinations (AA x AA, AAB x AA and ABB x AA) and seed set was observed in 174 bunches (Total seeds 10294 and Sunken-6579). All the hybrid seeds were initiated under *in vitro* condition. The highest germination was recorded in ABB x AA cross combination. The highest germination percentage was recorded in the Kothia based crosses followed by Saba and Bangrier. For the first time seed set was observed in plantain group (Ginde-AAB) and 250 sunken seeds were obtained from 338 total seeds. The embryos of Ginde X Pisang Lilin were successfully germinated and regenerated *in vitro*.

Improvement of Pisang Awak bananas (ABB) (Table 7)

Udhayam: A total of 29 bunches were crossed and seed set was recorded only in 8 bunches (27.5 %). Totally 412 seeds were collected. Only 36.8 % of embryos were isolated from 331 good seeds. Percent germination with respect to total embryos and total number of good seeds was 21.3 % and 6.3 %, respectively.

Karpuravalli: A total of 91 bunches were crossed and seed set was noticed in 30 bunches with seeds (32.9 %). Totally 554 seeds were collected. Only 14.8 % of embryos were isolated from 378 good seeds. Percent germination with respect to total embryos was 21.4 % while with respect to total number of good seeds, it was low (3.1%).

Bankela: A total of 4 bunches were crossed but seed set was observed with 100 %. Totally 623 seeds were collected and only 33.5 % of embryos were isolated from 600 good seeds. Percent germination was 13.9 % with respect to total embryos and 4.6% with respect to total number of seeds.

Maximum seed germination percentage was observed in cvs. Karpuravalli and Udhayam. Bankela, recorded maximum number of seeds, but germination percentage was very low (Table 7).

Improvement of Cooking Bananas (ABB) (Table 7)

Bangrier: A total of 62 bunches were crossed of which 20 bunches set seeds (20.9 %).

Table 7. Seed setting ability of Pisang Awak and cooking bananas

Female Parent	Tot. No. of seeds	Total No of good Seeds	% of goods seeds with embryo	% of good seed germination	% of embryo germination
Bankela	623	600	33.5 (201)	4.6	13.9 (28)
Udhayam	412	331	36.8 (122)	6.3	21.3 (26)
Karpuravalli	554	378	14.8 (56)	3.1	21.4 (12)
Bangrier	206	100	80.0 (80)	30.0	37.5 (30)
Saba	890	425	20.2 (96)	1.1	5.2 (5)
Kothia	2002	1060	38.6 (394)	12.5	32.4 (128)
Total / average	4687	2854	37.2	9.6	21.9

Totally 206 seeds were collected. Only 80.0 % of embryos were isolated from 100 good seeds. Percent germination was 37.5 % with respect to total embryos and 30.0% with respect to total number of good seeds.

Saba: A total of 116 bunches were crossed of which 35 bunches set seeds (30.1 %). Totally 890 seeds were collected. Only 20.2 % of embryos were isolated from 425 good seeds. Percent germination with respect to total embryos and total number of good seeds was 5.1% and 1.2%, respectively.

Kothia: A total of 130 bunches were crossed of which 46 bunches set seeds (35.3%). Totally 2002 seeds were obtained. Only 36.6% of embryos were isolated from 1060 good seeds. Percent germination with respect to total embryos and total number of good seeds was 32.4% and 12.5%, respectively. Among the cooking bananas, Kothia and Bangrier recorded maximum and minimum germination percentage (Table 7).

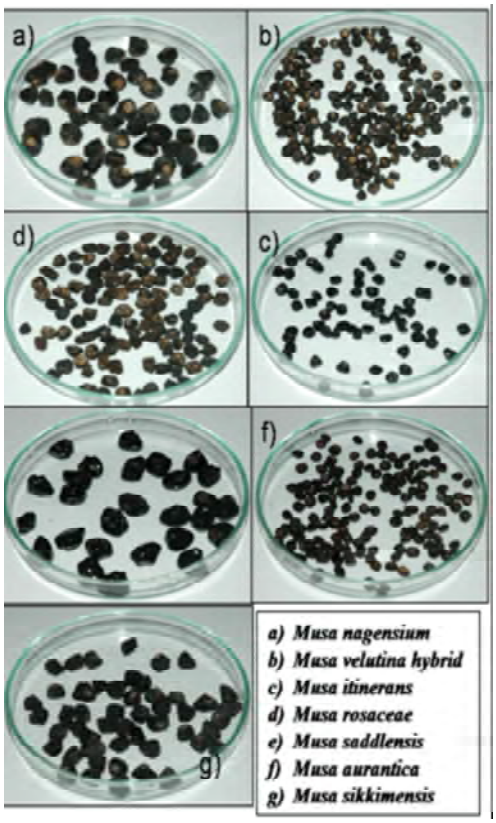


Fig. 13. Morphological variation in seeds of *Musa* wild species

M. nagensium, M. sikkimensis, M. velutina hybrid, *M. rosaceae, M. aurantiaca, M. saddlensis* and *M. itinerans* seeds were collected from Arunachal Pradesh. Morphological variations were observed in seeds of *Musa* wild species (Fig. 13). Developed 30 wild variety *M. velutina* hybrid plants which are in primary hardening. The rest of the germinated wild varieties are being maintained at different stages under *in vitro*.

Study on pollen tube growth in compatible cross combination

The frequency of pollen tube penetration in the compatible combination cv. Saba (ABB) x Calcutta-4 (AA) was studied by collecting the pollen and the ovules at different time intervals of 24 hrs after pollination, fixed in FAA and stained with aniline blue. Number of pollen tubes traversing across the length of the ovary was studied over 24 hrs. Maximum no of pollen tubes was noticed in S1 while least in segment 4 (S4). This result is in corroboration with general findings that maximum seed set is observed in distal end of the fruit (Fig. 14).

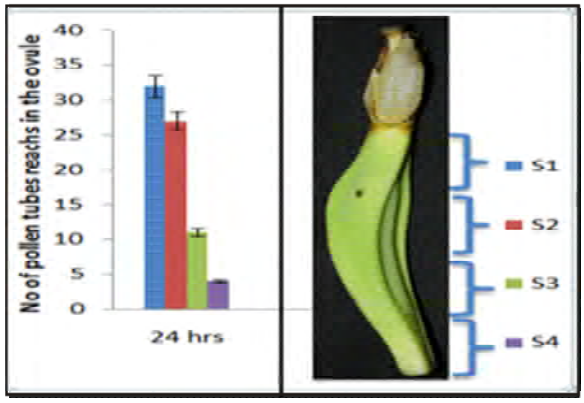


Fig. 14. Study on pollen tube growth in the ovary

Kinetics of pollen tube growth was studied in both *in vivo* and *in vitro* conditions, using pollen germination medium. The pollen tube growth was recorded at different time intervals

of 1 hr to 24 hrs. Pollinated pistils collected at various time intervals were fixed in 10 % acetic acid and stained in 0.1 % aniline blue solutions. The pollen tube development was 3.27mm/hr as against 0.05mm/hr under *in vitro* conditions (Fig. 15).

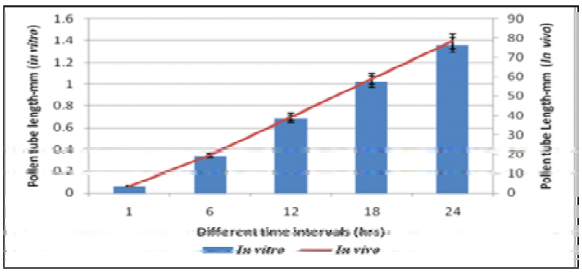


Fig. 15. Kinetics of pollen tube growth under *in vivo* and *in vitro* conditions

The pollen germination and tube elongation under *in vitro* was studied in cv. Calcutta-4 using four different phytohormones (IAA, Zeatin, GA_3 and ABA) in the medium in three concentrations, *viz.,* 10 µM, 50 µM and100 µM. All the phytohormones were found to influence pollen germination and pollen tube growth except ABA and the best result was recorded in 10 µM GA_3 followed by 10 µM Zeatin (Fig. 16).

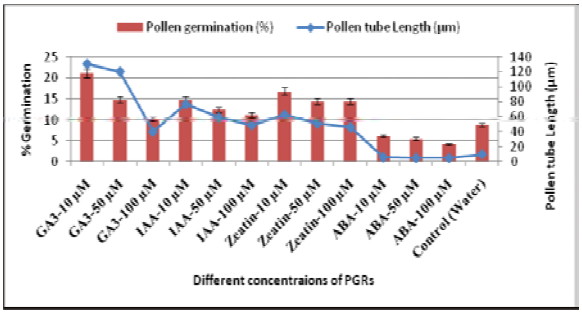


Fig. 16. Effect of plant growth regulators on pollen germination and tube elongation under *in vitro* conditions

Effect of anti auxin (2-Methyl Propinoic Acid) in seed setting of banana

Each unopened flower buds of Saba was sprayed with 2-Methyl Propinoic Acid, an anti auxin chemical, with the concentration of 100ppm before pollination and then pollinated with Pisang Lilin pollen grains. This resulted in 195% of increased seed set in the anti auxin sprayed bunches (62 seeds) over unsprayed bunches (21 seeds). It suggested that anti-auxin spray before pollination will enhance the seed setting in banana.

4.1.3 Improvement of Rasthali through induced mutagenesis

Rasthali mutated plants (200) were subjected for pot screening against *Foc* (VCG 0124) and identified eight putative Fusarium wilt resistant mutants. The identified putative plants were multiplied further through *in vitro*. In the second batch, 120 putative fusaric acid resistant/tolerant mutant plants were planted in pots for *Foc* resistance screening.

4.1.4 Development of trait specific markers for Fusarium wilt resistance through association mapping studies in banana

153 accessions have been selected from 310 core accessions to form a Mini core for use in association mapping studies. Forty accessions of the mini core have been planted in pots (five replications each) for phenotyping against Fusarium wilt resistance. Genomic DNA has been isolated for the same forty accessions for use in genotyping.

4.1.5 Identification and characterization of nematode resistant genes in banana

Involvement of lignin biosynthesis pathway in nematode resistance mechanism of banana was proved through transcriptome, qRTPCR and estimation of lignin.

Transcriptomic data analysis for expression of lignin genes

Digital gene expression (DGE) analysis of transcriptomic data on nematode challenged and unchallenged resistant and susceptible cultivars proved that six genes

involved in lignin biosynthesis pathway namely Phenylalanine ammonia-lyase, (PAL), Trans-cinnamate 4-monooxygenase (C4H), 4-coumarate-CoA ligase (4CL), Hydroxy-cinnamoyl transferase (HCT), Caffeoyl-CoA O-methyltransferase (CCoAMT), and Cinnamoyl-CoA reductase (CCR) were significantly upregulated by more than 2 fold change in the nematode inoculated root tissues of resistant and susceptible cultivars after challenged with nematodes (Table 8). But the highest fold change expression was observed in resistant cultivar when compared to susceptible cultivar for all the genes involved in the lignin biosynthesis pathway except for CCR. Interestingly it was observed that none of the Cinnamyl alcohol dehydrogenase (CAD) isoforms was significantly upregulated with > 2 fold change in susceptible cultivar whereas two CAD isoforms had eight fold upregulation in resistant cultivar. Thus the expression of CAD, which catalyzes the reduction of cinnamyl aldehyde to cinnamyl alcohol prior to polymerization into the lignin polymer, at nil level in susceptible cultivar might be the one of the reasons for lower accumulation of lignin.

qRT PCR analysis of lignin genes

qRT PCR was performed to validate transcriptome of three genes namely PAL, 4CL, and COMT. It was observed that the level of expression of all the three genes was high

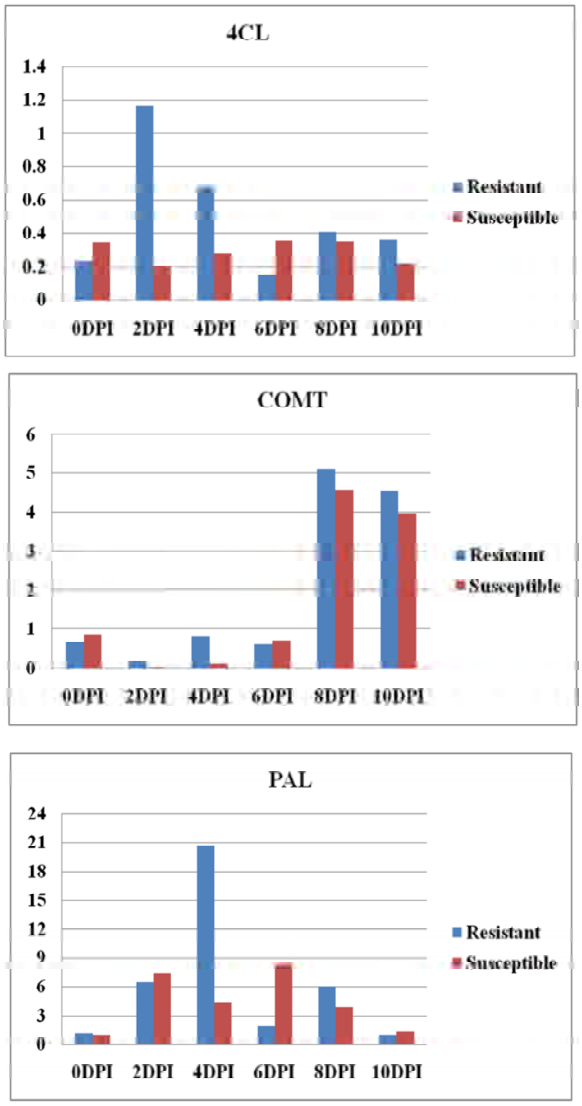


Fig. 17. Time course expression analysis of genes involved in lignin biosysnthesis pathway

Table 8. Expression of genes involved in lignin biosynthesis pathway

Genes involved in Lignin biosynthesis pathway	UR vs CR	R-isoforms	US vs CS	S-isoforms
Phenylalanine ammonia-lyase (PAL)	18.16	7	2.56	1
Trans-cinnamate 4-monooxygenase (C4H)	8.60	3	2.56	3
4-coumarate-CoA ligase (4CL)	23.87	7	2.95	1
Hydroxycinnamoyl transferase (HCT)	5.97	2	2.77	1
Cinnamoyl-CoA reductase (CCR)	7.53	4	8.17	1
Caffeic acid 3-O-methyltransferase (COMT)	37.70	7	32.22	6
Cinnamyl alcohol dehydrogenase (CAD)	7.90	2	0	0

in resistant cultivar when compared to susceptible cultivar (Fig. 17). This result showed a positive correlation with the result obtained through transcriptome analysis.

Estimation of lignin is root tissues of nematode infested and uninfested resistant and susceptible cultivar

Quantification of lignin content revealed that higher lignin was recorded in resistant cultivar than the susceptible cultivar in the un-inoculated root tissues. It was observed that 410µg and 135 µg of lignin were recorded on 10th day after inoculation (DAI) in resistant and susceptible cultivar respectively, whereas the lignin content reduced on 30 DAI in both the cultivars.

Transcriptome wide analysis of MusaWRKY transcription factors

The digital gene expressions of MusaWRKYs were shortlisted from the cuffdiff analysis of RNAseq data on nematode resistant and susceptible cultivars under nematode challenged and unchallenged conditions. It was observed that out of 153 MusaWRKYs identified in Musa genome, 118 and 112 MusaWRKYs were expressed in resistant and susceptible cultivars respectively. The non expression of 33 MusaWRKYs in nematode challenged and unchallenged root tissues of both the cultivars revealed that these MusaWRKYs are not have vital role in root development and/or nematode resistance. Interestingly, nine WRKYs (MusaWRKY19, 43, 54, 95, 103, 107, 111, 126 and 138) were uniquely expressed in resistant cultivar whereas none of the WRKYs were uniquely expressed in susceptible one (Fig. 18). The MusaWRKY95 had >5 fold expression in resistant cultivar under nematode challenged condition whereas it was not even expressed in susceptible one. This unique expression with high fold expression after nematode challenged highlighting the key role of MusaWRKY95, an orthologue of AtWRKY50, in nematode resistant mechanism.

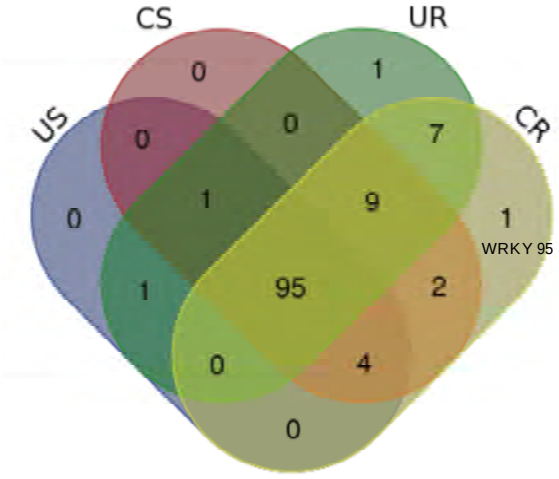


Fig.18. Venn diagram shows the expression of MusaWRKYs in unchallenged resistant (UR),challenged resistant (CR), unchallenged susceptible (US) and challenged susceptible (CS).

Expression of MusaWRKY95 was observed only in nematode challenged roots of resistant cultivar. Whereas it was not expressed in susceptible cultivar even after challenged with nematode. This confirmed the unique expression of this gene in resistant cultivar.

Analysis of MusaWRKYs through quantitative real-time PCR (qRT-PCR)

A total of seven MusaWRKYs (MusaWRKY144, MusaWRKY119, Musa WRKY33, MusaWRKY142, Musa WRKY72 and MusaWRKY32) were randomly selected and their expressions at different time intervals (0, 2, 4, 6, 8 and 10) after challenged with *P. coffeae* were analyzed through qRT-PCR in both the resistant and susceptible cultivars (Fig. 19). The result obtained from qRT-PCR was compared with the expression profiling of WRKYs in the transcriptome data of both the contrasting cultivars which suggested qRT-PCR showed similar expression pattern as transcriptome data obtained through next generation sequencing.

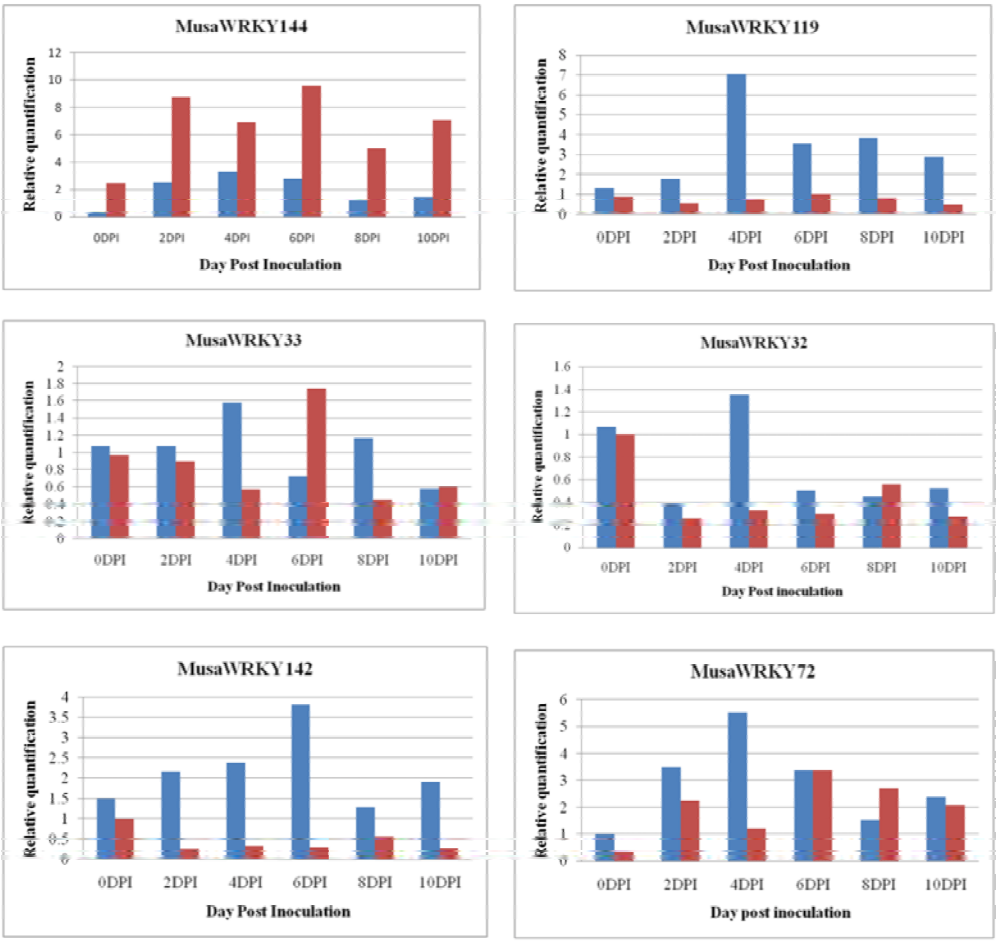


Fig. 19. Time course analysis of MusaWRKYs expression by qRT-PCR in root lesion nematode challenged and unchallenged root tissues of resistant and susceptible banana cultivars

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

4.2.1 Studies on nutrient dynamics in banana

Neypoovan

At 20 leaf stage in Neypoovan, banana the dry weight was maximum (1166g) in pseudostem followed by leaves (976g) and the lowest was recorded in roots (177g) (Fig. 20). The whole plant dry weight decreased at 150% rec.NPK 2848g but was maximum (3866g) at 100% rec. NPK (Fig. 22). The accumulation range and pattern of macro and micro nutrients in different segments of the plant are given in Figs. 24 and 26. The highest total nutrient accumulation was recorded in the psuedostem and the lowest in the root. The total uptake of different nutrients by whole plant (g) were N-32.5, P-9.5, K-145.6, Cu-2.7, Mn-8.4, Zn-0.7 and Fe-9.1.

In Neypoovan, at shooting stage, the dry weight was the highest in pseudostem (2215g) followed by leaves (1626g) and lowest was recorded in flower bud (153g) (Fig. 21). The whole plant dry matter increased with fertilizer application and was maximum (6624g) at 150% rec. NPK followed by 5949g in 125%

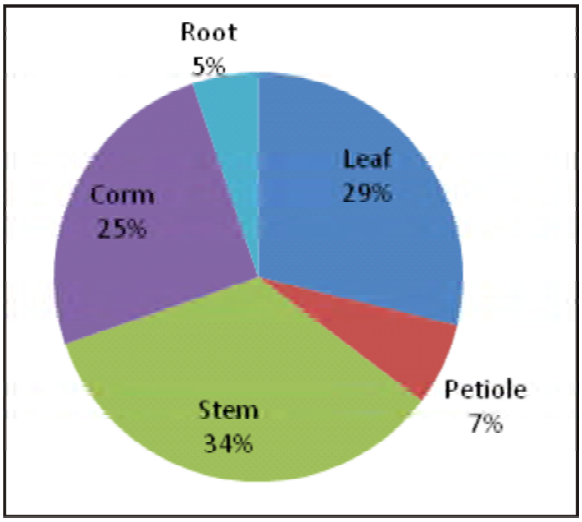


Fig. 20. Dry matter accumulation in Neypoovan at 20 leaf stage

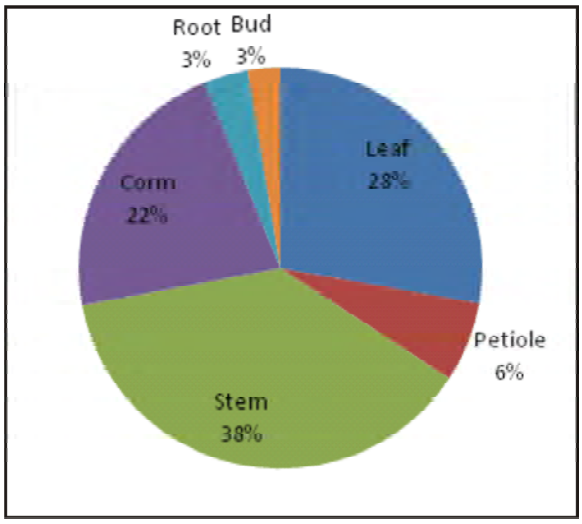


Fig. 21. Dry matter accumulation in Neypoovan at shooting stage

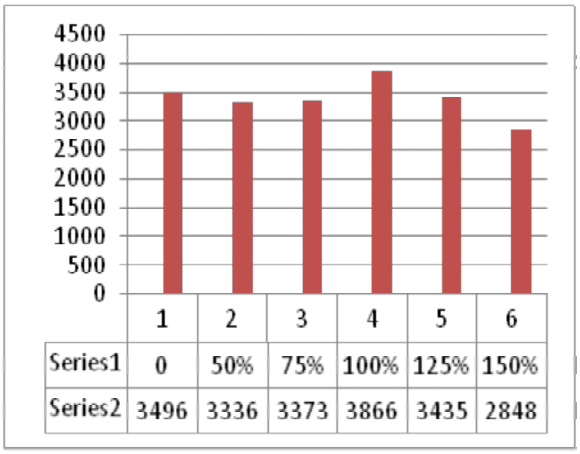


Fig. 22. Effect of graded levels of NPK on DMP (g) of Neypoovan at 20 leaf stage

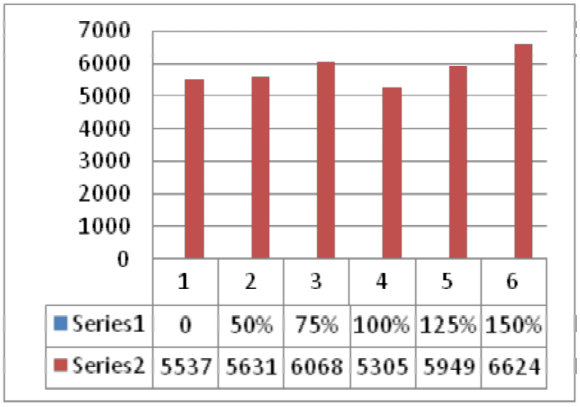


Fig. 23. Effect of graded levels of NPK on DMP (g) of Neypoovan at shooting stage

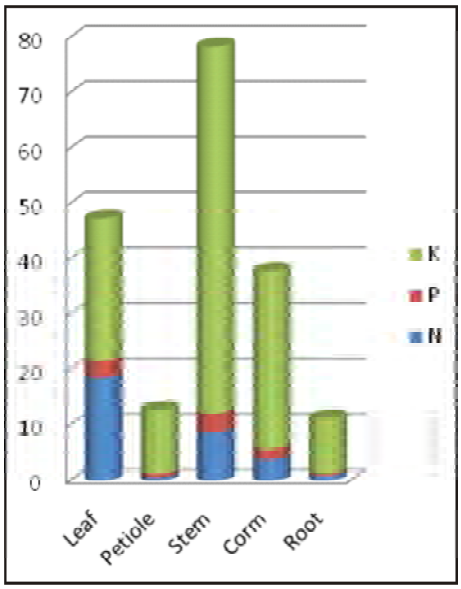


Fig. 24. Accumulation (g/plant) of N, P & K in different segments of Neypoovan at 20 leaf stage

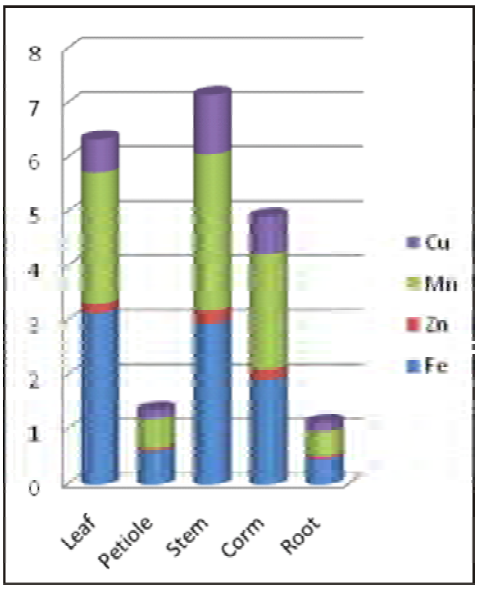


Fig. 26. Accumulation (g/plant) of Fe, Zn, Mn & Cu in different segments of Neypoovan at 20 leaf stage

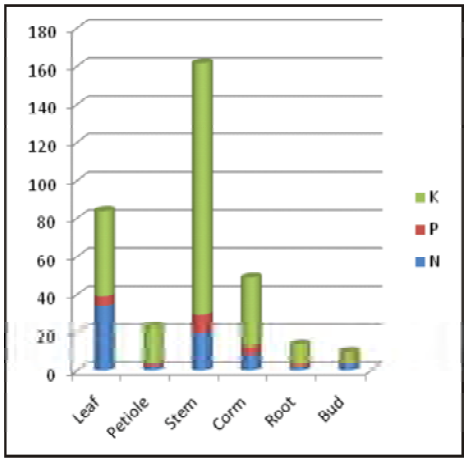


Fig. 25. Accumulation (g/plant) of N, P & K in different segments of Neypoovan at shooting stage

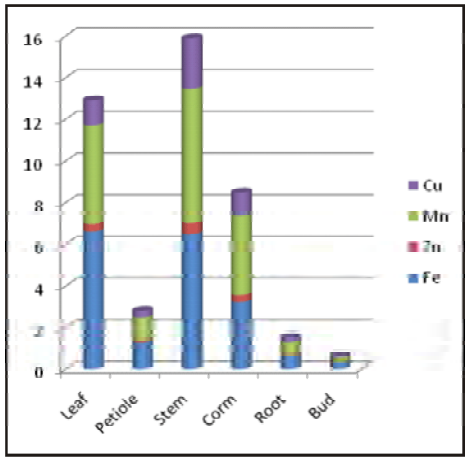


Fig. 27. Accumulation (g/plant) of Fe, Zn, Mn & Cu in different segments of Neypoovan at shooting stage

rec.NPK (Fig. 23). The accumulation range and pattern of macro and micro nutrients in different segments of the plant are given in the Figs. 25 and 27. The highest total nutrient accumulation was observed in the psuedostem and the lowest in the bud. The total uptake of different nutrients by whole plant (g) were N-69.4, P-22.1, K-249.9, Cu-5.4, Mn-16.9, Zn-1.4 and Fe-18.6.

Rasthali

At 20 leaf stage in Rasthali banana the dry weight was maximum (1918g) in pseudostem followed by corm (1598g) and the lowest was recorded in roots (310g) (Fig. 28). The whole plant dry weight decreased at 150% rec.NPK (4650g) and was maximum (6944g) at 125% rec.NPK (Fig. 30). The accumulation range and pattern of macro and micro nutrients in different segments of the plant are given in the Figs. 32 and 34. The highest total nutrient accumulation was recorded in the psuedostem and the lowest in the root. The total uptake of nutrients by whole plant (g) were N-42.1, P-14.3, K-234.4, Cu-4.8, Mn-10.4, Zn-1.2 and Fe-11.1.

In Rasthali, at shooting stage, the dry weight was the highest in pseudostem (2585g) followed by corm (2106g) and lowest was recorded in flower bud (263g) (Fig. 29). The whole plant dry matter increased with fertilizer application and was maximum (9218g) at 150% rec.NPK followed by 8253g in 125% rec.NPK (Fig. 31). The accumulation range and pattern of macro and micro nutrients in different segments of the plant are given in the Figs.33 and 35. The highest total nutrient accumulation was recorded in the psuedostem and the lowest in the bud. The total uptake of nutrients by whole plant (g) were N-123.6, P-29.3, K-285.1, Cu-7.9, Mn-19.1, Zn-2.1 and Fe-21.6.

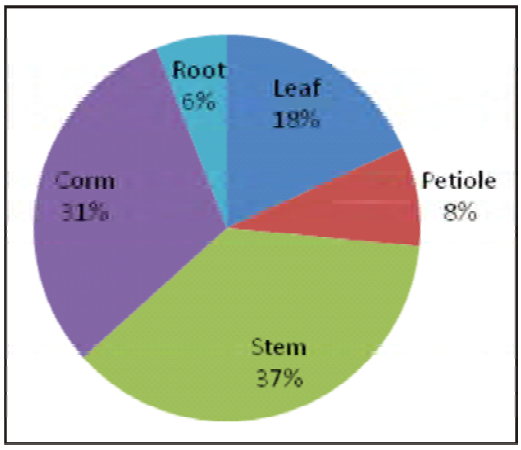


Fig. 28. Dry matter accumulation in Rasthali at 20 leaf stage

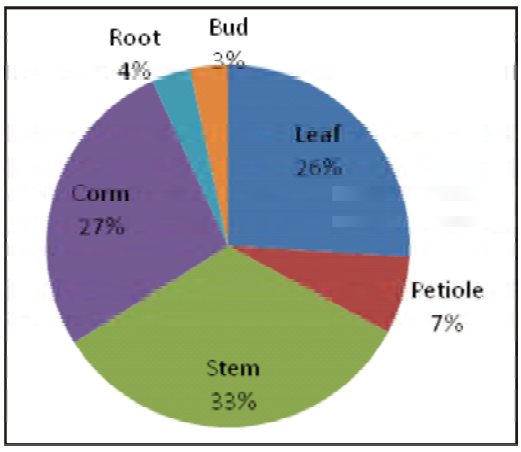


Fig. 29. Dry matter accumulation in Rasthali at shooting stage

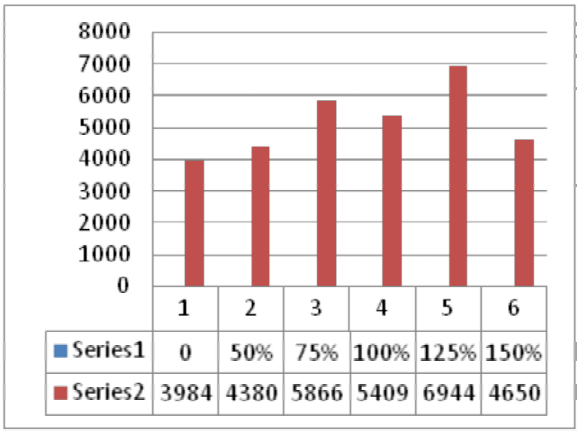


Fig. 30. Effect of graded levels of NPK on DMP (g) of Rasthali at 20 leaf stage

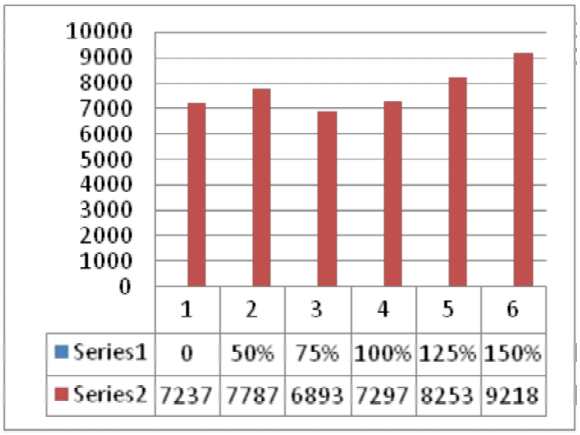


Fig. 31. Effect of graded levels of NPK on DMP (g) of Rasthali at shooting stage

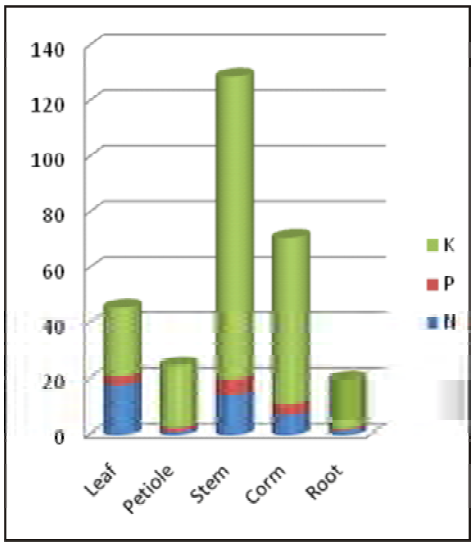


Fig. 32. Accumulation (g/plant) of N, P & K in different segments of Neypoovan at 20 leaf stage

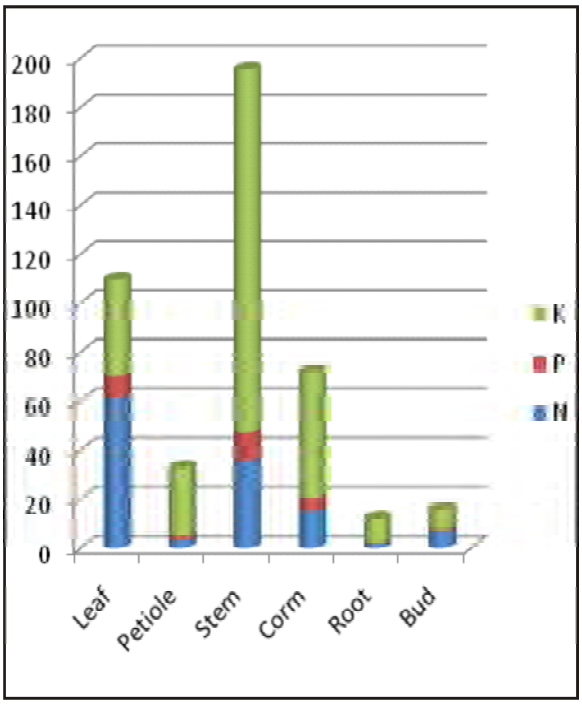


Fig. 33. Accumulation (g/plant) of N, P & K in different segments of Neypoovan at shooting stage

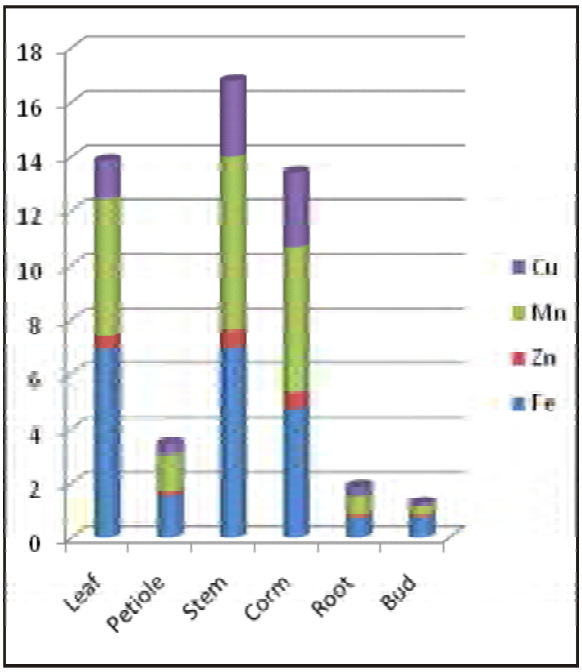


Fig. 34. Accumulation (g/plant) of Fe, Zn, Mn & Cu in different segments of Neypoovan plant at shooting stage

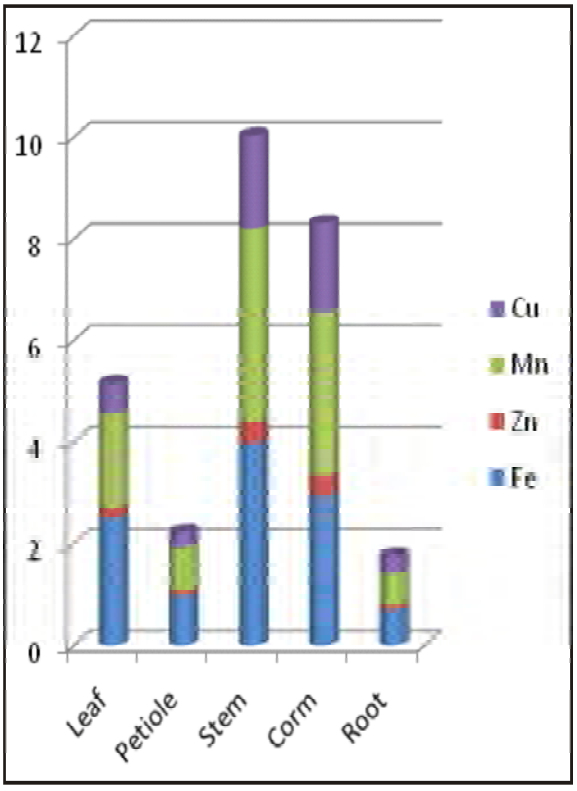


Fig. 35. Accumulation (g/plant) of Fe, Zn, Mn & Cu in different segments of 20 leaved Neypoovan plant

Root studies

Under nutrient dynamics studies the Root Length Densities (RLD in $mm.cm^{-3}$) were determined at different distances from the base of the plant and at different depths, in Neypoovan and Rasthali bananas at 20 leaf stage (Table 9 and Figs. 36 and 37). In Neypoovan banana the Specific-Root-Length (cm/g) increased rapidly with increasing distance from base of the plant but in Rasthali, it increased gradually. These observations inferred more rapid tapering roots in Neypoovan than in Rasthali. (Table 10).

Table 9. Root Length Density (mm.cm) in different banana varieties at 20 leaf stage

Depth	Distance from base of the plant					
	Neypoovan			Rasthali		
	0 – 30 cm	30 – 60 cm	60 – 90 cm	0 – 30 cm	30 – 60 cm	60 – 90 cm
0 – 15 cm	0.259	0.047	0.026	0.205	0.067	0.044
15 – 30 cm	0.804	0.161	0.068	0.616	0.199	0.139
30 – 45 cm	0.492	0.086	0.053	0.406	0.128	0.093

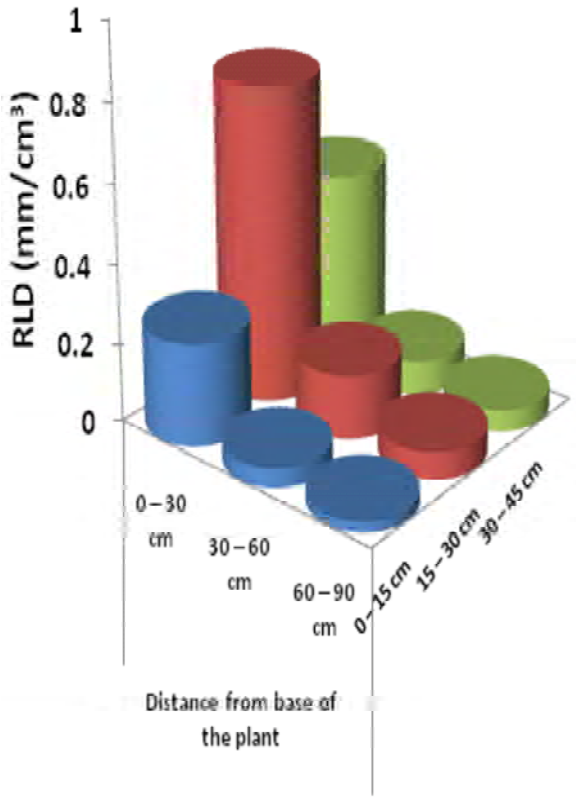


Fig. 36. Root Length Density (RLD - mm/cm³) in Neypoovan at 20 leaf stage

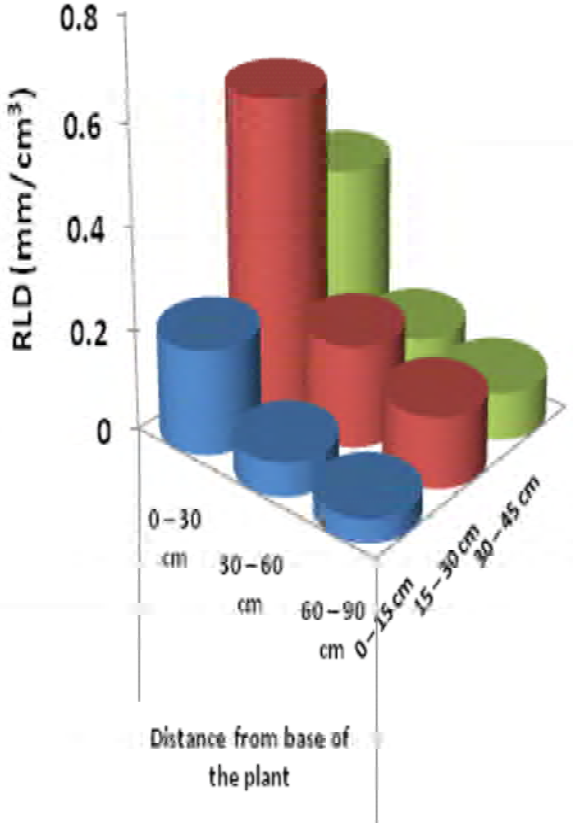


Fig. 37. Root Length Density (RLD - mm/cm³) in Rasthali at 20 leaf stage

Table 10. Specific Root Length (cm.g^{-1}) of Neypoovan and Rasthali at 20 leaf stage

Variety	Distance from base of the plant		
	0 – 30 cm	30 – 60 cm	60 – 90 cm
Neypoovan	6.90	6.77	9.99
Rasthali	6.11	6.34	6.24

4.2.2 Post harvest technology

Changes in thickness and colour index of the banana leaves on shelf-life

Shelf-life of banana leaves of ten commercial varieties and five wild species at room temperature varied from three to six days. Among the varieties, Poovan with leaf thickness of 0.13 mm and color intensity of L* (25.86) a* (-7.51) and b* (7.61), Karpuravalli with thickness of 0.20 mm and color intensity of L* (33.68), a* (-10.77) and b* (12.61) and Udhayam with thickness of 0.20 mm and color intensity of L* (28), a* (-7.67) and b* (8.25) had six days shelf-life, which is comparable with wild species like Elavazhai with thickness of 0.22 mm and color intensity of L* (25.69), a* (-5.18) and b* (5.88) and Phirima with thickness of 0.21 mm and color intensity of L* (29.22), a* (-5.94) and b* (5.43) (Fig. 38).

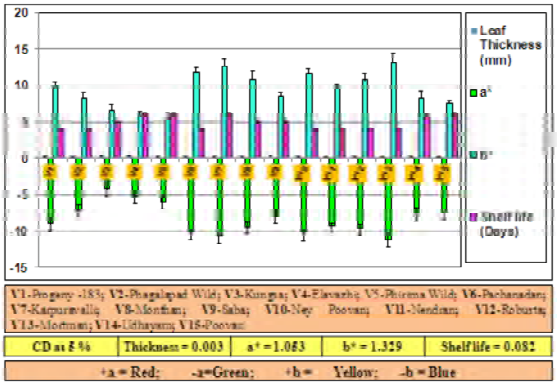


Fig. 38. Evaluation of shelf-life of banana leaves in different genotypes of banana

Storage temperatures on shelf-life of leaves in different varieties of banana

Shelf-life of banana leaves of ten commercial varieties and five wild species were evaluated at various storage temperatures and compared against room temperature as control. At 10°C, leaves of commercial varieties retained freshness up to 30 days, but the leaves have become paper like. The shelf-life of leaves in commercial varieties of banana was extended up to 14 days at 15°C, 8 days at 20°C and 6 days at 25°C. However, the shelf-life of leaves in wild species last up to 16 days at 15°C, 10 days at 20°C and 9 days at 25°C.

Post harvest losses in banana

A survey conducted at various levels of banana from harvesting to retailer level channel in Trichy Dt., revealed that 5% loss at farm gate level (harvesting and loading) and 5% loss at whole sale level and 5-10% at whole sale market- retailer level (in the market itself) and 10-30% at retailer level (Table 11).

Improved post harvest management practices in banana

Under improved postharvest handling, packing and storage of banana, maximum shelf-life of 28 days was recorded with 'Saba' at 100% maturity under active modified atmosphere packaging (MAP) at 13.5°C against 8 days in control. However, in 'Poovan', maximum shelf-life of 35 days was recorded with 90% maturity under active MAP at 13.5°C against 8 days in control. 'Nendran' at 75% maturity can be stored up to 68 days under active MAP at 13.5°C against 10 days in control.

Prevention of enzymatic browning in central core stem of banana

Various preservatives were attempted to prevent enzymatic browning in the central core stem of banana. Among the preservatives, 0.5 per cent citric acid solution was found best for retaining natural colour in 'Pachanadan' and 'Poovan', while it was 0.5 per cent KMS solution for 'Karpuravalli', 'Ney Poovan' and 'Saba' to arrest enzymatic browning and 0.5 per cent KMS solution along with 0.5 per cent NaCl for Mortman (Andhra Rasthali).

Juice content from central core stem of banana varieties

Of the three portions (bottom, middle and top) of banana central core stem utilized for extraction of juice in ten commercial

varieties of banana, the maximum juice recovery was registered in the middle portion of the stem (89.37 %) while the lowest with the top portion of the stem. Of the ten commercial varieties of banana compared for extraction of juice from central core stem, maximum recovery was recorded in Udhayam (94.60 %), followed by Red Banana (94%) and Saba (91.50 %) (Table 12).

Banana central core stem based products

Among the various flavoured ready-to-serve (RTS) stem juices, four per cent ginger flavoured central core stem juice and four and six per cent '*Nannari*' flavoured RTS central core stem juice were highly accepted each with hedonic scale of 8.00 out of 9. Of the banana central core stem juice flavoured with ginger and '*Nannari*' and stored for six months, ginger (4%) flavour was highly acceptable with hedonic scale of 8.2 to 8.3 at room temperature (RT) and 13.5°C, respectively. Micronutrients and potassium content were also found high in the flavored juices, as compared to control. Banana central core stem juice based Jelly was developed by blending stem juice with sugar and citric acid having TSS content of 65°Brix and acidity of 0.2%, which was highly accepted (Hedonic scale: 8.38).

Table 11. Post-harvest losses in banana at various levels

Level	Loss (%)	Possible causes
Farm level (Harvesting and Loading)	5	Over maturity, rust thrips, Sun scorching, overloading
Wholesale level	5	Loading in vehicle and Unloading in market, Deterioration of quality due to over loading
Wholesale market – retailer level (in the market itself)	5-10	Forcible handling leads to bottom fruits gets damaged during ripening in the smoking room
Retailer level	10-30	The bruised/damaged fruits getting spoiled only after over ripening

Table 12. Juice recovery / content (%) from central core stem of banana commercial varieties

Variety	Juice recovery / content (%)			Mean
	Stem Portion			
	Top	Middle	Bottom	
Pachanadan	82.20	82.00	85.00	**83.07**
Poovan	83.81	88.16	93.94	**88.64**
Karpuravalli	83.65	87.28	89.21	**86.71**
Saba	92.33	90.28	91.93	**91.51**
Ney poovan	88.50	87.61	82.14	**86.08**
Rasthali	86.18	86.81	85.71	**86.23**
Mortman (Andhra Rasthali)	90.01	93.79	83.28	**89.03**
Red Banana	95.06	95.01	91.85	**93.97**
Udhayam	96.29	92.27	95.25	**94.60**
Monthan	89.35	90.46	85.07	**88.29**
Mean	88.74	89.37	88.34	
CD at 5 %	Variety (V) = 0.838 Stem portion (S) = 0.459 Interaction (V x S) = 1.452			

4.3 PHYSIOLOGY AND BIOCHEMISTRY

4.3.1. Physiology

Drought stress tolerance in banana

Effect of soil moistures stress and alleviation through biochemical means on bunch weight was studied in first ratoon cv. Grand Nain. The plants were foliar primed with 0.1 mM salicylic acid at 3rd, 5thmonth stages and at flowering before imposition of soil moisture deficit stress by withholding irrigation till soil moisture reaches at -0.6 to -0.7 MPa and subsequently the stress was relieved by providing irrigation.

At harvest, the bunch weight decreased in all the soil moisture stressed plants compared to control, however, the bunch weight recorded the lowest in T3. The plants foliar primed with 0.1mM salicylic acid at 5th month (T6) the bunch weight was more than untreated plants at 5th month stage (T3) (Table 13). Besides, these plants did not show any bunch deformation.

In the first ratoon crop of banana cv. Grand Naine was foliar primedwith20 mM glycine betaine (GB) (a compatible osmotic solute) at one month before flowering before imposition of soil moisture deficit stress. At harvest, primed plants (GB) with drought treatment recorded bunch weight (18.0 Kg) and finger length increased by 11.24%. Whereas in non-primed drought imposed plants, the bunch weight (16.7 Kg) and finger length decreased.

Soil moisture deficit stress was imposed as progressive stress by withholding irrigation through drip in banana cv. Grand Naine in the field, at 3rdand5thmonth stages in the 2nd ratoon crop. The soil moisture is allowed to deplete to the level of 18-20 % from field capacity (34-36% of soil moisture). Before imposition of soil moisture deficit stress, the plants were primed with Salicylic acid + BHT, Glycine betaine (20mM), Beta amino butyric acid (200uM) and urea (2%). The growth observations indicated that, leaf emergence started declining after the soil moisture decreased to the level of 26-28%. The turgidity of leaf decreased as a result, the cigar leaves started drooping. Besides, due to high light and

Table 13. Effect of drought alleviation chemicals (salicylic acid (SA) 0.1mM) on bunch weight parameters in banana cv. Grand Naine

Treatment Name	Bunch wt.(kg)	Hands nos.	Fingers nos.
T1- Control	24.13^{A}	16.75^{A}	151.25^{A}
T2- Soil Moisture stress at 3rd Month	16.75^{B}	12.75^{BC}	128.50^{B}
T3- Soil Moisture stress at 5th Month	7.00^{D}	5.50^{E}	45.50^{D}
T4- Soil Moisture stress at Flowering	15.75^{B}	13.75^{B}	137.00^{B}
T5-SA + Soil Moisture stress at 3rd Month	16.75^{B}	12.00^{C}	131.00^{B}
T6-SA + Moisture stress at 5th Month	12.50^{C}	7.75^{D}	76.50^{C}
T7-SA+ Soil Moisture stress at Flowering	17.75^{B}	14.00^{B}	139.00^{AB}
General Mean	15.80	11.79	115.54
CV (%)	6.80	5.61	4.63

Note: Means with atleast one letter common are not statistically significant using TUKEY's Honest Significant Difference

heat, the top leaves, including cigar leaves affected with sunburn. These symptoms were recorded invariably in all the treatments, but it was severe in non-primed banana plants after 3-4 weeks of the treatment. The gas exchange parameters, *viz.*, photosynthesis (Pn) decreased drastically in all drought treatments (0.34 to 3.03µmol of CO_2 m^{-2} s^{-1}) compared to irrigated control (21.73 µmol of CO_2 m^{-2} s^{-1}) after 4 weeks of the soil moisture stress treatment (Fig. 39). Upto 3 weeks all the stress treated plants sustained some amount of photosynthesis, but after 4 weeks of stress, Pn reduced drastically due to drop in soil moisture below threshold level, except the plants primed with ASA +BHT, due to better photosynthetic machinery thereby higher leaf water content. The plants primed with amino butyric acid (BABA) (200µM) recorded 12-fold increase in ascorbate peroxidase (APX) activity under soil moisture deficit stress and higher APX activity enabledprotection of chloroplast from oxidative damage by H_2O_2.

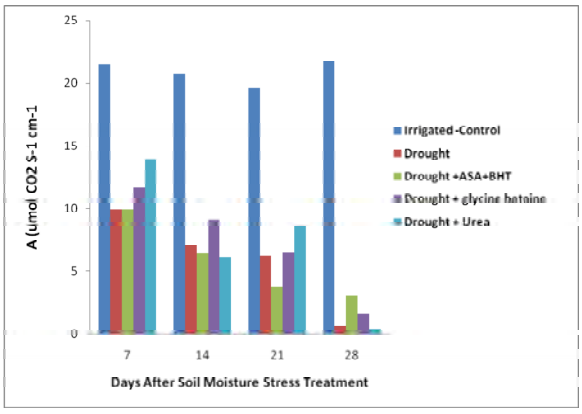


Fig. 39. Effect of soil moisture stress alleviation chemicals on photosynthesis

A number of spectral reflectance indices showed the most reliable associations with the plant water status related parameters under field conditions, i.e. leaf water potential, relative water content. Spectral water indices are also a potential high throughput screening tool for water relations related traits in comparison to other methods. The spectral reflectance was used to detect leaf water content in banana. Spectral reflectance (Fig. 40) at 900 and 970 nm for Water Index ([970-900] / [970+900]) apparently correlated with leaf water content in banana leaves.

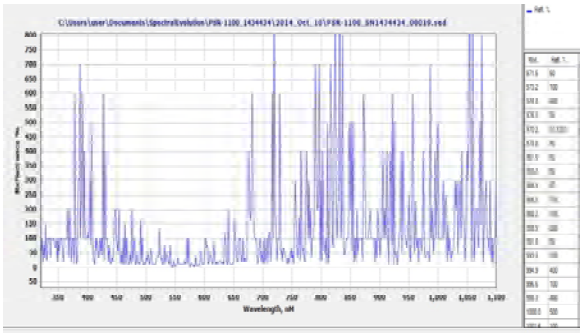


Fig. 40. Spectral Reflectance of a banana leaf for water index

Salt stress tolerance in banana

In a controlled pot experiment studies, salt alleviation chemicals on gas exchange parameters, dry matter production, Na^+ and K^+ absorption and leaf anatomy was studied in cv. Grand Naine. The Grand Naine plants primed with 200 µM beta amino butyric acid (BABA) and subsequent imposition of salt

Table 14. Effect of Salt stress (100 mM NaCl) on dry matter production in banana cultivars at 3rd month stage

Cultivars	Total dry matter (g/plant) Control	Total dry matter (g/plant) (100mM NaCl)
Grand Naine	164.88^{E}	126.67^{B}
Karpuravalli	274.75^{C}	163.67^{AB}
Ney Poovan	240.50^{D}	143.67^{B}
Poovan	276.50^{C}	204.17^{AB}
Rasthali	332.00^{B}	187.00^{AB}
Saba	749.75^{A}	390.67^{A}
General Mean	339.73	202.64
CV (%)	11.69	6.35

Note: Means with atleast one letter common are not statistically significant using TUKEY's Honest Significant Difference

stress with 50 mM NaCl recorded two fold more photosynthesis than salicylic acid (100 µM) primed plants. But the stomatal conductance and transpiration did not vary among the primed plants. However, the gas exchange parameters recorded 10-12 folds less in primed plants than control plants. Saba produced higher dry matter production than other genotypes (Table 14). The susceptibility index of Rasthali (0.58), Ney Poovan (0.93) and Poovan (0.69) were higher as compared to Saba (0.01).

In cv. Grand Naine plants primed with Glycine betaine (20mM) and subsequent imposition of salt stress with 50mM NaCl increased two and five fold dry matter production (T6) compared to unprimed salt stressed plants (50 mM (T2) and 100 mM NaCl (T3)) respectively. (Fig. 41).

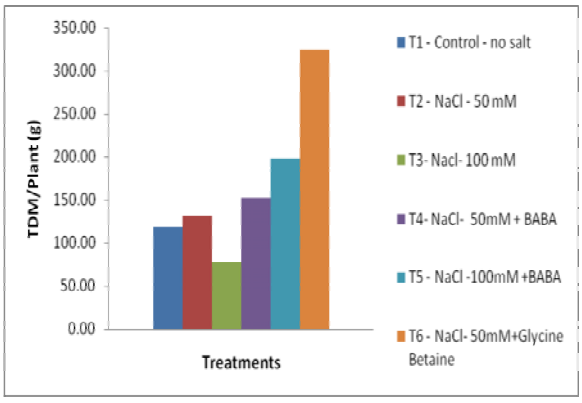


Fig. 41. Effect of salt alleviation chemicals on total dry matter (TDM) production in cv. Grand Naine

Foliar priming of three month old banana cv. Grand Naine with 200µM beta amino butyric acid (BABA) before imposition of salt stress (50mM NaCl) recorded significantly less Na^+(0.03%) accumulation in leaves than non-primed plants (0.18%) and increased K^+ accumulation (3.45%) than non-primed plant leaves (1.82%).

Salt stress (100 ppm of NaCl) in tolerant banana genotype (Saba) increased intercellular space and mesophyll cells were not affected compared to susceptible cv. Grand Naine. Increase of intercellular spaces makes the leaf more succulent and adoptable to the salt stress.

4.3.2 Biochemistry

Biochemical mechanism of resistance of banana to root lesion nematode

Highly differentially expressed enzymes *viz*., glutamine reductase, â-galactosidase and cinnamyl alcohol dehydrogenase chosen from proteomic analysis of *Pratylenchus coffeae*-infected and uninfected control roots of resistant cv. Anaikomban and susceptible cv. Nendran were validated by semi-quantitative reverse transcriptase-PCR. The transcript levels of these enzymes/proteins were higher in roots of Anaikomban and Nendran infected with the root-lesion nematode as compared to control roots confirming the over-expression/ upregulation of these enzymes due to infection of the nematode (Fig. 42).

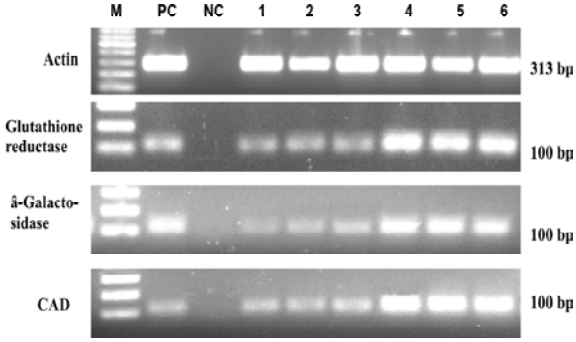


Fig. 42. Expression profile of enzymes in root of nematode resistant and susceptible bananas; M-Marker; PC-genomic DNA; NC-Negative control; 1-Nendran control; 2&3-Anaikomban control; 4-Nendran infected and 5 &6 - Anaikomban infected

Enhancement of green life of bananas

1-MCP treatment prolonged green life by 44 and 20 days at 13.5 and 21 °C respectively of full three quarter (90%) mature Grand Naine banana. Similarly, full three quarter mature Poovan bananas with 1-MCP enhanced the green life by 30 and 20 days at 13.5 and 21 °C respectively. The enhancement of green life for both bananas was lower at 29 °C (Table 15). Overall, the green life of full three quarter (90%) mature preclimacteric Grand Naine and

Poovan bananas enhanced 20 days more by exposing to 1-MCP at 1 µl/L for 12 hrs and storing at 21 °C. Gibberellic acid at 30 and 50 mg/L concentration treatment of 100% and 90% mature Grand Naine and Poovan bananas enhanced green life by less than five days at 13.5 and 21 °C.

Table 15. Duration of green life of full three quarter mature Grand Naine and Poovan banana treated with 1-Methylcyclopropene

Temp. (°C)	Sample	Grand Naine	Poovan
13.5	Control	91	56
	Treatment	135	82
21	Control	17	13
	Treatment	37	33
29	Control	15	10
	Treatment	23	17

The physiological parameters of CO_2 release were 14.3 ppm in and at the end of preclimacteric stages, 22.4 ppm at breaking stage and 15.5 ppm at stage-6 of ripening (Fig. 43) and ethylene release was of 0.35 ppm in and at the end of preclimacteric stages, 1.4 ppm at breaking stage and 2.67 ppm at stage-6 of ripening (Fig. 44), which were similar to untreated control fruits. The ripening enzyme polygalacturonase activity was 0.005 unit activity/g fresh wt. in preclimacteric stage and at the end of preclimacteric stage, 0.04 u/g at breaking stage and 0.27 u/g at stage-6 of ripening (Fig. 45). The physiological parameters, biochemical characteristics and qualitative parameters (TSS and acidity) of 1-MCP and GA_3 treated bananas during ripening were similar to untreated control fruits. Qualitative parameters like TSS in the range of 22.8-23.3 and 20.13-22.7 °B and acidity in the range of 0.278-0.31 and 0.564-.571% for Grand Naine and Poovan fruits respectively for ripening stage-6 of 1-MCP treated bananas, which were similar to untreated control bananas.

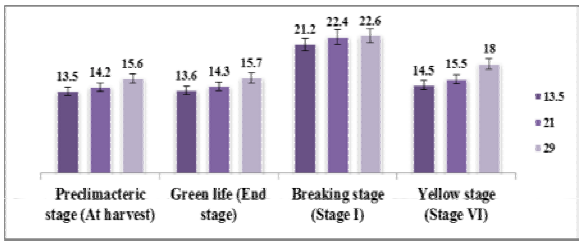


Fig. 43. CO_2 release in 1-MCP treated Grand Naine banana during green life and ripening

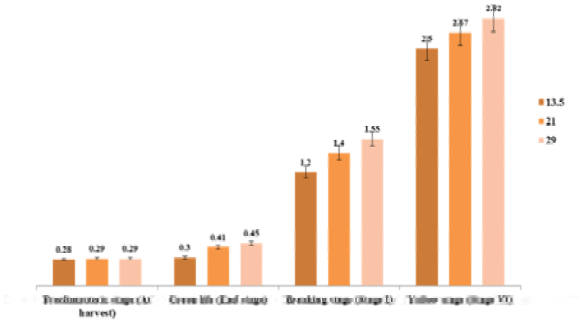


Fig. 44. Ethylene release in 1-MCP treated Poovan banana during green life and ripening

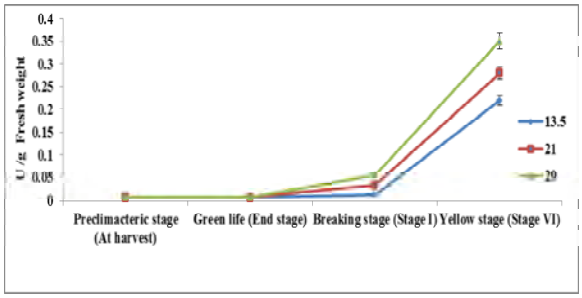


Fig. 45. Polygalacturonase activity in 1-MCP treated Poovan banana during green life and ripening

Mechanism of delayed ripening of banana treated with 1-MCP

Proteome mapping of banana pulp was studied to understand the biochemical mechanism of enhancement of green life of bananas by 1-MCP treatment. Around 800 protein spots in 2-DE gels could be detected in both 1-MCP treated and untreated Poovan banana pulp. On analysis by Melanie 7, sixty six differentially expressed proteins were identified and thirty highly abundant differentially expressed proteins were being mass fingerprinted by MALDI-TOF.

Study on temperature-dependent green ripening of Cavendish bananas

Preclimacteric full (100%) mature Cavendish (Grand Naine) bananas stored at 21, 31 and 35 °C showed similar enzyme activities with respect to ripening; however, the Mg-dechelatase activity was lower in fingers stored at 31 and 35 °C as compared to fingers stored at 21 °C and the pheophorphide a oxygenase activity (Fig. 46) was totally absent at 31 and 35 °C compared to fingers stored at 21 °C.

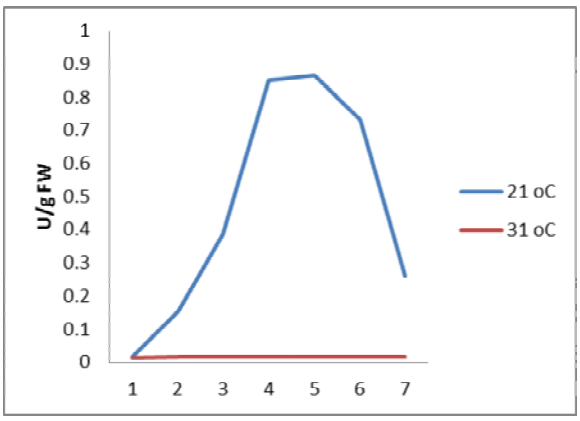


Fig. 46. Pheophorphide a oxygenase activity in yellow ripening (21 °C) and green ripening (31 °C) Cavendish (grand Naine) banana

Also, HPLC-estimation of chlorophyll catabolites (chlorophyllide a and pheophorphide a) showed stay green bananas (stored at 31 °C) have significantly relatively low level of catabolites than at 21°C. The pheophorbide a and red chlorophyll catabolite accumulation in yellow ripe banana directly correlated with low activity of magnesium dechelatase and pheophorbide a oxygenase and impairment of pheophorbide a oxygenase activity at high temperature that might contribute to the absence of degreening and 'stay green' character in Cavendish bananas.

Mechanism of temperature-dependent green ripening of Cavendish bananas

Preclimacteric full (100%) mature Cavendish (Grand Naine) fingers were ripened at 21 and 31 °C in ripening incubators. Comparative analysis of proteome maps of peel tissues of 'green' and 'yellow' ripe fruits Cavendish (Grand Naine) revealed 74 differentially expressed proteins, out of which 20 up-regulated and nine down-regulated highly abundant proteins were mass fingerprinted (Fig. 47), biological identity established using MASCOT and Swiss Prot database, which include ACC oxidase, ACC synthase, CASP-like proteins and Mg-dechelatase and their functional annotation revealed seven categories.

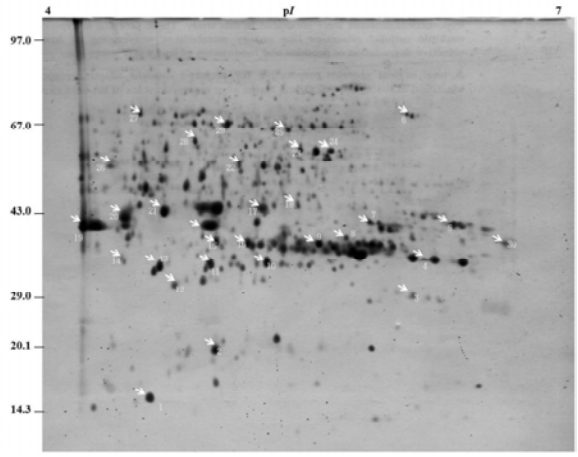


Fig. 47. Proteome map (reference gel) of peel tissue of 'green ripe' Grand Naine banana

Biochemistry of finger drop in bananas

Finger drop, a physiological disorder associated with postharvest ripening of banana, is the dislodgement of individual fruits from hand at the pedicel abscission zone. A comparative enzymatic changes and proteome mapping by two-dimensional gel electrophoresis (2-DE) of pedicel abscission zone peel tissues of Rasthali (AAB, Silk subgroup), a sensitive cultivar and Poovan (AAB, Mysore subgroup), a resistant cultivar to finger drop was performed to propose putative candidate proteins. Cell wall modifying and ethylene biosynthesis enzymes *viz*., polygalacturonase, pectate lyase and ACC oxidase activities peaked with concomitant massive finger drop occurring on fifth day of ripening in Rasthali whereas subdued activities of the enzymes and no finger drop was

observed in Poovan. More than 900 reproducible proteins were detected in 2-DE maps including 135 differentially expressed proteins (DEPs) of which 70 abundant DEPs (44 up-regulated and 26 down-regulated) in Rasthali compared to Poovan were identified by MALDI-TOF MS (Fig. 48).

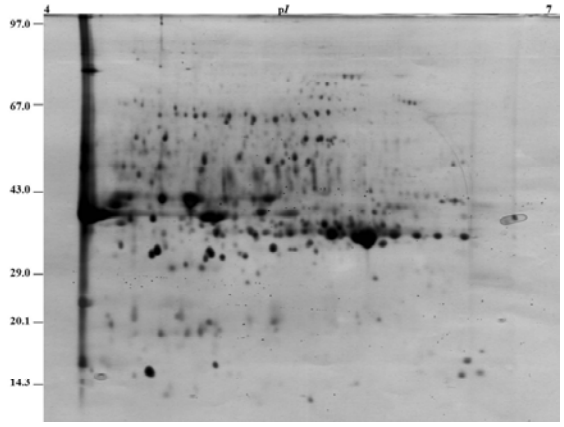


Fig. 48. Proteome map (reference gel) of peel tissue of pedicel abscission zone of cv. Poovan

The proteins were classified into eight main categories related to the metabolic changes occurring during ripening and finger drop and these proteins were involved in carbon and energy metabolism (16 proteins), nucleic acid metabolism (5), cell membrane and cytoskeleton (6), stress and defence (13), fruit ripening and senescence (8), amino acid metabolism (4), secondary metabolism (5) and protein metabolism (5). Comparative analysis revealed five finger drop-responsive DEPs *viz*., ACC oxidase, polygalacturonase, pectate lyase, xyloglucan endotransglycosylase/hydrolase and expansin involving in ethylene biosynthesis and cell wall modifications were significantly up-regulated in Rasthali banana and these enzymes/proteins are suggested as putative candidates of finger drop phenomenon.

4.4 CROP PROTECTION

4.4.1 Entomology

Management of banana weevils

In vitro evaluation of deterrent semiochemical against banana weevils

Deterrent semiochemical was screened against corm weevil and stem weevil under *in vitro* by pit fall trap and wind tunnel bioassay methods. Among the seven treatments, 100 per cent deterrence was observed for both weevils. In the same experiment, attractant semiochemical and the host (leaf sheath for stem weevil /corm for corm weevil) indicated an attraction of 50 and 66.66 percent to corm weevil and 63.33 and 26.66 % for stem weevil respectively.

Consortium for the management of corm weevil

Two consortium groups comprising of fungal endophytes *Beauveria bassiana* I & II and *Metarhizium anisopliae* I & II were tested for persistence in the tissue culture Grand Naine plant and corm weevil mortality due to endophyte. The endophytes were administered to the plant by root dip for 2 hours at $1.5x10^7$ CFU/ml and soil application at $1x10.5^7$ CFU/ml concentrations respectively. The fungal persistence was monitored up to 6 months (March-August 2014). The persistence of the inoculated fungal pathogen , *B.bassiana* indicated a concentration of $1.50x10^9$ CFU/ml and $1.30x10^9$ CFU/ml for Group-I and II respectively (Fig. 49). In the soil application method persistence was recorded upto four months after application and the concentrations are as follows: $1.30x10^9$ and $1.31x10^9$ in Group-I and Group-II (Fig. 50). The persistence of *M.anisopliae* was also recorded up to July in root feeding, which indicated $3.08x10^9$ CFU/ml in G-I and $0.70x10^9$ CFU/ml in G-II (upto July). In soil drenching of *M.anisopliae* the persistence was recorded up to December in G-I (concentration of $1.81x10^9$ CFU/ml) and $1.05x10^9$ CFU/ml in G-II respectively. The weevil mortality upto 100 % was recorded till May 2014 in both Group-I and Group-II isolates of *B.bassiana* by root dip method. In the soil drench method , *M.anisopliae* recorded 75 % mortality up to November 2014 by Group-I and Group-II respectively.

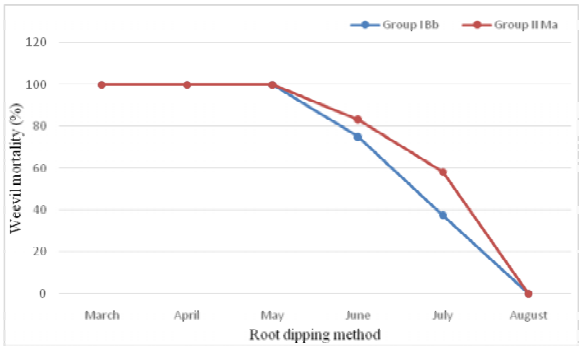


Fig. 49. The mortality was recorded in the root dipping method

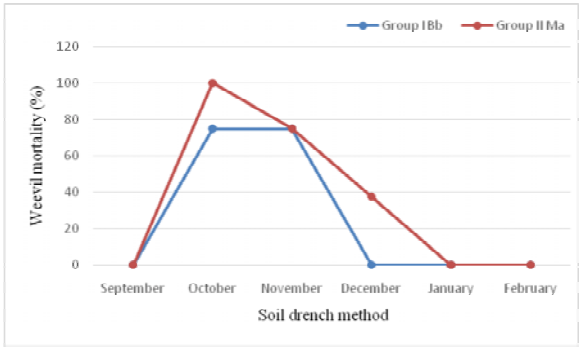


Fig. 50. The weevil mortality was recorded in the soil drench method

Evaluation of zimmu extracts against banana weevils

The aqueous and hexane extracts of zimmu were tested against corm weevil and stem weevil, at four concentrations (25%, 50%, 75% and 100 %.) by two methods *viz.,* insect dip and feeding the treated leaf sheath. The observations on feeding and mortality were recorded daily for 10 days.

Among the four concentrations tested against stem weevil by insect dip method,

maximum mortality (100%) was recorded at the 100% concentration of aqueous extract on 10th day, while 93.75% mortality was recorded in 75% concentration on 10th day. 75% and 56.25% mortality was recorded in the concentration of 50% and 25% zimmu aqueous extract shown Fig 51. In leaf sheath feeding method against banana stem weevil, maximum 87.5% mortality at 100% on 10th day and 68.75% and 56.25% weevil mortality was recorded in the concentrations 75% and 50% respectively on 10th day. The minimum (43.75%) mortality was recorded in 25% concentration of zimmu aqueous extract (Fig. 52). The zimmu has no effect on banana corm weevil.

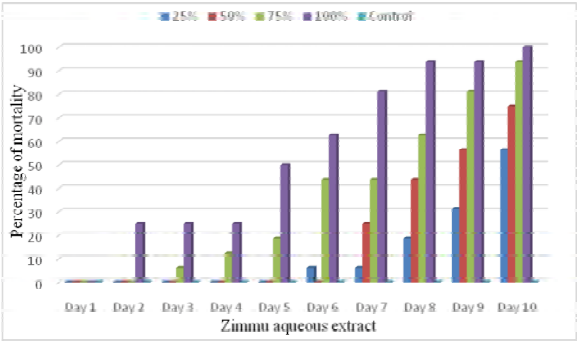


Fig . 51. Mean percentage of stem weevil mortality recorded for 10 days in insect dip method

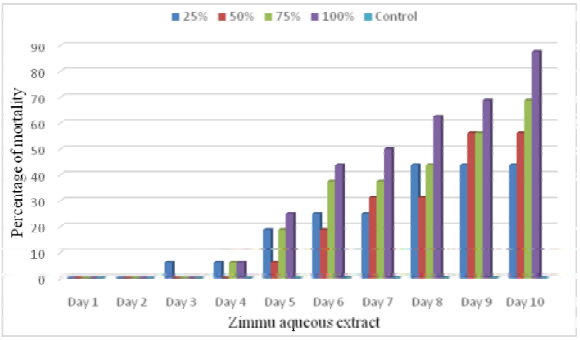


Fig. 52. Mean percentage of stem weevil mortality recorded for 10 days in leaf sheath feeding method

Zimmu solvent extract was tested against banana stem weevil by leaf sheath feeding method. Among the four concentrations tried (25%, 50%, 75% and 100%), maximum (100%) mortality was recorded in 100% conc. on 4th day, while 100% mortality was recorded in the concentrations *viz.,* 75%, 50% and 25% on 6th day (Fig. 53). The solvent extract tested against banana corm weevil indicated maximum (100%) mortality in the 100% concentration on 6th day. In the remaining three concentrations, no mortality was recorded (Fig. 54). The insect dipping method was tested against both weevils which indicated no mortality.

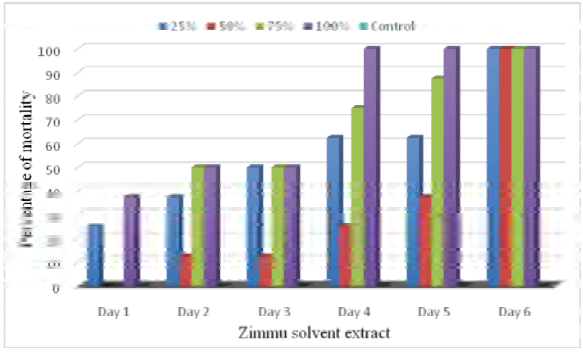


Fig. 53. Mean percentage of stem weevil mortality recorded for 6 days in leaf sheath dip method

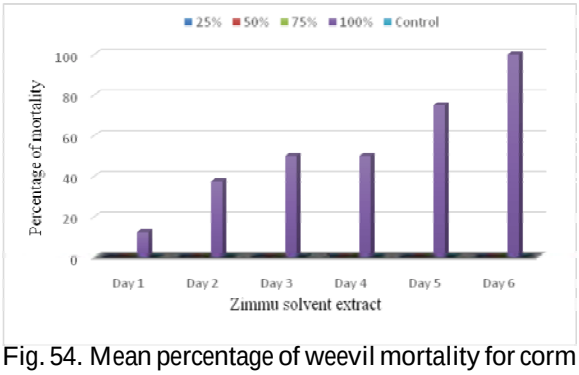


Fig. 54. Mean percentage of weevil mortality for corm weevil in leaf sheath dip method

4.4.2 Pathology

Investigation on fungal and bacterial diseases of banana and their management

Evaluation of zimmu against *Fusarium oxysporum* f. sp. *cubense* (*Foc*)

Zimmu planting on soil inoculum of *Foc* was evaluated under pot using *Foc* sick soil. Sampling at 80 days after planting revealed that soil population of *Foc* was reduced from 5.60 x 10^5 to 6.6 x 10^2 (Fig. 55).

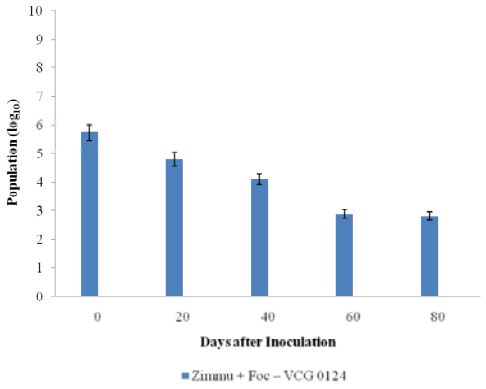


Fig. 55. Effect of zimmu planting on *Foc* inoculum in the soil

Evaluation of biocontrol agents on leaf spot disease

Field spraying of Nendran banana plants with *Bacillus* spp. (1e2 and 12acy) at shooting stage resulted in reduction of eumusae leaf spot disease by 56.8% and 54.3% respectively, compared to fungicide Propiconazole (0.1%) + mineral oil (1%) treatment. Biocontrol agents treatment also increased the number of green leaves (53.3%) and bunch weight (14.6%) significantly as compared to control (Fig. 56).

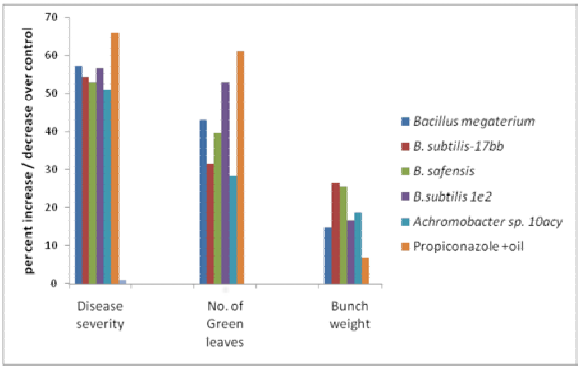


Fig. 56. Field evaluation of biocontrol agents for the suppression of leaf spot disease, no. of green leaves and bunch weight of cv. Nendran

Management of banana root-knot nematode using biocontrol agents

Under pot experiment on cv. Grand Naine, six biocontrol agents were applied against root-knot nematode, *Meloidogyne incognita* and results indicated that soil application of wild endophytic *Trichoderma asperellum* was found better in controlling the nematode while the Caldon treatment was the best with no galls (Fig. 57).

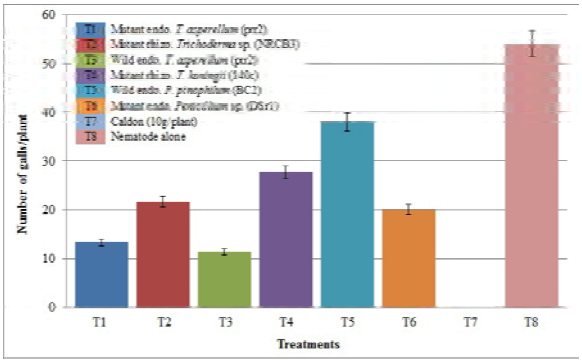


Fig. 57. Effect of soil application of biocontrol agents on galls

4.4.3 Virology

Studies on viral diseases and their management

Survey for viral diseases

Incidence (12 to 30.5%) of Banana Bunchy Top Virus (BBTV) and Banana Bract Mosaic virus (BBrMV) (2.5% to 40%) was recorded in Poovan (AAB) grown in Thirukattupalli and Thanjavur areas in Tamil Nadu.

Molecular characterization of banana viruses

Three complete genomes (7.6 Kbp) of Banana Streak Virus (BSV) species infecting cvs. Rasthali and Poovan were amplified by RCA and cloned. Sequence analysis revealed 99% similarity with BSMYV-TRY. BSV species infecting Hill banana comprised of 6591bp nucleotide (nt) and has 99% similarity with the Banana Streak GF Virus (BSGFV).

Genetic variability studies of Banana Streak Mysore Virus (BSMYV) isolates revealed that all the isolates belonged to BSMYV. Partial BSMYV sequences displayed 78-100% homology at the nucleotide levels. Totally 18 isolates originating from different regions had 100% sequence homology at nucleotide level. Phylogenetic analysis showed

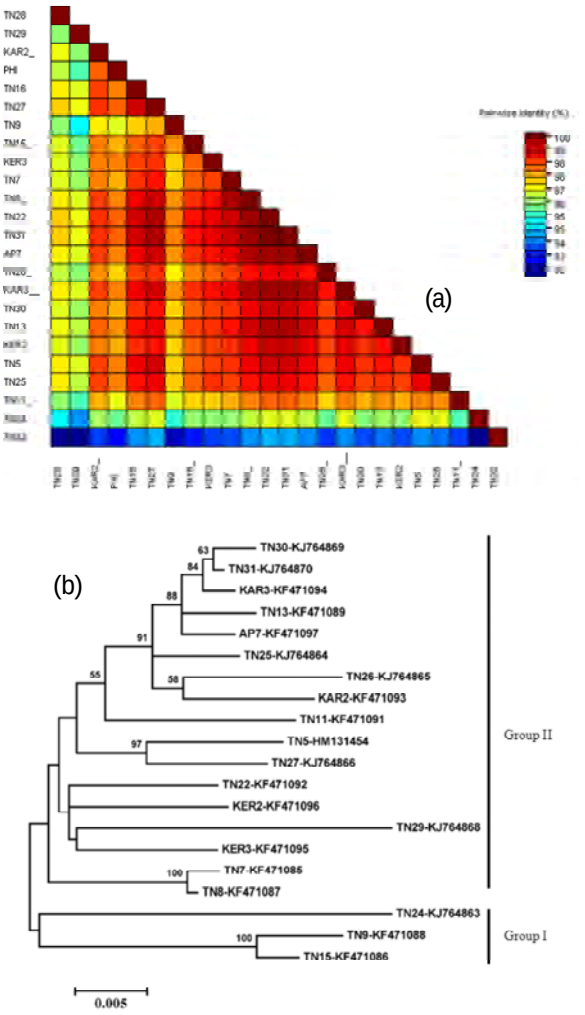


Fig. (58a) Graphical representation of pair wise and amino acid identity (with percentage identity scale) of 24 BBrMV isolates. TN-Tamil Nadu, AP-Andhra Pradesh, KER-Kerala, KAR-Karnataka, TN5, TN7, TN11, TN15, TN16, TN22, TN25, TN26, TN27, TN28, TN29, TN30 -Tiruchirapalli, TN8, TN9 and TN32-Theni, TN24-Karur, TN 31-Tanjore, AP7-Kovur, KAR2-Bangalore, KAR3-Arabhavi, KER2-Kasargod, KER3-Kayankulam, TN, AP, KER, KAR, are belongs to Indian origins. PHI-Philippines. (58b). Phylogenetic analysis of the HC-Pro gene of nucleotide sequences of non recombinant BBrMV isolates from India using Maximum Likelihood method. The tree is drawn to scale, with branch lengths in the same units as those of the evolutionary distances used to infer the phylogenetic tree. Bootstrap scores above 50 % (1000 replicates) are placed at the tree nodes. The scale bar represents the number of nucleotide substitutions per site.

that except T2, K3, T1, V2 and LAL3 isolates formed one cluster (clade I) along with BSMYV-TRY, BSMYV-AUS isolates. Isolate T1 and V2 clustered into clade - II and T2 and K3 formed another clade-III.

Helper Component Protease (HC-Pro) gene sequence of 22 BBrMV isolates showed 92 to 100 % identity both at the nucleotide (nt) and amino acid (aa) level **(**Fig.58a). Phylogenetic analysis based on nt sequences of non-recombinant isolates showed that TN15, TN9 and TN24 formed one cluster and all the remaining isolates formed another cluster **(**Fig. 58b**)**. The study suggested that negative selection and recombination were important evolutionary factors driving the genetic diversification and population structure of Indian BBrMV isolates.

For complete genome characterization of CMV-Banana isolate, four partial genomes of CMV were cloned. Putative BSOLV genome amplified using new abutting primers was cloned to identify its origin of integration in cv. Poovan. RFLP was performed for full length genome of BSV species infecting banana cultivars Virupakshi (Hill banana) and Poovan.

Diagnostic techniques for banana viruses

Real time PCR assay showed higher concentration of BBrMV in root tissues followed by bract, leaf sheath, meristem, cigar leaf and unopened leaf of infected cv. Poovan during summer months when there are no external symptoms. A solvent free simple extraction protocol was developed and validated for the detection of BBTV in PCR, loop mediated isothermal amplification **(**Fig. 59) and Quantitative-PCR. This protocol is cheaper and more sensitive than other protocols. Sensitivity of LAMP assay was standardized for detection of BBTV with a detection limit of 0.0001ng. This assay was 100 times more sensitive than PCR. Various parameters for RT-LAMP assay for detection of BBrMV and LAMP based detection of

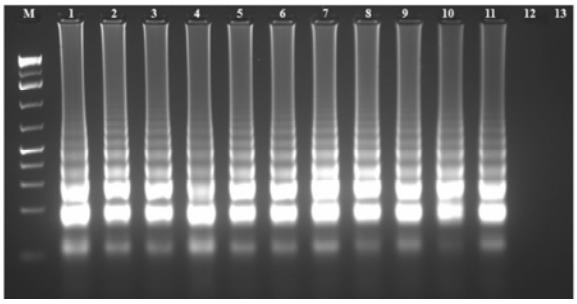


Fig. 59. Detection of BBTV by LAMP assay using SEP extracts as template from BBTV infected banana samples. Lane M: 1 kb ladder plus (MBI Fermentas,USA); Lanes 1-5: Standard SEP extract; Lanes 6–10: SEP extract at 1:100 dilution; Lane 11: Positive control; Lane 12: Healthy control; Lane 13: Non template control

CMV and BSMYV were standardized. Using SYBR green chemistry, BBTV and BBrMV were simultaneously detected in real time PCR with distinct melting curves. Primers were designed to express cp of two viruses in a single vector for expression of fused viral proteins and to produce antiserum.

Virus-vector relationship in banana

Mealybug, *Planococcus citrus* fed on BBTV infected leaves did not acquire the virus, whereas cotton aphid, *Aphis gossypii* acquired BBTV experimentally which was confirmed by PCR.

Host-virus interaction in Banana: Molecular mechanism of resistance and susceptibility, latency, integration and episomal expression of EPRVs

Analysis of yield, expression of BSV symptoms, symptom severity in the permanent field trial for cv. Poovan

Non-symptomatic Poovan plants planted during 2005-06 were continued as 9th ratoon crop in 2014-15. Expression of BSV symptom was observed newly in 29 plants. Out of 560 plants planted, so far 156 plants have expressed the symptoms of streak disease for the past 9 years. Analysis of disease severity index, yield, girth and plant height over the years indicated great variation between the years and weather factors that prevailed in the corresponding year might have an influence on these variations. Further, plants which exhibited symptoms previously have turned out to be healthy subsequently.

Comparison of BSV severity in tissue culture (TC) and sucker derived plants of second ratoon crop of cv. Poovan

Streak virus severity index and yield loss were significantly higher in TC plants than healthy and BSMYV infected sucker grown plants.

Identifying the stress factors for inducing expression of BSMYV in Poovan through pot culture experiment

Wounding and nutrient stress imposed cv. Poovan plants did not have any influence on the expression of BSMYV symptoms.

Developing infectious partial dimer construct of BSMYV genome

Full length clone of BSMYV was cloned into binary vector pBin19 in KPN RE site and further half the length or the full length need to be cloned for infectivity assay.

Transcriptomic analysis of banana dually infected with BBTV/ BSMYV

Complete genomes of BSMYV and BBTV were obtained in dually infected Poovan sample. Nearly 30-35 million reads with 100% high quality were obtained. 108421 and 95815 contigs were generated both in healthy (but latent) and infected samples. Minimum Contig length: 200; Max. Contig length: 17218; Gene ontology (GO) terms are assigned to query sequences, producing a broad overview of groups of genes catalogued in the transcriptome for each of three ontology vocabularies, biological processes, molecular functions and cellular components. The

majority of the GO terms were assigned to molecular function (52.55 %) followed by cellular components (33.72 %) and the least were categorized under the biological process (24.76). Totally 84874 transcripts were expressed. Among 84874, 12410 were up regulated, 10211 were down regulated and 62253 were neutrally expressed. Totally 37810 and 34764 annotated transcripts were recorded in both healthy (latent) and infected Poovan samples. Totally 308 and 245 Simple Sequence Repeats (SSRs) were predicted both in healthy (latent) and infected samples.

Two sets for each of the differentially expressed protein coding genes were designed and three sets of primers coding for Peroxiredoxin and GAG-POL Poly protein genes were validated in semi-quantative PCR.Southern blot analysis revealed that B genome containing commercial banana varieties such as Karpuravalli, Poovan, Rasthali, Monthan, Saba, Nendran and Ney Poovan were found integrated with BSOLV genome whereas Grande Naine (AAA) does not have integration.

Virus-vector interaction

Real time PCR quantification of BBTV in banana and cotton aphid, *A. gossypii* revealed higher virus titre in banana aphid compared to cotton aphid.

Proteomic analysis of host–BBTV interaction in banana

Phloem proteomics

Acetone - HCl protein extraction method was standardized for phloem protein isolation. More than 50 reproducible spots were identified and 25 spots were showing two-fold difference. Peptide Mass Fingerprinting (PMF) by Mass Spectrometry (MS) indicated that all the 25 spots were upregulated in the healthy Hill banana samples. These proteins were found to be involved in defence, signal transduction, energy, plant growth, protein designation transcription and translation.

Validation of proteomics through semi-quantitative–PCR and sequencing

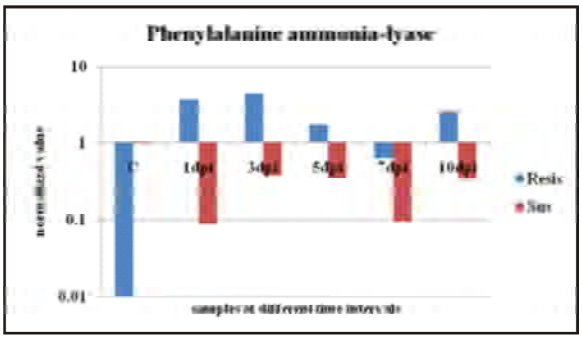
Semi-quantitative PCR analysis of genes from each functional category showed that seven genes produced single band and corroborated the protein. All the genes were cloned and sequenced.

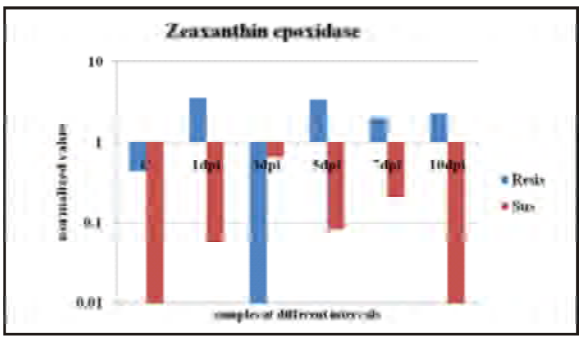
4.5 EXTERNALLY FUNDED PROJECTS

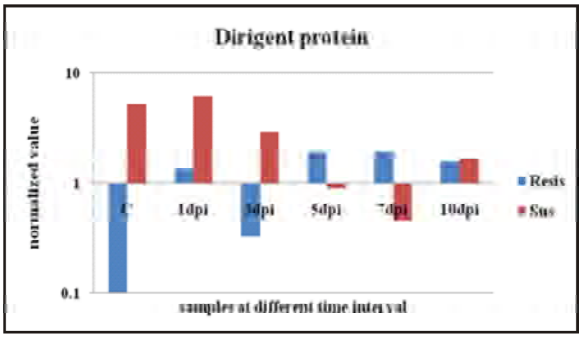
4.5.1 Functional Genomics – Sigatoka Component (S.Uma)

Gene expression studies of *Musa* transcriptome for *Eumusae* leaf spot tolerance

Defense related genes (37) were selected from the digital gene expression analysis of *M. eumusae* challenged transcriptome of contrasting cultivars and validated their expression through qRT-PCR in *M. eumusae* challenged *Musa* resistant and susceptible cultivar with respective controls. The upregulation of 31 out of 37 genes in resistant







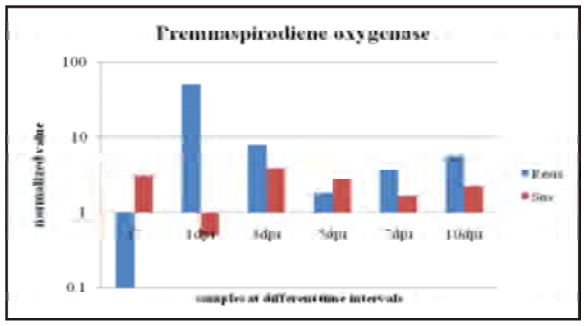


Fig. 60. *Musa* defense related genes resulted from *Musa* and *M. eumusae* transcriptome studies

cultivar suggested that these genes involved in hypersensitive, signal transduction, antifungal, basal immunity, JAS, ethylene, SA, PAMPS, lignin biosynthesis, phenylpropanoid, shikimate, isoprenoid pathways which played major roles in *eumusae* leaf spot resistance mechanism (Fig. 60).

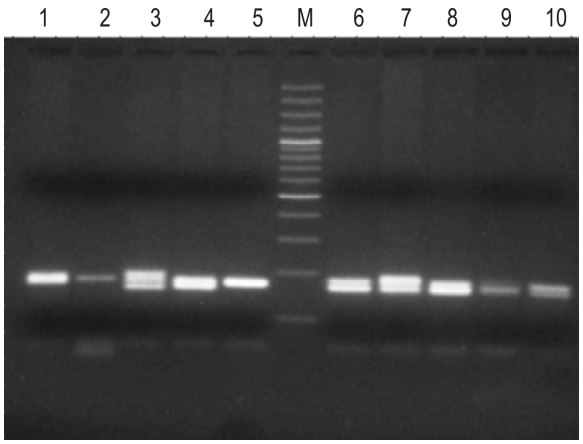
Trancriptome analysis of MYB transcription factor

The MYB TF acts as flavonol specific activator of flavonoid biosynthesis and hormonal signaling pathways. More members of MYB TFs family were expressed in eumusae leaf spot resistant (736) cultivars than susceptible cultivars (672). Of these 175 MYB TFs were found to be upregulated in resistant cultivars whereas only 118 MYB TFs were upregulated in susceptible cultivars. Interestingly it was observed that ten MYB TFs were uniquely expressed in resistant cultivars of which five MYB TFs had more than 400FPKM whereas one out of eight MYB TFs expressed only in susceptible cultivar recorded more than 300 FPKM. The transcriptome data were confirmed through qRT PCR analysis with the randomly selected upregulated MYB TFs in resistant cultivar.

Validation of EST-SSRs derived from *M. eumusae* challenged *Musa* transcriptome

Totally 98 SSR containing resistant genes were identified from transcriptome data of eumuase leaf spot resistant cultivars of which

40 primers were selected based on their expression pattern and validated against contrasting accessions (each five) for *eumusae* leaf spot disease resistance. All the primers showed polymorphism among the accessions but none of them showed clear banding pattern between resistant and susceptible accessions (Fig. 61).



1 - 5 = Resistant Cultivars
6 - 10 = Susceptible Cultivars

Fig. 61. EST-SSRs validation of *Musa* and *M. eumusae* transcriptome of resistant and susceptible genotypes

Evaluation of defense genes and its pathway genes in *Musa* resistance against *M. eumusae*

Analysis of *M. eumusae* challenged transcriptome data of resistant and susceptible cultivars revealed that genes involved in lignin biosynthesis pathway were highly expressed in unchallenged resistant cultivars compared to challenged resistant and challenged susceptible cultivars, whereas ethylene biosynthesis genes were highly upregulated in eumuase challenged resistant cultivar. Thus it is suggested that the resistance mechanism for eumusae leaf spot in Musa might be due to over accumulation of lignin which plays a major role in preventing the entry of fungus and over production of ethylene which enhances the induced systemic resistance.

Secondary analysis of *Musa* transcriptome data

Detection of SNPs from *Musa* transcriptome data

The transcriptome sequences of Manoranjitham in comparison with *Musa* reference genome map resulted in the identification of 1054 SNPs. Similarly comparison of trasnscriptome sequences of contrasting parents for eumusae leaf spot resistance, *viz*., Manoranjtham (resistant) and Grand Naine (susceptible) resulted in identification of 700 SNPs, which will be useful for developing markers for eumusae leaf spot resistance.

Prediction of miRNA from *Musa* transcriptome data

The transcriptome data of resistant/ tolerant cultivars for eumusae leaf spot, nematode and drought were subjected to Plant MicroRNA Database (PMRD) indicated that maximum number of miRNAs in Saba (ABB), a drought tolerant cultivar (222miRNAs), followed by Karthobiumtham, a root lesion nematode resistant cultivar (59 miRNAs) and Manoranjitham, a eumusae leaf spot resistant cultivar (18miRNAs). The prediction of the respective target genes for each miRNAs during biotic and abiotic stresses indicated that upregulation of maximum number of miRNAs under drought exposed condition (221) followed by eumusae leaf spot

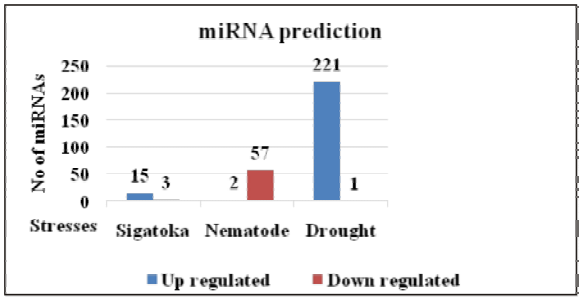


Fig. 62. Prediction of miRNA expression under different biotic and abiotic stress conditions

Table 16. Number of predicted transcription factors across three stresses

Stresses	Transcription factor			
	Resistant		Susceptible	
	UR	CR	US	CS
Eumusae leaf spot	91	93	91	92
Nematode	96	93	91	94
Drought	93	93	92	96

UR - Un challenged Resistant; US - Un challenged Susceptible
CR - Challenged Resistant; CS - Challenged Susceptible

challenged condition (15). In contrast, maximum number of miRNAs (57) were downregulated under nematode challenged condition (Table 16, Fig. 62).

Transcription factors (TFs) were predicted from transcriptome data available at NRCB and observed that C2H2 TFs were abundant when compared to other TFs irrespective of the cultivar.

*Musa*Transcriptome SSR database

MusatransSSRDB - *Musa*Tanscriptome SSR database was developed and hosted at ICAR - NRCB Website. URL: http://nrcb.res.in/nrcbbio/. The database provides information on 48,298 *Musa* SSRs namely type of SSRs, primer details, annealing temperature, product size, putative function and metabolic pathways of the SSR containing genes and their expression profiles under specific stresses (Fig. 63 a & b). More than 5500 SSRs were detected in ABB (Saba and Karthombiumtham) and AAB (Nendran) cultivars, whereas more than 5000 SSRs were detected in AAA (Grand Naine and Manoranjitham) cultivars. Information on 633, 740 and 602 *in silico* polymorphic SSRs for contrasting cultivars for eumusase leaf spot resistance, nematode resistance and drought tolerance also available. This will be useful in the detection of biotic and abitoic stress resistant markers. Information on *in-silico* polymorphic SSRs (1074) among the five cultivars, a total of 18 *in silico* polymorphic SSRs were randomly selected and tested against eight *Musa* accessions for confirming their polymorphism through gel electrophoresis (Fig. 64). All the primers showed polymorphic banding pattern among the accessions, for developing finger printing of Musa accessions and also for

Fig. 63a. Musatrans SSR Database architecture.

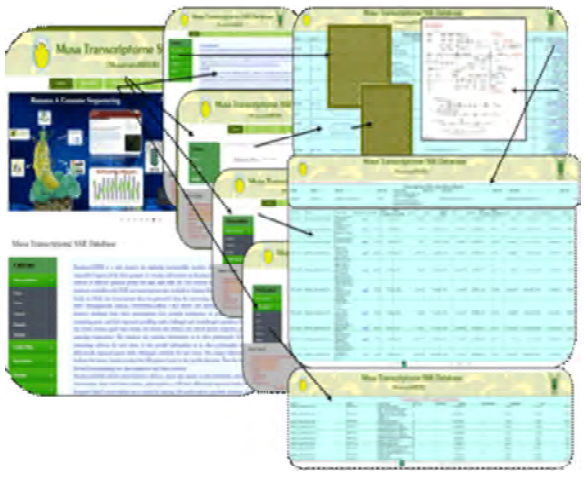


Fig. 63b. MusatransSSR Database web interface

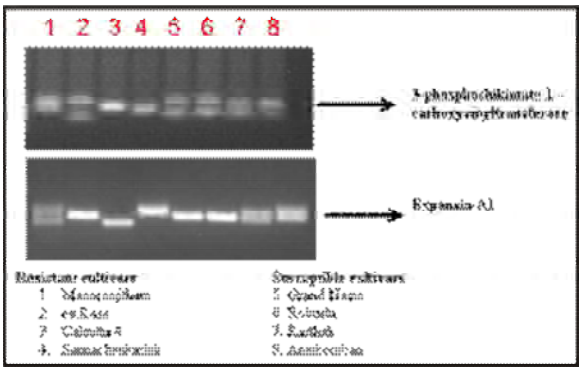


Fig. 64. Validation of SSR derived from *Musa* transcriptome

developing molecular markers for various traits.

Sequences and SRA submission

The whole transcriptome of *Musa balbisiana* reads were submitted to NCBI-SRA database with the accession.

4.5.2 Income generation through conservation and cultivation of near extinct banana landraces of Kolli Hills, Tamil Nadu (S.Uma)

Disease free quality planting material produced through tissue culture technique of cvs. *viz*., Manoranjitham (1230 nos.) and Numaran (340 nos.), bio-fertilizer and plant protection kits to the beneficiaries. In order to maintain the supplied TC plants, a training programme on macropropagation and production and protection techniques for banana landraces was organized at Kolli Hills.

4.5.3 Lab Accreditation facility genetic fidelity testing (M.S. Saraswathi)

A total of 602 batches of tissue cultured Grand Naine, Robusta, Williams and Nendran were tested for their genetic fidelity using SSR and ISSR markers and test reports have been issued under DBT–ATL. Another 207 million tissue culture plants of cv. Grand Naine have been issued quality certificates for distribution to farmers. This has generated an income of Rs. 10.15 lakh to the institute.

4.5.4 DBT-QUT project on Biofortification and development of disease resistant bananas

Component - I. Transfer and evaluation of Indian banana with PVA constructs and providing authentic virus free IMFB to Indian partners (S. Backiyarani)

Putative transformed plants of cvs. Rasthali and Grand Naine derived from transforming four pVA constructs were confirmed with Vir C primer (for confirmation of *Agrobacterium* contamination) and primers specific to gene of interests namely DC35, DC 34, DC 12 and DC32. (Fig. 65). The confirmed transgenic plants are maintained at *in-vitro* conditions for multiplication (Fig. 66).

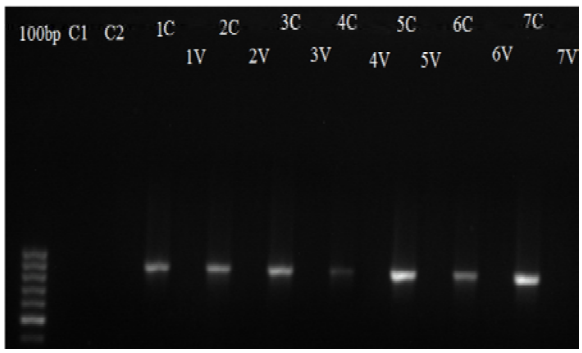


Fig. 65. Confirmation of transformed plants. C1 and C2 Untransformed Grand Naine with pVA primer VirC primers. Amplification of putative transgenic plants with pVA primer and VirC primers. C represents construct primers and V represents VirC primers

Fig. 66. PCR confirmed transgenic plants in primiary hardened stage

One set of PCR confirmed Grand Naine transgenic plants with DC-35 have been transferred to primary hardening after transformation and monitored regularly for any morphological changes or variations.

Component - II. Transfer and evaluation of Indian bananas with iron gene constructs (M. Mayil Vaganan)

A total of 60 cocultivations were carried out using ECSs of Rasthali and Grand Naine with *Agrobacterium* strain AGL1 individually containing four iron gene constructs of *p*BMGF-DC-52 with gene *Fea*; *p*BMGF-53 with gene *OsNas1*; *p*BMGF-57 with two genes *OsYSL2* & *OsNas1* and *p*BMGF -58 with three genes *SoyFer*, *OsYSL2* & *OsNas1* and from these, around 600 transgenic plants were produced. As decided in the Second Annual Review Meeting the Project in December, 2015, the work on three constructs *viz*., *p*BMGF-DC-52, -57 and -58 were discontinued. More than 100 transformed transgenic plants of Grand Naine and Rasthali generated using construct *p*BMGF-53 are maintained in growth media in bottles (Fig. 67 & 68).

Fig. 67. Rasthali transgenic plants in growth media.

Fig. 68. Grand Naine transgenic plants in growth media

From the genetic DNA of 101 transgenics (53 Rasthali and 48 Grand Naine) generated from construct *p*BMGF-DC-53, presence of selectable marker *nptII* and gene of interest *OsNAS1* were confirmed using the gene-specific primers (Fig. 69).

PCR test was also performed with the primers of virC gene to check *Agrobacterium* contamination in transgenics and none of the transformed plants were found contaminated with *Agrobacterium*. Reverse Transcriptase-PCR confirmation were also carried in nine each of PCR-positive Rasthali and Grand Naine transgenics from the total RNA extraction and cDNA synthesis with â-actin gene as an internal reference gene.

Component - III. Development of efficient ECS for Rasthali and providing to Indian partners (S. Uma)

Sixty male flower buds of cv. Rasthali were supplied to IIHR, Bengaluru. Male flower buds of cv. Rasthali and Grand Naine were initiated at NRCB, Tiruchirapalli. To enhance the production of ideal callus in cv. Rasthali, different concentrations of 2,4-D was applied and ideal callus formation was observed in medium supplemented with 16.6 µM 2,4-D.

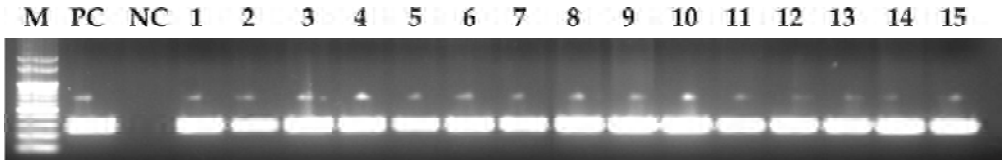


Fig. 69. Confirmation of presence of marker(*nptII*) and gene (*OsNAS*1) in transformed plants: M-Marker; PC-pBMGF-DC-53 plasmid DNA; NC-Negative control; 1-8-Rasthali transformed with *p*BMGF-DC-53 and 9-15-Grand Naine transformed with *p*BMGF-DC-53

Effect of different media on establishment and proliferation of embryogenic cell suspension of cv.Rasthali

Among six medium compositions tried, M6 (MS medium supplemented with 1.0 mg 2,4-D/l with 250mg/l zeatin and ascorbic acid 10mg/l) was found to the best in terms of suspension survival and proliferation after 3 months of initiation. Medium with half strength MS supplemented with growth regulators on transfer of calli resulted in browning of cultures thereby suggesting that nutrients in half strength are insufficient for proliferating cells to survive. In M5 medium the cells survived but the multiplication rate of cells was low due to the production of phenolics.

Time course growth of embryogenic cell suspension of cv. Rasthali

Grand Naine recorded the maximum proliferation rate in comparison with cv. Rasthali. The settled cell volume of cells increased with time period, but it is not necessary that SCV is directly proportional to germination percentage. It has been observed that with time and age, the germination capacity of cells tends to decline. Although the settled cell volume increases with time, the age of the suspension also determines the efficiency of germination of plantlets. The highest percentage of germination was recorded within 8-12 months of initiation of embryogenic cell suspension.

Effect of age and proliferation capacity of suspension on regeneration and germination percentage of plants in cv. Rasthali

The effect of age on regeneration capacity and germination of embryos was studied. The suspension cells were plated at different time intervals on regeneration medium and the number of somatic embryos produced was recorded. The maximum number of somatic embryos and percentage of healthy embryo production were recorded in 12th month. The regeneration percentage of 452.6 and germination percentage of 419.6 were observed to be the maximum and hence it was concluded that the optimum period of cell proliferation and effective regeneration of cells was 12 months after the initiation of suspension after which the regeneration percentage of the cell started to decline. However, cell proliferation and regeneration recorded a gradual decrease (Table 17).

Table 17. Effect of age and proliferation capacity of suspension on regeneration and germination percentage of plants in cv. Rasthali

Age of suspension (months)	No. of somatic embryos	Regeneration percentage	Germination percentage
3	256.0±1.30^{a}	149.2±1.77^{a}	141.8±1.28^{a}
6	391.8±0.66^{b}	327.4±2.21^{b}	310.4±1.77^{b}
8	455.0±1.73^{c}	429.4±1.63^{e}	415.7±1.31^{e}
10	461.8±2.45^{e}	432.4±0.50^{f}	416.2±1.37^{e}
12	482.4±0.50^{g}	452.6±2.01^{g}	419.6±1.72^{f}
14	456.3± 1.7^{d}	411.8±0.96^{d}	381.0±1.76^{d}
16	465.0±1.34^{f}	371.0±2.1^{c}	348.0±1.52^{c}

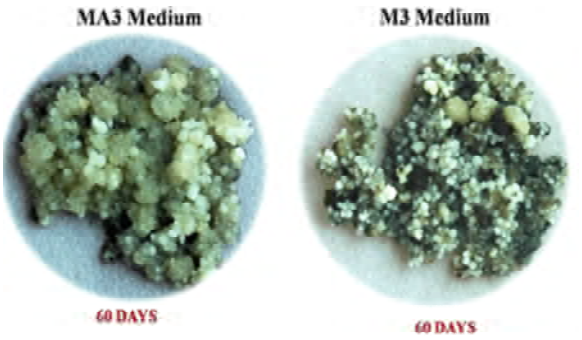
Means and percentages within columns with different letters are significant at the 0.05 level
Comparisons between different treatments were assessed by Student's t test analysis

ECS regeneration efficiency of cv. Grand Naine and cv. Rasthali of NRCB accession

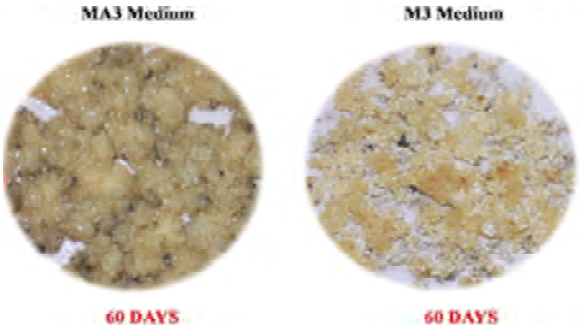
In cv. Grand Naine (NGFB0189) the regeneration efficiency of cell suspension was determined and it was found to produce 5877 somatic embryos from 1mL of settled cell volume (SCV). Rasthali ECS (NRFB0179) produced around 4017 somatic embryos from 1ml of SCV.

Standardization of medium for regeneration of somatic embryos in cv. Grand Naine

Two media (MA3 of INIBAP and M3 of QUT protocol) were subjected to the experiments and observed well developed somatic embryos after 60 days in cv. Grand Naine and cv.Rasthali (BARC) on M3 medium. The somatic embryos which developed on MA3 medium were translucent and not completely mature. (Fig. 70). The modified M3 medium with Proline (nitrogen source) and 2iP(cytokinin) performed better by regenerating somatic embryos.



cv.Grand Naine



cv.Rasthali

Fig. 70. Standardization of medium for regeneration of somatic embryos in cv. Grand Naine & Rasthali

4.5.5 Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis (M.S. Saraswathi)

Immature male flower buds of Rasthali (140) was initiated for callus induction and subsequent development of ECS. The calli derived from immature flower buds were suspended in liquid MA2 medium and developed ECS. ECS has been treated with EMS of 0.1, 0.2 and 0.3% concentrations at ½, 1, 1½ and 2 hour time intervals for the determination of LD_{50} (Fig. 71).

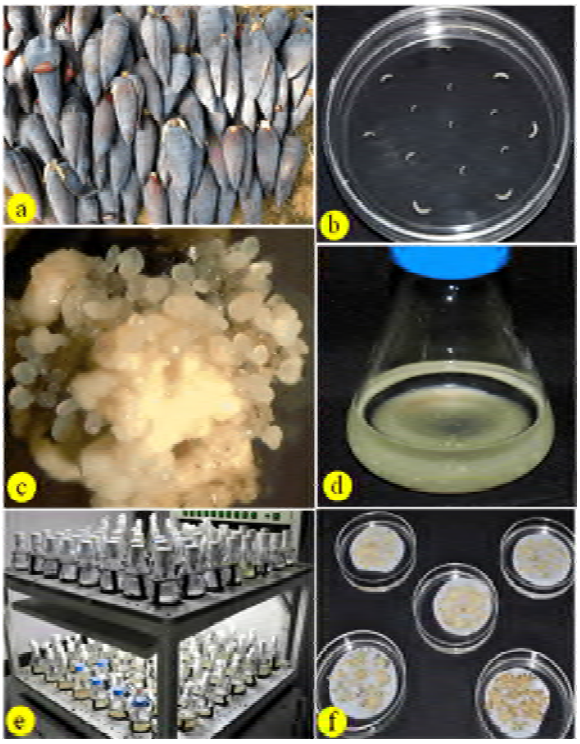


Fig. 71. Rasthali male flower buds, b. Initiated floral hands in callus induction medium, c. Ideal calli with pro embryos, d. Proliferation of cell suspension, e. Development of cell suspension under controlled environmental conditions, f. Mutagen treated cells in regeneration medium

4.5.6 DBT Project: Molecular approaches for the control of *Odoiporus longicollis*. Bio-assay trials using the wheat inhibitor against banana stem weevil grub, *Odoiporus longicollis* (B. Padmanaban)

Amylase inhibitor bioassay was conducted for monitoring banana stem weevil larval growth in amylase inhibitor infiltrated banana stem discs. One grub per stem disc was released and observed daily for grub mortality. Amylase inhibitor assay was conducted with seven treatments against 3rd instar stem weevil grub. 100% mortality was recorded on 10th day in the maximum concentration (75mg/20ml containing 150 units AI at 300x conc.) and in the treatment 37.5mg/20ml of concentration 90% mortality was recorded on 10th day. The low concentration (3.5mg/20ml) recorded 20% mortality on 10th day.

4.5.7 DST Project: Identification of molecular strategies for the control of *Cosmopolites sordidus*. Amylase inhibitor was activity was tested against corm weevil grubs (B. Padmanaban)

Wheat amylase inhibitor at 100x concentration (75mg/20ml) was tested against third instar grubs of corm weevil. The percentage inhibition was 56.33% and the enzyme activity was 4.04 units per larva.

4.5.8 CRP on Borers on network mode (B. Padmanaban)

Survey was conducted in search of natural enemies in the high land banana growing areas of Tamil Nadu (Kolli Hills, Shevroy Hills, Lower Pulney Hills, Sirumalai and Thenmalai hills). The search resulted in the collection of predatory insects like *Dermaptera, Formicids, Hydrophyllids* and *Staphylinids* and entomopathogenic fungi.

4.5.9 CRP on Nanotechnology on net work mode (B. Padmanaban)

Host solvent extract of susceptible cultivar was prepared and incorporated into the alginate gels for the evaluation of release rate and attractiveness.

4.5.10 Coffee Board Project: "Eco-friendly approaches for the management Coffee white stem borer, *Xylotrechus quadripes* Chev. (Coleoptera: Cerambycidae) (B. Padmanaban)

Research issues on the following such as importance of fumigation to the stem borer affected plants before disposal to prevent the spread of beetles to other areas. Modified funnel trap is suggested for pheromone trap to prevent the trapping of other insect fauna other than CWSB adults were carried out. Results indicated the complete destruction of stages present inside the stem and the modified funnel trap reduced the trapping of non-target insects.

4.5.11 Development of bio-pesticide formulation for reducing postharvest losses and for achieving export quality and increased shelf life of banana fruits (R. Thangavelu)

Evaluation of biocontrol agents for the management of post harvest diseases

Among 61 bacterial and 9 fungal biocontrol agents tested for mycelial inhibition of *Colletotrichum musae* and *Lasiodiplodia theobromae, Trichoderma asperellum* completely (100%) inhibited *C. musae* and *L. theobromae* whereas *T. longibrachiatum* inhibited *C. musae* (100%) and *L. theobromae* (80%). Further, the evaluation of volatiles of bio-control agents indicated that two fungal species, *viz*., *T. asperellum and T. longibrachiatum* was found inhibitory against *C. musae*.

Assessment of non-volatiles of biocontrol agents for inhibition of postharvest pathogens under *in vitro* condition

The effect of non-volatile metabolite production indicated that two fungal isolates viz. *T. asperellum and T. longibrachiatum* exhibited inhibitory activity against *C. musae* and *L. theobromae*. *T. asperellum* completely inhibited (100%) both *C. musae* and *L. theobromae* pathogens. *T. longibrachiatum* inhibited *C. musae* by 100% and *L. theobromae* by 80%. The metabolites of *T. asperellum* and *T. longibrachiatum* extracted from ethyl acetate fraction inhibited postharvest pathogens significantly at 50 µl concentration. The combined effect of metabolites extracted from ethyl acetate and *n*-butanol from individual organisms also inhibited both pathogens significantly.

Screening of different botanicals against postharvest pathogens of banana

In vitro screening of 55 botanical leaf extracts against *C. musae* and *L. theobromae* indicated that leaf extracts of *Solanum torvum, Rhinacanthus nasutus,* and zimmu inhibited > 50% mycelial growth of both *C. musae* and *L. theobromae*. Zimmu leaf extract at 50% v/v concentration recorded 100% mycelial inhibition and spore germination of both pathogens.

Evaluation of biocontrol agents and botanicals for inhibition of postharvest diseases and extension of shelf life of banana fruit

In vivo evaluation of biocontrol agents and botanicals on Grand Naine banana fruits indicated that *T. asperellum* (prr2) extended shelf life by 28 days at 23°C and 55 days at 13°C while bacterial isolate ACC13 extended the shelf life by 24 days at 23°C and 50 days at 13°C significantly as compared to control (15 days at 23°C and 22 days at 13°C) (Fig. 72).

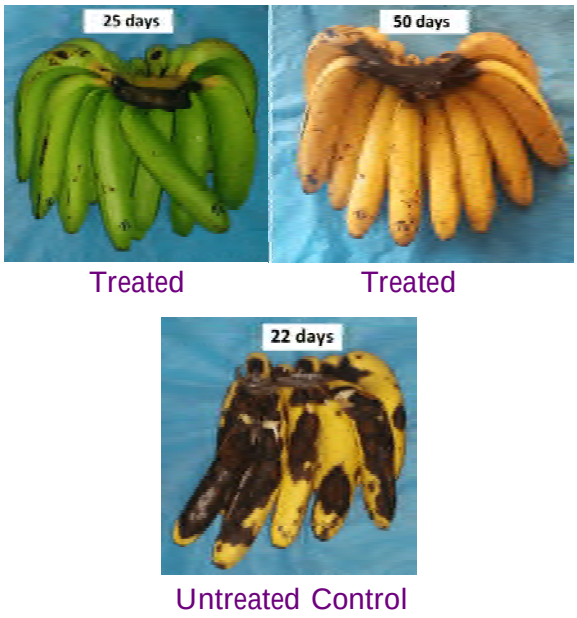


Fig. 72. Effect of *T. asperellum* treatment on the shelf life of banana fruits cv. Grand Naine

Isolation of principle compound from zimmu leaf extract

Out of eight fractions obtained from the ethyl acetate fraction of zimmu leaf extract by column chromatography, 7th and 8th fractions showed inhibitory effect against *C. musae* and *L. theobromae* under *in vitro* conditions.

4.5.12 ICAR-Network project on Fusarium wilt disease (R. Thangavelu)

Identification of differentially expressed genes in Fusarium wilt and biocontrol agent interaction in banana by SSH approach

Suppressive Subtractive Hybridization (SSH) was carried out on cv. Grand Naine retrieved 28 contigs and 44 single sequences with various functions. Three contigs (contig 6, 7 and 10) were identified to contain defence related functions. The gene ontology based annotation revealed that contig 6 was involved in peroxidase activity, contig 7 was involved in catabolic process and contig 10 was responsible for callose deposition in cell wall,

defence response to fungus, bacterium and chitin. These contigs were also involved in KEGG pathway (Kyoto Encyclopaedia for Genes and Genomes) in phenylalanine and phenylpropanoid biosynthesis. Functional annotation of hypothetical proteins yielded contig21 as endoribonuclease. Sequential docking showed that it has a role in defense pathway. miRNA binding properties and phytoalexin binding confirm that contig21 is a NPR1 homolog.

Profiling of non-volatile metabolites from *T. asperellum* for bioactivity against *Foc*

The extracellular and intracellular metabolites of *T. asperellum* obtained by re-suspension in methanol was found effective in inhibiting the mycelial growth of *Foc*. Out of 12 fractions of *T. asperellum* (Prr2) separated by column chromatography, fraction 12 inhibited mycelial growth as well as 100% inhibition of spore germination of *Foc* under *in vitro* conditions (Fig. 73 & 74).

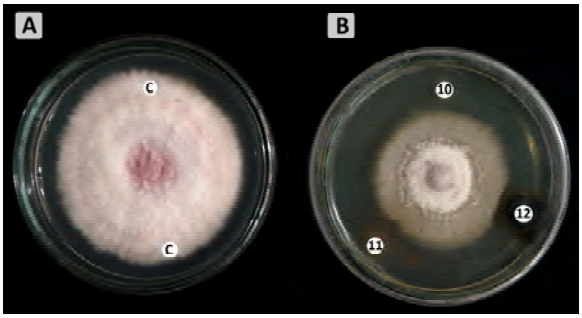


Fig. 73. Effect of *T. asperellum* (prr2) metabolites fractionated by column chromatography on *Foc* by disc diffusion method. A) Control with methanol, B) Column fractions 10, 11 and 12 against *Foc*.

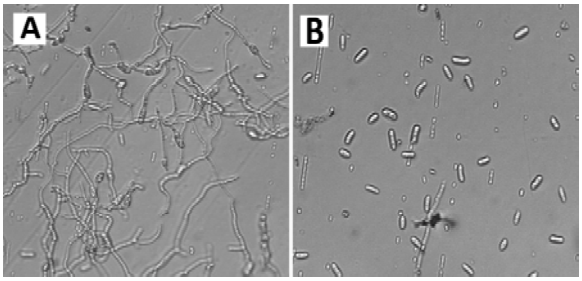


Fig. 74. Spore inhibition screen for *Foc* by column fractioned metabolites of *T. asperellum* (prr2). A) *Foc* control (72hrs), B) *Foc* with fraction 12 metabolite of *T. asperellum* (prr2)

4.5.13 DBT Project: Evaluation of transgenic banana for resistance to banana bunchy top virus (R. Selvarajan)

One hundred and two batches of co-cultivation were carried out with 8 ECS-lines using BBTV-rep gene construct to generate transgenic plants. Fifty-two plants were regenerated and are in hardening stage. Among 52, three were positive in PCR. Five southern positive transgenic lines were multiplied through shoot tip culture. Challenge inoculation was done with viruliferous banana aphid (*Pentalonia nigronervosa*). All the untransformed control plants showed typical BBTD symptoms after 11-15 days of inoculation whereas all tested transgenic lines did not show any symptoms.

4.5.14 Network project on transgenics in crops-transgenic component (R. Selvarajan)

Twenty-two batches of co-cultivation were done with pBINAR: BBTVCP construct from twelve fresh lines of ECS. Thirty batches of co-cultivation were carried out with eight ECS-lines using RNAi construct for multivirus to generate transgenic plants. Both co-cultivated batches are under regeneration stage. Southern positive (BBTV-CP) plants were maintained in transgenic glass house. These plants were inoculated with BBTV using insect vector *P. nigronervosa* and were kept in a contained area for monitoring symptom expression or resistance. No expression of symptoms was observed in three lines.

4.5.15 DBT-ATL scheme for virus indexing - contract services (R. Selvarajan)

Mother cultures of tissue cultured banana plants received from 47 TC industries were

tested for banana viruses under contract service as well as DBT–ATL scheme. Totally 15373 samples were tested for the presence of viruses. The number of positives for BBTV, BBrMV and CMV were 13, 10 and 6, respectively. This year, certificate of quality was issued for 19.17 million TC plants.

4.5.16 Proteomic studies of host-pathogen interactions in banana-banana bract mosaic virus (BBrMV) system (C. Anuradha)

Protein isolation from leaf, bract and pseudostem

Four protein extraction methods, *viz*., chloroform/acetone, tris-base/acetone, Phenol/Ammonium acetate (PAA) and TCA methods were evaluated for leaf, bract and pseudo stem of banana cv. Nendran for 2-DE analysis. Proteins were extracted from cigar leaf, bract and pseudostem of BBrMV infected and healthy banana plants and separated by SDS and 2-DE. Both PAA and TCA extraction gave higher protein yield and greater number of proteins spots than the other two methods for all the tissues under study. The spot resolution was higher in PAA method as compared to the other three methods. Different parameters such as quantity of protein required, rehydration time, and volt hours required for focusing of protein for 2DE were optimized.

Leaf proteomics

A total of H"1000 reproducible spots were identified in each of the healthy and infected Nendran banana leaves. Forty protein spots that showed two-fold difference in intensity were selected for PMF (Fig. 75). Of these, 13 were - and 27 were down-regulated. These proteins were found to be involved in defence, signal transduction, cell structure and function, photosynthesis and energy, plant growth, protein designation/storage and transcription/translation. Phosphoglycerate mutase-like protein, rice tungro bacilliform virus P46 protein, pre-sequence translocase-associated protein import motor (PAM), peptidyl-prolyl cis-transisomerase, ring finger domain were upregulated upon infection and can be exploited as disease biomarkers.

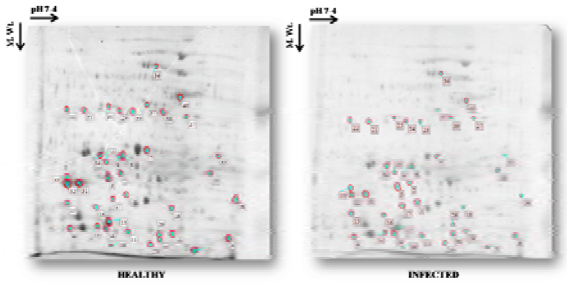


Fig. 75. CCB-stained 2-DE gel of proteins from healthy and infected Nendran leaf

Pseudostem proteomics

Over 1000 reproducible spots were identified and 30 spots which were found to show two-fold difference were sent for PMF by MS (Fig. 76). Of these 27 proteins identified by PMF, 15 were up-regulated and 12 got down-regulated in BBrMV infected samples. These proteins were found to be involved in defense, signal transduction, cell structure and function, photosynthesis and energy, plant growth, protein designation/storage and transcription/translation. Translation initiation factor IF-2, small heat shock protein 23.6, rho GDP-dissociation inhibitor 1-like, glutathione S-transferase, and tubulin—tyrosine ligase-like protein 12 were upregulated upon infection.

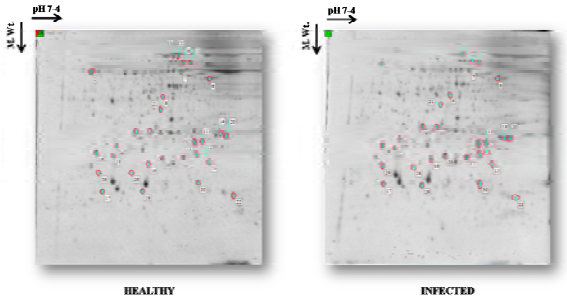


Fig. 76. CCB-stained 2-DE gel of proteins from healthy and infected Nendran pseudostem

Bract proteomics

More than 1000 reproducible spots were identified and 30 spots which were found to show two-fold difference were sent for PMF by MS (Fig. 77). Of those, 13 were up-regulated and 17 got down-regulated in BBrMV infected samples. These proteins were found to be involved in defence, signal transduction, cell structure and function, photosynthesis and energy, plant growth, protein designation/storage and transcription/translation. Putative receptor kinase, granule-bound starch synthase, putative disease resistance protein RGA1-like, 8S globulin alpha isoform precursor, electron transfer flavoprotein subunit beta, mitochondrial were upregulated upon infection.

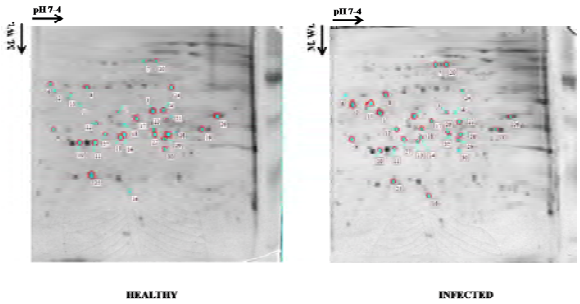
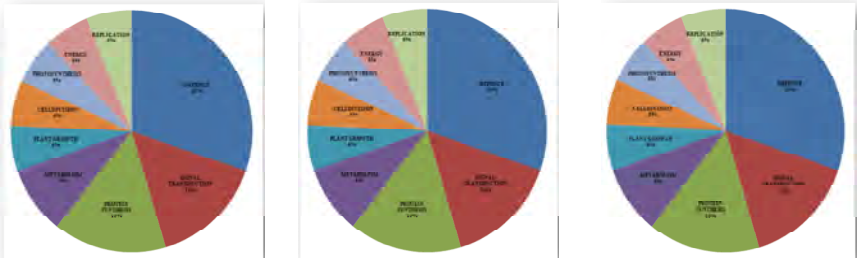


Fig. 77. CCB-stained 2-DE gel of proteins from healthy and infected Nendran bract

Functional annotation was carried out for these identified proteins from different tissues of healthy and infected Nendran plants. These proteins were found to be involved in defence, signal transduction, cell structure and function, photosynthesis and energy, plant growth, protein designation/storage and transcription/translation (Fig. 78).

Validation of differentially expressed proteins from shoot by biochemical analysis of antioxidative enzymes

Oxidative stress in compatible virus-host plant interactions was studied in BBTV-infected cvs. Nendran and Poovan. Quantifiable changes in physiological and biochemical parameters such as proteins, phenolic compounds, polyphenol oxidase (PPO), peroxidase (POX), ascorbate peroxidase (APX), guaiacol peroxidase (GPX), catalase (CAT) and superoxide dismutase (SOD) activities were observed between BBrMV infected and healthy leaves of banana cultivars. Phenols, total proteins, SOD and GPX activities were significantly higher in leaves of BBrMV infected plants of both the cultivars than in healthy plants, whereas catalase, APX, PPO and POX activities showed a reverse trend.



Shoot Bract Pseudostem

Fig. 78. Functional annotation of differentially regulated proteins

5 TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Training

More than 5800 visitors comprising banana farmers/ entrepreneurs/ horticultural/ agricultural officers/ college students visited ICAR-NRCB and they were briefed about improved production, protection technology, postharvest management and value addition of banana.

5.2 Radio talks through All India Radio, Tiruchirapalli

Name of the Scientist	Topic	Date of broadcast
K.J. Jeyabaskaran	Soil and fertilizer management in banana (Tamil)	12 April, 2014
K.N. Shiva	Importance of dehydrated banana and its marketing strategies (Tamil)	18 June, 2014

5.3 Television talks

Name of the Scientist	Topic	Date of telecast & TV Channel
K.N. Shiva	Value added products from banana (Vazhayiliruinthu mathiputtapatta porutkkal - Tamil)	24 -25 Dec., 2014, DD - Pothigai, Chennai
	Production of handicrafts from banana fiber (Vazhai naarilirunthu khaivinai porutkkal undakkuthal –Tamil)	12 - 14 Jan., 2015, Puthiya Thalaimurai, Chennai

5.4 Exhibitions organised / participated

Name of the Events	Organiser / venue	Date(s)
Organised		
Kissan Mela - 2014	ICAR-NRCB, Tiruchirapalli, Tamil Nadu	21Aug., 2014
Workshop on village farmers	ICAR-NRCB and NAARM, Koppu, Karur District, Tamil Nadu	3 Sep., 2014
Musa germplasm: Identification towards optimizing use'-Exhibition on indigenous *Musa* diversity	ICAR-NRCB, Tiruchirapalli, Tamil Nadu	6 Dec., 2014
3rd CII Banana Festival	CII, ICAR-NRCB & TABAGRFD, Tiruchirapalli, Tamil Nadu	20 - 21Dec., 2014
National Science Day-2015	ICAR-NRCB, Tiruchirapalli, Tamil Nadu	11 Mar., 2015

Name of the Events	Organiser / venue	Date(s)
Participated		
International HORTI INTEX - 2014	TNAU and CODISSIA, CODISSIA trade fair complex, Coimbatore, Tamil Nadu	7 - 9 Sep., 2014
Agri Expo – 2014	Dinamalar (Tamil Daily), Thanjavur, Tamil Nadu	19-22 Dec., 2014
Southern Regional Agricultural Fair - 2015	TNAU, Coimbatore, Tamil Nadu	7- 9 Jan., 2015
National Agri Fest -2015	KAU and Govt. of Kerala, Pupoly, Ambalavayal, Kerala	20 Jan., 2015 to 3 Feb., 2015
12th Agricultural Science Congress/ India Expo-2015	NDRI and NAAS, NDRI, Karnal, Haryana	3 - 6 Feb., 2015
Eastern Zone Regional Agriculture Fair-2015	CPRI – RS, Patna, Bihar	19 - 21 Feb., 2015
National Agri Fest -2015	Ministry of Agriculture and Govt. of Kerala, Wayanad, Kerala	10 - 17 Feb., 2015
National Farmer's Meet	TNAU, Regional Station, Paiyur, Tamil Nadu	14 Mar., 2015
Workshop on Banana technology cum Farmer's Fair	IIVR, Kushinagar, U.P.	26 Mar., 2015
TSP Programme	Mananthavadi and Agali, Kerala	18 - 20 Mar., 2015
5th SICCI Agri Summit- 2015	SICCI, St. John's Vestry School, Tiruchirapalli, Tamil Nadu	13 - 15 Mar., 2015

Thiru. R. Vaithilingam, Minister for Housing, Urban Development and Agriculture, Govt. of Tamil Nadu and Dr.N.K.Krishna Kumar, DDG (Hortl. Sci.), ICAR, New Delhi visit to ICAR-NRCB stall during National Farmer's Meet, at TNAU-RRS, Paiyur, Tamil Nadu on 14. 03.2015

Farmers visit to ICAR-NRCB stall during CII Banana Festival at Tiruchirapalli, Tamil Nadu on 20.12.2014

5.5. Publicity

Different press notes on ICAR-NRCB activities/ function/ technological information/ articles totaling 25 nos. were published in different national and local dailies including Tamil magazines/ journals, AIR-farm division etc. for the benefit of farmers.

Dr. N.K. Krishna Kumar, DDG (Hortl. Sci.) - ICAR interview with press during 2nd *Musa* workshop

Subject	Date
About ICAR-NRCB activities	8 Apr., 2014
Banana waste recycling – Vermicomposting	16 Apr., 2014 & 24 Feb., 2015
Management of banana cultivation during raining season	10 May, 2014
Abiotic stress management in banana cultivation	17 May, 2014 & 28 May, 2014
Management of banana cultivation during wind and summer seasons	28 May, 2014
Advances in banana fruit care	29 May, 2014
Tissue culture-banana cultivation	31Jun., 2014 & 15 Nov., 2014
Banana cultivation through micropropagation	1 Jul., 2014
NRCB at a glance and advanced technologies on banana cultivation	2 Jul., 2014
Tissue culture technology in banana	8 Jul., 2014 & 31 Jul., 2014 & 2 Aug., 2014
Wilt and leaf spot diseases management in banana cultivation	12 Jul., 2014
Banana production technology and post-harvest technology	8 Aug., 2014
Banana kissan mela with the theme on "Drought management in banana" at ICAR-NRCB	20 Aug., 2014
21th ICAR-NRCB Foundation day	21 Aug., 2014
Soil management in banana production	26 Nov., 2014
Aphid management in banana cultivation	24 Oct., 2014 & 19 Mar., 2015
Nutrient management in banana cultivation during the raining seasons	25 Oct., 2014

Subject	Date
Udhayam and export varieties of banana	29 Oct., 2014
Leaf spot disease management in banana	27 Oct., 2014
Importance of banana and success stories of ICAR-NRCB	10 Nov., 2014
Commercial varieties of banana	18 Nov., 2014
Fungal disease management in banana cultivation during the raining and winter seasons	1 Dec., 2014
MusaNet workshop on '*Musa* germplasm'	6 Dec., 2014
Sucker selection and sucker treatment in banana cultivation	16 Dec., 2014
Advanced technologies on banana cultivation and disease management in banana	1 Jan., 2015
High density planting techniques in banana	10 Jan., 2015
Weevil management in banana cultivation	8 Feb., 2015

6 EDUCATION AND TRAINING

6.1 Students guided

Student Name	Degree	Project title	Guide
R. Kushpu	M.Sc., (Microbiology)	Screening of endophytic fungi and their secondary metabolites against banana aphid, *Pentalonia nigronervosa*	B. Padmanaban
S. Sathish	M. Phil., (Biotechnology)	Isolation and characterization of rhizome rot pathogen of banana and its suppression using biocontrol agents and botanicals	R. Thangavelu
Susila Subbiah	M.Tech., (Biotechnology)	Molecular cloning and sequence analysis of complete genome of banana streak virus species infecting banana cv. Rasthali	R. Selvarajan
C.P. Sri Snehaa	M.Tech., (Biotechnology)	Cloning, sequencing analysis of banana bract mosaic virus (BBrMV) genes (Vpg and NIa) in banana cultivars	
R. Akila Sri Krithika	B.Tech., (Biotechnology)	Quantification of banana bract mosaic virus in different plant tissues and mass multiplication of hill banana through shoot tip culture	
T. Ananth	M.Sc., (Biotechnology)	Iron content and ferritin gene expression in different parts of banana cv. Rasthali	M. Mayil Vaganan
R. Radhika	M.Sc., (Biotechnology)	Validation of putative nematode resistant SSR and SNP markers across resistant and susceptible *Musa* cultivar	S. Backiyarani
J. Sindhuja	M.Sc., (Biotechnology)	Expression profiling of genes involved in lignin biosynthesis pathway during *Pratylenchus coffeae* infestation in banana	
U. Udhayavani	M.Sc., (Biotechnology)	DNA profiling of *Musa* wild species of North Eastern India using ISSR markers	M.S. Saraswathi
S. Minnalkodi	M.Sc., (Biotechnology)	Studies on the effect of microbial cultures on rooting and hardening of banana (*Musa* spp.) variety Udhayam (Pisang Awak – ABB)	
M. Illakeya	M.Sc., (Biotechnology)	Genetic fidelity testing of tissue cultured banana cv.Rasthali raised using low cost tissue culture medium and effect of anti-oxidants and growth regulators on *in vitro* multiplication of *Musa* spp. variety Neypoovan (AB)	

6.2 Trainings

6.2.1. On-Campus Training

Title	Date	No.of Participants	Course Coordinator(s)
Advances in banana cultivation (sponsored by Agriculture Skill Council of India (ASCI), Gurgaon, Haryana)	14-17 May, 2014	25	V. Kumar & all scientists
Production of banana through macropropagation	26 June, 2014	1	M.S. Saraswathi
Improved production and post harvest management technologies in banana (to the officials of Vegetable and Fruit Promotion Council Keralam (VFPCK), Kerala)	15 July, 2014	15	V. Kumar & B. Padmanaban
Production of banana flour and biscuits	8-10 Sept., 2014	1	K.N. Shiva
Improved production and post harvest management of banana under the Capacity Building for the Adoption of Technologies (CAT) Visit program of NABARD for the banana growers of Andhra Pradesh	5 Nov., 2014	30	V. Kumar & B. Padmanaban
MusaNet training cum workshop on *Musa* germplasm: Identification towards optimizing use	6-12 Dec., 2014	31	S. Uma
Production of banana flour and flour based baby food, health drink and central core stem juice	29-31 Dec., 2014	1	K.N. Shiva
Production of banana fig	10-11 Mar., 2015	1	K.N. Shiva
Improved production and post harvest management of banana (to the farmers/ officials of Malappuram, Kerala)	19 Feb., 2015	25	V. Kumar & B. Padmanaban

6.2.2. Off-Campus Training

Title	Period	No. of participants	Course Co-ordinator(s)
Improved production and integrated pest and disease management for enhancing the productivity of quality Grand Naine tissue culture bananas in collaboration with CII-FACE, New Delhi (USAID Programme) at Pollerhat in South 24 Parganas Dist., Karuigachi and Harekrishnapur, Nadia District, West Bengal	15 - 17 April, 2014	220	V. Kumar, B. Padmanaban & R. Thangavelu
Production and protection of banana landraces under the DBT funded project on conservation and regeneration of near extinct landraces of Kolli Hills, Semmedu, Kolli Hills, Namakkal District, Tamil Nadu	19 June, 2014	110	S. Uma, M.S. Saraswathi, K.J. Jeyabaskaran, B. Padmanaban & R. Thangavelu
Value addition for entrepreneurship development, Saraswathi-KVK, Pulutheri, Karur District, Tamil Nadu	22 Aug., 2014	50	K.N. Shiva
Production and post-harvest management, value addition and waste utilization of banana in collaboration with CII-FACE, New Delhi at Pollerhat in South 24 Parganas and Nadia Districts, West Bengal	3-6 Sept., 2014	170	V. Kumar & K.N. Shiva
Farmers' training programme on macropropagation at Semmedu, Kolli Hills, Namakkal District, Tamil Nadu	24 Sept., 2014	32	S. Uma
Farmers' training programme on macropropagation at Vellarikattupatti, Kolli Hills, Namakkal District, Tamil Nadu	25 Sept., 2014	28	S. Uma
Training cum demonstration of banana fibre extraction machine and distribution of farm inputs to the tribal banana farmers of Mananthavady, Wayanad district and Agali, Palakkad district Kerala under the TSP programme	19-20 Mar., 2015	300	M.M. Mustaffa & V. Kumar
Training cum demonstration of banana fibre extraction machine and distributed	30 Mar., 2015	150	M.M. Mustaffa & V. Kumar

Title	Period	No. of participants	Course Co-ordinator(s)
inputs to the tribal farmers of Rampachodavaram, East Godavari, Andhra Pradesh under TSP programme			
Demonstration of bunch and mat management techniques and identification of pests and diseases, deficiency symptoms etc., in banana cultivation in the farmers' fields in and around Vijayawada, Andhra Pradesh	31 Mar., 2015	75	M.M. Mustaffa & V. Kumar

Demonstration of banana fibre extraction machine to the tribal farmers of Mananthavady, Wayanad district, Kerala

Off Campus training under consultancy programme on improved cultivation of tissue culture Grand Naine banana at West Bengal

Distribution of bnanana bunch sleves to the banana tribal farmers of Mananthavady, Wayanad district, Kerala

Distribution of banana inputs to the tribal banana farmers in Agali, Palakkad district, Kerala

7 AWARDS AND RECOGNITIONS

7.1 Awards

Name of Scientist	Name of the award	Awarded by / Organizer / Place / Date
B. Padmanaban R. Thangavelu	"Fellow of CHAI for the year 2014"	Confederation of Horticulture Associations of India (CHAI), New Delhi

7.2 Recognitions

Name of the Scientist	Particulars
B. Padmanaban	Life Member, Confederation of Horticultural Association of India (CHAI)
	Life Member, Plant Protection Association of India, Hyderabad
S. Uma	Member in international scientific committee of the ISHS
	External member for Ph.D student in TNAU, Coimbatore
	Horticulture society of India as executive councilor (southern zone) for the period 2015-2018
	Editorial member of the journal - Current Horticulture
	Key speaker in the Brain storming session on somatic embryogenesis and use of bioreactors at CPCRI, Kasaragod, Kerala
R. Thangavelu	External examiner for M.Sc. and Ph.D. students at KAU, Thiruvananthapuram, Kerala; CAU, Meghalaya and TNAU-Tamil Nadu
	Reviewer for European journal of plant pathology, Indian
	phytopathology and African journal of microbiology research
R. Selvarajan	Local coordinator for Field Experience Training (FET) programme 100th FOCARS, NAARM
	Co-organizing secretary for National Conference of Indian Virological Society (IVS), TNAU, Coimbatore
	Secretary (Plant Virus) of the IVS (2014-2017)
	Nodal officer for Knowledge Based Resources Information Systems Hub for Innovations in Agriculture (KRISHI) portal of ICAR –NRC BANANA and Agricultural Science & Technology Indicators (ASTI) of ICAR-NRCB
	Member in the evaluation committee, TNAU, Coimbatore

Name of the Scientist	Particulars
	Editor of Virus Disease (2014-15)
	External examiner for M.Sc/ Ph.D thesis, TNAU, Coimbatore; Department of Plant Biotechnology-Madurai Kamaraj University and Kuvembu University, Karnataka
V. Kumar	External examiner for M.Sc. (Hort.)/ Ph.D. thesis at TNAU, Coimbatore
K.N. Shiva	Evaluated 'DPR on Establishment of Integrated Pack-house in Tiruchirapalli'
	Nodal Officer of NEH (North East Hill Region) programme
	Member in the assessment committee for Ph.D. at Bharathidasan University, Tiruchirappalli
	Member, Executive Council of Indian Society for Spices, IISR, Calicut (2013-2015)
M.S. Saraswathi	Member, Ph.D. Bharathidasan University, Tiruchirapalli
	Reviewer for the Indian journal of experimental botany
	External examiner for Ph.D - thesis VNMKV, Parbhani, Maharashtra
C. Anuradha	Member, Agricultural bioinformatics and computational biology (NARES)

8 LINKAGES AND COLLABORATIONS

- A collaborative project on "Development of mechanization package for rope making from outer sheath of banana pseudostem" was initiated between CIAE-RS, Coimbatore and ICAR-NRCB, Tiruchirapalli, Tamil Nadu.
- An externally funded collaborative project on 'Developing post-harvest mechanization package for banana central core' was initiated on April, 2014 between CIAE-RS, Coimbatore and ICAR-NRCB, Tiruchirapalli sponsored by MoFPI (GoI), New Delhi.

9 PUBLICATIONS

9.1 Research Papers

9.1.1 International

Backiyarani, S., Uma, S., Nithya, S., Chandrasekar, A., Saraswathi, M.S., Thangavelu, R., Mayil Vaganan, M., Sundararaju, P. and Singh, N.K. 2015. Genome-wide analysis and differential expression of chitinases in banana against root lesion nematode (*Pratylenchus coffeae*) and eumusae leaf spot (*Mycosphaerella eumusae*) pathogens. *App. Biochem. and Biotech.* DOI 10.10007/s/2010-015-1528-Z.

Backiyarani, S., Uma, S., Saraswathi, M. S., Saravanakumar, A.S. and Chandrasekar, A. 2015. Transcriptome analysis of banana (*Musa balbisiana*) based on next generation sequencing technology. *Turkish Jr. Agrl. and Forestry*. **39**: DOI: 10. 3906/tar-1406-171.

Elayabalan, S., Subramaniam, S., Selvarajan, R. 2015. Banana bunchy top disease (BBTD) symptom expression in banana and strategies for transgenic resistance. *Emirates J. Food and Agrl.* **27**(1): 55 - 74.

Gopi, M. and Thangavelu, R. 2014. Suppression of Fusarium wilt disease of banana by Zimmu (*Allium cepa* x *Allium sativum*) leaf extract. *African J. Microbiol. Res*. **8**(31): 2904 - 2915.

Ravichamy, P., Nandakumar, S. and Sivabalan, K.C. 2014. Mass media interventions and technology transfer among banana growers: Experiences from Tamil Nadu, India. *Inter. J.Emerging Tech. Comp. App. Sci.* **9**(3): 204 - 209.

Selvarajan, R., Balasubramanian, V. and Sasireka, T. 2015. A simple, rapid and solvent free nucleic acid extraction protocol for detection of banana bunchy top virus by polymerase chain reaction and loop-mediated isothermal amplification. *European J. Plant Path.* **142**: 389 - 396.

9.1.2 National

Balasubramanian, V., Sukanya, R. S., Anuradha, C., Selvarajan, R. 2014. Population structure of banana bract mosaic virus reveals recombination and negative selection in the helper component protease (HC-Pro) gene. *Virus Disease.* **25**(4): 460 - 466.

Ganga Devi, P. and Thangavelu, R. 2014. Genetic diversity analysis of *Mycosphaerella eumusae* causing *Septoria* leaf spot disease of banana in India. *Indian Phytopath*. **67**(4): 388-395.

Jeyabaskaran, K.J., Mustaffa, M.M. and Murugan, V. 2013. Development and evaluation of soil test based fertilizer tailoring equations for Ney Poovan and Nendran bananas. *Inter. J. Innovative Hort.* **2**(2): 142-148.

Lava Kumar, P., Selvarajan, R., Iskra-Caruana, M.L., Chabannes, M., Hanna, R. 2015. Biology, etiology, and control of virus diseases of banana and plantain. *Adv. Virus Res.* **91**:229-269.

Mayil Vaganan, M., Sarumathi, S., Nandakumar, A., Ravi, I. and Mustaffa, M. M. 2015. Evaluation of different protein extraction methods for banana (*Musa* spp.) root proteome analysis by two-dimensional electrophoresis. *Ind. J. Biochem. Biophys*. **52**: 101-106.

Ravi, I. and Mustaffa, M.M. 2014. Leaf gas exchange characters of *Musa* AB 'Ney Poovan' and *Musa* ABB (Pisang awak) 'Karpuravalli'. *The Andhra Agricultural J.* **61**(4): 890 - 896.

Ravi, I., Mayil Vaganan, M. and Mustaffa, M.M. 2014. Bananas grown in salt affected soil impairs fruit development in susceptible cultivars. *The Andhra Agricultural J.* **61**(3): 638 - 642.

Sajith, K.P., Uma, S., Saraswathi, M.S., Backiyarani, S. and Durai, P. 2014. Macropropagation of banana - Effect of bio-fertilizers and plant hormones. *Indian J. Hort.* **71**(3): 299 - 305.

Saraswathi, M.S., Praveena, S., Uma, S., Thangavelu, R., Kannan, G., Backiyarani, S. and Arivazhagan, T. 2014. Development of an efficient micropropagation technique for *Musa* cv. Udhayam (ABB). *Indian J. Hort.* **71**(4): 452 - 457.

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9.2 Popular articles

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Jeyabaskaran, K.J. and Mustaffa, M.M. 2014. *Vaazhaiyil kaalanilai pirachchanaigalai samaalippathu eppadi?* (Tamil). How to overcome inclement weather in banana cultivation? *Kootturavu*. **87**(6): 60 - 64.

Jeyabaskaran, K.J. and Mustaffa, M.M. 2015. *Vaazhai pannai kazhivukalai marusuzharchi seythal* (Tamil). Recycling of banana waste. *Vanoli Uzhavar Sanga Seithikathir.* March, pp. 40 - 43.

Jeyabaskaran, K.J., Kumar, V. and Mustaffa, M.M. 2014. Production of vermicompost using banana farm wastes (Tamil). *Kootturavu.* **87**(2): 48 - 54.

Kumar, V. 2015. How to select ideal planting materials for banana? (Tamil). *Pasumai Vikatan.* January. pp. 46 - 48.

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Saraswathi, M.S. and Mustaffa, M.M. 2014. *Thisu valarppu vazhai sagupadi. Velan Vaniga Ulagam*. September, pp. 34 - 37.

Saraswathi, M.S. and Mustaffa, M.M. 2014. *Thisu valarppu vazhai sagupadi. Indraiya Velanmai*. November, pp. 14 - 17.

Saraswathi, M.S. and Mustaffa, M.M. 2015. *Thisu valarppu vazhai sagupadi. Naveena Velanmai*. January, pp. 26 - 30.

Selvarajan, R. 2015. "On-site detection of plant pathogens using nano-technological approaches". in ICAR sponsored short course on 'Nanotechnology tools for crop health and risk assessment techniques' organized by Dept. of Nano science and Technology, TNAU, Coimbatore. February 18 to 27.

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Selvarajan, R., Balasubramanian, V. and Shiv Kant Shukla. 2014. Diagnostics to ensure virus free quality tissue culture banana under national certification system. 'In: XXIII National conference of indian virological society (IVS), 'VIROCON 2014' on 'Recent trends in virology research in the omics era' at the Department of Plant Pathology, TNAU, Coimbatore. December 18 to 20. pp. 15 - 25.

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Uma, S. and Kumar, V. 2014. Bananas after banana - commercial varieties of banana (Tamil). *Pasumai Vikatan*. December, pp. 30 - 32.

Uma, S. and Saraswathi, M.S. 2014. *Kuzhandaikalukku Matti, Samaiyalukku Adukku Monthan*. *Pasumai Vikatan*. December, pp. 55 - 57.

9.3 Books / Book Chapters

Backiyarani, S., Uma, S., Saraswathi, M.S. and Chandrasekar, A. 2014. Transcriptome analysis of *Musa* and its applications in banana improvement (Ed. Nandwani, D.). *Sustainable horticultural system issues technology and innovation series: Sustainable development and biodiversity*, Vol. 2 Springer International Publishing pp. 275 - 299. ISBN 978-3-319-06904-3.

Hazarika, B.N., Sankaran, M., Rema Menon, Sudha, R., Jai Prakash, Suresh Kumar, P., Shiva, K.N., Romen Singh, S. and Rabha, A. 2014. Banana. In: *Tropical and Sub tropical fruit crops: Crop improvement and varietal wealth* (Part-1) (Ed. S.N. Ghosh). Jaya Publishing House, Delhi, pp. 71 - 136.

Mustaffa, M.M. and Shiva, K.N. 2014. Banana Industry: Way Forward – An Indian Perspective. In: *Horticulture for inclusive growth* (Eds. Chadha K.L., Kalia, P. and Singh, S.K.). The Horticultural Society of India and Westville Publishing House, New Delhi, pp. 33 - 40.

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9.4 Technical bulletins

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Jeyabaskaran, K.J. and Mustaffa, M.M. 2014. Nutritional deficiencies and their remedies in banana (English). ICAR-National Research Centre for Banana, Tiruchirapalli. p10.

Kumar, V. and Mustaffa, M.M. 2014. Improved banana cultivation practices (English). ICAR-National Research Centre for Banana, Tiruchirapalli. p. 42.

Selvarajan, R. and Mustaffa, M.M. 2014. Viral diseases of banana (Tamil). ICAR-National Research Centre for Banana, Tiruchirapalli. p. 20.

Selvarajan, R. and Mustaffa, M.M. 2014. Viral diseases of banana (English). ICAR-National Research Centre for Banana, Tiruchirapalli. p. 20.

Uma, S., Saraswathi, M.S., Backiyarani, S., Durai., P. and Mustaffa, M.M. 2014. Banana -Less exploited landraces in India (English). ICAR-National Research Centre for Banana, Tiruchirapalli. p. 60.

Uma, S., Saraswathi, M.S., Durai., P., Mustaffa, M.M. and Anushma, P. 2014. Description of wild *Musa* species of Arunachal Pradesh, India. p. 56.

9.5 Extension / technical folders / reports / scientific reviews

Anuradha, C. and Mustaffa, M.M. (Eds.). 2013. *E*-Newsletter of ITMU, Vol. II, Issue No. 2. ICAR-National Research Centre for Banana, Tiruchirapalli. p. 4.

Mayil Vaganan, M., Ravi, I. and Mustaffa, M. M. 2014. Banana: A nutritive and nutraceuticals-rich fruit (English). Tech. folder no. 4. ICAR-National Research Centre for Banana, Tiruchirapalli. p.4.

Mayil Vaganan, M., Ravi, I. and Mustaffa, M. M. 2014. Banana: A nutritive and nutraceuticals-rich fruit (Tamil). Tech. folder no. 5. ICAR-National Research Centre for Banana, Tiruchirappalli. p.4.

Padmanaban, B., Mayil Vaganan, M., Ravichamy, P., Anuradha, C. and Saraswathi, M. S. 2014. Annual Report 2013 - 14. ICAR-National Research Centre for Banana, Tiruchirapalli. p.104.

Ravi, I., Mayil Vaganan, M. and Mustaffa, M. M. 2014. Management of drought and salt stresses in banana (English). Tech. folder no. 6. ICAR-National Research Centre for Banana, Tiruchirappalli. p.4.

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9.6 Training Manuals

Kumar, V. and Mustaffa, M. M. 2014. Improved production technologies including post harvest management and value addition in banana. ICAR-National Research Centre for Banana, Tiruchirapalli. p.60.

Shiva, K.N. and Marimuthu, N. 2014. Technical know-how of banana flour and biscuits. ICAR-National Research Centre for Banana, Tiruchirapalli, Tamil Nadu. p. 27.

Shiva, K.N. and Marimuthu, N. 2014. Technical know-how of banana flour, banana flour based baby food and health drink and banana central core (stem) juice. ICAR- National Research Centre for Banana, Tiruchirapalli, Tamil Nadu. p. 33.

Shiva, K.N. and Marimuthu, N. 2015. Technical know-how of banana fig. ICAR - National Research Centre for Banana, Tiruchirapalli, Tamil Nadu, P. 30.

9.7 Research papers/ Abstracts/ Presentations in Conferences/ Symposia/ Seminars/ workshop and other fora

9.7.1 International

Backiyarani, S., Uma, S., Chandrasekar, A., Saravana Kumar, A.S. and Saraswathi, M.S. 2015. Musatrans SSRDB- A transcriptome derived SSR database: An advanced tool for banana improvement. 5th International conference on next generation genomics and integrated breeding for crop improvement, ICRISAT, India. February 18 - 20. pp114.

9.7.2 National

Anuradha, C. and Selvarajan, R. 2014. Proteomics to unravel the interaction of banana bract mosaic virus in plantain cv. Nendran. *In*. XXIII National conference of indian virological society (IVS), 'VIROCON 2014' on 'Recent trends in virology research in the omics era' at the Department of Plant Pathology, TNAU, Coimbatore, Tamil Nadu. December 18-20. pp.130.

Anuradha, C., Selvarajan, R., Vasantha, S., Salin, K.P. and Suresha, G.S. 2014. Physiological and hormonal changes in response to banana bunchy top virus (BBTV) infection in banana. *Ibid.* pp.131.

Anuradha, C. and Selvarajan, R. 2014. Proteomic changes in banana in response to banana bunchy top virus (BBTV). *Ibid.* pp.132.

Elayabalan, S., Subramanian, S. and Selvarajan, R. 2014. Problem associated with production of virus free embryogenic cell line system in hill banana. *Ibid.* pp.143.

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Padmanaban, B., Marimuthu, R. and Mustaffa, M.M. 2015. Management of banana skipper , *Erionata thrax* (Insecta: Lepidoptera: Hesperiidae) - a defoliator pest of banana (Abstract). International conference on innovative insect management for sustainable agro-ecosystem (IIMASAE), organized by TNAU, Madurai, Tamil Nadu. January 27-30. pp. 730.

Padmanaban, B., Alagesan, A., Kalita, D.N. and Mustaffa, M.M. 2014. Occurrence of *Cyperus* root borer, *Athesapeuta cyperi* (Curculionidae: Coleoptera) a minor pest of banana in Asom. National symposium on entomology as a science and IPM as a technology - the way forward. College of Horticulture and Forestry,CAU, Pasighat, Arunachal Pradesh. November 14 - 15.

Padmanaban, B. 2014. Occurrence of banana skipper, *Erionata thrax* (Insecta: Lepidoptera: Hesperiidae), a defoliator pest of banana in certain parts of India. Global conference on technological challenges and human resources for climate smart horticulture - issues and strategies." Navsari, Gujarat. April 28 to May 3.

Ravi, I. 2015. Effect of soil moisture deficit stress in banana and its management. ISSP South zonal seminar on "Crop physiology-emerging challenges and opportunities for sustainable agriculture. S.V. Agricultural College, Tirupathi, Andhra Pradesh. March 3. pp. 30-33.

Sasireka, T. and Selvarajan, R. 2014. Simultaneous detection of multi components of banana bunchy top virus (BBTV). *In*. XXIII National conference of indian virological society (IVS), 'VIROCON 2014' on 'Recent trends in virology research in the omics era' at the Department of plant pathology, TNAU, Coimbatore, Tamil Nadu. December 18 - 20. pp. 80.

Shiva, K.N. 2014. Postharvest management and processing in banana. *In*: Brain storming session on pre- and post harvest management and processing of fruits & vegetables for food and nutritional security, AC & RI, Madurai, Tamil Nadu. November 20 - 21.

Shiva, K.N. 2014. Processing, value addition and packaging systems in banana. *In*: 3rd Tamil Nadu banana festival - 2014. Tiruchirapalli, Tamil Nadu. December 20.

Shiva, K.N. 2014. Value addition in banana. *In*: Collector meeting to explore the possibilities of equipping SHGs in the floor of value addition in banana. ICAR-NRCB, Tiruchirapalli, Tamil Nadu. December 13.

10 CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

- 602 batches of tissue cultured bananas of three varieties namely Grand Naine, Robusta and Nendran were tested for their genetic fidelity using SSR and ISSR markers under DBT – ATL project and generated an income of Rs. 10.15 lakhs.
- A contract research project on "Transforming eastern india's economies through innovative rural business hubs (RBH) in West Bengal was successfully completed and improved production technologies including cultivation of tissue cultured Grand Naine bananas were demonstrated.
- A contract research project on "Evaluation of high yielding technology®™ system formulations for higher productivity of banana" by M/s South Asia AGRINOS India Pvt.Ltd., New Delhi with Rs. 6.98 lakh budget.
- A total of 15,373 samples were tested for the presence of virus and revenue of Rs. 94,19,944 /- was generated under virus testing contract service.
- Polyclonal antiserum produced for CMV, BBrMV and BBTV was sold to tissue culture companies and also to the state agricultural universities *viz.,* KAU, APHU and Department of Horticulture, Kerala.
- *In vitro* evaluation of bio-nematicide to root-knot nematode, *Meloidogyne incognita* with M/s. Subramaniyan & Co, Salem with Rs. one lakh budget.
- Licensing of Technical know-how transferred to three entrepreneurs *viz.,* banana flour and biscuits to Mr. K. Dinesh, Nellore, Andhra Pradesh for Rs. 35,000/- ; Banana flour, baby food, health drink and central core stem juice to Mr. M. Prabakaran, Jayankondam, Tamilnadu, for Rs. 55,000/-; Banana Fig to Mr. Somarajan, Pathanamthitta, Kerala for Rs. 10,000/-.

11 RAC/ IRC MEETINGS

RAC MEETINGS

The 16th Research Advisory Committee meeting of the Centre was conducted on 12 and 13 November, 2014, wherein all the members of RAC including the Chairman Dr. G. L. Kaul, Former VC, AAU chaired the meeting. Recommendations generated from the meeting were approved by the Council.

Dr. G.L. Kaul Chairing the RAC meeting

Name and address	Position
Dr. G.L. Kaul, Former VC, AAU, Asom	Chairman
Dr. T. Jankiram, ADG (Hortl. Sci.), ICAR, New Delhi	Member
Dr. R.T. Patil, Former Director, CIPHET, Ludhiana	Member
Dr. S.K. Apte, Director, Bio-Science Group, BARC, Mumbai	Member
Dr. R.K. Tyagi, Head, Division of Germplasm, NBPGR, New Delhi	Member
Dr. M.M. Mustaffa, Director, ICAR-NRC for Banana, Tiruchirapalli, Tamil Nadu	Member
Shri Shaker Nagarajan, President, TNHBGF, Pattiveeranpatti, Tamil Nadu	Member (IMC Rep.)
Shri Bopanna Venkata Rao, Banana Growers, Kovvur, Andhra Pradesh	Member (IMC Rep.)
Dr. B. Padmanaban, Principal Scientist, ICAR-NRC for Banana, Tiruchirapalli, Tamil Nadu	Member Secretary

Recommendations

- The germplasm collected from North Eastern Hill (NEH) region needs to be safely maintained at ICAR-NRCB. The entire area of NEH region has to be surveyed and the exploration area for every year may be demarcated and explored with the assistance of NBPGR, New Delhi.
- The request for ITC collection may be made directly to NBPGR, New Delhi and a copy may be sent to IIHR, Bengaluru for speedy completion of the work.
- As recommended during last RAC (Pt. No.16), readily available 25 accessions may be sent immediately to NBPGR for registration. Empirical data of wild bananas has to be registered under PPVFR or NBPGR.
- Multiplication of Udhayam has to be increased to meet the demands of farmers. Alternate propagation methods may be tried to increase the production. Target for Udhayam production was fixed as 10000 nos. M/s Shanthi Agro-tech, Bengaluru may be contacted for its mass multiplication. Production technology may be transferred to the firm to multiply the planting material.
- Local engineering college may be contacted for developing APP /SMS for

fertilizer tailoring equation. The package may be patented. Ready reckoner on fertilizer tailoring equation may be given to farmers.

- Contact all ATIC Centers in ICAR system and inform about the value added banana products available at ICAR-NRCB. Encourage the entrepreneurs to take up banana value added products in their respective places.
- Screening of banana germplasm for resistant sources identification to major biotic stresses has to be given top priority on continuous basis.
- Pest risk analysis of the new pest needs to be addressed and documented so that the export of bananas to other countries is not affected due to quarantine issues.
- A policy paper on viral diseases may be prepared and sent to peers in ICAR for getting suggestions. Discussion at state level and submission of the proposal to Government of Tamil Nadu needs to be done. Hill Banana Growers' Association to co-ordinate in this activity.

IRC Meeting

The 18th Institute Research Council meeting was held on 9, 13, 19 May, 2014 and 1 & 3 November, 2015 under the chairmanship of Dr. M.M. Mustaffa, Director, ICAR-NRCB. The member secretary welcomed the chairman and other members of IRC. After introductory remarks by the chairman, the research programmes, comments of the last IRC, action taken on the comments, salient achievements for the year 2013-14 and technical programme for the year 2014-15 were presented by the scientists reviewed.

Dr. M.M. Mustaffa, Director NRCB, chairing the 18th IRC meeting

12 TRAINING / REFRESHER COURSE/ SUMMER/ WINTER INSTITUTES/ SEMINAR/ CONFERENCE/ SYMPOSIA/ WORKSHOP ATTENDED BY THE SCIENTISTS AND STAFFS

12.1. Human Resource Development

The budget allocation under HRD for ICAR - NRCB during 2014-15 is Rs.3.00 lakhs and Rs.2.66 lakhs was utilized for training ICAR - NRCB staffs. Two administrative staffs, four technical staffs and five scientists received training on capacity building and leadership development programme.

Name of the staff	Name of the programme /Venue	Period
B. Padmanaban	International training programme on pest risk analysis organized by NIPHM &US-AID, National Institute of Plant Health Management (NIPHM), Hyderabad	1-5 Sept., 2014
	Workshop on training needs in human resource management, NAARM, Hyderabad	26 Feb., 2015
R. Selvarajan	Management development programme on PME of agricultural research project, NAARM, Hyderabad	4-8 Aug., 2014
I. Ravi	Management development programme on leadership development (a pre-RMP programme) NAARM, Hyderabad	15-6 June, 2014
P. Ravichamy	Capacity building programme for technical personal, IIPA, New Delhi	24-27Aug., 2014
P. Durai D. Ramachandramurthi and N. Marimuthu	Capacity building programme for technical assistants, IIPA, New Delhi	2-13 Feb., 2015
P. Murugan	Organization special programme for ICAR employees, ISTM, New Delhi	25 Aug., to 5 Sept., 2014
A.V. Suja	Organization special programme for ICAR employees, ISTM, New Delhi	10-11Nov.,2014
Mr. Kishor Kumar Mahanti	BRS, Dr. YSR Hortl. University, Kovvur, Andhra Pradesh	1-31 March, 2015

12.2 Scientific Seminars /Conferences /Symposia / Workshops / Meetings etc.

Name of the Scientist	Name of the programme /Venue	Period
M.M.Mustaffa	ICAR regional committee meeting at CTCRI, Thiruvananthapuram, Kerala	2-4 May, 2014
	ICAR-DAC interface meeting at Krishi Bhawan, New Delhi	15-16 May, 2014

Name of the Scientist	Name of the programme / Venue	Period
	National seminar on physiology and flowering in perennial fruit crops, CISH, Lucknow, U.P.	25th May, 2014
	NABMGR project review meeting, IIHR, Bengaluru, Karnataka	30-31 May, 2014
	ICAR institute directors' conference, ICAR, New Delhi	4-6 June, 2014
	12th FYP EFC finalization meeting, ICAR, New Delhi	14-16 July, 2014
	ICAR institute directors' conference, ICAR, New Delhi	28-30 July, 2014
	ICAR institute horticulture division meeting, ICAR, New Delhi	8-9 Sept., 2014
	AICRP - banana review meeting, ICAR, New Delhi	13-14 Oct., 2014
	BAPNET steering committee meeting / international conference on banana, Davao City, Philippines	16-22 Oct., 2014
	QUT-BARC - banana biofortification project review meeting, BARC, New Delhi	1-2 Dec., 2014
	MusaNet workshop on *Musa* germplasm- ICAR-NRCB, identification towards optimizing use, Tiruchirapalli, Tamil Nadu	6-12 Dec., 2014
	Annual group discussion of AICRP on fruits, RAU, Udaipur, Rajasthan	26 Feb., to 2 Mar., 2015
	National farmers' meet, RRS, TNAU, Paiyur, Tamil Nadu	14th Mar., 2015
All scientists of ICAR-NRCB	21st ICAR-NRCB foundation day cum Kissan mela-2014, ICAR-NRCB, Tiruchirapalli, Tamil Nadu	21st Aug., 2014
	Banana workers meet (AICRP-Fruits), ICAR-NRCB, Tiruchirapalli, Tamil Nadu	28-29 Jan., 2015
B. Padmanaban	DST Project review meeting, Indian National Science Academy (INSA), New Delhi	13 June, 2014
S. Uma, S. Backiyarani, M.S. Saraswathi & Kishore Kumar Mahanti	*MusaNet* workshop on *Musa* germplasm - identification towards optimizing use, ICAR-NRCB, Tiruchirapalli, Tamil Nadu	6-12 Dec., 2014
B. Padmanaban, S. Uma, R. Thangavelu & V. Kumar	Annual group discussion of AICRP on fruits, RAU, Udaipur, Rajasthan	26 Feb., to 2 Mar., 2015

Name of the Scientist	Name of the programme / Venue	Period
S. Uma	Brain storming session on somatic embryogenesis and use of bioreactors, CPCRI, Kasaragod, Kerala	2 Aug., 2014
S. Backiyarani	29th International horticulture congress -2014 and *ProMusa* Symposium, Brisbane, Australia	17 -22 Aug., 2014
	Second stewardship training, QUT, Brisbane, Australia	24-27 Aug., 2014
R. Thangavelu, B. Padmanaban & V. Kumar	National farmers' meet, RRS-TNAU, Paiyur, Tamil Nadu	14 Mar., 2015
R. Selvarajan	Doctoral committee meeting at department of plant science, Bharathidasan University, Tiruchirapalli, Tamil Nadu	4 April, and 19 Sept., 2014
	Board of studies meeting at department of biochemistry, Holy Cross College, Tiruchirapalli, Tamil Nadu	7 April., 2014
	Evaluation committee meeting, TNAU awards under staff development programme	21 May., 2014
	Workshop on priority setting monitoring and evaluation committee organized by NAIP-IFPRI, NASC complex, New Delhi	27 May, 2014
	Workshop on bio-safety and detection of GM crops, NBPGR, New Delhi	11-16 Aug., 2014
	Doctoral committee meeting, School of bio sciences and technology, VIT University, Vellore, Tamil Nadu	9 Dec., 2014
R. Selvarajan & C. Anuradha	XXIII National conference of Indian virological society (IVS), VIROCON 2014, TNAU, Coimbatore, Tamil Nadu	18 - 20 Dec., 2014
M. Mayil Vaganan	National conference of plant physiology-2014, Orissa University of Agriculture and Technology, Bhubaneshwar, Odisha	23 -25 Sept., 2014
	Second annual review meeting of DBT/BIRAC project: Biofortification and development of disease resistance in banana, BIRAC, New Delhi	1 & 2 Dec., 2014
	Training & awareness workshop on J-Gate@ CeRA for Southern Region,Telangana State Agricultural University, Rajendranagar, Hyderabad	23 Jan., 2015
I. Ravi	Workshop on impact of capacity building programs under NAIP, AP shinde auditorium, NASC Complex, Pusa, New Delhi	6-7June, 2014

Name of the Scientist	Name of the programme / Venue	Period
	ISSP South zonal seminar on crop physiology - emerging challenges and opportunities for sustainable agriculture. S.V. Agricultural College, Tirupathi, Andhra Pradesh	3 Mar., 2015
V. Kumar	80th Scientific workers conference, TNAU, Coimbatore, Tamil Nadu	30 May, 2014
	Midterm review workshop for the RFD Nodal Officers, New Delhi	24 Nov., 2014
	Dissemination meeting of rural business hub project for improving the economies in the eastern India' organized by CII-FACE, New Delhi at Kolkata	26 Nov., 2014
	Capacity building programme to kisan call centre experts, TNAU, Coimbatore, Tamil Nadu	12 Dec., 2014
	Seminar on 'Scientific banana cultivation for enhancing the production and productivity of banana' organized by Muthumalla Trust, Pondicherry	3 Jan., 2015
	National Agri Fest 2014 organized by the Govt. of Kerala at Mananthavady, Wayanad, Kerala	10-17 Jan., 2015
	3rd National Agri-Fiesta-2015 & Flower Show-2015 organized by the Kerala Agricultural University at Ambalavayal, Wayanad, Kerala	20 Jan., to 2 Feb., 2015
	One day workshop cum training on cultivation of tissue culture bananas, HC&RI, TNAU, Periyakulam, Theni, Tamil Nadu	14 Feb., 2015
	First steering committee meeting of Tamil Nadu banana festival 2014, Theni, Tamil Nadu	4 Aug, 2014
	Second steering committee meeting of CII-NRCB-TNBPC for organizing of 'Tamil Nadu Banana Festival-2014' at Trichirapalli	02 Sep., 014
	4th Steering Committee Meeting of Tamil Nadu Banana Festival 2014 at Tiruchirappalli	18 Sep., 2014
	District mission committee meeting of NHM/ MI/NBM and National mission on medicinal plants held at the district collectorate, Trichy	25 Jul., 26 Sep., and 31 Oct., 2014
	VI Scientific advisory committee meeting of the TNAU KVK, Papparappatti, Dharmapuri	19 Nov., 2014.
	IV Scientific advisory committee (SAC) meeting of the Dr. Perumal Krishi Vigyan Kendra, Krishnagiri	23 Dec., 2014

Name of the Scientist	Name of the programme / Venue	Period
K.N. Shiva	Interactive meeting on cluster development approach in identifying banana products for export, organized by APEDA-Bengaluru, AMI & BPC, Tiruchirapalli, Tamil Nadu	16 June, 2014
	Inaugural session of solar drier for drying banana, Thottiyum, Tamil Nadu	18 June, 2014
	12th Five year plan meeting in the ICAR, Krishi Bhavan, New Delhi	14 July, 2014
	TOLIC (Hindi) meeting organized by TOLIC, railway nest, cauvery officers club, Tiruchirapalli, Tamil Nadu	25 Sept., 2014 and 25 Feb., 2015
	Interactive meeting on cluster development for banana and banana products for export, Tiruchirapalli, Tamil Nadu	27 Oct., 2014
	Brainstorming session on pre and postharvest management and processing of fruits & vegetables for food and nutritional security', AC & RI, Madurai, Tamil Nadu	20 &21 Nov., 2014
	3rd Tamil Nadu banana festival-2014, organized by CII-Chennai, Tiruchirappalli, Tamil Nadu	20 Dec., 2014
	Farmer and scientists interactive meeting in the 2nd Agri Expo - 2014, organized by dinamalar daily newspaper at new bus stand ground, Thanjavur, Tamil Nadu	21 Dec., 2014
S. Backiyarani, S. Uma, M.S. Saraswathi & Kishore Kumar Mahanti	*MusaNet* workshop on *Musa* germplasm - identification towards optimizing use conducted by BIOVERSITY-France and ICAR-NRCB, Tiruchirapalli, Tamil Nadu	6-12 Dec., 2014
S. Backiyarani	Second annual review meeting, BIRAC, DBT, New Delhi and NPTC-Functional genomics, NRCPB, New Delhi	1 & 4 Dec., 2014
M.S. Saraswathi	RFD Review meeting, KAB - II, New Delhi	28 Aug., 2014
	BRNS/RTAC/ technical programme discussion meeting, Tirupati, Andhra Pradesh	30-31 Aug., 2014
C. Anuradha	Annual meeting-cum-workshop titled AgrIP 2014 Organized by South TMC in association with the Indian Institute of Horticulture Research (IIHR), Bengaluru	9-10 Oct., 2014
	Horticulture industry meet organized by ZTM-BPD Unit of IIHR, Bengaluru	10 Feb., 2015

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

Banana Kissan Mela- 2014

The ICAR-National Research Centre for Banana celebrated its 21st Foundation day as "Banana Kissan Mela" with the theme on "Drought management in banana" on 21st August 2014. Dr.M.M.Mustaffa, Director, ICAR-NRCB presided over the function and Thiru K. Tharpagaraj, District Collector in-charge, Tiruchirapalli was the chief guest of the function and delivered chief guest address. On the occasion, a series of publications were released by the chief guest. The "Kissan Mela" was organized to create awareness on the drought management strategies in all the banana growing regions in India.

An exhibition was also arranged to display various technologies for banana fruit care, banana production, quality tissue culture plants, value added product development, inputs for banana cultivation and management of pest and diseases etc. The scientists interacted with banana farmers on drought, nutrient and pest and disease management in banana. Around 450 banana growers, agricultural, horticultural officers, entrepreneurs from various districts of Tamil Nadu (Tiruchirapalli, Thanjavur, Karur, Theni, Salem, Erode, Namakkal, Kanchipuram, Virudhunagar, Pudukkottai, Dharmapuri, Villuppuram and Kanyakumari) and Pondicherry participated in the Mela.

Dr. M.M. Mustaffa, Director, ICAR-NRCB addressing the gathering

Farmer receives the "Best Banana Grower" award at Kissan Mela

The *Musa*Net workshop

The second workshop on *Musa* germplasm: Identification towards optimising use, organised by the global *Musa* genetic resources network (*MusaNet*) in collaboration with Bioversity International, France was held at the ICAR - National Research Centre for Banana (NRCB), Tiruchirapalli, Tamil Nadu during 6 -12 December, 2014. The goal of the workshop was to optimise the use of *Musa* germplasm through best description and management practices.The workshop was inaugurated by Dr.N.K.Krishna Kumar, Deputy Director General (HortL. Sci.), ICAR. Each Taxonomic Reference Collection Project (TRCP) partners from Burundi, Cameroon, Costa Rica, Indonesia, Nigeria, Philippines, Tahiti, Uganda, USA, Vietnam and India made short presentations on the current status of the project at their collections. Non-TRP members (Australia, Malaysia, Guadeloupe and Papua New Guinea) also presented their views. Discussions were held on the revision of the minimum descriptors. In conclusion, the *Mus*aNet workshop achieved the following key outcomes.

- Further identification of the important constraints and practices in establishing,

maintaining and managing the TRCP collection.

- Better understanding of how to score many *Musa* morphological descriptors.
- Agreement on the revision of the minimum illustrated descriptors.
- Understanding of the features of the new MGIS interface.
- Testing of and feedback on the mobile device (hand-held tablet) for collecting data in the field.
- Exchange of knowledge on best practice field management and documentation.
- Proposals on the next steps of the TRCP.
- Discussion and feedback on the revised global strategy for the conservation and use of *Musa* genetic resources.

Dr. N.K. Krishna Kumar DDG (Hortl. Sci.) - ICAR addressing at 2nd workshop on *Musa* germplasm

International delegates at 2nd workshop on *Musa* germplasm

Banana worker's meet (AICRP-Fruits)

Meeting on banana workers of AICRP (Fruits) was held at ICAR-National Research Centre for Banana, Tiruchirapalli, Tamil Nadu during 28-29th January, 2015. Dr.Prakash B. Patil, Co-ordinator AICRP(Fruits), briefed about the programme and informed about the budget details and the expected outcome from the project. Twenty nine Banana workers from various ICAR and SAUs participated in the meeting. In this meeting, the progress made in the on-going programme was presented by the team leaders and it was discussed. Dr. M.M.Mustaffa, Director, ICAR-NRCB emphasized the identified experiments has to be carried out in time to get the crop growth and related results.

Dr. M.M. Mustaffa, Director, ICAR-NRCB addressing at AICRP (Fruits) - banana workers meet

Participants in banana workers meet

14 DISTINGUISHED VISITORS

Name and Address	Date
Dr. S.K. Sharma, Director, ICAR-CIAH. Bikaner, Rajasthan	6 Apr., 2014
Mr. S. Suresh Kumar, CGM, NABARD, Chennai, Tamil Nadu	18 Oct., 2014
Dr. G.L. Kaul, Former VC, AAU, Asom	12 Nov., 2014
Dr. T. Jankiram, ADG (Hortl. Sci.), ICAR, New Delhi	12 Nov., 2014
Dr. R.T. Patil, Former Director, CIPHET, Ludhiana, Punjab	12 Nov., 2014
Dr. S.K. Apte, Director, Bio-Science Group, BARC, Mumbai	12 Nov., 2014
Dr. R.K. Tyagi, Head, Division of Germplasm, NBPGR, New Delhi	12 Nov., 2014
Dr. N.K. Krishna Kumar, Deputy Director General (Hortl. Sci.), ICAR, New Delhi	6 Dec., 2014
Mrs. Jayashree Muralidharan, IAS, District Collector, Tiruchirapalli, Tamil Nadu	14 Dec., 2014
Dr. R. Vijayakumar, IAS, Secretary, Ministry of Development of NE Regions, Governement of India, New Delhi	27 Feb., 2015
Dr. S.A. Patil, Former Director, IARI, New Delhi	27 Feb., 2015

RAC members meeting on 12 Nov., 2014

Mrs. Jayashree Muralitharan, IAS, District Collector, Tiruchirapalli, visit to the Centre

15 EMPOWERMENT OF WOMEN

- About 1250 women farmers including students, SHG members and other women entrepreneurs from different parts of country visited ICAR-NRCB and learnt various technologies on crop improvement, crop production, crop protection and post harvest.
- Farmers' training programme on macropropagation was conducted at Semmedu, Kolli Hills Namakkal district, Tamil Nadu for 110 women farmers beneficiaries.

Training the tribal women farmers on the significance of tissue cultured plants at Kolli hills, Namakkal district, Tamil Nadu

Women students of Horticulture college visit to ICAR-NRCB

16 PERSONNEL

16.1 Promotion

Name	Promoted	w.e.f.
Dr. M. Mayil Vaganan, Senior Scientist	Principal Scientist	20.02.2010
Dr. K.N. Shiva, Senior Scientist	Principal Scientist	28.07.2013
Dr. S. Backiyarani, Senior Scientist	Principal Scientist	29.08.2013
Dr. M.S. Saraswathi, Senior Scientist	Principal Scientist	02.03.2014
Mrs. C. Sagayam Jacqueline, Senior Technical Assistant	Technical Officer	01.01.2013
Mr. R. Pitchaimuthu, Technical Assistant	Senior Technical Assistant	01.01.2013
Mr. N. Marimuthu, Technical Assistant	Senior Technical Assistant	01.01.2013
Mr. K. Kamaraju, Technical Assistant	Senior Technical Assistant	10.03.2013

16.2 New Appointment/ Transfer

Name	Designation	Date
Mr. Kishor Kumar Mahanti	Scientist (Fruit Science)	13.10.2014
Dr. P. Giribabu (transferred from ICAR - IIOR, Hyderabad)	Scientist (Nematology)	01.12.2014

16.3 Superannuation

Name	Designation	Date
Mr. M. Krishnan	Administrative Officer	30.04.2014
Mr. A. Subramanian	Technical Assistant (Driver)	31.12.2014

Mr. M. Krishnan, Administrative Officer superannuated from service on 30.4.2014

Mr. A. Subramanian, Technical Assistant (Driver) superannuated from service on 31.12.2014

16.4 Staff position

Scientific Staff

Sl. No.	Name	Designation
1.	Dr. M.M. Mustaffa	Director
2.	Dr. B. Padmanaban	Principal Scientist (Entomology)
3.	Dr. S. Uma	Principal Scientist (Horticulture)
4.	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
5.	Dr. R. Selvarajan	Principal Scientist (Plant Pathology)
6.	Dr. M. Mayil Vaganan	Principal Scientist (Biochemistry)
7.	Dr. I. Ravi	Principal Scientist (Physiology)
8.	Dr. V. Kumar	Principal Scientist (Horticulture)
9.	Dr. K. J. Jeyabaskaran	Principal Scientist (Soil Science)
10.	Dr. K. N.Shiva	Principal Scientist (Horticulture)
11.	Dr. S. Backiyarani	Principal Scientist (Biotechnology)
12.	Dr. M.S. Saraswathi	Principal Scientist (Horticulture)
13.	Mr. R. Natarajan	Scientist (Economic Botany)
14.	Dr. C. Anuradha	Scientist (Biotechnology)
15.	Dr. P. Giribabu	Scientist (Nematology)
16.	Mr. Kishor Kumar Mahanti	Scientist (Horticulture)

Technical Staff

Sl. No.	Name	Designation
1.	Dr. S. Palanichamy	Senior Technical Officer (Field)
2.	Dr. P. Durai	Senior Technical Officer (Field)
3.	Mr. P. Ravichamy	Technical Officer (Journalism)
4.	Mrs. T. Anitha Sree	Technical Officer (Field)
5.	Mrs. C. Sagayam Jacqueline	Technical Officer (Computer Programmer)
6.	Mr. D. Ramachandramurthi	Senior Technical Assistant (Civil Overseer)
7.	Mr. V. Selvaraj	Senior Technical Assistant (Field)
8.	Mr. T. Sekar	Senior Technical Assistant (Lab)
9.	Mr. R. Pitchaimuthu	Senior Technical Assistant (Field)
10.	Mr. N. Marimuthu	Senior Technical Assistant (Lab)
11.	Mr. K. Kamaraju	Senior Technical Assistant (Lab)
12.	Mr. M. Bathrinath	Technical Assistant (Field)
13.	Mr. A. Subramanian	Technical Assistant (Driver) till 31.12.2014
14.	Mr. P. Mohan	Technical Assistant (Driver)
15.	Mr. V. Manoharan	Technical Assistant (Driver)

Administrative, Audits & Accounts and Supporting Staff

Sl. No.	Name	Designation
1.	Mr. M. Krishnan	Administrative Officer till 30.04.2014
2.	Mrs. C. Gomathi	Asst. Finance & Accounts Officer
3.	Mr. R. Krishnamurthy	Assistant Administrative Officer
4.	Mr. M. Krishnamoorthy	Private Secretary
5.	Mr. P. Murugan	Assistant
6.	Mr. R. Sridhar	Personal Assistant
7.	Mr. R. Neela Mega Shyamala Kannan	Steno Gr. III
8.	Mrs. S. Durgavathy	Upper Division Clerk
9.	Mr. M. Devarajan	Lower Division Clerk
10.	Mrs. A.V. Suja	Lower Division Clerk
11.	Mr. R. Mohanraj	Mali SSG-IV
12.	Mr. V. Pandiyan	Mali SSG-III
13.	Mr. V. Thangaraju	Messenger SSG-II
14.	Mr. P. Kamaraj	Mali SSG-II
15.	Mr. V. Ganesan	Mali SSG-I
16.	Mrs. K. Mariammal	Safaiwala SSG-I

17 OTHER INFORMATIONS

National Science Day Celebration at ICAR-NRCB

The ICAR-National Research Centre for Banana, Tiruchirapalli, Tamil Nadu celebrated 'National Science Day' on 11th March, 2015 remembering 87th year of Dr. C. V. Raman's Nobel Prize winning discovery of "Raman Effect" with a theme on 'Science for Nation Building' among school and college students. Director of the Centre, Dr. M. M. Mustaffa inaugurated the seminar and exhibition and delivered the presidential address. The primary

Dr. M.M. Mustaffa, Director, ICAR-NRCB addressing the students during National Science Day

objective was to expose the students to recent research developments on banana and also to create awareness and motivation among students. Students visited the exhibition and laboratories and interact with the scientists. Over 450 students from different schools and colleges visited the Centre on this occasion.

Scientists of the Centre explained research activities on banana varieties, tissue culture techniques, drip irrigation, fertigation method, eco-friendly bio-control agents available for management of pests, diseases, nematodes etc., and value added products from banana fruits and plant.

Hindi Week Celebrations at ICAR-NRC Banana

ICAR-National Research Centre for Banana celebrated 'Hindi Week' from 24th to 29th September 2014 at the Centre. As a part of the program, various competitions *viz*., Hindi essay writing, Hindi noting and drafting, Hindi film song, Hindi quiz (official language & general knowledge) and Hindi memory test were conducted for promoting Hindi as official language to Central Govt. offices under the auspices of the Indian Council of Agricultural Research (ICAR), New Delhi. As a part of the celebrations, concluding ceremony and prize distribution was organized at the Centre. Dr. N.K. Krishna Kumar, DDG (Hortl. Sci.), ICAR graced the occasion as Chief Guest and distributed prizes to the winners of various Hindi competitions. In his address, he emphasized the importance of promoting Hindi as official language and the necessity of learning Hindi as 'Rajbhasha' by every citizen. He appealed to the employees to use Hindi in

Students visiting ICAR-NRCB Lab during National Science Day

Dr. N.K. Krishna Kumar DDG (Hortl. Sci.) - ICAR distributing prize at Hindi Week celebrations

Staff of ICAR-NRCB during Hindi week award function

the day-to-day office activities. At the beginning, Dr. B. Padmanaban, Principal Scientist welcomed the gathering. Dr. M.M. Mustaffa, Director, ICAR-NRC Banana delivered the presidential address and spoke on Hindi week celebrations. The programme came to an end with the vote of thanks by Dr. K.N. Shiva, Senior Scientist and Member-Secretary, Official Language Implementation Committee of the Centre.

Swach Bharat

As per the directions of the Hon. Prime Minister, cleanliness week was observed at the ICAR- National Research Centre for Banana, Tiruchirapalli, Tamil Nadu on October 2, 2014. On this occasion, oath was taken by the staff members of the centre to maintain cleanliness in the campus. To mark the occasion, staff members participated in the cleaning of office

campus. The cleanliness drive was extended to farm and office quarters.

Sports Meet

A Sports Contingent of six members *viz*., K.N. Shiva, V. Kumar, D. Ramachandramurthi, R. Pitchaimuthu, T. Sekar and V. Selvaraj participated in the ICAR Zonal Sports meet (South Zone) organized by IIHR during October 13-17, 2014 at Bengaluru.

Sports contingent of ICAR-NRCB at zonal sports meet

NRCB Exhibition hall and Transgenic net house inauguration

During the DDG (Hortl. Sci.) visit to ICAR-National Research Centre for Banana, Dr. N.K. Krishna Kumar inaugurated the transgenic nethouse and exhibition hall at the centre.

Dr. N.K. Krishna Kumar DDG (Hortl. Sci.), ICAR opening new transgenic nethouse at ICAR-NRCB farm

Dr. N.K. Krishna Kumar DDG (Hortl. Sci.) - ICAR interacting with ICAR- NRCB scientists

Dr. N.K. Krishna Kumar DDG (Hortl. Sci.) - ICAR opening new exhibition hall at ICAR-NRCB

Dr. M.M. Mustaffa, Director, ICAR-NRCB explains to Dr. N.K. Krishna Kumar DDG (Hortl. Sci.) at new exhibition hall

18 RESEARCH PROJECTS

I. In-house projects

S.No	Name of the Project	Principal Investigator
1.	**Improvement**	
	Crop improvement of banana through conventional breeding	M.M. Mustaffa
	Improvement and management of banana genetic resources in Indian subcontinent	S. Uma
	Identification and characterisation of nematode resistance genes in banana	S. Backiyarani
	Improvement of Rasthali through induced mutagenesis	M.S. Saraswathi
	Development of trait specific markers for fusarium wilt resistance through association mapping studies in banana	M.S. Saraswathi
2.	**Production**	
	Studies on nutrient dynamics in banana	K.J. Jeyabaskaran
	Drought stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of drought tolerance	I. Ravi
	Salt stress tolerance in banana: Understanding the physiological, biochemical and molecular mechanism of salt tolerance	I. Ravi
	Physiological and biochemical mechanism of nematodes and pseudostem weevil resistance and identification of 'biomarker metabolites' in banana	M. Mayil Vaganan
	Biochemical and molecular basis of ripening of banana fruit and its manipulation with biochemicals	M. Mayil Vaganan
	Development of pre and post harvest techniques for leaf production in banana	K.N. Shiva
	Development of modified atmosphere packaging techniques in banana and plantain for domestic and export markets	K.N. Shiva
	Development and refinement of value added products in banana and plantain	K.N. Shiva
3.	**Protection**	
	Management of banana weevils	B. Padmanaban
	Investigation on fungal and bacterial diseases of banana and their management	R. Thangavelu

S.No	Name of the Project	Principal Investigator
	Studies on viral diseases of banana and their management	R. Selvarajan
	Host-virus interactions in banana : Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's	R. Selvarajan
	Proteomic analysis of host-BBTV interaction in banana	C. Anuradha

II. ICAR funded projects

S.No	Name of the Project	Principal Investigator
1.	Consortium research on borers in network mode	B. Padmanaban
2.	Nanotechnology project	B. Padmanaban, R. Selvarajan, M. Mayil Vaganan & I. Ravi
3.	Functional genomics	S. Uma
4.	*Phytophthora*, *Fusarium* & *Ralstonia* diseases of horticultural and field crops	R. Thangavelu
5.	Transgenics in crops	R. Selvarajan
6.	Post-harvest losses of fruits (banana)	K.N. Shiva
7.	Intellectual property management and transfer/ commercialization of agricultural technology scheme	C. Anuradha

III. Other Agencies funded projects

S.No.	Name of the Project	Funded by	Principal Investigator
1.	Molecular approaches for the control of *Odoiporus longicollis* (Oliver), a major pest of bananas	DBT	B. Padmanaban
2.	Identification of molecular strategies for the control of *Cosmopolites sordidus* Ger.) (Coleoptera: Curculionidae), a major pest of bananas	DST	
3.	"Eco-friendly approaches for the management of Coffee white stem borer, *Xylotrechus quadripes* Chev. (Coleoptera: Cerambycidae)	Coffee Board	
4.	Bio-fortification and development of disease resistance in banana	DBT – QUT	
	Component I : Tranfer and evaluation of Indian banana with pro vitamin A constructs		S. Backiyarani
	Component II : Transfer and evaluation of Indian banana with iron constructs		M. Mayil Vaganan

III. Other Agencies funded projects

S.No.	Name of the Project	Funded by	Principal Investigator
	Component III : Development of efficient ECS for Rasthali and providing authentic virus free IMFC to Indian partners		S. Uma
5.	Improved livelihoods through conservation and cultivation of extinct land races of banana of Kolli Hills	DBT	
6.	Drought - Screening of *Musa* germplasm for the benefit of resource poor farmers	Global Crop Diversity Trust	
7.	Development of bio-pesticide formulation for reducing post harvest losses and for achieving export quality and increased shelf life of banana fruits	DBT	R. Thangavelu
8.	CROPSAP	Government of Maharashtra	
9.	Molecular characterization of *Fusarium oxysporum* f.sp. *cubsene* causing Fusarium wilt of banana and its sustainable development	DBT	
10.	Evaluation of transgenic hill banana resistance to banana bunchy top virus	DBT	R. Selvarajan
11.	Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	BARC	M.S. Saraswathi
12.	Proteomic studies of host-pathogen interactions in banana-banana bract mosaic virus (BBrMV) system"	DST	C. Anuradha

IV. Contract research projects

1. Evalution of MET 52 EC and granules on banana against corm weevil (*Cosmopolites sordidus*). (B. Padmanaban)

2. Evaluation of high yielding technology System formulations for higher productivity of banana" M/s South Asia AGRINOS India Pvt. Ltd., New Delhi- (V. Kumar & B. Padmanaban)

3. *In vitro* evaluation of bio-nematicide (Bio-lipidomix) to banana root-knot nematode, *Meloidogyne incognita* (Private Company). (B. Padmanaban)

METEOROLOGICAL DATA

Month	Max.Temp (⁰C)	Min.Temp (⁰C)	Rain fall (mm)
April 2014	39.96	26.40	233.1
May 2014	37.22	25.48	-
June 2014	38.76	26.50	5.0
July 2014	38.87	26.70	91.1
August 2014	36.43	26.50	-
September 2014	36.46	25.74	70.0
October 2014	33.54	24.74	74.0
November 2014	30.13	23.16	162.5
December 2014	29.87	22.38	58.0
January 2015	31.06	21.80	4.4
February 2015	33.25	21.64	-
March 2015	36.00	24.03	-
Total			698.1

भाकृअनुप
ICAR

हर कदम, हर डगर
किसानों का हमसफर
भारतीय कृषि अनुसंधान परिषद

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तायनूर पोस्ठ तोगमलै रोड तिरूच्चिरापक्कि ६२० १०२, तमिल नाडु

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