वर्षिक प्रतिवेदन

ANNUAL REPORT 2016 - 17

भाकृअनुप
ICAR

ICAR - NRCB

भाकृअनुप - राष्ट्रीय केला अनुसंधान केंद्र

ICAR - NATIONAL RESEARCH CENTRE FOR BANANA

(ISO - 9001:2008 Certified Institute)

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ICAR-NATIONAL RESEARCH CENTRE FOR BANANA

(Indian Council of Agricultural Research)

Thayanur Post, Thogamalai Road, Tiruchirapalli - 620 102, Tamil Nadu

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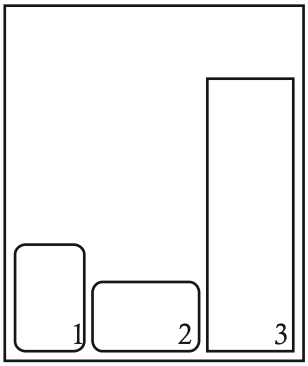

1. Tropical race-4 of Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*)
2. Rugose spiralling whitefly (*Aleurodicus rugioperculatus*)
3. High throughput planting material production using bioreactors

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PREFACE

It gives me an immense pleasure to present the Annual Report 2016-17 of ICAR-National Research Centre for Banana, Tiruchirapalli, Tamil Nadu which depicts an array of research activities and achievements of the Centre through multi-disciplinary approaches. Establishment of the Centre, research based technologies, farmer outreach programmes and Public-Private partnership has reaped dividends and country has witnessed a quantum jump in area, production and productivity.

The major thrust areas of research include viz, Improvement, Production, Post harvest Management and Protection. ICAR-NRCB has well-equipped research laboratories. The ICAR-NRCB has been a globally recognized field gene bank with more than 566 accessions including ornamental bananas with excellent complementary conservation programmes as *in-vitro*, seed, DNA and embryogenic cell suspension (ECS) banks. Centre has developed hybrids with high carotenoids (20%) less starchy and disease resistant synthetic diploids. Improvement of banana for Fusarium wilt through mutation breeding has resulted in 35 putative Rasthali mutants which are in sick plot screening. Exploitation of somatic embryogenesis for improvement through mutation, genetic transformation and also as a tool for high throughput planting material production has been very successful at the Centre.

The nutrient dynamics studies have revealed the nutrient accumulation pattern in different parts of the plant at different growth stages and nutrient recycling pattern in the banana-soil ecosystem. Drought and salt amelioration technologies through foliar sprays have given convincing results and enhancing green life of commercial varieties through *in-planta* spraying has large potential for planned and delayed harvesting during glut. Standardized protocol for making low glycemic extruded products with modified starch from banana. Modified atmospheric storage for enhancing shelf life by 25-102 days of commercial varieties have been standardized. Four products have been developed last year and six are commercialized.

The Rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin, is a new invasive pest in South India on banana and ICAR-NRCB has identified two parasitoids, *Encarsia guadeloupae* and *E. dispersa* and several indigenous predators, for whitefly. 342 volatile components from banana stem have been isolated and weevil attracting semiochemicals were identified and eco-friendly methods using botanical extracts for controlling stem weevils are found successful. Fusarium wilt tropical Race-4 (TR4) has been identified from Bihar state and is the first report of this dreadful strain in India. Principal compound from zimmu and *Trichoderma asperellum* are found to be promising for the management of Fusarium under laboratory conditions and its nano formulations are being synthesized. LAMP technique has been successfully used for rapid detection and diagnosis of *Mycosphaerella eumusae* leaf spot and CMV (Cucumber Mosaic Virus). Complete genome of CMV infecting banana has been characterized.

As a nodal Centre, ICAR-NRCB is actively engaged in many service oriented activities like plant certification (ATL for virus indexing and genetic fidelity testing), soil nutrient analyses, nutritional profiling of banana based products, supply of quality planting materials etc. The Centre is also involved in conducting contract research, providing both on-campus and off-campus trainings, signed MoU with

ten entrepreneurs. The Centre is also closely associated with Banana Growers Federations, State Agricultural Universities and KVKs across the country. At international level, new linkages have been developed with BIOVERSITY International, France, QUT Australia, IITA-Nigeria, NARO-Uganda etc. resulting in the sanction of project worth Rs. 2.80 crores.

The Centre has developed an App for guiding the farmers on improved production techniques. Electronic media has been widely used for out-reaching the clients especially through Facebook, Twitter and Webpage and as Whatsapp groups. ICAR-NRCB has renewed ISO 9001:2008 Certification license granted based on quality standards. The Centre has conducted one Kissan Mela and participated in 19 Exhibitions, 10 on-campus and 13 off-campus trainings. Apart from these, many programmes like *Mera Gaon Mera Gaurav* (MGMG), *Swachch Bharat*, Hindi Pakwada, Agricultural Education Day, International Yoga Day, Vigilance Awareness Week, Communal Harmony campaign, Constitution Day, National Science Day etc. have been successfully conducted.

I sincerely thank Dr. T. Mohapatra, Secretary, DARE and Director General, ICAR, for his trust in woman leadership with valuable guidance, past DDG's, Dr. N.K. Krishna Kumar and Dr. A.K Singh (DDG-I/c); Dr. A.K. Singh (DDG -HS), Dr. W.S. Dhillon and Dr. T. Janakiram, ADG's, for their constant inspiration and encouragement. Sincere thanks to staff members of SMD (HS) for continuous support and co-operation extended to ICAR-NRCB. I am also thankful to members of RAC and IMC for their guidance. I record my heartfelt thanks to all the scientists, technical, administrative and supporting staff of ICAR-NRCB for having stood by me in institute activities. Finally, my earnest thanks to the Publication committee for shaping this document and bringing it in time.

(S. UMA)

2. INTRODUCTION

Banana, revered as one of the three religious fruits of the Nation, has risen from the stalks of backyard crop to commercial crop witnessing a great leap in area, production and productivity. Although, it is is grown in more than 120 countries, India has the largest share in global production (27%) with productivity as high as 34.0T as against world productivity of 24.0 T. Inspite of its exponential growth as an industry, banana suffers from wide array of biotic and abiotic stresses. India (ICAR) realized the importance of this crop as early in 1980's and decided to establish an exclusive single crop institute for banana. Thus, 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 plantain through mission mode basic and strategic research approaches. The actual location of the Centre is in Podavur, 14 Kms away from the Tiruchirapalli city. The Centre has research farm of 36.5 ha and laboratory complex in 3.23 ha. ICAR-NRCB also has an area of 0.80 ha under residential complex in the main city. 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 major thrust areas of research include viz, Improvement, Production, Post harvest 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 post harvest technology.

The ICAR-NRCB has been a globally recognized field gene bank with more than 400 accessions with excellent complementary conservation programmes. *In-vitro*, seed, DNA and embryogenic cell suspension (ECS) banks are catering to the needs of the researchers across the country. Attempts to develop a genebank for ornamental bananas and breeding for novel hybrids is noteworthy. Banana improvement through breeding has witnessed good dividends where Centre has developed hybrids with high carotenoids (20%), less starchy and disease resistant synthetic diploids.

The ICAR-NRCB has been identified as National repository for banana germplasm. It has a field gene bank consisting of 566 banana germplasm of indigenous collections from North-Eastern region, Western Ghats, Andaman and Nicobar Islands and also exotic banana accessions from International Transit Centre (ITC), Belgium through ICAR-NBPGR, New Delhi. The Centre has completed nine in-house research projects and twenty three are in progress. Seventeen externally funded projects funded by ICAR, DBT, DAE etc are in progress. The Perspective Plan and 'Vision 2050' document on the research priorities and also reports by QRT and RAC reports were published. The Centre has conducted Institute Research Council meet and Research Advisory Council meet to review the on-going research projects and also monitor the progress made on the RAC and QRT recommendations. The Research Advisory Committee, under the Chairmanship of Dr. S.N.Pandey, Retd. ADG (Hort.Sci.), ICAR, New Delhi reviewed the research activities of the Centre and recommended future research activities for the progress of banana in India.

Vision

To be the world leader in production and productivity of bananas and plantains thereby meet the growing demand in India.

Mandate

- Basic, strategic and applied research on genetic resource management, crop

improvement and production technologies for sustainable and enhanced production and utilization of banana.

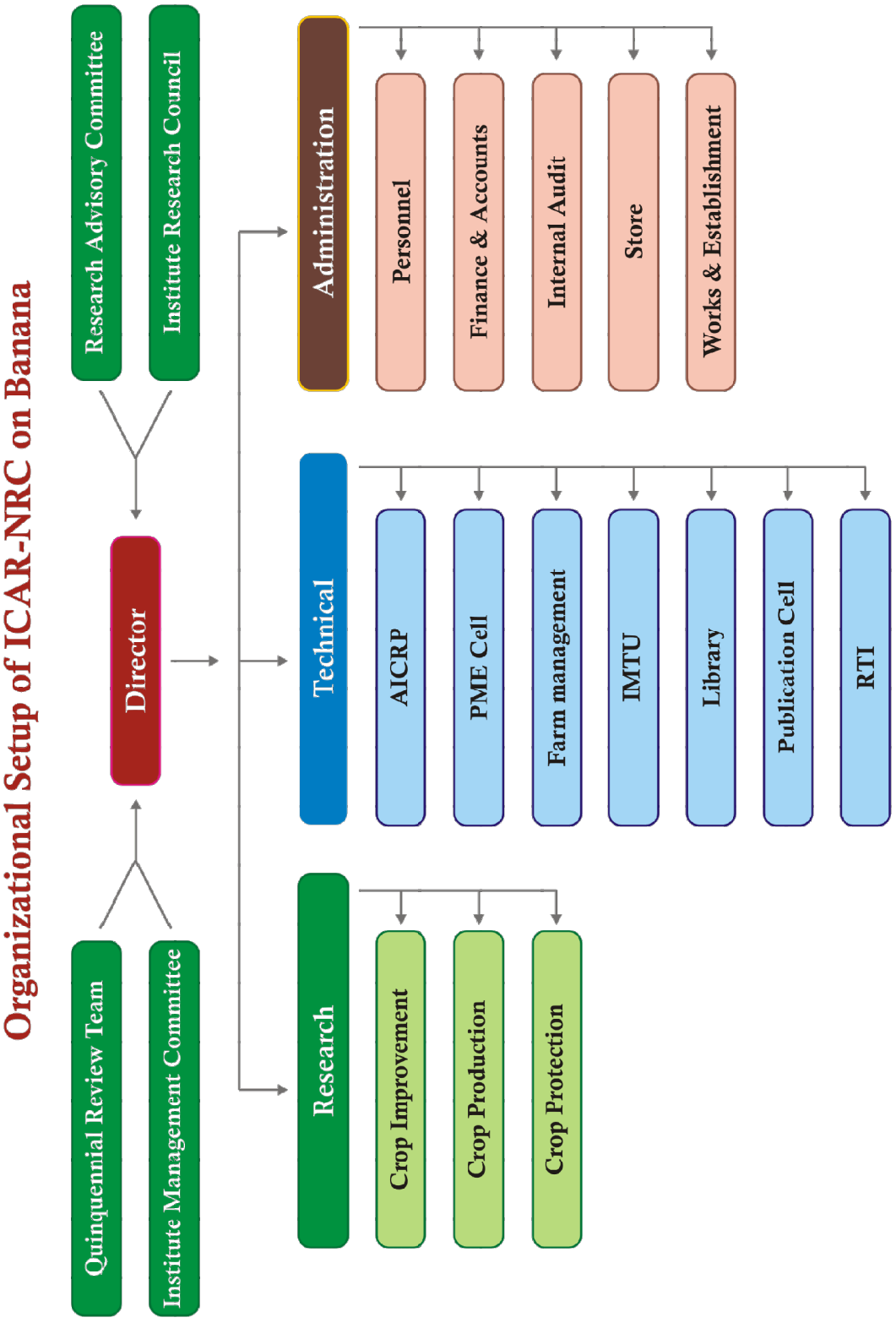
- National banana gene bank management, coordination and validation of research for enhancing and sustaining the productivity of banana.
- Transfer of technology and capacity building of stakeholders for enhanced and sustained production of banana.
- Referral laboratory for monitoring the quality of micro-propagated banana plants.

Budget details (Revised Estimate) for the year 2016 - 17 (Rs. in lakhs)

A sum of Rs. 65.12 lakh was generated by the centre during the financial year 2016 - 17.

S.No	Head of Account	Plan	Non-Plan
1	Establishment charges	0.00	473.12
2	Overtime Allowance	0.00	0.12
3	Travelling Allowance	3.62	6.97
4	Contingencies	91.47	201.96
5	HRD	2.18	0.00
6	Equipments	181.51	3.35
7	Works	90.00	0.00
8	Library & Journals	0.88	0.00
9	Pension and Retirement Benefits	0.00	1.80
	Total	**369.66**	**687.32**

Organizational Setup of ICAR-NRC on Banana



3. EXECUTIVE SUMMARY

Improvement

In the current year, the field gene bank of NRCB, Tiruchirappalli was added with 30 germplasm accessions mostly from secondary sources and another 70 exotic accessions from ITC, Belgium through ICAR-NBPGR, New Delhi. Morphotaxonomic characterization was completed for 15 germplasm accessions using *Musa* descriptor. DArT analysis has been completed for a set of 92 accessions. Performance evaluation of NRCB selections namely 10, 11 and 12 have given promising results and are being evaluated under various agro-climatic conditions.

Evaluation of hybrid progenies indicated that progeny nos. 429 (cv. Rose x Pisang Lilin) and 148 (Pisang Jajee x Lairawk) are superior synthetic hybrids which could be used in future banana improvement programmes. Recent evaluation of progenies have led to the identification of five diploid hybrid progenies of the cross *Musa ornata* x *Musa acuminata* ssp. *burmannica* (Progeny No.425 and 426) and three events of cv. Rose x Pisang Lilin (427, 428, 429) with resistance to Fusarium wilt. Fingerprinting of the Nendran based hybrids has been done using SSR markers. Studies on factors responsible for poor seed set in cv. Grand Naine indicated that though it was female fertile, presence of a barrier between the stigma and stylar region prevented fertilization and seed set. Breeding programmes on the development of ornamental hybrids and Sigatoka leaf spot resistant Grand Naine have been initiated.

Macropropagation using five and seven months old, steam sterilized corms planted in bed method produced more number of plants as against pot method in both cvs. Rasthali and Ney Poovan. Transgenic net house with a budget outlay of Rs. 252 lakhs is in progress at ICAR-NRCB research farm, Tiruchirapalli for the evaluation of transgenic plants of cvs. Rasthali and Grand Naine enriched with iron and pro vit. A constructs provided by QUT, Australia. The lethal dose LD50 has been determined for cv. Grand Naine using ECS (EMS - 0.1% for 1 hour) and shoot tip explants (EMS - 1% for 4 hours). Modification in the media composition based on the results of proteomic studies have led to the successful induction of embryogenic calli and their regeneration for the first time in recalcitrant varieties like Red banana, Ney Poovan, Monthan and Karpuravalli. Cold treatment of somatic embryos at 4^0C for 24 hrs and modified M4 liquid medium improved the regeneration and germination respectively irrespective of varieties.

About 1250 batches of tissue culture plants at various stages of production (Grand Naine, Williams, Robusta, Ney Poovan, Red banana, Quintal Nendran etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports issued (Revenue generated - Rs.21.56 lakhs). Mother cultures of cvs. Udhayam have been supplied to M/s. Hi-Fi Biotech, Salem. Highly regenerative ECS of cvs. Rasthali and Grand Naine were supplied to Indian partners (TNAU and ICAR-IIHR).

Production

In a nutrient dynamic studies, at harvesting stage in both cvs. Ney Poovan and Rasthali (ratoon-1), a gradual increase in dry matter production (DMP) was observed with increasing levels of RD-NPK from control to 150%. The total DMP in the plant was distributed in the order of bunch > stem > corm > leaf > peduncle > petiole > root > male bud. At harvesting stage, out of total uptake of nutrients by Ney Poovan (r-1), 24 to 52% of the nutrients were removed through the bunch harvest and remaining were recycled through reincorporation of residues in the soil. But in case of Rasthali (r-1), 16 to 56% of the nutrients were removed through bunch harvest and the rest were recycled in the soil. With respect to K-dynamics in banana, it was found

that though significant "potassium mining" occurs in banana cultivated soil, recycling of banana residues for ratooning significantly improved the Potential Buffering Capacity for Potassium (PBC-K) of soil by 159.5%. Thus, *in situ* recycling of banana residues for ratooning will ensure a sustainable potassium supplying power of soil for banana, through significant replenishment of K at "non-specific sites" of clay lattice, in long run.

Significant differences were observed in the plant growth parameters, leaf characteristics, interval between planting of suckers to flower emergence of cv. Ney Poovan. The bunch weight and other yield attributes varied significantly among different treatment combinations and the highest bunch weight was recorded with control. Mother plant + one sucker recorded the highest bunch weight in a population study. However, the bunch weight was found similar in all the three levels of fertilizers. Data on leaf nutrient concentrations showed significant differences among the different treatment combinations.

Ney Poovan, Grand Naine, Red Banana, Naatu Vazhai and Ottu Nattu Vazhai variety are used for leaf purpose at Theni Dist., while it is 'Monthan' followed by 'Poovan' in Cuddalore Dist.; Poovan and Karpuravalli in Coimbatore and adjoining Tirupur Dists. of Tamil Nadu. 'Poovan' leaves packed with foam sheet extended the shelf-life for 14 days at 13.5^{0}C cold storage, followed by wet gunny bags (13 days) compared to room temperature (9 days). Post-harvest handling techniques along with modified atmosphere packaging (MAP) and kept at cold storage (13.5^{0}C) extended the shelf life in cv. 'Ney Poovan' and 'Udhayam' bananas.

Banana nutri-bars refined with four different flavours and colors consisting of banana pulp, corn flour, groundnut, cashew nut, cardamom and clove powders have been developed. Pure banana jam refined with apple had better acceptability. Banana fig was refined by adding different proportions of honey, lemon juice and ginger juice to obtain good flavor, taste and storability. Banana flour and refined wheat flour at 60:40 resulted in good texture after blanching. Banana flour based pasta products were developed in combination with wheat flour and whey protein. 'Údhayam' recorded maximum recovery of corm juice, followed by 'Nendran' and 'Saba'.

Pre-treatment with KMS + citric acid (0.25% each) as blanching for three minutes resulted in better overall acceptability of flour (8.6) from rejected bananas of cv. Grand Naine from the export line. Modified page and logarithmic models proved to be the better models for thin layer drying of banana slices. Dehydration of banana at 55^{0}C provided better physico-chemical and rheological characteristics. From the ERH study, optimum RH for storing the banana flour is 55-60%. Addition of banana flour increased the antioxidant capacity, mineral content of the pasta prepared with modified starch with low glycemic index. The pasta with 70% wheat flour, 25% banana flour and 5% modified starch resulted in better pasta with good extrusion capability. The bread prepared with 12.5% replacement with banana flour and 7.5% with modified starch gave a good product compared to other combinations.

Application of soil moisture stress at 5th month after planting in cv. Grand Naine delayed the flowering by 12-23 days irrespective of soil alleviation chemicals. Grand Naine foliar primed with Acetyl Salicylic Acid + Glycine Betaine prior to the drought imposition recorded significantly higher bunch yield with more number of hands. Banana plants imposed with soil moisture deficit (-0.8 to -0.9 MPa) and salt stress (100 mM NaCl) under shaded condition (50% of light) recorded significant decrease in photosynthesis compared to stressed plants under natural light. Based on the growth parameters, Poovan, Ney Poovan, Grand Naine and Saba were identified as shade tolerant

cultivars, while Karpuravalli as a shade sensitive cultivar.

In biochemistry, treatment of full (100%) mature pre-harvest Poovan bunches by fumigation with 1-methylcyclopropene (1-MCP) at a concentration of 1 µl/L for 12 hr enhanced the *in planta* green life of for 10 days against 2 days, after which the full mature bunches showed maturity browning. The ripening behavior of pre-harvest Poovan bananas treated with 1-MCP during post-harvest self-ripening and induced-ripening were at par with the untreated control bananas. Study on the mechanism of enhanced green-life of bananas by 1-MCP indicated lower activity of ACC synthase and accumulation of S-adenocyl methionine in 1-MCP treated bananas compared to control indicating the 1-MCP blocked the activity ACC synthase and its substrate. Estimation of glycemic index of banana pulp was standardized in seven ripening stages of ripening using Poovan as standard. Parameters for maximum recovery of total flavonoids from banana fruit peel tissue was standardized using Poovan banana and the maximum amount of flavonoids was obtained from Poovan peel when extracted for 3 hr by using 95% ethanol solution at 80 °C with the ratio of raw materials to ethanol solution of 1:10.

Hundred plants each of cvs. Rasthali and Grand Naine transgenic plants with *Os*NAS1 iron gene are in the hardening process and the presence of gene *Os*NAS1 and absence of *Agrobacterium* contamination were confirmed by multiplex PCR with primers of gene and VirA in half of the transgenic plants. Using iron gene construct *p*BMGF-DC-68 carrying *Os*NAS2 gene, around fifty transgenic plants of Rasthali and Grand Naine were produced.

Protection

Around 342 volatile components from banana stem were isolated. Three antennal proteins were isolated and identified from stem weevil. Selected semiochemicals from banana leaf sheath gave weevil attraction to an extent of 70-85%. Out of six botanicals screened against stem weevil, zimmu extract was found more effective. Complete documentation of the natural enemy complex of banana skipper, *Erionota torus* was done. Molecular characterization was done for major banana pests. Severe infestation of rugose spiralling whitefly, *Aleurodicus rugioperculatus* was documented on banana from Pollachi and nearby places in Tamil Nadu. Parasitoids and several indigenous predators of this whitefly were documented.

Incidence of Tropical race 4 of Fusarium wilt disease (*Foc* TR4) was reported from banana cv. Grand Naine and Robusta grown in Katihar district of Bihar, India. Rapid detection and diagnosis technique of eumusae leafspot from crude DNA was developed using LAMP primers. Effective principal compounds against *Foc* TR4 were isolated from zimmu leaf extract and *Trichoderma asperellum*. Inhibition of *Foc* TR4 was observed with silver nano particles of zimmu under *in vitro* and pot conditions.

Complete genome of cucumber mosaic virus (CMV) infecting banana was characterized. The coat protein genes of BBrMV and CMV was amplified and cloned. Field evaluation of embryogenic cell suspension (ECS) derived banana bunchy top virus (BBTV) free Hill banana plants showed significant difference in the growth and yield parameters. Full length clones of BSMYV and banana streak gold finger virus (BSGFV) were made. Transmission of BBTV by banana aphid, *Pentalonia nigronervosa* showed that transmission rates were significantly higher at 25°C ± 1 than at 20°C ± 1 and 37 °C. Two ECS lines were developed for banana cv. Poovan and Hill banana for genome editing using CRISPR-Cas9 approach and transgenic generation. Using MVR-RNAi and hairpin-rep (BBTV) constructs, 22 putative transgenic lines were developed. CP, HC-Pro, VPg, NIa genes

of BBrMV and CAM19, eIF4E(Iso), eIF4E-4, eIF4E-6, PSKI genes were amplified and cloned in pTZ57R/T vector and sequenced. VPg gene sequences of 25 BBrMV isolates from different regions of Southern India were characterized.

Samples collected from North Eastern Indian states and Kerala showed incidence of root-lesion (*Pratylenchus* sp.), root-knot (*Meloidogyne* sp.) and spiral nematodes (*Helicotylenchus* sp.). Severe infestation of root-knot nematode was observed in soil and root samples collected from wilt sick fields of banana cv. Grand Naine in Theni District, Tamil Nadu. Interactions between root-lesion and root-knot nematode on banana cv. Nendran showed that reproduction of root-knot nematode was decreased in the presence of root-lesion nematode.

Transfer of Technology

Nearly 4720 visitors comprising of farmers, entrepreneurs, horticultural / agricultural officers and school / college students visited ICAR - NRCB and they were briefed about improved production, protection and post - harvest technologies and value addition of banana. Four radio talks (All India Radio) and one television talk (DD – Telugu) were delivered by scientists of ICAR – NRCB. Seventeen press notes in various dailies and magazines were published by ICAR - NRCB. The institute has participated/ organized 19 exhibitions at regional/ National levels and a total of 10 on-campus and 13 off-campus trainings were conducted to farmers and entrepreneurs. Totally 65 seminars / conferences / symposia / workshops / meetings were attended by the scientists of ICAR – NRCB at regional / National / International levels. A total of 10 MoU's were signed and technologies on post harvest handling, packing and storage were transferred to eight entrepreneurs. A total of 5747 banana cv. Udhayam were distributed to banana growers of various districts of Tamil Nadu.

Linkages and Collaborations

ICAR–NRCB has research collaborations with International institutes which include Bioversity International, France and Queensland University of Technology, Australia. The institute has linkages with National institutes, namely, ICAR – NBPGR, New Delhi; BARC, Mumbai; ICAR – IIHR, Bengaluru; ICAR – CIAE, Bhopal, DST and DBT, New Delhi; PAU, Ludhiana; TNAU, Coimbatore and NIT, Tiruchirapalli. ICAR – NRCB also coordinates with AICRP (Fruits) centers working on banana. Tissue culture industries involved in banana mass propagation, farmers, exporters, State Horticulture and Agriculture departments and self-help groups are linked with the centre for various research and developmental activities. The centre has research collaboration with ICAR – CIAE (RS), Coimbatore, for developing post-harvest mechanization package for banana central core and development of mechanization package for rope making from outer sheath of banana pseudostem.

HRD and Education

Under Human Resource Development, four scientific, seven technical and four administrative staff of ICAR – NRCB had participated in various training programs and updated their working knowledge. The centre has published 13 research papers in various journals of International and National repute and 16 research papers were presented in various conferences / symposia / seminars, etc. held across the country. Six students pursuing B.Tech., M.Tech. & M.Sc. from different Universities were guided by the centre's scientists for their dissertation work on banana.

Revenue Generated

A sum of Rs. 65.12 lakh was generated by the centre during the financial year 2016 - 17.

4. RESEARCH ACHIEVEMENTS

4.1 CROP IMPROVEMENT

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

Collection

Explorations conducted in the western parts of Meghalaya including West and East Garo hills resulted in the collection of 13 accessions. Eight and six accessions have been collected from secondary sources namely BRS, Kannara and Jalgaon respectively. Three accessions were collected from farmers' field at BR hills, Karnataka. The accessions collected during the current year is listed in the Table 1.

Seventy ITC accessions were introduced through ICAR-NBPGR, New Delhi and they have been established under *in vitro* conditions. After *in vitro* establishment, 44 accessions have been planted in the field for evaluation purpose (Table 2 & 3).

Table 1. List of germplasm collected during 2016 - 17

S.No.	Name of the accession	Place of collection
1.	Paka	BRS, Kannara
2.	SH- 3436-9	-do-
3.	Kadali	-do-
4.	FHIA –03	-do-
5.	*M.ac*.ssp.*zebrina*	-do-
6.	BRS-01	-do-
7.	BRS-02	-do-
8.	Manjeri Nendran	-do-
9.	Chaou	Tura, Meghalaya
10.	Champaghante	-do-
11.	Borjahaji	-do-
12.	Modan	-do-
13.	Sobokgire	-do-
14.	Ibok therek	-do-
15.	Sodogol	-do-
16.	*Musa flaviflora*	-do-
17.	Kechulepa	-do-
18.	Reshing	-do-
19.	Jahaji Mutant	-do-
20.	Chaou	-do-
21.	Monishal	-do-
22.	Pacha Kadali	BRS, Jalgaon
23.	Ambio Mohar	-do-
24.	FHIA-23	-do-
25.	Mutheli	-do-
26.	Hanuman	-do-
27.	Pacha Kadali	-do-
28.	Uthiran	BR Hills, Karnataka
29.	Durga	-do-
30.	Mathuranga	-do-

Table 2. List of ITC accessions planted at ICAR - NRCB farm, Tiruchirapalli

S.No.	NBPGR No.	ITC accession No.	Accession Name	No. field planted
1	EC409305	ITC0005	Guineo	4
2	EC653541	ITC0069	Type2x	2
3	EC653542	ITC0087	Kayinja	2
4	EC653545	ITC0095	Pelipita	4
5	EC653546	ITC0101	Fougamou 1	4
6	EC656727	ITC0123	Simili Radjah	8

S.No.	NBPGR No.	ITC accession No.	Accession Name	No. field planted
7	EC653547	ITC0180	Grand Naine	2
8	EC653548	ITC0200	Kelong Mekintu	2
9	EC653550	ITC0217	Akpakpak	4
10	EC656729	ITC0247	Honduras	1
11	EC653556	ITC0279	BieYeng	4
12	EC409307	ITC0280	Rajapuri India	2
13	EC653557	ITC0294	Pitu	1
14	EC653558	ITC0304	Palang	2
15	EC653559	ITC0319	Biu Ketip	7
16	EC653560	ITC0322	Maiden Plantain	4
17	EC446007	ITC0393	*Musa acuminata* ssp.*truncata*	1
18	EC653562	ITC0395	Lidi	4
19	EC846883	ITC0415	Pisang Cici Alas	2
20	EC653565	ITC0433	Pisang Mulik	2
21	EC653567	ITC0446	Pu-te La-Bun	1
22	EC653568	ITC0448	Pisang Keling	1
23	EC653569	ITC0451	Cocos	1
24	EC653570	ITC0466	Banksii	3
25	EC653571	ITC0471	Bebek	2
26	EC653572	ITC0480	Pisang Buntal	1
27	EC653574	ITC0513	Plantain no .2	2
28	EC653575	ITC0519	Obubit Ntanga green mutant	1
29	EC846884	ITC0530	A3617/9	4
30	EC653576	ITC0533	KluaiLep Mu Nang	2
31	EC653578	ITC0547	Chinese Cavendish	1
32	EC656758	ITC0647	Lep Chang Kut	2
33	EC656741	ITC0659	Namwa Khom	3
34	EC653586	ITC0724	Cocos	1
35	EC846891	ITC0727	Pahang	1
36	EC656743	ITC0766	Paliama	3
37	EC409308	ITC0823	Ambiri	10
38	EC656746	ITC0825	Uzakan	1
39	EC656759	ITC1016	*Musa balbisiana*	1
40	EC846893	ITC1067	THA018	2
41	EC656747	ITC1120	Tani	2
42	EC423203	ITC1139	*Musa acuminata* ssp. *zebrina*	1
43	EC656750	ITC1177	Zebrina	6
44	EC656752	ITC1287	Pisang Beragan	2

Table 3. ITC accessions maintained under *in vitro* conditions

S.No.	Alternate ID	Sp./Group	Ssp/SubGroup	Name of Cultivar
1	ITC0090	AA	Taju Lagada	Tjau Lagada
2	ITC0094	*Balbisiana*		*Balbisiana* (10852)
3	ITC0121			Ihitisim
4	ITC0250	*Acuminata*	*malaccensis*	*Musa acuminata* ssp.*malaccensis* type *malaccensis*
5	ITC0267	AA		NBA 14
6	ITC0404	*Acuminata*		*Musa acuminata* type Kluai Thong Det
7	ITC0472	ABB		Pelipita
8	ITC0507	AA		Pisang Madu
9	ITC0539	*Textilis*	*textilis*	*Musa textilis*
10	ITC0570	AAA	Cavendish	Williams (Bell South Johnstone)
11	ITC0588	*Jackeyi*	*jackeyi*	*Musa jackeyi*
12	ITC0591	AA		Kasaska
13	ITC0643	ABB	Bluggoe	Cachaco
14	ITC0668	*Acuminata*		Pa (Mysore) no .2
15	ITC1026	Boman		*Musa boman*
16	ITC1520	*Acuminata*		*Musa acuminata* (11\9-02)
17	ITC1588	*Acuminata*		Lal Velchi

Characterization

Fifteen accessions collected earlier were characterized morphotaxonomically using *Musa* descriptor and their subgroups have been identified (Table 4).

Table 4. List of germplasm characterized during 2016 – 17

S.No.	Name	Genome	NRCB accession number	Identified sub group
1.	Kanthali I	ABB	2304	Pisang Awak
2.	Baish Chharra	ABB	2305	Monthan
3.	Bagada	ABB	2306	Pisang Awak
4.	Baisha	ABB	2307	Pisang Awak
5.	Kanthali II	ABB	2309	Pisang Rajah
6.	Champa II	AAB	2310	Pome
7.	Panth Raj	ABB	2312	Bluggoe -Kothia
8.	Champa III	AAB	2314	Mysore
9.	Kanthali IV	ABB	2318	Silk
10.	Deshi Malbhog	AAB	2319	Silk
11.	Sabri	AAB	2320	Silk
12.	Champa IV	AAB	2323	Silk
13.	Martman	AAB	2324	Silk
14.	Alpan	AAB	2325	Mysore
15.	Pisang Awak	ABB	2327	Pisang Awak

Evaluation of NRCB selections

NRCB Selection 12 (AAB): Performance evaluation of this ITC introduction revealed that it had a short duration of 310-320 days with shorter maturation time of 50-55 days, yielding 14-15 kgs and fruit weight not less 150g. Suitable for making snacks (Fig. 1).

Fig. 1. Performance evaluation of NRCB Selection 12 (AAB) at ICAR - NRCB, Tiruchirapalli

NRCB Selection 10 (ABB): Performance evaluation done at two places namely ICAR - NRCB, Tiruchirapalli and BRS, Kannara indicated that plant height and crop duration were significantly different from local Karpuravalli, a check variety. But at ICAR - NRCB, Tiruchirapalli fruit weight and bunch weight were also significantly different from the local check (Fig. 2.).

Suckers and tissue culture plants of NRCB selection 10 have been provided to various AICRP centres namely Bhubaneshwar, Jorhat, Coimbatore, Andaman and Nicobar Islands and Arabhavi to evaluate their performance under varied agro-climatic conditions.

Fig. 2. Performance evaluation of NRCB Selection 10 (ABB)

NRCB Selection 11 (AAA): The performance of the high yielding somaclonal variant of cv. Manoranjitham was found to be stable even in the third ratoon (Table 5 and Fig. 3a & 3b). To evaluate the yield stability of the high yielding variant selected from Kolli hills, they were mass multiplied and planted at three different locations namely ICAR-NRCB,

Table 5. Yield parameters of cv.Manoranjitham variant

Characters	NRCB Selection-11(3rd Ratoon)
Plant height (cm)	490- 520 cm
Stem girth (cm)	106-110cm
No.of leaves at shooting	17-18
No. of leaves at harvest	13-14
Bunch weight (kg)	45-46
No.of hands	12-14
No.of fingers/hand	17-20
Finger length (cm)	15-16 cm
Finger girth	8-9 cm
Finger weight (g)	195-205
Days for shooting (days)	270-280
Days for harvest (days)	125-130
Crop duration (days)	395-410

Fig. 3a. NRCB Selection 11 in third ratoon at farmer's field in Kolli hills

Nadukombai (foot hills of Kolli hills) and Valappur Nadu of Kolli hills (1010 m above MSL). Regular package of practices are being adopted and the observations being recorded.

Fig. 3b. Field evaluation of NRCB Selection 11 at ICAR - NRCB farm, Tiruchirapalli

NRCB Selection 06 (ABB) : Performance evaluation was carried out at ICAR-NRCB, Trichy using local Monthan as check. Results indicated that it was superior to local check with respect to all vegetative and reproductive traits except for no. of leaves at harvest, no. of fingers per hand, their length and girth (Fig. 4).

Fig. 4. NRCB Selection 06 in shooting stage

Studies on regeneration systems in banana

Carrageenan is a low cost alternative for gelling agent that substantially reduced the medium cost by 42-61% when compared to control (agar). Plants derived from MS media gelled with carrageenan and agar were found to be on par in terms of growth and development at various stages of multiplication namely rooting, primary and secondary hardening. They have been field planted for evaluation purpose and the plants are in the vegetative phase (three months old) and regular observations are being recorded.

Tissue cultured plants of cv.Udhayam derived from three different explants namely shoot tip, cormlet and male flower bud along with sucker control were planted in the farmers field during last year. Regular package of practices were adopted and observations on vegetative parameters were recorded during the 3rd, 5th and 7th month after planting. Data analysis indicated that during 3rd month, the plants derived from different explants showed highly significant differences for important vegetative parameters like plant height, girth, no. of leaves, leaf length, width and petiolar length. During 5th month, they showed highly significant differences for all vegetative parameters except leaf width and during 7th month only height, girth and petiolar length exhibited highly significant differences among the different treatments. They are in the shooting stage and the yield parameters will be recorded at the time of harvest (Fig. 5).

Fig. 5. Field evaluation of cv. Udhayam derived from different explants

Effect of different growth regulators on multiplication of shoots derived from male flower buds of cv. Ney Poovan

BAP in combination with IAA was found optimum for shoot multiplication (10 shoots in 14 days) in male flower bud explants of cv. Ney Poovan (Fig. 6).

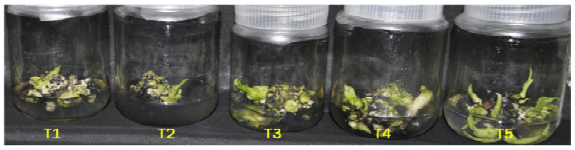


Fig. 6. Effect of different growth regulators on multiplication of shoots derived from male flower buds of cv. Ney Poovan

Standardization of macropropagation protocol for cvs. Rasthali and Ney Poovan in pot method

Macropropagation of cvs. Rasthali and Ney Poovan using three, five and seven months old, steam sterilized and non steamed corms were attempted both in pot and bed methods. In both the varieties, five and seven months old, steam sterilized corms planted in bed method produced more number of plants as against pot method (Fig. 7).

Ney Poovan Rasthali

Fig. 7. Effect of sucker age and steaming on number of shoots produced during various primary decortications in cvs. Ney Poovan and Rasthali

4.1.2 Improvement of banana through conventional breeding

Improvement of Pisang Awak group (ABB)

Pisang Awak members *viz.,* Karpuravalli, Bankela, and Udhayam were crossed with different male parents like Pisang Lilin, Pisang Jajee, Cultivar Rose and Calcutta-4. About 867 hybrid seeds were collected from 21 hybridized bunches. Out of 867 hybrid seeds, 70 plants were successfully germinated under *in vitro* conditions, 46 planted in field and 24 plantlets are in primary hardening. Similarly, Bhat Manohar (Pisang Awak type), a natural tetraploid was crossed with Pisang Jajee and Pisang Lilin and 1602 viable seeds were obtained, of which 10 plants were planted in field and 14 plants are under *in vitro* germination.

Improvement of cooking bananas (ABB)

A total of 36 ABB (Saba, Kothia and Bangrier) bunches were crossed with suitable male parents (Pisang Lilin, Cv.Rose and Pisang Jajee) and 1951 hybrid seeds were obtained. Of which, 15 plants were planted in field and 42 plants are under *in vitro* germination.

Evaluation of hybrids developed from commercial cultivars

A total of 76 seedlings of Karpuravalli (19), Bhat Monahar (10), Kothia (7), Chinia (5), Bankela (14), Saba (8), Udhayam (13) based hybrids which were developed using various male parents namely Pisang Jajee, Pisang Lilin, cv. Rose, Calcutta 4 were planted in the field for performance evaluation.

Development of improved diploids

Progeny No. 429 (Cv. Rose x Pisang Lilin) was found to be an improved diploid as it has some good agronomic qualities such as parthenocarpy, with average fruit size of 11cm and good TSS content (26^0brix), polleniferous nature, high pollen fertility, resistant to *Foc*, field tolerant to Sigatoka (*M. eumusae*) disease.

First time fruit filling was observed in Progeny No. 148 (Pisang Jajee x Lairawk) after five years of development. It produces 12-14 hands of fruits, 20 – 24 fruits per hand and 5-

10 seeds were found in few fruits. It is found to be field tolerant to Sigatoka (*M. eumusae*) disease and highly polleniferous in nature. Hence this valuable progeny may be utilized both as female and male parents for the banana improvement programme (Fig. 8).

Fig. 8. Progeny No. 148

Evaluation of improved diploids for Fusarium wilt resistance

To identify the *Foc* (VCG 0124) resistant hybrid progenies, each three suckers of 16 hybrids of various cross combinations were screened against *Foc* under pot culture. Disease scoring after three months of spore inoculation, led to the identification of five diploid resistant hybrid progenies (Fig. 9). They are from two different events of *M.ornata* x *M.ac.ssp. burmannica* (Progeny No.425 and 426) and three events of cv. Rose x Pisang Lilin (427, 428, 429). These potential improved diploids could be successfully utilized in banana breeding programmes as male parents.

Fig. 9. CS of *Foc* resistant banana hybrid progeny

Seed set in open pollination

Seed setting was observed in 16 germplasm accessions belonging to various

Table 6. Germplasm accessions showing seed set under open pollination conditions

Sl. No.	Acc.No.	Name	Genome	Sun group	No. of seeds in a bunch
1	2057	Bharatratnavalli	ABB	Pisang Awak	2
2	0117	Nepali Chinia	ABB	Pisang Awak	110
3	0059	Agni Malbhog	ABB	Pisang Awak	52
4	0089	Battisa Piro	ABB	Pisang Awak	23
5	2150	Namwa Khom	ABB	Pisang Awak	4
6	0499	Mannan	AAB	Pome	4
7	0554	Co-1	AAB	Pome	18
8	0501	Mottapoovan	AAB	Mysore	8
9	0619	Mysore Bale	AAB	Mysore	7
10	0485	Kullar Kanai	ABB	Bontha	12
11	2142	Blue Jawa	ABB	Bontha	22
12	0137	Singhalaji	ABB	Bontha	3
13	2153	Dole	ABB	Bontha	22
14	2110	Kothia	ABB	Bluggoe	50
15	2115	Dudhia	ABB	Blugggoe	27
16	0018	Borkal Baista	ABB	Unique	40

genomic groups (Table 6) under open pollinated condition. This preliminary information will facilitate the selection of female parent in concerned sub group for improvement programme.

4.1.3 Improvement of banana for root lesion nematode resistance and marker development

Development of nematode resistant hybrids

To develop root lesion nematode, *Pratylenchus coffeae* resistant commercial cultivars namely Karpuravalli and Poovan were crossed with *P.coffeae* resistant accessions namely Pisang Lilin, cv. Rose, Pisang Jajee and Calcutta 4. Though seed setting was observed in all the cross combinations, embryo germination was observed only in Karpuravalli x Pisang Lilin (Fig. 10) and Poovan x Pisang Lilin combinations. Out of 45 embryos of Karpuravalli x Pisang Lilin cross combination, 19 embryos germinated under *in vitro* conditions. Similarly, out of 15 embryos of Poovan x Pisang Lilin combination, only 5 embryos germinated under *in vitro* conditions. But, the variation in vigour of the seedlings of Karpuravalli x Pisang Lilin hybrid combination was observed in the seedling stage itself. Interestingly, it was observed that the embryos of Karpuravalli and Poovan based progenies are comparatively smaller in size when cv. Rose was used as male parent but none of the embryos germinated.

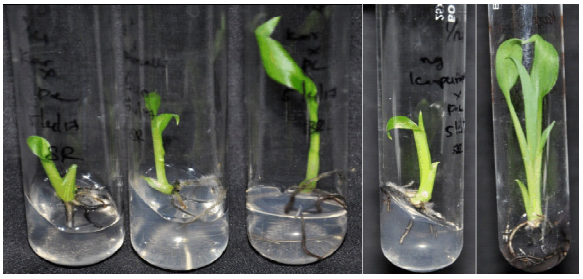


Fig. 10. Karpuravalli x Pisang Lilin hybrids developed through embryo culture

Initial evaluation trial of Nendran based hybrids

For conducting the initial evaluation trial (IET), twenty Nendran based hybrids have been multiplied. Both sucker and tissue culture plantlets were planted in the field for selection of best hybrids.

Fingerprinting of Nendran based hybrids

Molecular characterization of 21 Nendran based hybrids was carried out using SSR markers. This resulted in development of fingerprints for three hybrids namely NPL30, NPL33 and NCR5 with the SSR Primers NRSIP 14, NRSIP 22 and NRSIP 20 respectively (Fig. 11a, 11b & 11c). Out of 40 primers, 13 primers showed distinct polymorphism for NPL33 from other Nendran based hybrids.

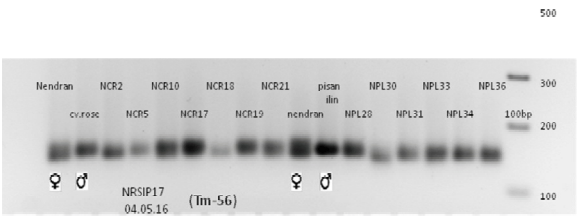


Fig. 11a. NRSIP14 primer showing distinct banding pattern in NPL30

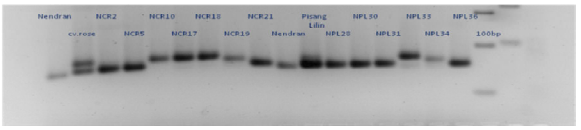


Fig. 11b. NRSIP22 primer showing distinct banding pattern in NPL33

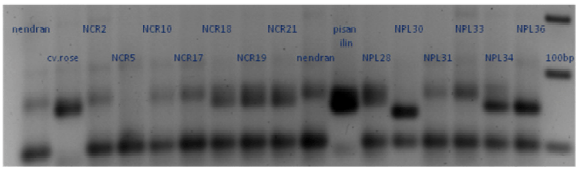


Fig. 11c. NRSIP 20 primer showing distinct banding pattern in NCR 5 and NPL30

Identification and detection of parental polymorphic markers

For parental polymorphism studies, a total of 40 i*n silico* polymorphic SSR primers were

selected from the MusatransSSR database (http://nrcb.res.in/nrcbbio) and tested against nematode resistant contrasting parents (three female and seven male parents). Except nine primers, all others showed polymorphism among any one of the female and male combinations (Fig. 12). This parental polymorphic information will be useful for molecular characterization of the progenies obtained from respective parents and to develop nematode resistant markers.

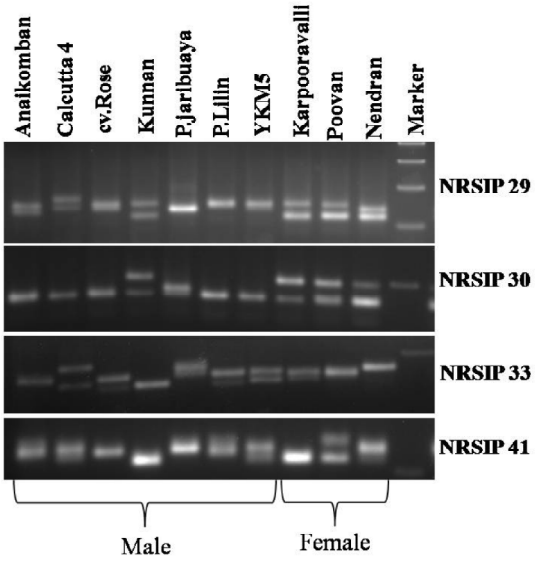


Fig. 12. Parental polymorphic primers for nematode resistance

4.1.4 Development of trait specific markers for Fusarium wilt resistance through association mapping studies in banana (*Musa* spp.)

Out of 99 accessions which were established in pots (five replications each) and inoculated with spores of *Foc* for phenotyping against Fusarium wilt resistance, surprisingly Thozuvan (AAB – Silk) was found to be resistant with disease score of zero (on the scale 0-5). Further results indicated that Manohar (BB) which was found resistant in the initial screening was found to be susceptible in the confirmatory pot culture studies. Genomic DNA has been isolated for 53 accessions for use in genotyping and PCR conditions have been standardized for the second set of 55 primers.

4.1.5 Improvement of cv. Grande Naine (Cavendish – AAA) for Fusarium wilt resistance through non-conventional breeding

Cv. Grand Naine

During the reporting period, about 50 shoot tips of cv. Grand Naine were treated with Ethyl Methane Sulfonate (EMS) at various concentrations *viz.* 1, 2 & 3% for 2, 3, 4 & 5 hours and LD_{50} was determined as 1% EMS for 4 hours based on fresh weight gain and survival percentage. About 150 immature male flower buds of cv. Grand Naine were initiated towards the development of embryogenic cell suspension (ECS). ECS was mutated with EMS 0.1, 0.2, 0.3 & 0.4% for ½, 1, 1 ½ and 2 hours and the LD_{50} was determined as EMS 0.1% for 1 hour based on fresh weight gain and regeneration efficiency (Fig. 13). Plants derived from irradiated (35 Gy) ECS of cv. Grand Naine have been planted in the sick plot at Theni even prior to pot screening to evaluate their resistance against Fusarium wilt (race 1 - VCG 0124).

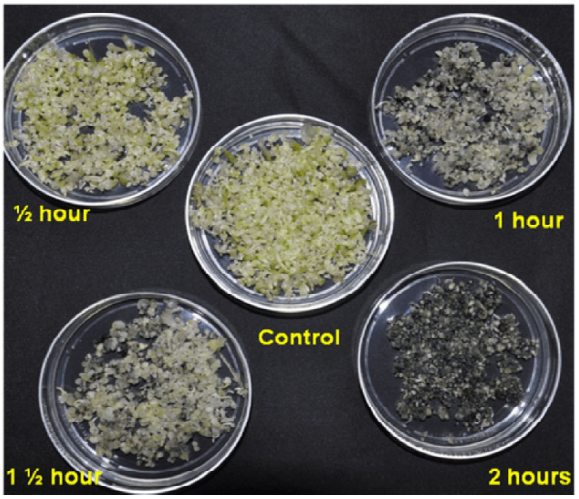


Fig. 13. Effect of EMS (0.1%) on ECS explants of cv. Grand Naine

Cv. Rasthali

About eight fusarium wilt resistant mutants of cv.Rasthali namely NRCB RM 60, 74, 133, 176, 207, 217, 219 and 230 which were planted in the field are in the shooting stage. Third round of pot screening of the foresaid eight fusarium wilt resistant mutants of cv. Rasthali indicated that only one mutant NRCB RM 217 sustained resistance. About 35 lines of fusarium wilt resistant mutants of cv. Rasthali have also been planted in the sick plot at Theni for confirmation of their resistance.

4.1.6 Improvement of banana for Sigatoka leaf spot resistance

Studies on factors responsible for poor seed set

Ovule viability and stigma receptivity were studied to identify their role on seed set in banana. Cvs. Poovan and Grand Naine recorded 220.9 and 341.9 ovules per ovary respectively. 57.4 % ovules were viable in Poovan and only 32.2 % ovules were viable in Grand Naine indicating that both Poovan and Grand Naine are female fertile. The stigma receptivity was studied based on hydrogen peroxide test and pollen germination test (using Calcutta 4 pollen). Stigma of cv. Poovan and wet stigma of cv. Grand Naine were highly receptive on the day of opening with score +++ in H_2O_2 test whereas Grand Naine dry stigma was not receptive and received a score of – in H_2O_2 test. In pollen germination test, pollen germination and pollen tube penetration was observed in cv. Poovan and pollen germination was found in wet stigma of Grand Naine and pollen tube did not penetrate into transmitting tissues of the style. These results on stigma receptivity study indicated that Poovan stigma was highly receptive and pollen pistil interaction is compatible. In case of Grand Naine, dry stigma was not receptive and wet stigma was receptive. However there could have been a presence of barrier between stigma and style region,because of which, pollen tube was not able to penetrate the pollen transmitting tissues of the style leading to failure of fertilization and seed set in Grand Naine.

Development of Sigatoka leaf spot resistant hybrids

Sigatoka is one of the most devastating diseases of banana causing 20-50 % yield loss. To develop resistant varieties for Sigatoka leaf spot, hybridization between Poovan x Pisang Lilin (624 fingers), Poovan x Calcutta 4 (327 fingers), Grand Naine x Pisang Lilin (492 fingers) and Grand Naine x Calcutta 4 (432 fingers) were attempted. Total of 73 hybrid seeds have been obtained from Poovan (51 seeds from Poovan x Pisang Lilin and 22 seeds from Poovan x Calcutta 4), while Grand Naine did not set any seeds. Out of 73 hybrid seeds obtained, 24 embryos were excised and germinated under *in vitro* conditions. But only three embryos of Poovan x Pisang Lilin have been developed into plantlets (Fig. 14).

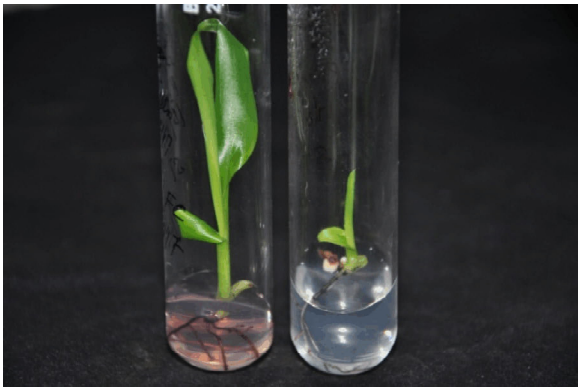


Fig. 14. *In vitro* development of Poovan x Pisang Lilin hybrids

4.1.7 Identification and evaluation of superior clones of cvs. Ney Poovan (AB) and Grand Naine (AAA)

Survey and collection of elite clones

Surveys were conducted in Theni (Periyakulam, Cumbum, Utthamapalayam and Chinnamanur), Erode (Gobichettipalayam and Sathiamangalam), Trichy (Thottiyam) and

Coimbatore (Mettupalayam, Sirumugai and Annur) districts for the collection of elite clones of cv. Grand Naine (AAA) and Ney Poovan (AB). This resulted in the collection of 288 clones (96 Ney Poovan and 192 Grand Naine). Selection criteria included specific traits *viz.,* short duration, high yield and wilt resistance in Ney Poovan (AB) and dwarf stature, high yield and leaf spot tolerance in Grand Naine (AAA). Elite clones were planted at NRCB farm for further evaluation (Table 7 and Fig. 15a, 15b & 15c).

Clone No. 16 Clone No. 19

Fig. 15. Dwarf clones of cv. Grand Naine (AAA)

Fig. 16. High yieding cv. Ney Poovan (AB)

Fig. 17. High yielding clone of cv. Grand Naine (AAA)

Table 7. Details of elite clones collected during surveys

S. No.	Variety	Areas covered	No. of clones collected
1	Grand Naine (AAA)	Lakshmipuram, Madhurapuri, Kombai (Theni Dt.)	8
2	Grand Naine (AAA)	Varattaaru, Madhurapuri, Annanji, Erasainaickanur (Theni Dt).	8
3	Ney Poovan (AB)	Thottium (Namakkal Dt.)	2
4	Grand Naine (AAA)	Kamegoundan Patty, Erasainaickanur, Theni Dt.	42
5	Ney Poovan (AB) & Grand Naine (AAA)	Dhasappagoundanpudur, Arakkankottai, Thoppur, Thookkanaickenpalayam, Bhavanisagar (Erode Dt.)	84
6	Ney Poovan (AB) & Grand Naine (AAA)	Kandiyur, Kumarapuram, Sirumugai, Akkarai, SengapalliKallar (Coimbatore Dt.)	144

4.2 CROP PRODUCTION AND POST HARVEST TECHNOLOGY

4.2.1 Studies on nutrient dynamics in banana

Ney Poovan (ratoon-1)

At harvesting stage in Ney Poovan (ratoon-1), a gradual increase in dry matter production (DMP) was observed with increasing levels of recomended dose of fertilizer (RDF) of NPK from control to 150%. The highest DMP of 14.18kg was recorded at 150% RDF while control recorded 11.98kg. The total DMP in a plant was distributed in the order of bunch (4182g) > stem (3123g) > corm (2005g) > leaf (1688g) > peduncle (997g) > petiole (358g) > root (334g) > malebud (133g) (Fig. 16).

The nitrogen concentrations (%) in different segments of a plant were leaf-2.33, petiole-1.53, stem-2.11, corm-0.51, root-0.62, peduncle-2.12, bunch-0.85 and bud-2.07 while, the phosphorus concentrations (%) were leaf-0.25, petiole-0.33, stem-0.26, corm-0.11, root-0.50, peduncle-0.20, bunch-0.18 and bud-0.17 and the potassium concentrations (%) were leaf-2.37, petiole-1.96, stem-4.02, corm-1.40, root-1.36, peduncle-10.34, bunch-2.82 and bud-1.42. The copper concentrations (ppm) in different segments of a plant were leaf-782, petiole-798, stem-1267, corm-917, root-966, peduncle-417, bunch-387 and bud-120 while the manganese concentrations (ppm) were leaf-1648, petiole-2299, stem-1500, corm-2593, root-2032, peduncle-586, bunch-211 and bud-504, the zinc concentrations (ppm) were leaf-1086, petiole-185, stem-1147, corm-735, root-323, peduncle-754, bunch-1311 and bud-112 and the iron concentrations (ppm) were leaf-3044, petiole-435, stem-3709, corm-2221, root-1113, peduncle-2739, bunch-1195 and bud-1224 (Fig. 18 & 19).

At harvesting stage, the total nutrient uptake (kg/ha) by Ney Poovan were worked out as N-454.7, P-68.8, K-1080.6, Cu-1.0, Mn-3.0, Zn-3.6 and Fe-1.5 and about 143.3kg N, 24.4kg P, 559.1kg K, 0.51kg Cu, 0.73kg Mn, 1.56kg Zn and 1.54kg Fe were removed through bunch harvest, in one hectare soil. The amount of nutrients recycled/added (kg/ha) through reincorporation of residues Ney Poovan after bunch harvest were worked out as 311.4kg N, 44.5kg P, 521.5kg K, 1.95kg Cu, 7.12kg Mn, 1.75kg Zn and 4.35kg Fe.

After bunch harvesting, the residues are vermicomposted. The average nutrient concentrations in vermicompost generated from a single plant of Ney Poovan plant after harvest of bunch were Nitrogen-1.22%, Phosphorus-0.18%, Potassium-2.10%, Copper-78.06ppm, Manganese-285.69ppm, Zinc-68.03ppm and Iron-164.37ppm. The average nutrient contents in vermicompost generated from a single plant of Ney Poovan plant after harvest of bunch were Nitrogen-117.09g, Phosphorus-16.90g, Potassium-202.36g, Copper-0.75g, Manganese-2.73g, Zinc-0.64g and Iron-1.58g.

Rasthali (ratoon-1)

At harvesting stage in Rasthali (ratoon-1), a gradual increase in DMP was observed in increasing levels of RDF of NPK from control to 150%. The highest DMP of 19.54kg was recorded at 150% RDF while control recorded 13.90kg. The total DMP in a plant was distributed in the order of bunch (5276g) > stem (3796g) > corm (3213g) > leaf (2048g) > peduncle (1068g) > root (520) > petiole (511g) > malebud (131). The per cent fractions of DMP in a plant were malebud-1%, bunch-32%, peduncle-7%, leaf-12%, petiole-3%, stem-23%, corm-19% and root-3% (Fig. 17).

The nitrogen concentrations (%) in different segments of a plant were leaf-2.53, petiole-0.56, stem-0.86, corm-0.50, root-0.47, peduncle-1.01, bunch-1.13 and bud-0.65 while the phosphorus concentrations (%) in different segments of a plant were leaf-0.25, petiole-0.23, stem-0.29, corm-0.14, root-0.12, peduncle-

0.14, bunch-0.20 and bud-0.16 and the potassium concentrations (%) in different segments of a plant were leaf-2.00, petiole-1.83, stem-2.99, corm-1.17, root-1.22, peduncle-8.40, bunch-3.24 and bud-0.76. The copper concentrations (ppm) in different segments of a plant were leaf-546, petiole-623, stem-813, corm-967, root-1016, peduncle-376, bunch-406 and bud-89 while the manganese concentrations (ppm) in different segments of a plant were leaf-1931, petiole-1879, stem-1872, corm-1945, root-1896, peduncle-735, bunch-224 and bud-655, the zinc concentrations (ppm) in different segments of a plant were leaf-1107, petiole-238, stem-198, corm-220, root-282, peduncle-187, bunch-734 and bud-131 and the iron concentrations (ppm) in different segments of a plant were leaf-2631, petiole-2217, stem-2040, corm-1711, root-2099, peduncle-2031, bunch-1430 and bud-778 (Fig. 20 & 21).

At harvesting stage, the total nutrient uptake (kg/ha) by Rasthali were worked out as N-450.7, P-87.6, K-1196.2, Cu-2.8, Mn-5.5, Zn-4.2 and Fe-5.4 and about 179.8kg N, 30.5kg P, 666.8kg K, 0.45kg Cu, 0.50kg Mn, 2.12kg Zn and 1.70kg Fe were removed through bunch harvest, in one hectare soil. The amount of nutrients recycled/added (kg/ha) through reincorporation of residues Rasthali after bunch harvest were worked out as 270.9kg N, 57.1kg P, 529.4kg K, 2.11kg Cu, 4.95kg Mn, 2.04kg Zn and 3.70kg Fe.

After bunch harvesting, the residues are vermicomposted. The average nutrient concentrations in vermicompost generated from a single plant of Ney Poovan plant after harvest of bunch were Nitrogen-0.76%, Phosphorus-0.16%, Potassium-1.45%, Copper-56.53ppm, Manganese-136.83ppm, Zinc-57.50ppm and Iron-98.11ppm. The average

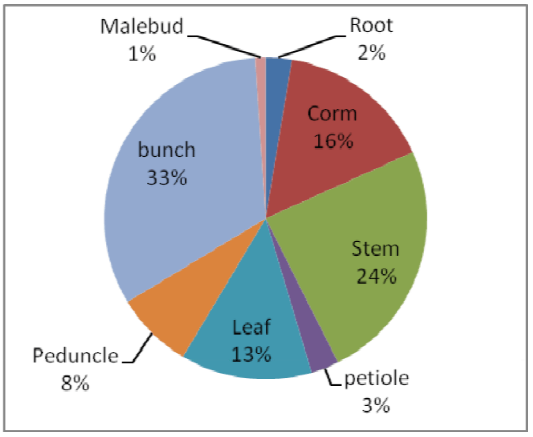


Fig. 16. DMP fraction of Ney Poovan (r-1) at harvest

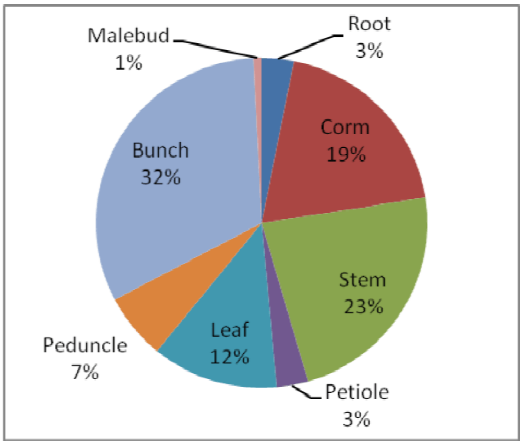


Fig. 17. DMP fraction of Rasthali (r-1) at harvest

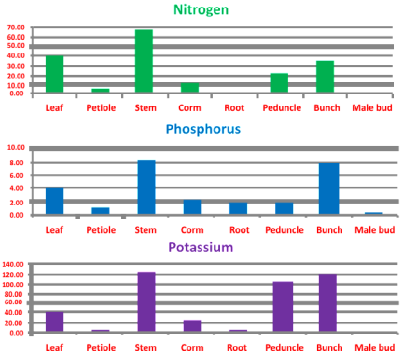


Fig. 18. NPK distribution (g/plant) in a Ney Poovan Plant at harvest

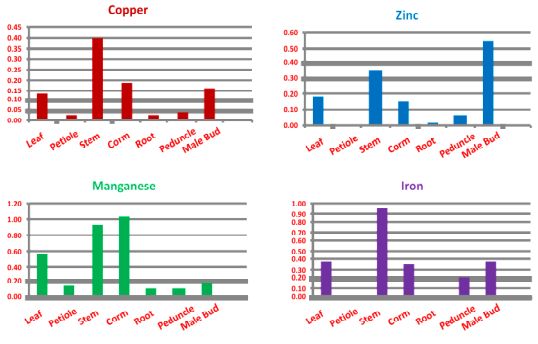


Fig. 19. Micronutrient distribution (g/plant) in a Ney Poovan plant at harvest

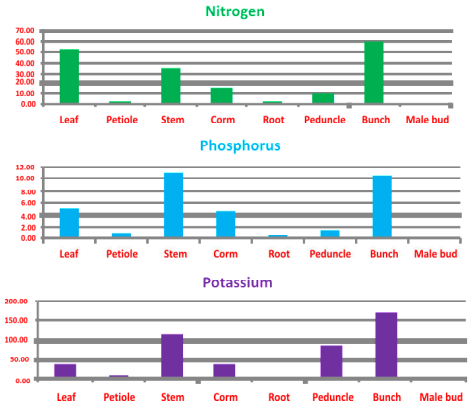


Fig. 20. NPK distribution (g/plant) in a Rathali Plant at harvest

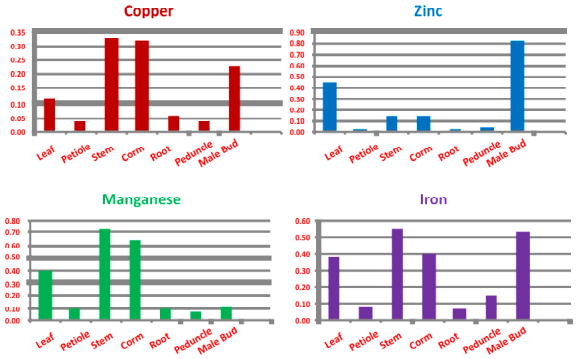


Fig. 21. Micronutrient distribution (g/plant) in a Rasthali plant at harvest

nutrient contents in vermicompost generated from a single plant of Ney Poovan plant after harvest of bunch were Nitrongen-101.86g, Phosphorus-21.02g, Potassium-194.82g, Copper-0.78g, Manganese-1.86g, Zinc-0.77g and Iron-1.38g.

Root studies

Under nutrient dynamics studies, in Ney Poovan (r-1) at harvesting stage, the Root Length Densities (RLD in $mm.cm^{-1}$) were 0.298, 0.054 and 0.030 at 0.0-0.5ft depth, 0-1, 1-2 and 2-3ft away from base of the plant, respectively. The corresponding RLDs were 0.925, 0.185 and 0.078 at 0.5-1.0ft depth and 0.566, 0.099 and 0.061 at 1.0-1.5ft depth. In Rasthali (r-1) at harvesting stage, the corresponding RLDs were 0.256, 0.084 and 0.055 at 0.0-0.5ft depth, 0.770, 0.249 and 0.174 at 0.5-1.0ft depth and 0.508, 0.160 and 0.116 at 1.0-1.5ft depth.

Quantity / Intensity studies of soil potassium

Quantity parameters (€ K expressed in cmol kg^{-1})

At 10-leaf stage, the plant crop soil recorded € K of 0.25, while the ratoon-1 crop soil recorded 0.23. At 20-leaf stage, the plant crop soil recorded € K of 0.23, while the ratoon-1 crop soil recorded 0.44. At shooting stage, the plant crop soil recorded € K of 0.19, while the ratoon-1 crop soil recorded 0.37. At harvesting stage, the plant crop soil recorded € K of 0.19, while the ratoon-1 crop soil recorded 0.34.

Intensity parameters (AR_e^K expressed in $(M/L)^{0.5}$)

At 10-leaf stage, the plant crop soil recorded AR_e^K of 13.38, while the ratoon-I crop soil recorded 9.14. At 20-leaf stage, the plant crop soil recorded AR_e^K of 12.66, while the ratoon-I crop soil recorded 8.04. At shooting stage, the plant crop soil recorded AR_e^K of 10.98, while the ratoon-I crop soil recorded 7.26. At shooting stage, the plant crop soil recorded AR_e^K of 9.82, while the ratoon-I crop soil recorded 7.22.

Potential Buffering Capacity of Soil for Potassium (PBC-K expressed in $cmol.kg^{-1}.(M/L)^{-0.5}$)

At 10-leaf stage, the plant crop soil recorded PBC-K of 18.56, while the ratoon-I crop soil recorded 45.56. At 20-leaf stage, the plant crop soil recorded PBC-K of 18.91, while the ratoon-I crop soil recorded 53.94. At shooting stage, the plant crop soil recorded PBC-K of 17.37, while the ratoon-I crop soil recorded 50.68. At harvesting stage, the plant crop soil recorded PBC-K of 19.22, while the ratoon-I crop soil recorded 49.88.

Comparison of adsorbed potassium

In ratoon-1 soil, the K adsorbed on non-specific (Knsp) site was greater than that of plant crop soil, at all crop growth stages. In ratoon-1 soil, the K adsorbed on the specific sites (Ksp) was less than that of plant crop soil, at all crop growth stages. Though significant "potassium mining" occurs in banana cultivated soil, recycling of banana residues for ratooning significantly improved the Potential Buffering Capacity for Potassium (PBC-K) of soil by 159.5%. Thus, *in situ* recycling of banana residues for ratooning will ensure a sustainable potassium supplying power of soil for banana, through significant replenishment of K at "non-specific sites" of clay lattice, in long run (Fig. 22).

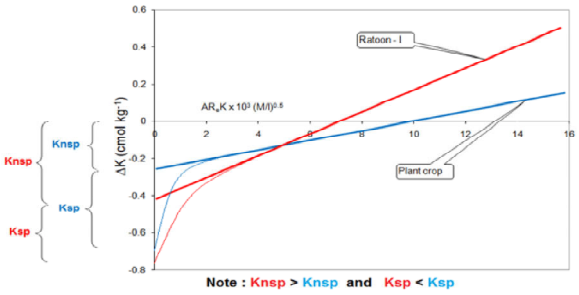


Fig. 22. Quantity / Intensity relation in soil of plant crop and ratoon – I (at harvesting stage)

4.2.2 Development of clump management technology for enhanced productivity in Banana

An experiment was laid out with banana cv. Ney Poovan and the treatment plants were planted at a spacing of 2.4m X 3.0m and four different plant population were maintained by allowing either 1 or 2 or 3 or 4 suckers per clump along with the mother plant at different stages of growth and the treatment plants were imposed with three different levels of fertilizers viz., 125% RDF, 150% RDF and 175% RDF per clump. Besides, a control was maintained by planting single sucker per pit at 2.0m X 2.0m spacing and allowing one sucker per plant after flowering of mother plant with 100% RDF (traditional farmers' practice). Observations recorded on various plant growth parameters, flowering, yield and yield attributes as well as plant nutrient status revealed significant differences among the treatment plants.

Effect on Growth

In the plant crop of cv. Ney Poovan, the data revealed that significant differences were observed with regard to the plant growth parameters such as plant height, pseudostem circumference, leaf characteristics, phyllochron (days) and leaf chlorophyll contents whereas, the number of healthy leaves at flowering was found non-significant among the treatments tried in this experiment. Among the various treatment combinations of different plant population and levels of fertilizers, the plant height ranged from 296.7cm (T2-S1N2) to 380.0cm (T10-S4N1).

Among the four populations, S4 (mother plant + 4 suckers) recorded the tallest plants (353.7cm) while the shortest plants were recorded in S1 (295.6 cm). The phyllochron i.e., days taken for emergence of leaf ranged

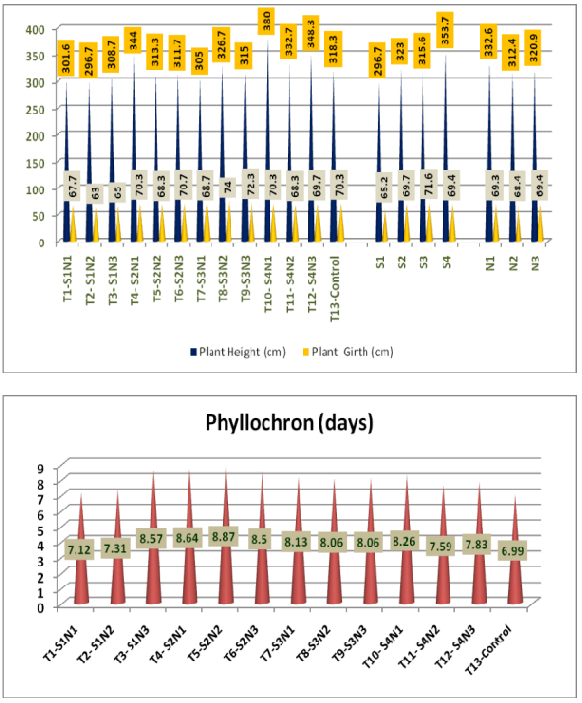


Fig. 23. Effect of clump management on plant growth parameters and phyllochron

from 7.12 days (T1- S1N1) to 8.87 days (T5-S2N2) and the control plants (T13) took 6.99 days per leaf. Among the levels of fertilizers, application of 150% RDF recorded lesser phyllochron while the highest fertilizer dose of 175% RDF slowed the leaf emergence as the treatment took 8.24 days for producing a leaf.

The leaf characteristics such as leaf length, leaf breadth, as well as specific leaf weight varied significantly among the treatments. The leaf length varied from 201.7cm (T2) to 226.7 cm (T11) and the lead breadth ranged from 54.7 cm (T2) to 66.7 cm. Whereas, the largest mean leaf area (1.08 m^2), total leaf area (18.04 m^2) and the highest specific leaf weight was recorded in the control (T13) i.e., allowing one side suckers after the bunch emergence of the mother plant (Fig. 23).

Effect on flowering

The data on the interval between planting of suckers to flower emergence was found highly significant among the treatments. Plants under the treatment T2 (S1N2) recorded the earliest flowering in 311.5 days while T12 (S4N3) took the longest time of 348.9 days for flowering. Among the three levels of fertilizers, the time taken for flowering was extended by the application of higher dose of 175% RDF (335.9 days) while the lowest dose of 125% RDF per clump showed early flowering (320.3 days) (Fig. 24).

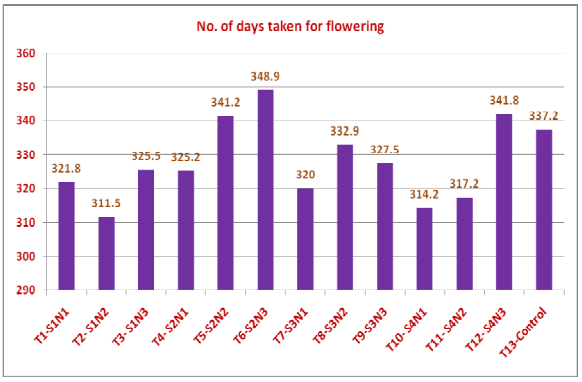


Fig. 24. Effect of clump management on flowering

Effect on fruit maturity

The bunch weight and other yield attributes varied significantly among different treatment combinations s and the highest bunch weight of 13.93 kg was recorded in T13 (Control) and that was on par with T3-S1N3 (13.1 kg) and T2-S1N2 (12.97 kg). Among the four populations tried, mother plant + one sucker recorded the highest bunch weight of 12.81 kg. Regarding the effect of levels of fertilizers, the bunch weight was found similar in all the three levels of fertilizers (Fig. 25).

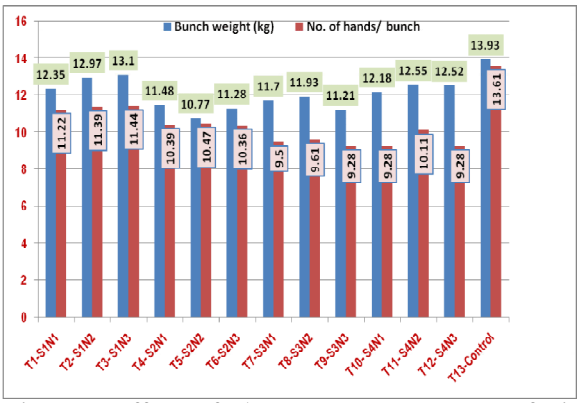


Fig. 25. Effect of clump management on fruit characters

Effect on leaf nutrient concentrations

Data on leaf nutrient concentrations showed significant different among the different treatment combinations. The N (%) ranged from 1.27% to 1.75% while the leaf K content was in the range of 1.80 to 2.66% (Fig. 26).

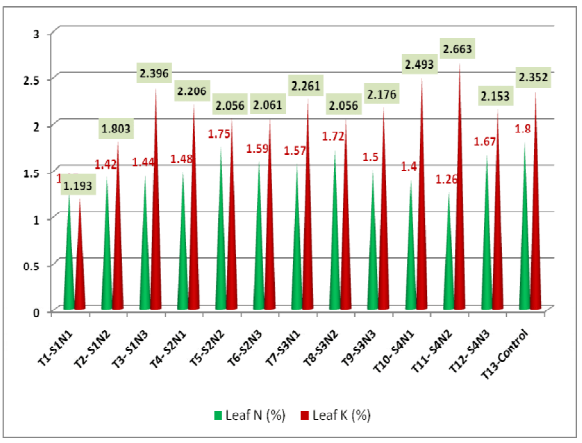


Fig. 26. Effect of clump management on leaf nutrient concentrations

Post Harvest Technology

4.2.3 Survey on varieties suitable for leaf purpose

Ney Poovan, Grand Naine, Red Banana, Naatu Vazhai and Ottu Nattu Vazhai are used for leaf purpose at Chinamannur and Cumbum areas of Theni District, Tamil Nadu, while it is 'Monthan' followed by 'Poovan' in Cuddalore District of Tamil Nadu. Poovan and Karpuravalli are cultivated and marketed in Coimbatore and adjoining Tirupur Districts of Tamil Nadu for leaf purpose.

Post-harvest management of banana leaves

Harvesting is done from 4th month onwards. Thirty to fourty leaves are harvested per hill. Leaves packed with green and dry banana leaf as packing materials can be stored for two to four days in Ney Poovan, three to four days in Robusta and four to six days in Red Banana. Naatu Vazhai and Ottu Nattu Vazhai can be stored for ten to twelve days. Leaves are harvested daily to the tune of two bundles and weekly 12 bundles, totaling to 48 bundles for a month, containing 200 numbers of leaves per bundle. Maximum number of leaf production was reported in Rasthali, when compared to other varities.

Packing of banana leaves

Of the packing materials used for packing the 'Poovan' banana leaves, foam sheet extended the shelf-life of leaves for 14 days at 13.5^{0}C cold storage, followed by leaves packed with wet gunny bags (13 days) compared to that stored at room temperature (9 days). However, single layer leaves registered the minimum shelf-life.

Pre-treatment on shelf-life of banana leaves

Banana leaves pre-treated with water for one hour daily by immersion expressed more shelf-life that of untreated control kept in room temperature. Of the different varieties used for pre-treatment with water for one hour daily by immersion, Kungsong wild gave maximum shelf-life (10.34 days), followed by Karpuravalli, Saba, Progeny 183, Pagalapad wild, Ezha Vazhai and Phrima wild 5 days each.

Starch content of commercial varieties of banana at different maturity levels

Maximum starch content (30.80%) was recorded in 'Nendran' at 95-100% maturity level, while it was 'Saba' (27.87%) at 80 - 85% maturity and 'Nendran' (25.60%) at 70 - 75% maturity level, among the three plantain (culinary) varieties evaluated at three maturity levels. The data recording on the different varieties of banana and plantain in the field are in progress for maturity and heat units. Of the different maturity levels evaluated for 'Pachanadan' banana, maximum total soluble solids (22-23°Brix) with high total sugar content (20 - 22%) and low acidity (0.45-0.46%) was recorded at 75% and 90% maturity levels, compared to full-maturity level.

4.2.4 Extending the shelf-life of banana cv. Ney Poovan using MAP

Post-harvest handling techniques along with modified atmosphere packaging (MAP) recorded 29 days shelf-life in cv. Ney Poovan with 90% maturity at room temperature when compared to absolute control (7 days). However, 49 days shelf-life in cv. 'Ney Poovan' was observed by adopting post-harvest handling techniques along with modified atmosphere packaging and cold storage (13.5°C).

Evaluation of banana varieties for corm juice

The recovery of banana corm juice was highest in 'Udhayam' (94.8%) and the lowest in Hill Banana (75%). Out of six varieties of banana evaluated for corm juice, Údhayam' recorded maximum recovery (94.8%), followed by 'Nendran' (91%) and Saba (88.55%). However, maximum total sugars and protein content were registered with 'Hill Banana'.

4.2.5 Development and refinement of banana pulp based products

Banana nutri-bars with four different flavours and colours consisting of banana pulp, corn flour, groundnut, cashew nut, cardamom and clove powders have been developed, which has been accepted. Pure banana jam was refined by mixing with different fruits. Among the various combinations, banana mixed with apple was accepted. Banana fig was refined by adding different proportions of honey, lemon and ginger juice to obtain good flavor, taste and storability. Among the various combinations, 85% honey + 15% water was accepted with hedonic scale of 7.23. However, maximum energy with high sugar level was registered with 95% honey + 5% water.

Standardization of banana flour based extruded (pasta) products

Among the several combinations, banana flour and refined wheat flour (maida) at 60:40 resulted in good texture after blanching. Banana flour based pasta products were developed in combination with wheat flour and whey protein.

4.2.6 Functions of resistant starch and designer food development from banana flour

Standardization of drying condition for banana flour

Pre-treatments for drying of banana cv. Grand Naine were standardized. Combination of KMS + citric acid (0.25% each) as pre-treatment for drying of banana resulted in better overall acceptability of flour (8.6) than the NaCl (1%) (7.3). Better rehydration ratio (1:2.4) and resistant starch content (49.26%) was observed at a drying temperature of 55°C than other temperatures. Swelling power of the flour irrespective of drying temperature is maintained to 4-6% till 70°C but it reached 12% with an increase in water temperature to 90°C. Non enzymatic browning B (0.43) increased with the increase in drying temperature (65°C) of the banana slices.

Standardization of packaging environment

Equilibrium relative humidity studies revealed that 13.13 % and 14.57% were the danger and critical point respectively for storing the banana flour. Optimum RH for storing the banana flour is 55-60% as the flour tends to develop fungal growth with higher RH and becomes highly dry with RH < 30% (Fig. 27).

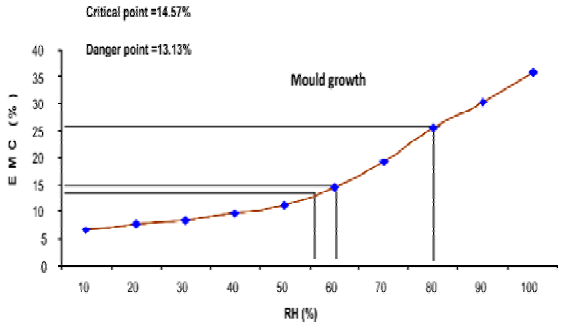


Fig. 27. Pattern of equilibrium relative humidity of Banana flour

Starch extraction procedures

Extraction of starch with three washes of water using 100 and 60 mesh sieves instead of

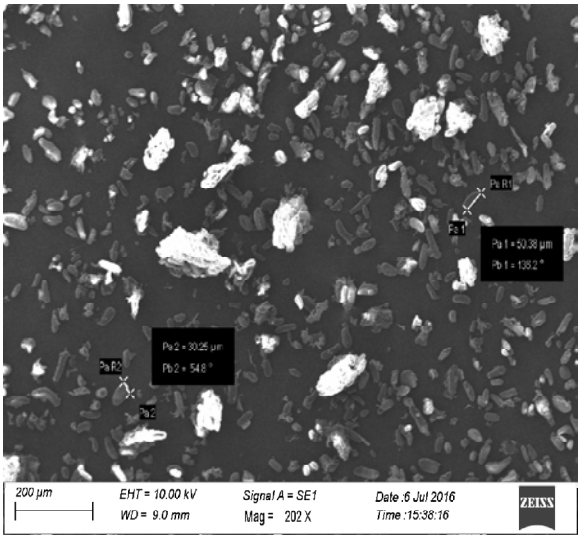


Fig. 28. Surface characters of banana powder dried at 55°C

single mesh has provided white starch powder from culled banana of cv. Grand Naine. This was standardized through physical and enzymatic methods. Banana varieties cv. Grand Naine, Monthan and Saba were studied for their physico-chemical properties with special emphasis on resistant starch content. Differential scanning calorimetry (DSC) and SEM analysis were carried out to study the functionality of starch of different cultivars. Swelling capacity, water and oil holding capacity of the samples were also standardized (Fig. 28 & 29).

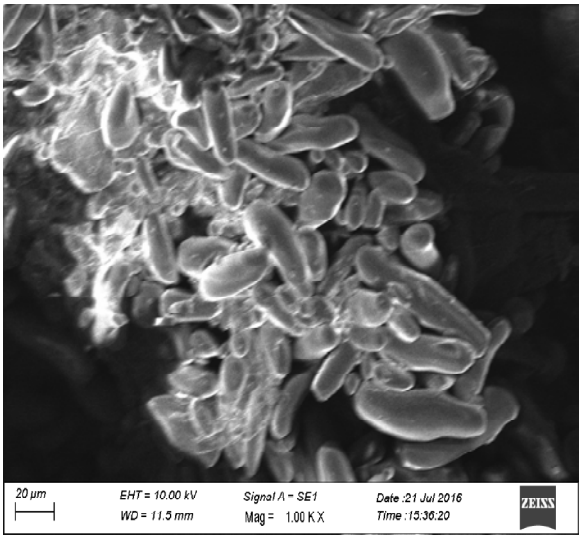


Fig. 29. Surface characters of banana starch

Preparation of resistant starch rich pasta (RSRP) from banana

Various formulations consisting of 100% durum wheat (control) and mixtures of wheat:banana flour and resistant starch were prepared for pasta processing. Nutritional composition and sensory characteristics were determined. The addition of banana flour increased the indigestible fraction and the content of phenolic compounds in the pasta. Moreover, addition of banana flour increased the antioxidant capacity and mineral content.

Preparation of bread and cookies

Low glycemic and slow calorie release bread and cookies were prepared with various mixtures of wheat: banana flour and resistant starch. Nutritional composition and sensory characteristics were determined. Addition of banana flour and resistant starch increased the antioxidant capacity and mineral content. The bread prepared with 15 % replacement with banana flour and 10% with resistant starch has given a good product compared to other combinations (Fig. 30).

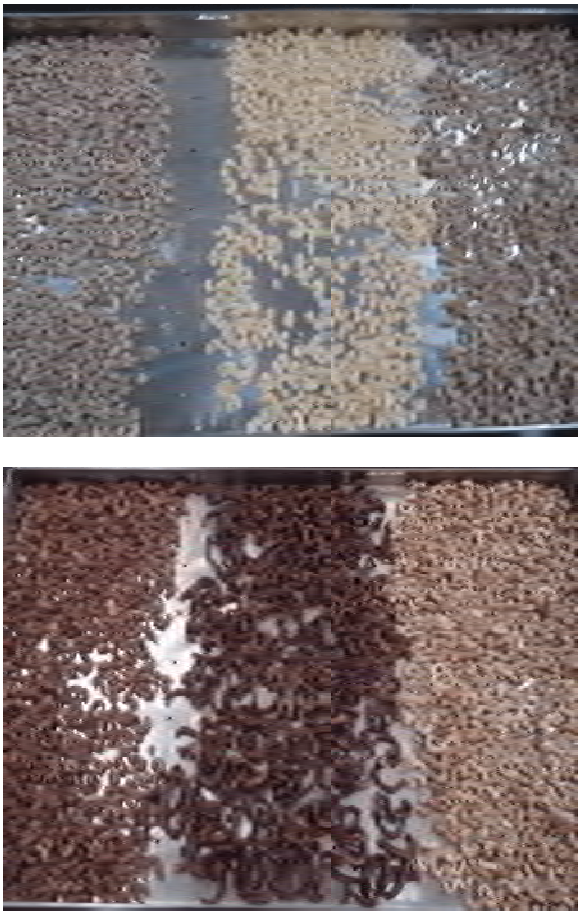


Fig.30. Dried pasta with different combinations of wheat, banana flour and resistant starch

4.3 PHYSIOLOGY AND BIOCHEMISTRY

4.3.1 Physiology

High temperature and soil moisture deficit stresses in banana

Studies on drought alleviation using biochemical in cv. Grand Naine

In a field, tissue cultured banana cv. Grand Naine were grown and soil moisture deficit stress imposed in the field at 5th month and at flowering. Five month after planting coincides with floral primordial initiation and during that period there is a sudden increase in plant height and girth (Fig. 31). The soil moisture is allowed to deplete to the level of - 0.8 to -0.9 MPa. The foliar priming of Grand Naine banana plants with 0.1mM acetyl salicylic acid, Butylated Hydroxyl Toluene (100 ppm), and Glycine Betaine (20 ppm) before imposition of soil moisture stress. The foliar primed plants sustained photosynthesis and stomatal conductance 5 - 6 fold higher than non-primed plants. But the Glycine betaine and BHT did not have much effect on gas exchange parameters.

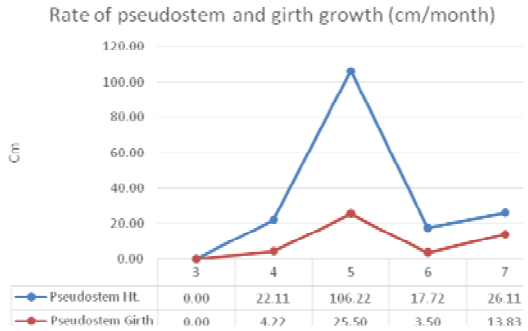


Fig. 31. Plant pseudostem height and girth from 3-7 months after planting

Application of soil moisture stress at 5th month after planting in cv. Grand Naine delayed flowering by 12-23 days irrespective of application of soil alleviation chemicals (Fig. 32).

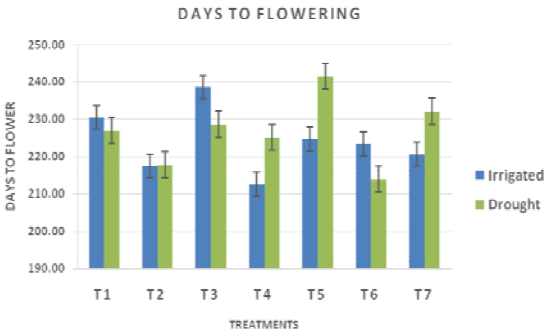


Fig. 32. Days taken from planting to flowering

The number of fingers decreased by soil moisture stress and application of stress alleviation chemicals (Glycine Betaine (T4) and Butylated Hydroxy Toluene (T5)) reduced the effect of soil moisture stress which is evidenced by increase in fingers numbers compared to non-alleviating stress treatment (Fig. 33).

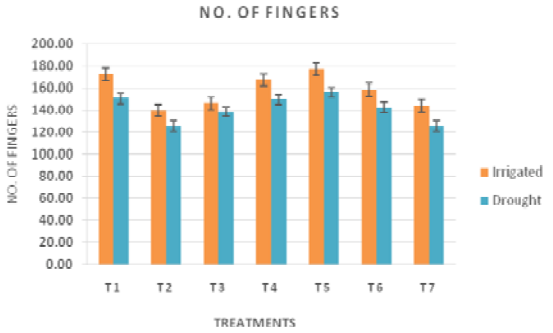


Fig. 33. Number of banana fingers affected by drought treatments

In a field grown banana cv. Grand Naine, plants were subjected to soil moisture deficit stress along with drought stress alleviation chemicals of Acetyl Salicylic Acid (ASA), Butylated Hydroxy Toluene (BHT) and Glycine Betaine (GB) in different combination. In an irrigated treatment, average bunch weight of 35.25 kg was recorded with 12.75 hands compared to 19.75kg with 9.25 hands in drought stressed treatment. However, the plants which were foliar primed (ASA + GB) prior to drought imposition recorded significantly higher bunch yield (27.75 kg) and more number of hands (10.25).

Effect of shade on drought and salt stress in Grand Naine

Banana plants imposed with soil moisture deficit (-0.8 to -0.9 MPa) and salt stress (100 mM NaCl) under shaded condition (50% of light) recorded significant decrease (14.3 – 17.15 %) in photosynthesis compared to stressed plants under natural light. However, in terms of total dry matter production significantly reduced (37-43%) in plants grown under full natural light with drought and salt stressed treatments after three weeks of stress period. The senescence of leaves significantly increased (45%) in drought stressed plants under natural light than under shade stressed plants. The survival rate of shade stressed plants were higher (94%) than natural light in drought and salt stressed plants (48%). The shade reduced the intensity of drought and salt stresses, evidenced by survival percentage. Based on growth parameters, it is revealed that Poovan, Ney Poovan, Grand Naine and Saba are shade tolerant and Karpuravalli is a shade sensitive cultivar.

4.3.2 Biochemistry

Enhancement of pre-harvest life of bananas

To study the enhancement of pre-harvest in planta life of bananas, Poovan bunches were selected from an experimental plot and were allowed to attain full (100%) maturity and also ripening of top first two hands. After excision of ripe hands, bunches were treated by fumigation with 1-methylcyclopropene (1-MCP) at a concentration of 1 µl/Lfor 12 hr and covering the bunches with polythene sleeves air-tight (Fig. 34a). Similarly, Poovan bunches were treated with lysophosphatidyl ethanolamine (LPE) (a lipid-derived senescence retardant) at 500 ppm concentration. Distilled water treatment was used as control in both cases and bunches were allowed to ripe. The control bunches started ripening on the same day and fifty percent of the hands ripened in two days (Fig. 34b) and the 1-MCP treated bunches started ripening on eleventh day simultaneously showing maturity browning thus enhancing the *in planta* green life of Poovan bunches for 10 days (Fig. 34c) after which the bunches showed maturity browning. The LPE treatment on full mature Poovan bananas had the *in planta* green life for four days against control of two days resulting in enhancement of pre-harvest green life only by two days.

Fig. 34: Treatment of 1-MCP to increase the green life pre-harvest *in planta* life of bananas - (a): Treatment of 1-MCP on full mature Poovan bunch; (b): Water-treated control bunch and (c) 1-MCP treated bunch after 10 days.

The ripening behavior of pre-harvest Poovan bananas treated with 1-MCP during post-harvest self-ripening and induced-ripening following ethylene (2-chloroethylphosphonic acid, ethrel) treatment were evaluated. The control bananas and 1-MCP treated bananas with ethylene spray ripened within three days, but the 1-MCP treated bananas on self-ripening ripened after seven days (Fig. 35).

Fig. 35. Ripe hand of 1-MCP treated Poovan hand.

The ethylene evolution rate in self-ripening and induced-ripening of 1-MCP treated bananas was 2.10 and 2.18 ppm/hr respectively against 4.64 ppm/hr of control bananas during colour breaking stage and 3.14 and 3.56 ppm/hr respectively against 4.92 ppm/hr of control bananas at ripening stage-6. The polygalacturanase activity in self-ripening and induced-ripening of 1-MCP treated bananas were 0.042 and 0.048 Unit activity/g fr. wt. respectively against 0.092 U/g in control bananas at colour breaking stage and 0.36 and 0.38 U/g respectively against 0.56 U/g in control bananas at ripening stage-6 indicating that the ethylene release and consequently cell wall depolymerizing enzymes activity were blocked by the 1-MCP treatment. The qualitative parameters (TSS and acidity) of pre-harvest Poovan bananas treated with 1-MCP after ripening were in acceptable levels as those of untreated control fruits. The TSS of Poovan bananas ranged from 22.4-24.7°B and acidity (%) from 0.31-0.38.

Enhancement of post-harvest green life of bananas

Grand Naine and Poovan (full and full three quarter maturity) hands, after water cleaning and fungicide treatment, were treated with LPE and other lysophospholipids such as lysophosphatidic acid, lysophosphatidyl-choline, lysophosphatidyl glycerol and lysophosphatidyl inositol and lysophosphatidyl serine at different concentrations of 50, 100, 250, 500 and 1000 ppm by dipping for 30 min. and stored at 13.5°C and ambient temperature (24-27°C). Except LPE, other lyso-phospholipids did not have any effect on green life enhancement on post-harvest bananas. The LPE too at the concentrations of 50, 100 and 250ppm did not have much effect on enhancement of green life of bananas and only 500 and 1000 ppm concentrations had the same effect and enhanced the green life of bananas to 11 days at 13.5°C and four days at ambient temperature. There was no difference in enhancement of green life period between the full maturity and full three quarter maturity at both 13.5°C and ambient temperatures.

Mechanism of 1-MCP and LPE action on ripening delaying

To understand the action of 1-MCP on delaying of ripening, the enzymes involved in biosynthesis of ethylene such as S-adenosylmethionine synthetase, 1-aminocyclopropane 1-carboxylase (ACC) synthase and ACC oxidase were assayed and also the metabolite precursors of ethylene biosynthesis such as methionine, S-adenosyl methionine and 1-aminocyclopropane 1-carboxylic acid were quantified spectro photometrically during different ripening stages for 7 days in 1-MCP treated and untreated control Poovan bananas. Only theACC synthase showed lower activity and higher levels of S-adenocylmethionine in 1-MCP treated bananas compared to control bananas throughout the ripening stages indicating the 1-MCP tends to block the ACC synthase activity and consequently causing accumulation of S-adenosyl-methionine, the substrate for ACC synthase. The activity of ACC synthase in 1-MCP treated bananas was 5.26 nmol/g fresh tissues as against 2.32 nmol/g fresh weight pulp tissue on seven days after 1-MCP treatment. Similarly, the accumulation of S-adenosyl methionine was higher (5.82 nmol/g pulp tissue) in 1-MCP treated bananas compared to untreated control bananas (0.74 nmol/g) (Fig. 36). The activity of other

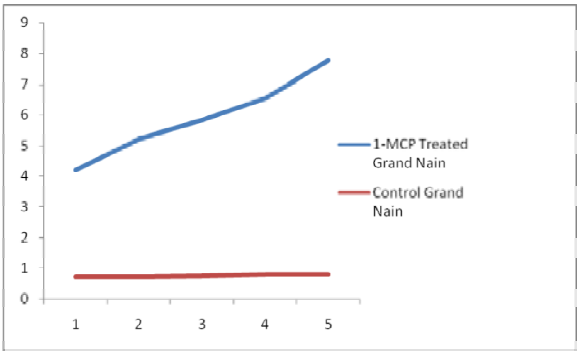


Fig. 36. Accumulation of S-adenocylmethionine (nmol/g) in 1-MCP treated Poovan bananas.

enzymes and levels of other substrates were equal in both 1-MCP treated and control.

To understand the mechanism of delaying of ripening by LPE, activities of phospholipase D (PLD), phospholipase A & C and lipolytic acyl hydrolase were assayed in peel tissues LPE-treated and untreated control Grand Naine bananas.The PLD showed lower levels of activity (1.26 µmole/min/mg) in LPE - treated bananas whereas the activity was higher (15.34 µmole/min/mg) in untreated control bananas on day two after treatment (Fig. 37) and activity of other enzymes showed no difference implying that LPE inhibited only PLD activity, which plays major role in maintaining membrane integrity during early stage of senescence.

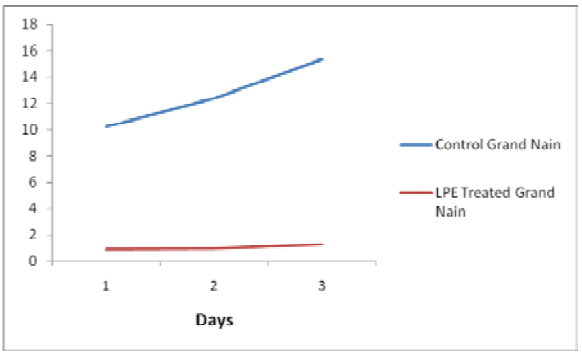


Fig. 37. Activity level of phospholipase D in LPE treated Grand Naine bananas.

Biochemical characterization of fruits and flower

The estimation of glycemic index (GI) was standardized in seven ripening stages of Poovan banana by estimation of total starch and resistant starch enzymatically, estimation of amylose content and glucose estimation by starch digestion and preparation of starch hydrolysis index curve and calculation of GI. The GI of seven ripening stages of Poovan was 18.3, 21.6, 26.8, 34.2, 46.5, 55.2 and 77.2. Parameters required for maximum recovery of total flavonoids from banana fruit peel tissue was standardized in Poovan. Extraction duration of 1 to 4 hr, ethanol concentration of 50 to 100%, temperature of 60 to 95 °C and material to solvent ratio of 1:1 to 1:20 were analyzed and the maximum amount of flavonoids of 23.3 mg/g dry was obtained from Poovan peel when extracted for 3 hr by using 95% ethanol solution at 80°C with the ratio of raw materials to ethanol solution of 1:10. The total flavonoid contents in peel of Grand Naine, Rasthali, Poovan and Karpooravalli were estimated using the above method and found to be 19.6, 22.5, 23.3 and 21.7 mg/g dry weight.

Flowers of six banana cultivars viz., Kothia (ABB), Ginde (ABB), Pisang Lilin (AA), Calcutta 4 (AA), Pisang Jajee (AA) and Cv. Rose (AA) were collected and total anthocyanin pigments were extracted from the bract using acidified methanol and anthocyanins were estimated spectro-photometrically. The contents of total anthocyanins in bracts were: Kothia - 84; Ginde - 111; Pisang Lilin - 108; Calcutta 4 - 122; Pisang Jajee - 116 and Cv. Rose - 102 mg/ 100 g fresh weight.

4.4 CROP PROTECTION

4.4.1 Management of banana weevils

Isolation of banana true stem volatiles and other bio-molecules for weevil monitoring and their management

More than 342 volatile components were extracted and analyzed through GC-MS and identified from eleven commercial banana cultivars' *viz.*, Poovan (AAB), Ney Poovan (AB), Nendran (AAB), Monthan (ABB), Karpuravalli (ABB), Rasthali (AAB), Grand Naine (AAA), Red banana (AAB), Pachaladan (AAB), Saba (ABB) and Virupakshi (AAB).

Isolation of pheromone components from banana stem weevil

Volatile compounds from banana stem weevil were collected by air-entrainment method and analysed by GC-MS and identified using NIST Library. Using GC-EAD facility, six volatile compounds were identified from weevils.

Isolation of antennal proteins of stem weevil to identify Odorant Binding Proteins (ODP)

Antennal and larval hemolymph proteins were isolated and separated by SDS-PAGE from antenna of stem weevil and its grub. Three proteins – odorant binding protein, chitinase 2 and chitinase 1 were identified using MASCOT analysis.

Bio-assay of leaf sheath volatiles and stem weevil volatiles against stem weevil

Selected semiochemicals were tested individually by subtractive bio-assay method and in combination with olfactometry and wind tunnel. Weevil attraction was up to 70-85 %. The volatile bio-molecules attracted both male and female weevils.

***In vitro* evaluation of Zimmu extract under against banana weevils**

Out of six botanicals (Zimmu, Nanma, Menma, Gallic acid, Azadirachtin and Chlorpyriphos) screened against banana stem weevil, Zimmu extract was found more effective followed by Menma and Gallic acid.

Isolation of endophytes from *Musa*

Entomopathogenic endophytes such as *Beauveria* sp., *Metarhizium* sp., *Penicillium citrinum* and *Simplicillium obclavatum* were isolated from *Musa* accessions 190, 1066, 0015, 0028 and 0078.

Survey of banana insects and collection of banana scarring beetle

Survey was conducted in banana growing areas of Kholapur District (Mahagaon, Nesari, Kandewadi, Satawane (Chandgad), Basarge, Sohale (Azara), Nipani (Karnataka), Majale (Hatkalngda),Chipari and Shirol. Banana stem weevil, fruit fly and skipper butterfly damage were recorded. Survey in Kerala revealed the banana slug caterpillar leaf damage. Scarring beetles were collected from Jorhat and Sibsagar districts of Assam. Banana tingid bug was collected from Manipur and mites were collected from developing fingers of *Rhodochlamys* at Lower Dibang Valley.

4.4.2 Pest mapping in bananas and plantains in India

Field collection surveys carried out in Thadiyankudisai, Periyakulam, Pollachi and nearby areas (Tamil Nadu), B.R. Hills (Karnataka) and Kerala resulted in a establishment of a reference collection of insect pests of banana, their natural enemies and other insects associated with banana ecosystem. Documentation of the natural enemy complex of banana skipper, *Erionota torus* was done for the first time in India and nearly 10 parasitoids were identified from Tamil Nadu, Kerala, Karnataka, and Mizoram.

Two parasitoids, *Ooencyrtus pallidipes* and *Elasmus brevicornis* were identified as major parasitoids in South India. *Pediobius* sp., *Tetrastichus* sp. (Eulophidae), two undetermined species of Tachinidae, *Cotesia erionotae* (Braconidae), and an indeterminate species of Ichneumonidae were the other parasitoids recorded on *E. torus. Spatulifimbria castaneiceps, Spatulifimbria* nr. *grisea* and *Amata passalis* were recorded as pests of banana from Tamil Nadu. New parasitoids of *Olene mendosa, Amata passalis,* and *Kophene cuprea* on banana were identified. Molecular characterization by sequencing the mitochondrial COX1 gene was done for banana pests including *Cosmopolites sordidus, Odoiporus longicollis, Basilepta subcostata, Olepa ricini, Erionota torus, Thrips hawaiiensis, Aleurolobus musae, Stephanitis typica, Kophene cuprea* and one predator, *Stethorus pauperculus.* GenBank accession numbers were obtained for some of these sequences and DNA barcodes were generated for *T. hawaiiensis, A. musae* and *S. typica*.

Rugose spiralling whitefly, a new invasive pest on banana

The rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin, recently reported from India from Tamil Nadu, Kerala and Karnataka was documented on banana and the extent of damage and natural enemy complex were assessed. In Pollachi and nearby places in Tamil Nadu, severe infestation of this pest was observed on banana besides coconut. All the stages of the whitefly were observed on the leaves and fruits of banana. *Encarsia guadeloupae*, an exotic parasitoid was found to cause 60–70% parasitism of this whitefly. *Encarsia dispersa*, a species that was accidentally introduced along with the spiralling whitefly, was also found to parasitize this whitefly. This is the first report of this host association for *E. dispersa.* Several indigenous predators *viz.*, *Pseudomallada* sp., *Cybocephalus* sp., *Diadiplosis* sp., *Jauravia pallidula*, *Scymnus nubilus*, *Menochilus sexmaculatus* and *Scymnus coccivora* were observed to feed on this whitefly (Fig. 38a & 38b).

Fig. 38. a) Rugose spiralling whitefly; b) *Encarsia guadeloupae*

4.4.3 Investigation on fungal and bacterial diseases of banana and their management

Rapid detection and diagnosis of eumusae leaf spot pathogen from crude DNA

A rapid detection and diagnosis technique of eumusae leaf spot from crude DNA was developed using LAMP primers, FIP1L and BIP1L which were highly specific to eumusae leaf spot pathogen (Fig. 39).

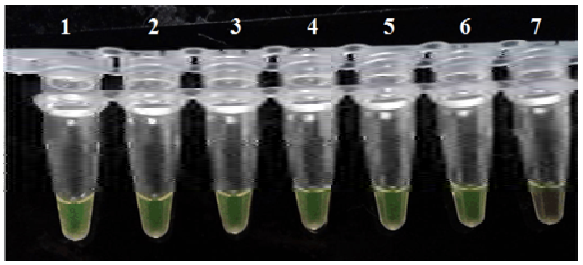


Fig. 39. Pure DNA samples from *M. eumusae* culture, 2-3 Crude DNA samples extracted from the pure cultures of *M. eumusae* isolated from cvs. Grand Naine and Rasthali, 4-6- Crude DNA samples extracted from the single leaf spot tissue of cvs. Grand Naine, Rasthali and Monthan, 7- Non template control

First report of the occurrence of Tropical race 4 of Fusarium wilt in India

Surveys conducted on cv. Grand Naine and Robusta grown in Vaishali, Khagaria, Bhagalpur, Katihar and Purnia districts of Bihar

revealed the incidence of Fusarium wilt disease (0.5% to 26%) from Katihar and Purnia districts. Analysis of the disease samples further confirmed the presence of Tropical race 4. This is the first authentic report of Tropical race 4 infecting banana in India. Damage symptoms include yellowing and drooping of leaves around the pseudostem, longitudinal splitting of pseudostem, and black to brown vascular discoloration in the corm and pseudostem. Awareness meetings were organized with farmers of Katihar and Purnia districts to prevent further spread (Fig. 40).

Fig. 40. Fusarium wilt infected banana cv. Grand Naine

Isolation, characterization and evaluation of principle compounds from Zimmu against tropical race 4 of Fusarium wilt (*Foc* TR4)

Principle compounds were captured from Zimmu leaves and roots and analyzed by GC - MS. A total of 16 compounds were identified. *In vitro* evaluation of the principle compounds carried out against *Foc* TR4 pathogen by agar well diffusion method showed that the principle compounds PC-1, 2, 3, and 4 at 1% conc. recorded 100% mycelial inhibition of pathogen. Principle compound 1 showed 100% inhibition of mycelial growth and spore germination at 0.1%.

Isolation and characterization of principle compounds from fusarium wilt (*Foc*) suppressive *Trichoderma asperellum*

A total of nine principle compounds were extracted, separated and identified from secondary metabolites of *Trichoderma asperellum*. *In vitro* evaluation of these nine compounds against *Foc* TR4 at 0.1%, 0.5% and 1.0% indicated that only PC- T3 at 1% exhibited 100% inhibition of mycelial growth of *Foc* TR4.

Effect of silver nanoparticles (AgNPs) from zimmu leaf extract against *Foc*

Silver nano particles from Zimmu plant extract were synthesized with particle size of 13.5 nm in diameter. SEM analysis confirmed the silver nano particles synthesized from Zimmu plant extract were uniformly dispersed and spherical in shape (Fig. 41).

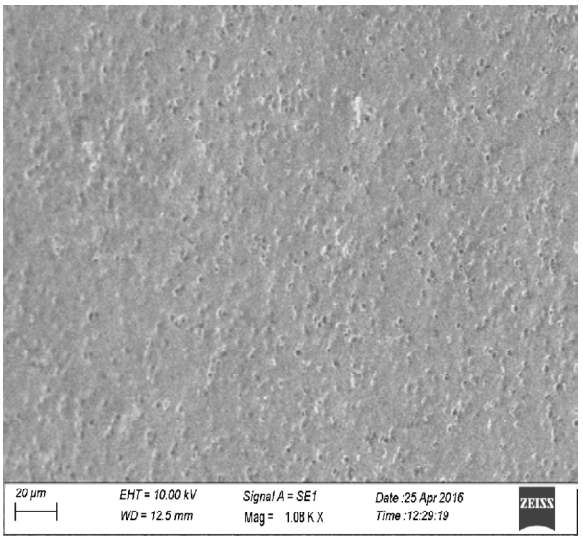


Fig. 41. SEM image of Zimmu silver nanoparticles.

In vitro and *in vivo* evaluations against *Foc* TR4

The *in vitro* evaluation of AgNPs at 50, 75 and 100ppm against *Foc* TR4 showed that the AgNPs at 100 ppm conc. recorded 100% inhibition of mycelial growth and spore germination. The activity of these biologically synthesized AgNPs increased as the

concentration of nano particles increased. In a pot culture experiment, the banana cv. Grand Naine treated with AgNPs at 100 ppm recorded complete inhibition of *Foc*. In addition, significant increase in plant growth parameters were observed with AgNPs treated plants (Fig. 42).

Fig. 42. Effect of Zimmu leaf extract mediated silver nanoparticles (AgNPs) against *Foc* under pot culture evaluation. A – Control (*Foc* alone), B – Control (without *Foc*), C –dipping in Zimmu silver nano particles, D - drenching the plants with Zimmu silver nano particles, E - dipping + drenching.

SEM analysis of *Foc* colonization in banana roots

A pot culture experiment on the effect of silver nano particles on *Foc* colonization in banana root by SEM analysis showed that there was a structural deformation and inhibition of mycelial growth of *Foc* pathogen in the root tissue of *Foc* - AgNPs treated banana plants. In the *Foc* alone inoculated plants, complete intra-cellular blocking of the xylem vessel by the mycelia was observed.

4.4.4 Studies on viral diseases of banana and their management

Molecular characterization of banana viruses

Occurrence of banana bract mosaic virus (BBrMV) in banana cv. Chini Champa (Syn: Mysore, AAB) was recorded for the first time in Kahikuchi, Assam and it was confirmed using ELISA and RT - PCR. Full length genome sequence of BBrMV of this isolate was obtained through RNA-SEQ using Next generation sequencing approach in Illumina platform. This complete gene was compared with three other complete genome is available in the public domain which showed variation and distinguishable in phylogenic tree. Twenty-five BBrMV isolates were used for the study on the population structure and diversity based on VPg gene of the virus. Molecular characterization and analysis was performed for the sequences of the gene. BBrMV was found to be seed transmitted and it was confirmed by detecting the virus using RT-PCR and also by growing-out test.

Complete genome of cucumber mosaic virus (CMV) infecting banana of Karnataka was characterized. Phylogenetic analysis based on cp gene of CMV revealed that the present isolate was grouped in the IB subgroup. Two common weed species viz., *Passiflora foetida* and *Commelina benghalensis* were found to be infected with CMV.

Diagnostic techniques for banana viruses

Loop-mediated Isothermal Amplification (LAMP) based detection protocol was developed for CMV and banana streak mysore virus (BSMYV). It was highly specific, 100 times more sensitive than RT-PCR and PCR. LAMP assay developed for detection of BBTV and BSMYV was also used to detect the respective viruses in their vectors.

The coat protein (CP) genes of BBrMV and CMV- Trichy isolate were amplified (by RT-PCR), fused (by overlap extension PCR procedure using linkers to create recombinant products of 1557 bp) and inserted into pGEM-T vector and subcloned into a bacterial expression vector pET 28a+ using a directional cloning strategy. This fusion protein was expressed in a soluble form; however, the protein is disintegrated into two different proteins as confirmed by western blot study.

Evaluation of banana bunchy top virus (BBTV) free Hill banana plants derived from ECS technology

In field evaluation, ECS derived BBTV free Hill banana plants showed significant difference in the growth and yield parameters compared to sucker grown plants. However yield and growth parameters were on par with tissue culture raised plants.

Screening germplasm against banana viruses

Screening of germplasm accessions for resistance against BBTV has been initiated for 20 BB and 20 AA accessions under net house and pot cultures respectively. Thirteen germplasm accessions were found positive for BBrMV in the field genebank of ICAR-NRCB. One of the clumps of a promising clone, Popoulu and two of the hybrid progenies were positive for BBrMV.

Impact analysis of the use of virus indexed certified plants at Theni District

A preliminary survey conducted in Theni District showed that certified tissue culture banana plants outperformed sucker grown plants.

4.4.5 Host-virus interactions in banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's

Selection and mass propagation of BSMYV free plants from mother plants identified in long term experimental field trial

Ten thousand episomal BSMYV free Poovan plants were produced from plants identified from 11 years old long term field trial for natural spontaneous expression of the virus from putative EPRV sequences and an experiment has been designed to undertake validation of the same through AICRP (Fruits).

4.4.6 Molecular approaches to understand the host-virus-vector- environment interactions and RNAi for the management of banana viruses

Development of infectious partial dimer construct of BBTV and BSMYV genome

Full length clones of BSMYV and BSGFV have been made and further partial clones need to be cloned in binary vectors for testing the infectivity. Three components of BBTV clones were constructed for infectivity. Infectivity assay using RCA products of BBTV bombarded through Helios gene gun onto 52 tissue culture plants were tried, none of them expressed symptoms even after 6 months.

Transcriptomic analysis of banana dually infected with BBTV/ BSMYV

Transcriptome analysis of banana infected with BBTV/ BBTV+BSMYV/ BBTV latently infected plant and / healthy cv Poovan was performed and digital gene expression was distinguished BBTV infected with that of latently infected plant.

Transmission studies

Studies on transmission of BBTV by banana aphid, *Pentalonia nigronervosa* in cv. Ney Poovan (AB) showed that transmission rates were significantly higher at 25°C ± 1 than at 20°C ± 1 and 37 °C with corresponding percentage of humidity in a particular span of time. This study showed that at extreme temperatures, the rate of transmission of BBTV into the host is significantly less.

Transgenic development

Two ECS lines were developed for cv. Poovan and Hill banana cv. Virupakshi for genome editing using CRISPR-Cas9 approach and transgenic generation. Using MVR-RNAi and hairpin-rep (BBTV) constructs, 22 putative transgenic lines were developed which were planted in the insect proof net house.

44.7 Proteomic analysis of host–BBTV interaction in banana

CP, HC-Pro, VPg, NIa genes of BBrMV and CAM19, eIF4E(Iso), eIF4E-4, eIF4E-6, PSKI genes were amplified and cloned in pTZ57R/T vector and sequenced. All the BBrMV and plant genes were sub-cloned in bait and prey plasmids, respectively. Seventeen combinations were made to study the viral gene interaction and viral gene interaction with plant genes and co-transformation was carried out into yeast strain EGY48. Colony–PCR was done to know the presence of both the plasmids. Further quantitative â-galactosidase assay was performed to study the interaction of the two proteins. The interaction studies revealed the homodimerization of HC-Pro and the functional HC-Pro may be a homodimer and VPg interacts with eIF4E with the formation of a translational initiation complex on cellular mRNAs by sequestering the translation factor and it also plays an important role in Potyvirus replication. *rip* and *mvt* genes from BBTV were amplified and cloned in pTZ vector and sequenced and sub-cloned in yeast vectors. *pcna*, *rbp* and *sumo conjugating enzymes1* and 2 cloned in pTZ were then sub-cloned in yeast vectors. The clones were confirmed through restriction analysis and co-transformed into yeast strain EGY48.

VPg gene sequences of 25 BBrMV isolates from different regions of Southern India where this virus is a major problem were characterized along with known BBrMV isolates from other parts of the world. Sequence identity of VPg gene between 29 BBrMV isolates showed a range of nucleotide (nt) and amino acid (aa) identity of 75-100% and 95-100%, respectively (Fig. 43a & 43b). Phylogenetic analysis based on nt revealed that except TN1 and TN2, all Indian isolates clustered together. Different functional motifs of VPg gene were identified and found conserved. Single recombination event was detected using recombination detection programme. The codon based

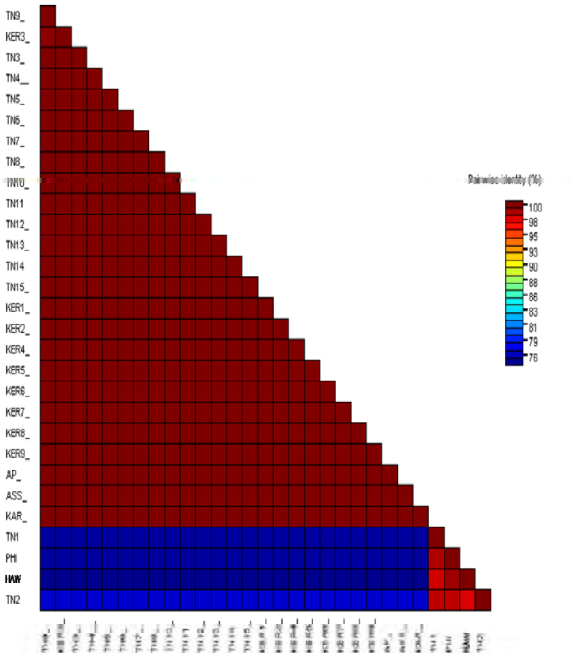


Fig. 43a Graphical representation of pair wise and nucleotide identity (with percentage identity scale) of VPg gene of 29 BBrMV isolates.

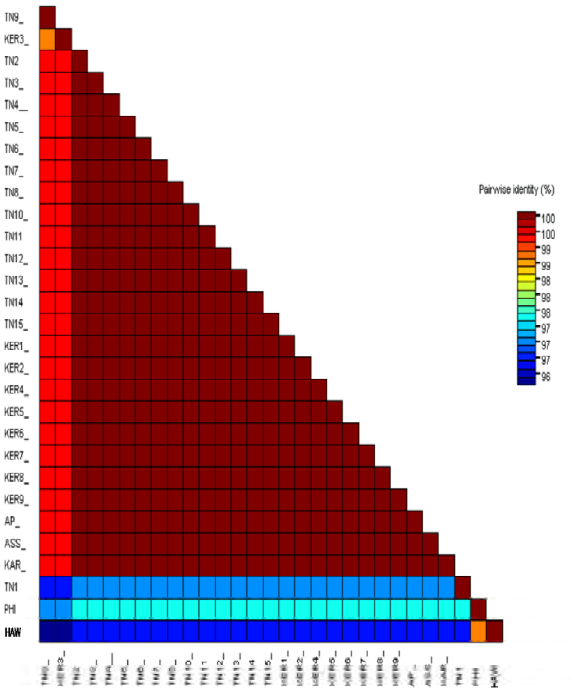


Fig. 43b Graphical representation of pair wise and amino acid (with percentage identity scale) of VPg gene of 29 BBrMV isolates.

selection analysis revealed that most of the codons in the VPg gene were under purifying selection except for the codons at position 46, 47, 71, 107, 149,153, 156, 175, 176, and 178 which were under positive selection. Gene flow between different populations of banana from India was relatively low. This is the first report on genetic diversity and evolution of VPg gene of BBrMV.

4.4.8 Investigations on *Musa* nematode's diversity, biology, behavior and their interactions

Survey for banana nematodes

Soil and root samples collected from Asom and Meghalaya contained root-lesion (*Pratylenchus* sp.) and root-knot nematodes (*Meloidogyne* sp.) with an absolute frequency of 57% and 85% respectively. Samples from Mizoram contained root-lesion, root-knot and spiral nematodes whereas, samples from Manipur and Arunachal Pradesh contained root-knot nematode. Root samples from banana grown in Agali, Kerala showed higher population of root-lesion nematode. Spiral nematode (*Helicotylenchus* sp.) and root-knot nematodes were found associated with Hill banana and Red banana grown at Thadiyankudisai, Tamil Nadu.

Severe infestation of root-knot nematode was observed in soil and root samples collected from wilt sick fields of cv. Grand Naine in Gudalur, Cumbam areas of Theni District, Tamil Nadu.

Penetration behaviour and biology of root-lesion nematode on susceptible and resistant genotypes of banana

An experiment on penetration of root-lesion nematode, *Pratylenchus coffeae* on susceptible cv. Nendran showed that out of 500 nematodes inoculated, an average of 158 nematodes penetrated the roots, whereas, less than ten nematodes entered in resistant genotype Karthobiumtham. An experiment on the biology of root-lesion nematode showed that the reproduction factor (pf/pi) was five-fold higher in susceptible cv. Nendran compared to resistant genotype Karthobiumtham.

Studies on interaction between root-lesion (RLN) and root-knot nematode (RKN) on cv. Nendran

Interactions between root-lesion and root-knot nematode on cv. Nendran showed that reproduction of root-knot nematode decreased in the presence of root-lesion nematode. Moreover, root-lesion nematode dominated root-knot nematode as final root population of root-lesion nematode was 10 times higher when both the nematodes are inoculated concomitantly (Fig. 44).

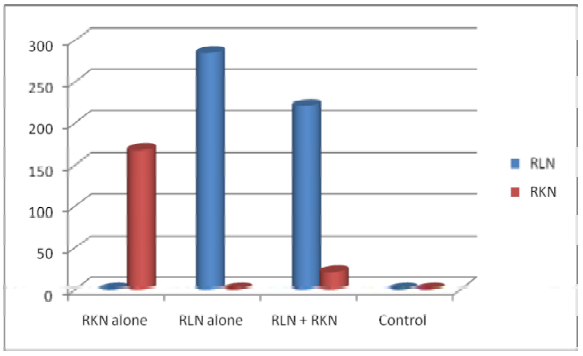


Fig. 44. Interaction between root-lesion nematode, *Pratylenchus coffeae* and root-knot nematode, *Meloidogyne incognita* on cv. Grand Naine

Nematode mapping of ICAR–NRCB farm

Soil and root sampling was done on blocks A, B, C, D, K, L, N, P and R. The results showed that block K was found infested with root-knot nematode.

4.5 EXTERNALLY FUNDED PROJECTS

4.5.1 CRP on Agro-biodiversity (S. Uma, M. S. Saraswathi and S. Backiyarani)

Morpho-molecular characterization of banana accessions

About 92 accessions were characterized for 30 vegetative and flowering traits and data have been recorded as per the INBAP / IPGRI Descriptor. The same set of accessions were characterized using DArT markers which is a robust and cost effective microarray based technique that offers high multiplexing, independent of sequence information (Jaccoud *et al.*, 2001). The 92 accessions were characterized in two sets of 55 and 37 accessions respectively. Analysis of the first set indicated the distinct grouping of wild species of *Musa acuminata* (AA) and *M. balbisiana* (BB) away from their hybrids. Members of *Rhodochlamys* clustered with *M. acuminata* indicating genetic closeness among the sections *Eumusa* and *Rhodochlamys*. Genus *Ensete* clustered separately and exhibited its distinctness. Among ABB genotypes, dessert Pisang Awak members and the cooking bananas were grouped separately. (Fig. 45).

Analysis of the second set of 37 accessions indicated that grouping was based on genomic and subgroups. All the Pome members grouped together. Likewise all the Silk members grouped together with which the AB members namely Elakkiebale and Nendrakunnan joined indicating that either A or B of the Silk members contributed for the evolution of the AB types. AA and members of AAA grouped together except for Chenkadali which has grouped with Pome subgroup. Besides grouping of dessert and cooking types of the ABB genomic group in two different clades, Monthan and Bontha members also grouped separately within the same clade. The plantain types clustered in a single group. (Fig. 46).

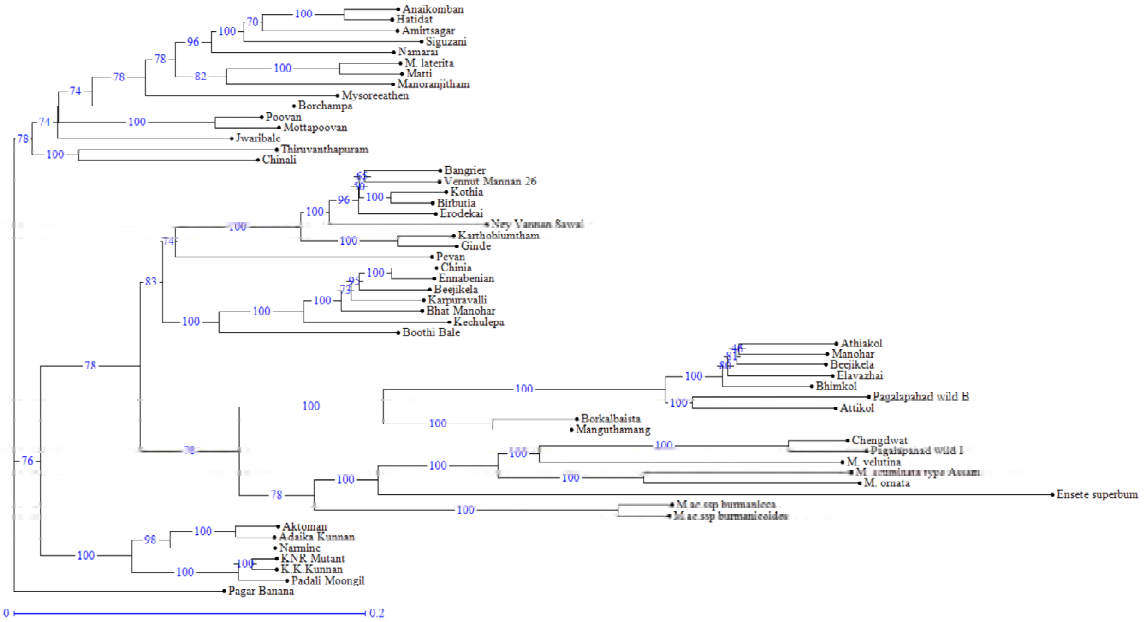


Fig. 45. Dendrogram of DArT markers for 55 Banana Accessions

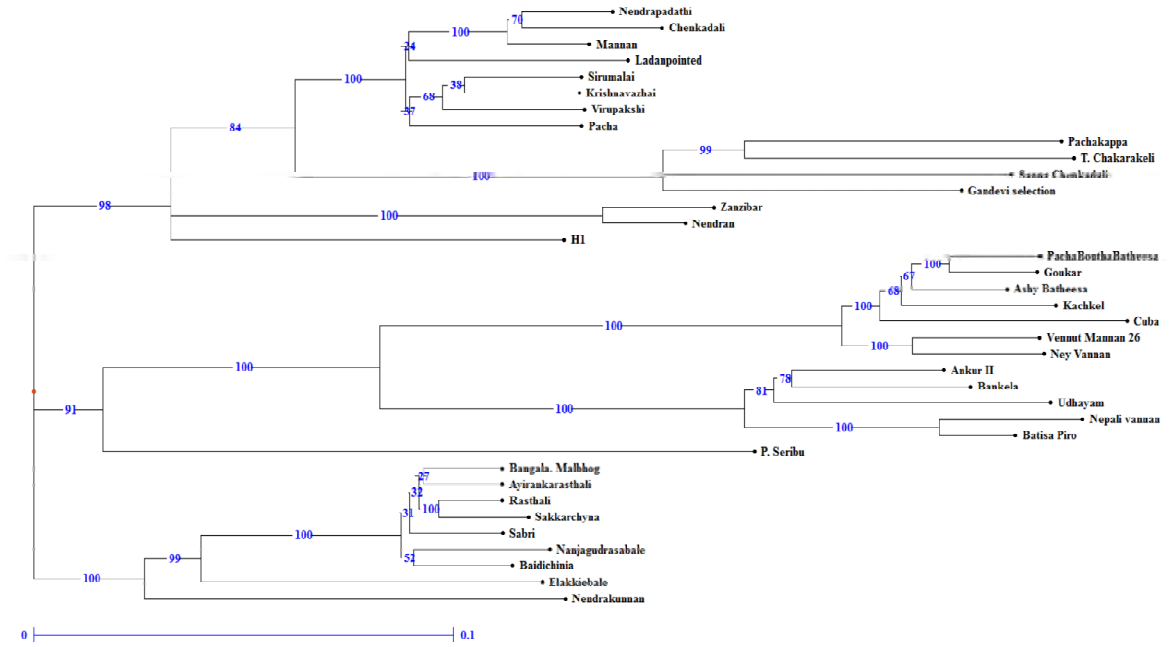


Fig. 46. Dendrogram of DArT markers for 37 Banana Accessions

DBT-QUT Project

4.5.2 Biofortification and development of disease resistance in Banana

Component I - Biofortification of Indian commercial varieties with PVA (S. Backyiarani and S. Uma)

Transformation of cv.Rasthali and Grand Nine with new construct pBMGF-DC49

Five batches of transformation were carried out in each of cvs. Rasthali and Grand Naine using pBMGF-DC49 construct. In cv. Rasthali, three batches are in rooting and remaining two batches in germination medium. In cv. Grand Naine, three batches are in selection and remaining two batches in germination medium (Fig. 47). Transformation with pBMGF-DC 34 constructs in three batches in Rasthali and five batches in Grand Naine have been completed. In cv. Rasthali, three batches are in rooting and in Grand Naine two batches in rooting and remaining three batches in germination medium.

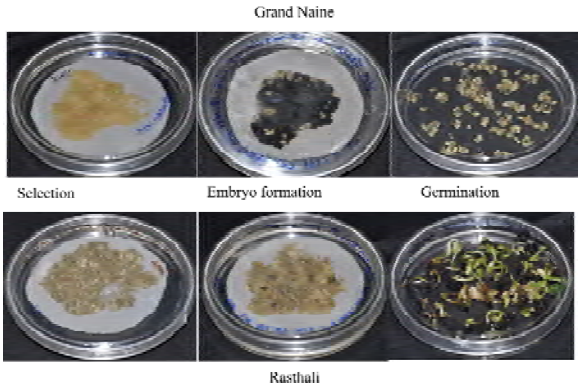


Fig. 47. Selection and regeneration of transformed ECS of cvs. Rasthali and Grand Naine (pBMGF – DC49)

Fig. 48. View of transformed plants maintained in glass house

Each fifty PCR confirmed transgenic plants developed using pBMGF-DC 32 and pBMGF-DC 24 constructs both in cvs. Rasthali and Grand Naine maintained under glass house (Fig. 48) and they are ready for field evaluation which will be taken up after the construction of transgenic net house.

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

Hundred transgenic plants each of cvs. Rasthali and Grand Naine produced using the iron gene construct *p*BMGF-DC-53 carrying *Os*NAS1 gene are in hardening process and 100 plants of each genotype are maintained in growth media in bottles and sub-cultured regularly. The presence of selectable marker gene *nptII* and gene of interest *Os*NAS1 were confirmed using PCR. Twenty each of cvs. Grand Naine and Rasthali were analyzed by multiplex PCR with primers of gene and VirA for confirming the transformation simultaneously ruling out *Agrobacterium* contamination. A new iron gene construct *p*BMGF-DC-68 carrying *Os*NAS2 gene was received QUT, Australia was PCR confirmed with the gene specific primers. *Agrobacterium* culture carrying gene construct was successfully revived, regularly sub-cultured and PCR confirmed before every co-cultivation. A total of 35 and 30 co-cultivations were performed in cvs. Rasthali and Grand Naine respectively. Co-cultivated Rasthali and Grand Naine are regularly sub-cultured in respective growth medium related to its growth stage and till now around fifty plants were produced from the earliest co-cultivations.

For the field trials of iron enriched transgenic plants of cvs. Grand Naine and Rasthali, construction of net-houses with a budget of Rs. 252 lakhs is in progress at ICAR-NRCB Research Farm, Trichy.

Component III - Development of efficient ECS of cv. Rasthali and providing to Indian partners (S. Uma, S. Backiyarani and M. S. Saraswathi)

Supply of cv. Rasthali and cv.Grand Naine ECS

Efficient ECS of cvs. Rasthali and Grand Naine were provided to the Indian partners based on their requirements. A total of 17 and 8 ml ECS and 25 and 14 ml of cvs. Rasthali and Grand Naine were distributed to TNAU and ICAR-IIHR partners respectively. Similarly around 36.5 mL and 75.5 mL SCV of cv. Grand Naine and 10 mL and 60.5 mL SCV of cv. Rasthali were supplied to component I and II of ICAR-NRCB respectively.

Induction of somatic embryogenic callus in recalcitrant cultivars

Based on the proteomic information on differentially expressed proteins of embryogenic and non embryogenic calli of cvs. Rasthali and Grand Naine, the callus induction media was modified to trigger the genes, which are involved in somatic embryogenesis. Around 9 different media combinations were tried along with the control medium MA1. The experiment was carried out in four banana varieties with different genome (Grand Naine- AAA, Red Banana- AAA, Monthan- ABB, Karpooravalli- ABB and Ney Poovan- AB). After 5-8 months of incubation in dark, irrespective of the cultivars, high embryogenic callus (EC) induction was recorded in the modified media as against control (M4 media). In Grand Naine (AAA), increased concentration of IAA recorded highest EC induction of 12.14 % while the same genome Red Banana (AAA) showed maximum EC induction of 9.48% in Kinetin enriched medium. Similarly, though both cvs. Monthan and Karpooravalli belongs to ABB genome, maximum EC induction of 4.27% was observed in tryptophan enriched medium and 8.67% calli in calcium chloride supplemented

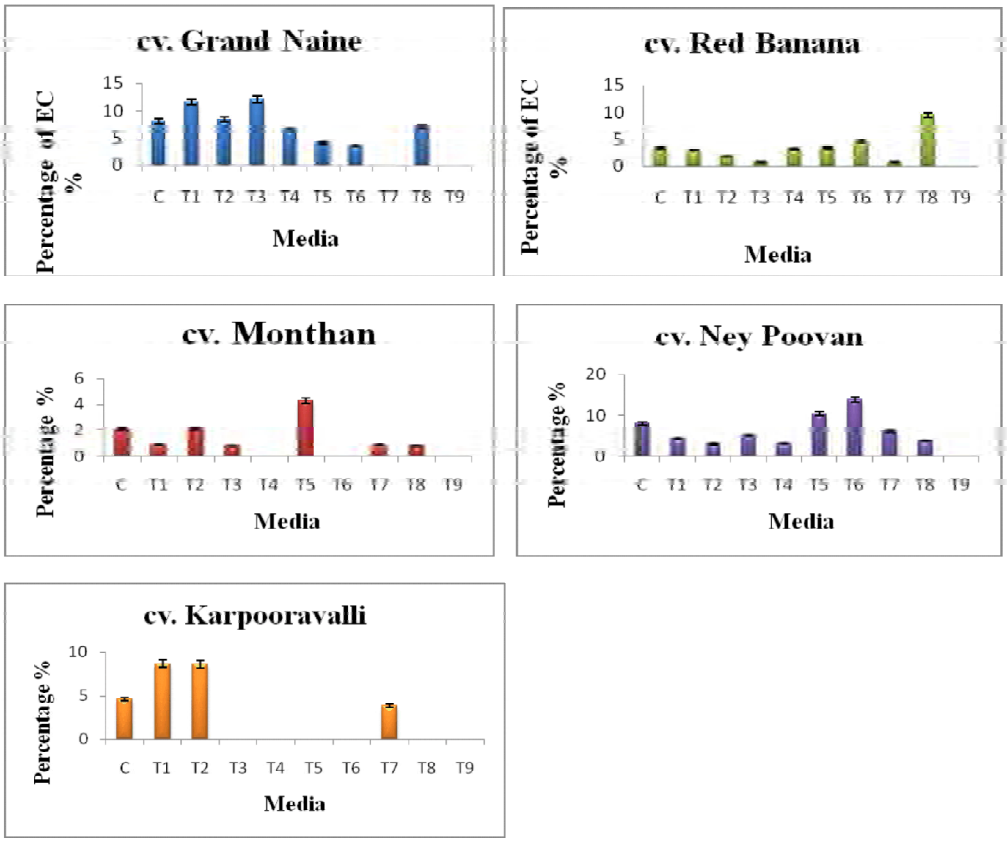


Fig. 49. Effect of modified MA1 media in induction of somatic embryogenic callus in recalcitrant cultivars

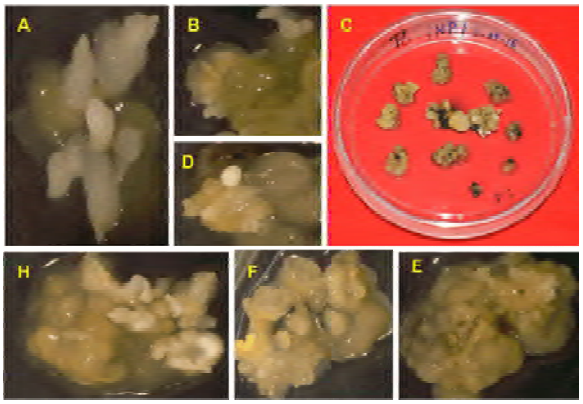


Fig. 50. EC from cv.Ney Poovan :A, B, D,E,F,H –EC with proembryos. C- Test media with Ney Poovan EC.

medium in cvs. Monthan and Karpooravalli respectively. Whereas tryptophan enriched medium induced high embryogenic callus in AB genome of cv. Ney Poovan (Fig. 49). These results revealed that EC induction in banana is not only genome dependent but also cultivar dependent (Fig. 50).

Improving the germination efficiency of somatic embryos in cvs. Grand Naine and Rasthali

To improve the germination efficiency of somatic embryos of cvs. Grand Naine and Rasthali, the media composition was modified based on information of differential expressed proteins of germinating and non germinating somatic embryos of these cultivars. A total of 11 different compositions were tried in M4 media (both in liquid and solid states). After transferring the somatic embryos in these media composition in two different states namely solid and liquid, they were exposed to 4^0C for different time durations namely 0 hr, 12 hrs and 24 hrs. In general, it was observed that somatic embryos treated at 4^0C for 24 hrs and modified M4 liquid medium showed better germination irrespective of cultivars. But upto 92% germination was observed in cv. Grand

Naine in GA3 enriched medium and 88% germination was recorded in cv. Rasthali in the same GA3 enriched medium while in solid MS medium enriched with NAA + GA3 only 50% and 55% of germination was observed in cvs. Grand Naine and cv.Rasthali respectively (Fig. 51).

The initial response like bulging and greening of somatic embryos was much faster in liquid medium when compared to solid medium. In liquid medium, it takes only five days to greening of somatic embryos while in solid medium it takes around 7-9 days to attain greening and germination percentage was also more in liquid medium (85%) compared with solid medium (55%) (Fig. 52). But in liquid medium the chances of contamination is high when compared to solid medium. This suggested that germinated somatic embryos should not be maintained in liquid medium for longer period of days and should be transferred to solid medium to avoid contamination.

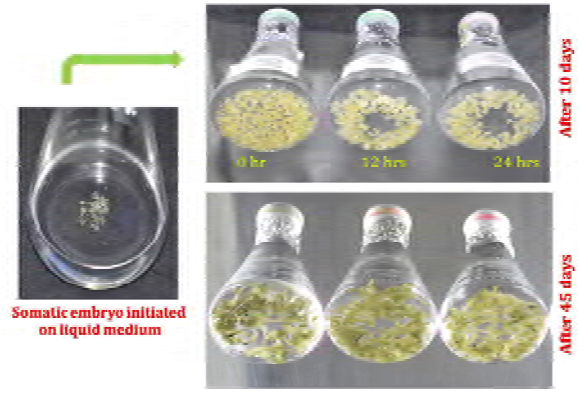


Fig. 51. Somatic embryos matured in GT3 liquid medium (modification- GA3 0.5mg/L)

Fig. 52. Comparison of germination efficiency of cold treated somatic embryos in modified (enriched GA3) liquid and solid M4 medium in medium

DAE Project

4.5.3 Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis (M. S. Saraswathi, S. Uma, S. Backiyarani and R. Thangavelu)

Using the embryogenic cell suspension, the lethal dose LD50 has been determined for the chemical mutagen, DES based on fresh weight gain (FWG), SCV and regeneration efficiency. Determination of LD_{50} for Sodium Azide is in progress. With respect to physical mutagen, the ECS was irradiated at different doses ranging from 5 to 50 Gy using Co_{60} source and the LD_{50} based on fresh weight gain was determined as 35Gy.

The secondary hardened plants derived from various mutagens were inoculated with

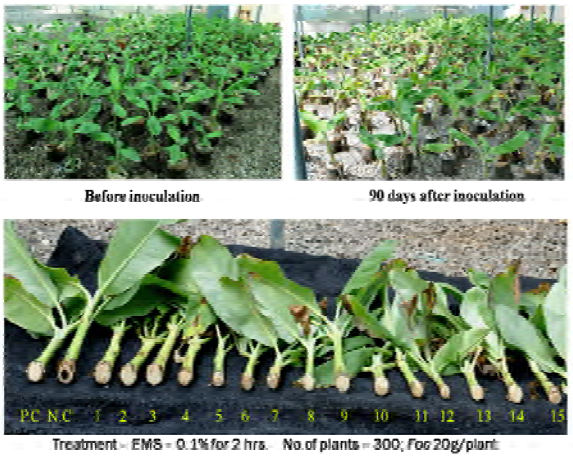


Fig.53. Fusarium wilt resistant mutants of cv. Rasthali identified under pot culture conditions. N.C – Negative control; P.C – Positive Control; 1 to 15 – Resistant lines

the sand maize meal inoculum of Foc race (VCG 0124/5) at the rate of 30 g per pot (12 x 10^9 cfu/ml). After three months of pathogen inoculation, the morphological data on plant height, pseudostem girth, number of leaves, leaf area, root mass and the disease severity were recorded. The disease severity was estimated by observing external and internal symptoms. The plants were uprooted and the corm was observed for vascular discoloration and a scale of 0-5 was adopted for disease scoring. Among the five hundred mutated plants derived from two different doses of EMS, 16 plants (15-EMS -0.1% and 1- EMS - 0.2%) were found to be resistant with score 0 and the resistant lines were further reinitiated for mass multiplication. They are under various stages of multiplication (Fig. 53).

DBT-ATL Project

4.5.4 Lab accreditation facility for virus indexing and genetic fidelity testing of tissue culture plants - Genetic fidelity component (M. S. Saraswathi)

A total of 1250 batches of tissue culture plants at secondary hardening stage (Grand Naine, Williams, Robusta, Ney Poovan, Red banana, Quintal Nendran etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports issued.

ICAR-Extramural Project

4.5.5 Harnessing the potential of *Musa* species in ornamental and leaf industries and screening for better edible flower and pseudostem (A. Thirugnanavel, M. S. Saraswathi and S. Uma)

Survey, collection and characterization

Systematic surveys were conducted in Tamil Nadu, Kerala, Meghalaya, Arunachal Pradesh and Manipur to identify and collect

Fig. 54. Ornamental banana species

the wild bananas with ornamental potential. *Ensete glaucum*, *Musa velutina, M. laterita, M. rosacea, M. aurantiaca*, and intersectional hybrids of *M. velutina* are spread across Northeast India particularly Arunachal Pradesh. *M. velutina, M. rosacea* and *M. velutina* hybrids were collected from Arunachal Pradesh; *E. glaucum* was collected from Garo hills, Meghalaya; *M. rubra* was collected from ICAR-IIHR, Bengaluru; and *M. siamensis*, *M. beccari*, and *M. coccinea* were collected from private nurseries in Trivandrum, Kerala. (Fig. 54). The floral biology of *M. siamensis*, *M. laterita* and *M. ornata* has been documented. Maximum pollen out put per anther was observed in *M. ornata* (58988.1) followed by *Musa siamensis* (41428.5) and *M. laterita* (6845.2). Among the three species, *M. ornata* registered highest pollen viability (94.82 %) and pollen germination (84.48 %) (Fig. 55 & 56).

Fig. 55. Hybrid seeds of ornamental *Musa* spp.

Fig. 56. *In vitro* raised ornamental hybrids

Screening of banana germplasm for better edible flower types

36 banana germplasm have been screened for flower quality. The moisture content, dry matter content, phenols, flavonoids and tannins have been estimated. The samples have been prepared and are ready for nutrient profiling.

PPV & FRA project

4.5.6 Framing crop specific DUS guidelines for banana (*Musa spp.*) (A. Thirugnanavel, S. Uma, S. Backiyarani and M. S. Saraswathi)

Awareness programs in Northeast India

Northeast India is rich in banana genetic diversity. Bhim Kol, Athi Kol, Jati Kol, Amrit Sagar, Sabri, etc. are the popular cultivars grown in this region. Besides, *M. laterita, M. velutina* and its intersectional hybrids, *M. cheesmani, M. itinerans, M. aurantiaca*, *M. flaviflora, M. balbisiana* types, *M. acuminata* wild types are spread across the Northeast region. However, no steps have been taken towards the registration of these vast germplasm under PPV&FRA. ICAR NRCB along with KVKs have initiated their registration process. Four awareness programmes have been conducted at Dudhnoi, Garo Hills, Meghalaya, Roing and Namsai, Arunachal Pradesh, and Ukhrul, Manipur. The farmers, Agricultural and Horticultural State Dept staffs, and KVK staffs were sensitized on the role of PPV& FRA and importance of varietal registration with them.

ICAR–Extramural project

4.5.7 A new vision for quality planting material (QPM) Production system in India (S.Uma, M.S.Saraswathi and S.Backiyarani)

Development of bioreactor prototypes for mass multiplication of ECS

Embryogenic calli generated from male inflorescences were transferred to liquid

medium using different sizes of conical flask for cell growth optimization in a large scale. Designed and fabricated three different types of vessels such as balloon type, bubble column balloon type and bubble column type for mass multiplication of ECS. However only bubble column balloon type vessel showed significant results in cv. Rasthali (108ml SCV) and Grand Naine (92 ml SCV) within 21 days.

Somatic Embryo regeneration and maturation in Temporary Immersion bioreactor

Designed and fabricated a temporary immersion bioreactor for regeneration and maturation of somatic embryos. ECS (cv. Rasthali and Grand Naine - 2 ml SCV) grown in bubble column balloon type bioreactor harvested on 12th day and used for regeneration and maturation of somatic embryos in temporary immersion bioreactor using M3 media. The conversion of embryogenic cells into somatic embryos was successful in both varieties cv. Rasthali (20%) and Grand Naine (99%).

Germination of Somatic Embryos in Temporary Immersion bioreactor

Matured somatic embryos (about 2g) were transferred to temporary immersion vessels for germination of plantlets using MA4 media with an immersion frequency of 2 min every 6 h. The conversion of somatic embryos into plantlets is successful in Grand Naine (96%). Approximately 45000 plantlets could be derived from 1ml of ECS.

Rooting and simultaneous hardening

Plantlets of 2.0 cm height were transferred to coir dust containing 1/10, 1/2, and full strength MA4, MS and All 19 media respectively without sucrose. All the plants were incubated at high humidity (90%), 25 ± 2°C under a 16/8-h light/dark photoperiod using white-light LED lamps. No mortality was observed and there was a significant response to rooting (99%) within 14 days in all the three media tested (Fig. 57).

ICAR Project

4.5.8 Assessment of post harvest losses in banana (K. N. Shiva)

In Tamil Nadu, four districts *viz.*, Theni (more than 70% cultivated area) and Erode (less than 70%) for Grand Naine (internationally popular variety); Trichy (more than 70%) and Tuticorin (less than 70%) for Poovan (local commercial variety) were identified based on primary and secondary data provided by State Department of Horticulture (DDH and ADH offices of respective districts and Taluks). Similarly two taluks in each district having five villages and five orchards in each village have been selected for the study.

Survey and observation on post harvest losses in 'Grand Naine' banana

In the present study, a survey conducted in Theni and Erode districts variety Grand Naine, to estimate the post harvest losses in banana at various levels *viz.*, field level, transport level, assembly/wholesale market, storage and ripening level. Results showed that losses are 3.45 % and 4.50 % at Theni and Erode district respectively, during field level. The losses during transport level are 1.12 % and 3.04 % at Theni and Erode Districts respectively. At Assembly market level estimated losses are 3.57 % and 3.79 % at Theni and Erode Districts respectively. However, storage and ripening level loss were 5.62 % and 1.24 % at Theni and Erode Districts respectively. Finally losses in retail market level are 3.20 % and 6.55 % at Theni and Erode Districts respectively.

Survey and observation on post harvest losses in 'Poovan' banana

Surveys were conducted in Trichy and Tuticorin districts at various levels from field level to storage and ripening level to assess the

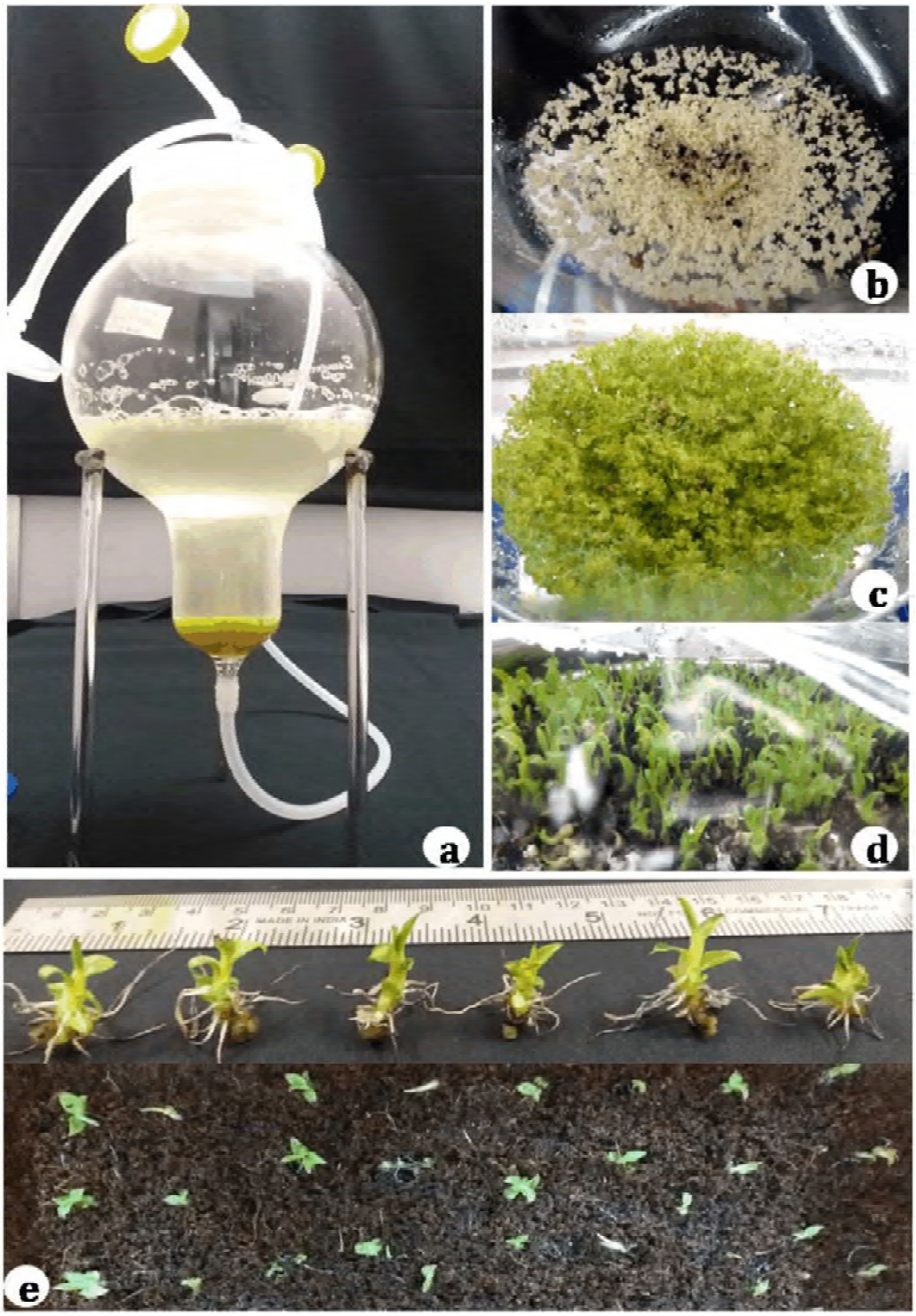


Fig. 57. High throughput system for large scale production of banana plantlets using bioreactors (a) Mass multiplication of embryogenic cell suspension in bubble column balloon type bioreactor, (b) Regeneration and maturation of somatic embryos in temporary immersion bioreactor, (c) Germination of somatic embryos in temporary immersion bioreactor, (d) Development of plantlets in plate type disposable temporary immersion bioreactor, (e) Rooting and simultaneous hardening in sterile coir dust.

post harvest losses in banana var. Poovan. The losses in Trichy and Tuticorin districts were reported as 1.42 % and 2.40 % at field level respectively. While losses during transport level were 3.48 % and 1.77 % at Trichy and Tuticorin district, respectively. At Assembly market level estimated losses were 2.58 % and 2.67 % at Trichy and Tuticorin district respectively. However, storage and ripening level loss was 3.15 % and 3.11 % at Trichy and Tuticorin district respectively. Losses recorded at retail market level were 4.18% and 4.51% at Trichy and Tuticorin Districts respectively.

Post harvest losses in banana under AICRP-Fruits

As a lead center, compiled the surveys carried out by the four different centers namely, Bengaluru, Jalgaon, Kannara, Kovvur including Trichy (ICAR-NRCB). Results showed that overall post harvest losses of banana recorded were 18.62, 31.94, 16.84, 34.40 and 12.13% at Kannara, Kovvur, Trichy, Jalgaon and Bengaluru centers, respectively. Among the centers, Bengaluru registered the lowest post harvest loss of 12.13%, while Jalgaon recorded with the highest value of post harvest losses of 34.40 %.

ICAR–Extramural project

4.5.9 Studies on active packaging on extending the shelf-life of banana

(K. N. Shiva)

Among the various treatment combinations (active packing materials *viz.*, ethylene absorber, O2 remover, moisture remover, etc.) employed in 'Udhayam' bananas, fruits harvested with 85% maturity and treated with improved postharvest treatments followed by packing in polybag and kept at room temperature resulted in shelf life of 23 days when compared to control (without treatment + without poly bag + room temperature) recording 14 days shelf-life. However, the treatment combinations under 13.5°C cold storage extended the shelf life upto 102 days, compared to absolute control (8 days).

Contract Research Project

4.5.10 Sea6 Energy Ltd., Bengaluru

(I. Ravi)

A contract project was conducted to evaluate the Sea6-biostimulant formulations. It is natural product from sea plant. There were 11 treatments (different formulations of sea weeds along with their competitor product ASN-1) were imposed to evaluate the effect on its growth and yield. In the result LBS6 formulation given higher yield (27%) than their non-sprayed treatment (control).

4.5.11 CRP on borers in network mode

(B. Padmanaban)

Survey in search of natural enemies of banana weevils

Survey in search of natural enemies of banana weevils resulted in the collection of dermapterans and a reduvid bug. Natural enemies and general predators were collected during surveys: *Eubrellia* sp. (Family: Anisolabididae: Dermoptera); Oriental spiny orb-weaver, *Gasteracantha geminata* (F.) (Araneae:); *Sybra* sp. (Cermbycidae: Coleoptera) and entomopathogenic fungi, *Metarrhizum anisopliae.*

ICAR–Extramural project

4.5.12 On-site diagnostics for insect pests of selected horticulture crops to enable timely pest management decision making

(J. Poorani)

Surveys were conducted to collect and document insect pests of banana, mango, citrus, and pomegranate from different parts

of South India. Several poorly known insect pests of mango such as mango shoot miner, inflorescence feeding caterpillars, quarantine pests like *Citripestis eutraphera,* etc. were collected and specimens were curated. Parasitoids and predators of some pests of fruit crops such as sapota, citrus and mango were documented for the first time. A rare pest of mango, the shoot miner, *Spulerina isonoma* (Lepidoptera: Gracillariidae) was recorded in NRCB farm and a new species of braconid was documented on it. Parasitoids of citrus bagworms were documented.

The mango fruit borer, *Citripestis eutraphera* (Meyrick) (Lepidoptera: Pyralidae), a quarantine pest recently reported from India, was found to infest mango fruits at NRCB farm and its diagnostic characters including male genitalia were documented. A new species of *Stethorus* Weise and *Stethorus tetranychi* Kapur (Coleoptera: Coccinellidae) were recorded as effective natural enemies of the citrus hindu mite, *Schizotetranychus hindustanicus* (Hirst) (Acari: Tetranychidae) for the first time. The new species of *Stethorus* was described and illustrated. Visuals of the general appearance of several insect pests of banana, citrus, mango, pomegranate and sapota, their immature stages and diagnostic characters were generated for the development of identification aids. Field damage symptoms of pests of the selected fruit crops were also generated for developing farmer-friendly pest diagnostic tools. A prototype Android app on insect pests of banana, their diagnosis and management was prepared. It will be deployed in Google Play Store shortly.

ICAR project

4.5.13 Outreach project on *Phytophthora*, *Ralstonia* and *Fusarium* wilt diseases of horticultural and agricultural crops

(R. Thangavelu)

Effect of *Trichoderma asperellum* fungal extract mediated silver nano particles against Fusarium wilt disease (VCG 0124 of race 1 infecting Cavendish banana)

The silver nanoparticles (AgNPs) from *Trichoderma asperellum* fungal extract which was found effective against *Foc* were synthesized and confirmed by UV-Vis absorption spectroscopy at 420 nm; Fourier transform infra red spectroscopy; Dynamic light scattering and scanning electron microscope. These measurements indicated that extracellular biosynthesis of AgNPs using *Trichoderma asperellum* produced AgNPs with the diameters of 10-15 nm. The study on the *in vitro* efficacy showed that *T. asperellum* AgNps at 100 ppm concentration had inhibited both mycelial growth and spore germination of *Fusarium oxysporum.*f.sp. *cubense.* In a pot culture evaluation, the soil drenching of *T. asperellum* culture filtrate mediated silver nano particles at 100 ppm conc. recorded suppression of Fusarium wilt disease with an internal score of 1.0 as compared to control plants (score 6.0). In addition, this AgNPs enhanced the plant growth parameters like plant height (43%), girth (70%), total number of leaves (166%) and roots (121%) as compared to *Foc* alone inoculated control plants.

Effect of zimmu principle compound 2 mediated silver nanoparticles against *Foc*

Synthesis and characterization

The PC2 mediated silver nanoparticles were synthesized by following five different methods viz., using autoclave, aater bath, UV-irradiation, microwave oven and direct sunlight. Among these, autoclave method was found to be the best as it was fast and increased the stability of nanoparticle whose Zeta potential (1.725e-002) was very low when compared to other methods and also useful for large scale production. The fabrication of silver nanoparticles was confirmed by UV-Vis spectra, FTIR and DLS methods.

In vitro and *in vivo* evaluation against *Foc*

The PC2 mediated AgNPs when tested at 150 ppm concentration against *Foc* pathogen by spore germination assay indicated complete inhibition of spore germination of *Foc* pathogen of both race 4 and race 1 infecting Cavendish bananas. Further, the pot culture evaluation of PC2 fabricated Silver nanoparticles (AgNps) at different concentration viz., 50ppm, 100ppm, 150ppm under pot culture condition in cv. Grand Naine recorded an internal wilt disease score of 2.0 at 150ppm concentration and the wilt disease of 6.0 score in all other treatments like Zimmu 50%, $AgNO_3$ alone, PC2 compound alone and *Foc* inoculated control plants.

Differential gene expression study due to the interaction of *Foc* (Tropical Race 4) with *Trichoderma asperellum* (Prr2) in banana cv. Grand Naine

Differential gene expression study due to the interaction of *Foc* (Tropical Race 4) with *Trichoderma asperellum* (Prr2) was carried out in banana plants cv. Grand Naine. The cDNAs from the roots of banana cv. Grand Naine infected by *Foc* (Race 4) were used as driver and cDNAs from *Foc* + *T. asperellum* inoculated banana plants were used as the tester and the suppression subtractive hybridization (SSH) was done proceeded. After hybridization, the analysis of PCR product revealed that the size of the subtracted cDNA ranged from 220 to 1000 bp whereas the unsubtracted cDNA ranged from 450 to 800 bp. A total of about 850 clones were obtained and the respective plasmid DNA is being isolated.

ICAR-Extramural project

4.5.14 Survey, characterization and management of a most virulent strain of Foc (TR4) infecting banana in India

(R. Thangavelu and S. Backiyarani)

Characterization of *Foc* isolates obtained from Bihar by VCG and molecular methods

The characterization of 15 *Foc* isolates isolated from 15 different samples of *Foc* infected banana plants collected from different banana regions of Bihar by VCG and molecular methods using race specific molecular marker showed that 14 out of 16 *Foc* obtained from cvs. Robusta, Grand Naine and Kothia belong to VCG 01213/16 of race 4 and remaining one sample from Muthia (ABB) belong to VCG 01220 of race 1/race 4.

Designing of specific molecular marker for *Foc* race 4 and race 1 infecting Cavendish banana

While screening Foc isolates of Bihar,, India using the molecular marker particularly TR4 specific primer (*Foc* TR4F& Foc-TR4R), resulted in the amplification of bands from VCG 0120/01211 and hence effords are in process to design our own molecular marker specific to TR4 using RAPD analysis.

For the designing of specific marker for *Foc* (race 4 infecting Cavendish bananas), the DNA isolated from the *Foc* isolates of different VCGs VCG0124 infecting Cavendish bananas, VCG 01213/16, 0125, 0126, 0128, 0129, 01216, 01217 and 0120/01211 were screened using 40 different RAPD primers. Among these primers, OPC and OPD generated unique amplicons for TR4 of Bihar and VCG 0124 of race1 infecting Cavendish banana. These unique amplicons were excised from the gel, cloned into pTZ57R/T vector and the respective plasmid DNA obtained from the transformed colonies was sent for sequencing. From the sequences obtained, primers were designed using Prime 3 software and the primers synthesized are being evaluated for their specificity to *Foc* -TR4.

Evaluation of different fungicides against *Foc*-VCG 01213/16 under *in vitro* conditions

The *in vitro* evaluation of five different fungicides viz., Nativo (Tebuconazole 50% +

Trifloxystrobin 25% WG), Tilt (Propiconazole 25% EC), Carbendazim, Roko 70 wp (Thiophanate methyl 70% wp) and Score (Difenoconazole 25% EC) at various concentrations (1, 0.5, 0.25, 0.1 and 0.05%) against TR4 revealed that the fungicide Carbendazim alone recorded complete inhibition of mycelial growth of *Foc* at all concentrations tested.

DBT Project

4.5.15 Twinning project on Fusarium wilt disease management (R. Thangavelu and S. Backiyarani)

Genetic diversity of *Fusarium oxysporum* f.sp. *cubense* isolates (*Foc*) of Assam, India by Inter Simple Sequence Repeats (ISSR) analysis

Isolation and characterization of *Foc* isolates of Mizoram and Assam

A total of 35 *Foc* isolates were isolated from the Fusarium wilt infected vascular strands of six different cultivars of banana (Banria, Balhlakual, Balhlathur, Kawrmawt, Lawngbalhla and Malbhog) which belong to different genomic groups (AAB,AAA and ABB) grown in 19 different regions of Mizoram and Assam (Selesih, Neihbawih, Lungdai, Serkhan, Zanlawn, Kawnpui, Bualpui, Khamrang, Dialdawk, Rawpuichhip, Kanghmun, Lungchangkam, Lawngtlai, Kawlchaw, Saiha, Phuloguri, Singra, MadangBakrapara and DhenuBanga). The genomic DNA isolated from all these 35 *Foc* isolates were subjected to genetic diversity analysis using five different ISSR primers viz., $(GAC)_5$, $(GTG)_5$, $(ACC)_6$, $CCA(TG)_5TG$ and (AC)8YG. The ISSR amplification produced 04–12 bands and out of which the number of polymorphic bands produced were 2–10. The size of PCR fragments generated ranged from 100 to 5000 bp (Fig. 58).

The data analysis were performed using NTSYS PC 2.0 software and the data set of isolates and reproducible bands were used to calculate Jaccard's co-efficient and the matrices

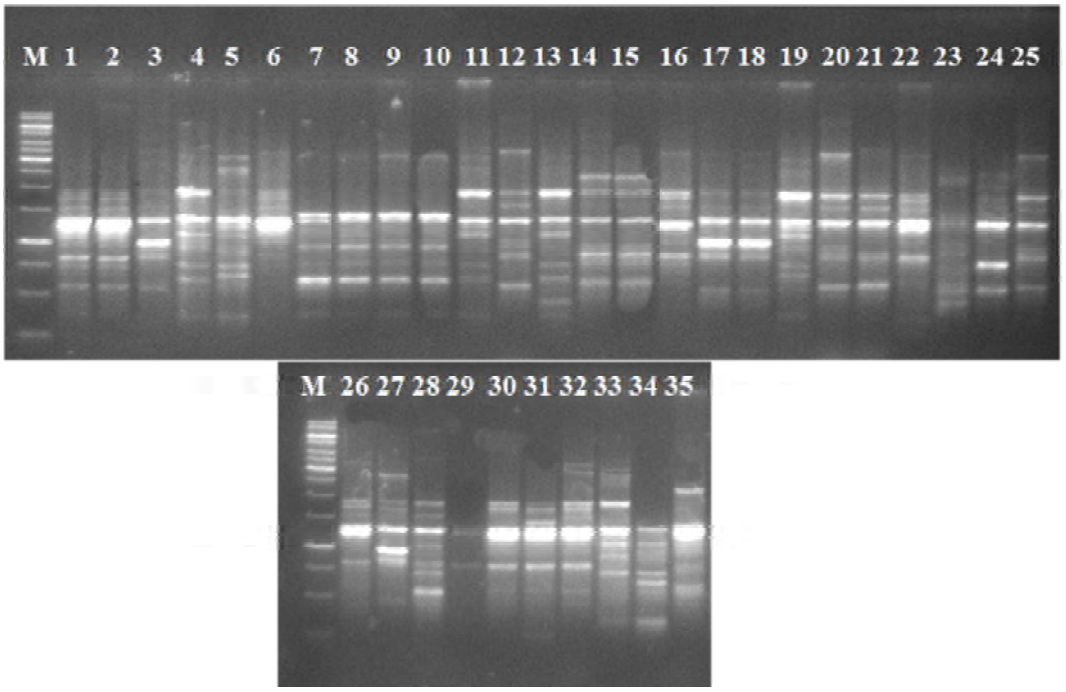


Fig. 58. ISSR finger printing of *Foc* isolates of different cultivars of banana and VCGs generated by (GTG) Primer

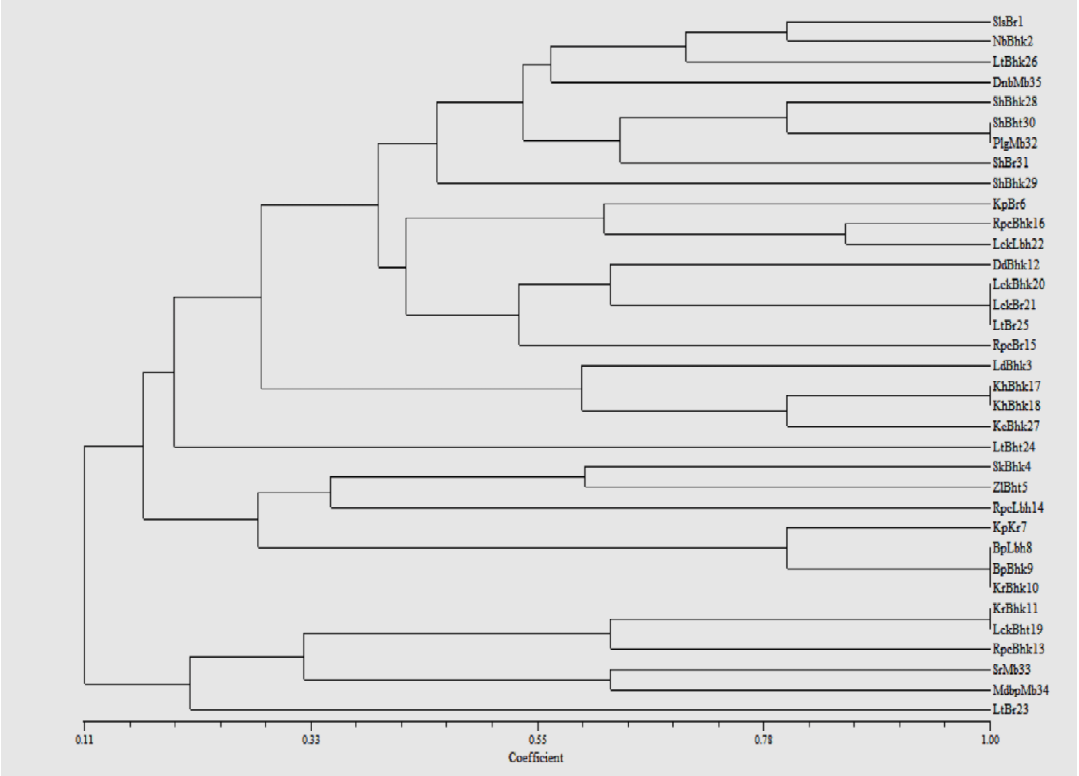


Fig. 59. Dendrogram based on ISSR analysis for 35 isolates of *Fusarium oxysporum* f. sp. *cubense* by UPGMA cluster analysis

of similarity co-efficient were subjected to unweighted pair group method with arithmetic mean (UPGMA) to generate a dendrogram. In order to assess the genetic relatedness between the *Foc* isolates of banana, the distance matrix was calculated based on the fingerprints obtained and it ranged from 0.11 to 1.00. The dendrogram consisted of two major clusters A and B (Fig. 59). The cluster ''A'' contains only six *Foc* isolates and whereas the cluster ''B'' contained all the remaining 29 *Foc* isolates which were isolated from banana belong to different genomic groups AAB, AAA and ABB. The results of the study clearly indicated that there is an existence of wide genetic diversity among the *Foc* isolates obtained particularly from Mizoram thereby proving the polyphyletic nature of the *Foc* isolates. However, the ISSR analysis carried out could not differentiate the *Foc* isolates based on the cultivars/genomic status or geographical origin.

DBT Project

4.5.16 Development of bio-pesticide formulation for reducing post harvest losses and for achieving export quality and increased shelf life of banana fruits

(R. Thangavelu)

In vivo evaluation of zimmu leaf extract and its principle compound (PC1) in banana cv. Grand Naine under packing house condition at 13.5°C

The evaluation of zimmu leaf extract and its principle compound (PC1) for the management of postharvest diseases and extension of shelf-life of banana, in packing house condition (13.5 °C) at Cumbum, Theni district of Tamil Nadu revealed that banana hands of 46, 48, 50 calliper size treated with zimmu leaf extract (50%) and PC1 (0.1%) completely inhibited the emergence of

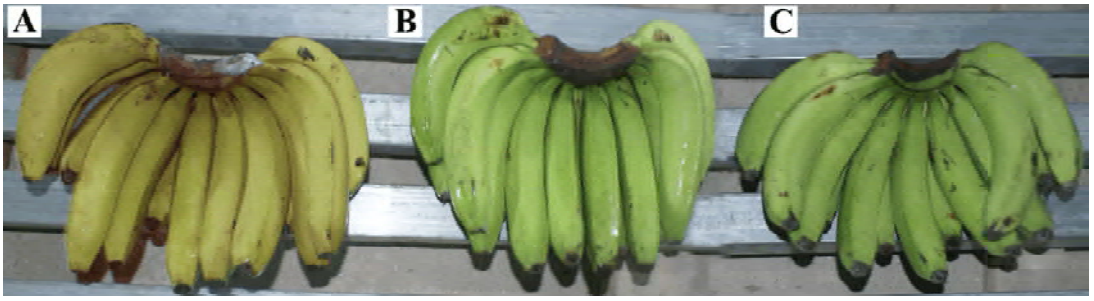


Fig. 60. Banana hands at of 50 calliper size treated with A) Standard control (carbendazim 500 ppm), B) Principle compound-1 at 0.1% conc.and C) Zimmu leaf extract (50%).

postharvest diseases. The results also indicated that banana hands treated with the fungicide carbendazim (standard control) recorded a crown rot disease score of 2.0 (0-5 scale). Moreover, these treatments also extended the shelf-life of banana hands of 46, 48, 50 calliper size upto 78 days with PC1 recording a maximum of 78 days followed by zimmu leaf extract (67 days) as compared to standard control (57 days). The banana hands of 52 calliper size, treated with zimmu leaf extract and PC1 extended the shelf-life of banana up to 58 and 43 days respectively as compared to standard control (37 days) (Fig. 60).

4.5.17 CRP-on vaccines and diagnostics

(R. Selvarajan and C. Anuradha)

Development of Diagnostics for viruses of banana

Bacterially expressed viral coat protein has been purified for raising polyclonal antiserum for CMV. Polyclonal antiserum for BBrMV was produced freshly for developing DIPSTICK (Lateral flow immuno-assay). Antigen and antisera dilution were standardized for newly produced polyclonal antiserum of BBrMV. The titre of polyclonal antiserum raised against BBrMV was assessed and found that the titre was 1:8000 for the antiserum obtained from Rabbit B. A protocol has been standardized for conjugating the gold nano-particles with IgG of BBrMV for developing lateral flow assay (immuno-strip or dipstick). Dipstick has been prepared to detect the virus from expressed proteins and further standardization is required for detection of BBrMV from the infected sap. Real time LAMP for detection of BBTV and CMV has been standardized. Multiplex PCR-/RT-PCR developed to detect four viruses simultaneously were validated by testing 100 field collected samples.

DBT-ATL Project

4.5.18 National certification system for tissue culture raised plants for virus indexing / virus indexing -contract services

(R. Selvarajan)

Mother cultures of Tissue culture banana plant received from twenty-four DBT recognized TC production units (TCPU) were tested for banana viruses under contract service as well as DBT-ATL scheme. Totally 17335 samples were tested for the presence of four viruses. This year certificate of quality was issued for 89.54 million TC plants. These certificates were issued after testing genetic fidelity for TC raised plants (by other component of the project) of viruses indexed stock cultures.

5. TECHNOLOGY ASSESSED AND TRANSFERRED

5.1 Training

About 2400 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. Under out reach programmes, ICAR-NRCB scientists have trained more than 6000 farmers across the country.

5.2 Radio talks through All India Radio, Tiruchirappalli

Name of the Scientist	Topic	Date of broadcast
Dr. V. Kumar	Bunch and mat management in banana (Tamil)	12 June, 2016
Dr. K. J. Jeyabaskaran	Nutrient management in banana (Tamil)	7 August, 2016
Dr. P. Giribabu	Nematode management in banana (Tamil)	7 October, 2016
Dr. P. Suresh Kumar	Banana flour and its uses (Tamil)	4 November, 2016

5.3 Television talks

Name of the Scientist	Topic	Date of telecast & TV channel
Dr. K.N. Shiva	Post-harvest technologies for domestic and export markets	28 April, 2016 DD - Telugu

5.4 Exhibitions conducted / participated

Name of the Events	Organizer / Venue	Date
Sixth SICCI AGRI SUMMIT & EXPO 2016	SICCI and TNAU, Coimbatore, Tamil Nadu at PGP College of Agri. Sciences, Namakkal, Tamil Nadu	11 - 12 June, 2016
Improved cultivation and value addition practices in banana (Under TSP)	ICAR – NRCB, Tamil Nadu at B.R. Hills, Karnataka	24 June, 2016
Seminar on Banana cultivation and cold storage	Tamil Nadu State Direc. Hort. & Plantn. Crops Alukkuli, Erode Dist., Tamil Nadu	25 June, 2016
PMBFY awareness program & Farmers Fair	ICAR - KVK, Saraswathi Foundation, Karur, Tamil Nadu	15 July, 2016
Pradhan Mantri Fasal Bhima Yojana and Farmers' Fair	ICAR - KVK, Karur, Tamil Nadu	16 July, 2016
ICAR – NRCB foundation day and Kisan Mela	ICAR – NRCB, Tiruchirapalli, Tamil Nadu	21 August, 2016

Name of the Events	Organizer / Venue	Date
ICAR – SBI foundation Day and Kisan Mela	ICAR – SBI, Coimbatore, Tamil Nadu	26 - 27 August, 2016
Seminar on 'Banana cultivation techniques'	ICAR – NRCB, T.N. at Kalluvizhai, Nagarcoil Dist., Tamil Nadu	30 August, 2016
Ulzhavar Kalangium 2016 - Seminar cum Grand Agri Expo'.	VIT, Vellore, Tamil Nadu	3 - 4 September, 2016
Banana Seminar	Dept. of Horticulture under NHM at Naduveeran pattu village, Cuddalore Dist., Tamil Nadu	17 September, 2016
National conference on tropical tuber crops for the sustenance and welfare of tribal communities (NCTTC-2016)	ICAR - CTCRI & Indian Society for Root Crops (ISRC) at ICAR - CTCRI, Thiruvananthapuram, Kerala	20 - 22 October, 2016
First International Congress on Agro-biodiversity - Science, Technology, Policy and Partnership	NASC Complex, New Delhi	6 – 9 November, 2016
Banana farmers' meet, under Tribal Sub-Plan Program	ICAR - NRCB & ICAR - IIOPR at ICAR -IIOPR, Palode, Thiruvananthapuram, Kerala	16 November, 2016
International workshop on agro-processing and value addition	Dept. of Agriculture Development & Farmers' Welfare, Govt. of Kerala, VAIGA - 2016 at Kanakakkunnu Palace, Trivandrum, Kerala	2 December, 2016
Rabi Campaign and World Soil Health Day	ICAR - NRCB and KVK, Sirugamani, TNAU at KVK, Sirugamani, TNAU, Tamil Nadu	5 December, 2016
Centenary Agri Expo cum Kisan Mela-2016	ICAR - CPCRI, Kasaragod, Kerala	10 - 13 December, 2016
Horticulture Fair (Totagarike Mela) - 2016	UHS, Bagalkot, Karnataka	17 - 19 December, 2016
Regional Horticultural Fair – 'Horticulture for Rural and Urban Prosperity'	ICAR - IIHR, Bengaluru, Karnataka	15 - 19 January, 2017
Krishi Unnati Mela, 2017	ICAR - IARI, New Delhi	15 – 17 March, 2017

6. EDUCATION AND TRAINING

6.1 Students guided

Student Name	Degree	Project title	Chairperson
Mr. S. Vinoth	B.Tech., (Biotechnology)	Identification of Phytochemicals from Banana true stem volatiles of cultivars of Grand Naine and Nendran	Dr. B. Padmanaban
Ms. S. Judy	B.Tech., (Biotechnology)	Proteomic investigation of antenna of Banana stem weevil, *Odoiporus longicollis*	Dr. B. Padmanaban
Ms. K. Abitha	B.Tech., (Biotechnology)	Isolation of entomopathogenic fungi from *Musa* germplasm for molecular identification	Dr. B. Padmanaban
Ms. L. Madhumathi	B.Tech., (Biotechnology)	Cloning, sequencing and bioinformatic analysis of CI, Nia and VPg genes of Banana Bract Mosaic Virus (BBrMV) isolate	Dr. R. Selvarajan
Ms. Rachel Stepheena Samuel	M.Tech., (Biotechnology)	Banana Bunchy Top Virus: Standardisation of protocol for infectivity assay using multiple genomic segments of the virus by Particle Bombardment	Dr. R. Selvarajan
Ms. G. Nithya,	M.Sc., (Microbiology)	Molecular characterization of an isolate of Cucumber Mosaic Virus (CMV) infecting banana	Dr. R. Selvarajan

6.2 Trainings

6.2.1. On-Campus Training

Title of the Training Program	Course Co-ordinator(s)	Date
Banana fig	Dr. K.N. Shiva	3 - 4 May, 2016
'Banana Tissue culture' to M/s. Madappally Service Co - Operative Bank Ltd., Kottayam, Kerala	Dr. M. S. Saraswathi	21 - 24 June, 2016
Post-harvest handling, packing, storage and ripening in banana for domestic and export markets	Dr. K.N. Shiva	12 - 14 July, 2016
Banana flower Pickle (thokku)	Dr. K.N. Shiva	21 - 22 July, 2016

Title of the Training Program	Course Co-ordinator(s)	Date
Advances in Integrated nutrient management (INM) and Integrated pests and diseases management (IPDM) in bananas and plantain	Dr. V. Kumar & Dr. J. Poorani	28 – 30 July, 2016
Banana chips and banana flour based baby food	Dr. K. N. Shiva	14 - 15 September, 2016
Banana fig	Dr. K. N. Shiva	24 - 25 October, 2016
'Hi-tech banana cultivation for enhancing the production and productivity of quality bananas' for the Officials of Mahindra & Mahindra Agri. Business Pvt. Limited, Maharashtra	Dr. V. Kumar & Dr. S. Uma	13 - 15 December, 2016
'Hi-tech banana cultivation for enhancing the production and productivity of quality bananas' for the officials of Vegetable and Fruit Promotion Council Keralam (VFPCK), Kochi, Kerala	Dr. V. Kumar & Dr. S. Uma	13 - 14 March 2017

6.2.2. Off-Campus Training

Title of the Training Program	Course Co-ordinator(s)	Date
Postharvest management and value addition in banana at BR Hills, Karnataka	Dr. P. Suresh Kumar	24 June, 2016
"Improved Production Technologies in Banana" to the banana farmers in Bhivani, Haryana	Dr. V. Kumar	2 July, 2016
'Hi-tech banana cultivation to the tribal farmers' & 'Pre & postharvest management in Banana' under TSP at BR Hills, Karnataka	Dr. V. Kumar & Dr. P. Suresh Kumar	26 July, 2016
Improved cultivation of banana at Pattukottai, Thanjavur Dist. & Gandarvakottai, Pudukottai Dist., Tamil Nadu	Dr. V. Kumar	16 August, 2016
One day training on "Improved Cultivation Techniques and Value Addition in Banana' and distribution of inputs / machineries to tribal farmers / women of Kanyakumari at TNAU-HRS, Pechipparai, Tamil Nadu	Dr. V. Kumar & Dr. K. N. Shiva	18 October, 2016
One day awareness training on 'Good agricultural practices (GAP) in cultivation of Nendran' at Thiruvananthapuram, Kerala	Dr. V. Kumar	31 October, 2016

Title of the Training Program	Course Co-ordinator(s)	Date
One day training cum demonstration on 'Cultivation Techniques and Value Addition in Banana' at Palode, Thiruvananthapuram, Kerala	Dr. V. Kumar & Dr. K. N. Shiva	16 November, 2016
One day training on "Cultivation Techniques and Value Addition in Banana" & 'Banana Fibre Extraction from Pseudostem'; Demonstration of equipments to the tribal farmers / women at BR Hills, Chamrajanagara District, Karnataka under TSP	Dr. V. Kumar & Dr. P. Suresh Kumar	25 November, 2016
'Crop specific GAP, package of practices and good hygienic practices in banana' at one day awareness training on 'Cluster development activity' at Theni, Tamil Nadu.	Dr. V. Kumar	29 November, 2016
Training on 'Improved Production Technologies' for SHGs / farmers at Dudhnoi, Meghalaya	Dr. S. Uma	19 February, 2017
Training on 'Improved Production Technologies for Enhancing Productivity and Profitability of Bananas' and distribution of inputs to the farmers / SHGs at Tura, Meghalaya; Agartala and Khowai, Tripura under NEH plan	Dr. V. Kumar & Dr. S. Uma	20, 22 & 23 February, 2017
'Hi-tech Cultivation, Processing and Value Addition in Banana' at KVK, Roing, Arunachal Pradesh to 70 farmers under NEH plan	Dr. B. Padmanaban Dr. P. Suresh Kumar & Dr. A. Thirugnanavel	24 March, 2017
'Improved Scientific Cultivation and Value Addition in Banana' at KVK, Namsai, Lohit, Arunachal Pradesh to 85 farmers under NEH plan	Dr. B. Padmanaban Dr. P. Suresh Kumar & Dr. A. Thirugnanavel	25 March, 2017
'Improved Scientific Cultivation and Value Addition in Banana' at KVK, Ukrul, Manipur to 60 farmers under NEH plan	Dr. B. Padmanaban Dr. P. Suresh Kumar & Dr. A. Thirugnanavel	28 March, 2017

7. AWARDS AND RECOGNITIONS

7.1 Awards

Authors	Award details
Dr. R. Selvarajan	Fellow of National Academy of Biological Sciences (FNABS) at 9th NABS' National Conference on New Biological Researches: Opportunities and Challenges for Sustainable Development held at Madurai Kamaraj University, Madurai on 11-12 August, 2016
Mr. K. Arun Dr. S. Uma Dr. S. Backiyarani Dr. M.S. Saraswathi Mr. A.S. Saravanakumar	Best presentation Award for the paper 'Expression profile of candidate genes in seed setting and non seed setting genotypes of banana' at 'National Conference on Fruit Breeding in Tropics and subtropics - An Indian Perspective' held at ICAR - Indian Institute of Horticultural Research, Bengaluru from 27 - 29 April, 2016
Dr. S. Backiyarani Dr. S. Uma Dr. G. Tharani Dr. P. Durai Dr. M.S. Saraswathi	Consolation Award for the poster titled 'Development of A and B genome specific markers in banana'. In: Abstracts of the First International Agrobiodiversity Congress held at NASC, New Delhi on 6 - 9 November, 2016

7.2 Recognitions

Name of the Scientist	Details
Dr. S. Uma	Invited expert for improving banana industries in Meghalaya for World Bank project
	Expert in DBT-National project evaluation committee operating at Agartala, Tripura
	Co-Chair of the DBT-Banana consortium meeting and project evaluation under NEH programme
	Member of IBSC committee of Bharathidasan University, Trichy
	Member of State Co ordination committee on Agriculture
	Chairperson for conducting 'Brainstorming session on successful banana production in Northern Plains'
Dr. B. Padmanaban	69th Board meeting of IICPT, Thanjavur held at IICPT, Thanjavur, Tamil Nadu
Dr. R. Thangavelu	Participated as country representative in the 10th BAPNET steering committee meeting, Gunagzhou, Guangdong, China
	Convenor for the session on disease management at 4th Group discussion of AICRP (Fruits) held at ICAR - IIHR, Bengaluru, Karnataka

Name of the Scientist	Details
Dr. R. Selvarajan	Member; co-chairman for technical session at 8th International Geminivirus Symposium and the 6th International ssDNA comparative virology workshop held at Vivanta by Taj, Dwarka, New Delhi
	Scientific Coordinator; co-chairman for technical session at VIROCON 2016- International conference on "Global Perspectives in Virus Disease Management" held at ICAR- IIHR, Bengaluru, Karnataka
	External expert for IBSC committee of ICAR – IIHR, Bengaluru, Karnataka
Dr. K. J. Jeyabaskaran	Member in selection committee for selecting Subject Matter Specialist (Soil Science) in ICAR-KVK (CREED-KVK), Jeyankondam, Tamil Nadu
Dr. S. Backiyarani	Convenor for the Brainstorming session on Problems and Prospects of Banana in North East Region held at AAU, Jorhat
Dr. K. N. Shiva	Panel member in the Technical committee meeting of SAMETI at International workshop on value addition and agro processing held at SAMETI, Anayara, Thiruvananthapuram
	Panel member in the DBT sponsored projects screening committee on NER - Banana held at NER- BPMC, New Delhi

8. LINKAGES AND COLLABORATIONS

Project Title	Collaborating Institute(s)	Scientist(s) involved
Breeding for improved banana with Fusarium wilt (*Fusarium oxysporum* f. sp. *cubense*) resistance	IITA, Nigeria; Bioversity International, France; NARO, Tanzania; University of Malaya; SLU, Sweden; Stellenbosch University, South Africa; Cornell University, USA; KUL, Belgium; University of Queensland, Australia; Nelson Mandela African Institution of Science and Technology, Tanzania; Institute of Experimental Botany, Czech Republic and EMBRAPA, Brazil	Dr. S. Uma Dr. S. Backiyarani Dr. M. S. Saraswathi Dr. A. Thirugnanavel
Development of on - chimeral mutants with durable resistance to Fusarium wilt in Rasthali (AAB) through induced mutagenesis	DAE, Mumbai, Maharastra	Dr. M. S. Saraswathi

9. PUBLICATIONS

9.1 Research Papers

International

Kalai Ponmani , K., Thangavelu, R., and Varun, G. 2017. Optimization of protein isolation and comparative proteomics of pathogenic *Fusarium oxysporum* f. sp. *cubense* (P-*Foc*) and non pathogenic *Fusarium oxysporum* (np-*Fo*). *Journal of Plant Pathology*, **99**(2): 361 - 369.

Kaliyappan, R., Viswanathan, S., Suthanthiram, B., Subbaraya, U., Somasundram, S. M. and Mayil Vaganan, M. 2016. Evolutionary expansion of WRKY gene family in banana and its significance against root lesion nematode, *Pratylenchus coffeae. PloS ONE,* **11**(9):1 - 18.

Kumaravel, M., Uma, S., Backiyarani, S., Saraswathi, M. S., Mayil Vaganan, M., Muthusamy, M. and Sajith, K. P. 2017. Differential proteome analysis during early embryogenesis in *Musa* spp. (cv. Grand Naine - AAA). *Plant Cell Reports*, **36**(1): 163 – 178.

Muthusamy, M., Uma, S., Backiyarani, S., Saraswathi, M. S. and Chandrasekar, A. 2016. Transcriptomic changes of drought-tolerant and sensitive banana cultivars exposed to drought stress. *Frontiers in Plant Science*, **7**: 1609.

Saravanakumar, A. S., Uma, S., Thangavelu, R., Backiyarani, S., Saraswathi, M. S. and Sriram, V. 2016. Preliminary analysis on the transcripts involved in resistance responses to eumusae leaf spot disease of banana caused by *Mycosphaerella eumusae*, a recent add-on of the Sigatoka disease complex. *Turkish Journal of Botany*, **40**: 461 - 471.

Selvarajan. R. and Balasubramanian, V. 2017. First report of banana bract mosaic virus in banana in Assam, India. *Journal of Plant Pathology*, **99**(2).

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Giribabu, P. and Anitha Sree, T. 2016. Screening of Banana cultivars for resistance against root - lesion nematode (*Pratylenchus coffeae*). *Indian Journal of Nematology*, **46** (2) : 175.

Nandakumar, S., Ravichamy, P. and Sivabalan, K.C. 2016. Farm telecast viewing behavior and knowledge management of banana growers in Tamil Nadu-An analysis. *Progressive Research – An International Journal,* **11**(4): 3993-3996.

Saraswathi, M. S., Kannan, G., Uma, S., Thangavelu, R. and Backiyarani, S. 2016. Improvement of banana cv. Rasthali against FoC (VCG 0124/5) through induced mutagenesis: Determination of LD50 specific to mutagen, explants, toxins and *in vitro* and *in vivo* screening for Fusarium wilt resistance. *Indian Journal of Experimental Biology*, **54**: 345 - 353.

Sumathi, S. and. Thangavelu, R. 2016. Biodiversity of Arbuscular Mycorrhizal Fungi (AMF) in banana plantations in India. *Plant Archives*, **16**(1): 210 - 216.

Sumathi, S. and. Thangavelu, R. 2016. Co-inoculation of Arbuscular Mycorrhizal Fungi (AMF) and their Mycorrhizae Helper Bacteria (MHB) effectively suppresses Fusarium Wilt in Banana. *Plant Archives*, **16**(1): 365 - 375.

9.2 Popular articles

Anuradha, C. and Ramasamy, S. 2017. Genetic diversity analysis, sequence motif comparison and homology modeling of VPg from Banana Bract Mosaic Virus. *F1000Research*, **6**: 545.

Anuradha, C. and Ramasamy, S. 2017. Proteomic changes in Banana in response

to Banana Bunchy Top Virus (BBTV). *F1000Research*, **6**: 546.

Anuradha, C., Selvarajan, R. and Vasantha, S. 2017. Physiological and hormonal changes in response to Bunchy Top Virus (BBTV) infection in Banana. *F1000Research*, **6**: 547.

Giribabu, P., Anitha Sree, T. and Uma, S. 2017. Monitoring burrowing and root-lesion nematode damage in Banana. (Tamil). *Vanoli uzhavar sanga seithikkathir*, **17**: 33 - 34.

Kumar, V. 2017. Farmer Banana Production technologies. In: Souvenir of the Regional Horticultural Fair for Rural and Urban Prosperity held at ICAR - IIHR, Bengaluru on 15 – 19 January, 2017. Pp.52 – 54.

Padmanaban, B. 2017. Banana stem trapping technology for banana weevil management and blemishless banana production. In: Souvenir of the Regional Horticultural Fair for Rural and Urban Prosperity held at ICAR - IIHR, Bengaluru on 15 – 19 January, 2017. Pp. 64 - 65.

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Padmanaban, B. 2016. Management of Banana stem weevil (Tamil) Dinamalar-Vivasayamalar (Tamil news daily) published on 7 April, 2016.

Shiva, K. N. and Uma, S. 2017. Recent advances in banana fruit care. (Tamil). *Vanoli Uzhavar Sanga Seithikathir*, **17**: 46 - 50.

Suresh Kumar, P., Ravi, I., Shiva, K. N., Dhivya, J., Vijayalakshmi, M. and Sangeetha, A. 2017. Resistant starch rich designer foods from banana. *Beverage & Food World*, **44** (1): 27 - 29.

Suresh Kumar, P., Dhivya, J., Shiva, K. N., Vijayalakshmi, M. and Sangeetha, A. 2016. Low glycemic, resistant starch rich functional foods from banana. *Processed Food Industry*, **19**(8): 19 - 22.

Uma, S., Saraswathi, M. S. and Durai, P. 2017. Kela Vruddhi – A low cost and farmer friendly macro-propagation technology. In: Souvenir of the Regional Horticultural Fair for Rural and Urban Prosperity held at ICAR - IIHR, Bengaluru on 15 – 19 January, 2017. Pp. 48 - 49.

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9.3 Books / Book chapters

Ravi, I. and Mayil Vaganan, M. 2016. Abiotic stress tolerance in banana, In: Abiotic Stress Physiology of Horticultural Crops. Srinivasa Rao, N. K., Shivasankara, K. S. and Laxman, R. H. (Eds.), Springer-VerlagGmBH Heidelberg, Germany, P. 207-222.

Selvarajan, R. and Balasubramanian, V. 2016. Cutting - Edge Technologies for Detection of Plant Viruses in Vegetatively Propagated Crop Plants, In: Plant Viruses: Evolution and Management. (Eds) Gaur, R. K., Petrov, N. M., Patil, B. L., Stoyanova, M. I. Springer.

9.4 Scientific reviews / Extension folders / Technical folders / Factsheets / Reports etc.

Bhat, A.I., Hohn, T. and Selvarajan, R. 2016. Badna viruses: the current global scenario. *Viruses* **8**:177.

Jeyabaskaran, K. J. 2016. Fertiliser management in banana cultivation (Tamil), Extension Folder No.23, ICAR -

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Mayil Vaganan, M., Ravi, I. and Uma, S. 2016. Nutritive values and medicinal benefits of banana flower (Tamil). Tech. Folder No. 8. ICAR - National Research Centre for Banana, Tiruchirappalli.

Ravindra Naik, Annamalai, S. J. K. and Shiva, K. N. 2016. Mechanization package for rope making from outer sheath of banana pseudostem. Extension folder: CIAE / RC / 2016 / 04. ICAR- Central Institute for Agricultural Engineering - Regional Centre, Coimbatore, Tamil Nadu.

Thangavelu, R. 2017. Fusarium Wilt – A Challenge to Banana Cultivation in India. Fact sheet No 1. ICAR - National Research Centre for Banana, Tiruchirappalli.

Thangavelu, R. and Uma, S. 2016. Leaf spot diseases of banana and their management (Tamil). Extension Folder No. 20. ICAR - National Research Centre for Banana, Tiruchirappalli.

Thangavelu, R. and Uma, S. 2016. Wilt disease management in banana (Tamil). Extension Folder No. 22. ICAR - National Research Centre for Banana, Tiruchirappalli.

Thangavelu,R. and Padmanaban, B. 2016. Fusarium wilt of banana. Banana fungal disease. Fact sheet No 1. ICAR - National Research Centre for Banana, Tiruchirappalli.

Uma, S., Saraswathi, M. S., Backiyarani, S. and Durai, P. 2015. Banana Breeding – A Brief Review. *International Journal of Innovative Horticulture*, **4** (1): 11-19.

9.5 Training manuals

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9.6 Research papers / Abstracts / Presentations in Conferences / Symposia / Seminars / Workshops etc.

9.6.1 International

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Management" held at ICAR - IIHR, Bengaluru from 8 - 10 December, 2016. P 91.

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Kumar, V. 2016. "Studies on the effect of organics on the growth, yield and disease severity of BSV and BBMV affected banana cv. Poovan". In Global Conference on 'Perspectives on Future Challenges and Options in Agriculture' held at. Jalgaon during 28 - 31 May, 2016.

Saraswathi, M. S., Uma, S., Jithu, G., Bahrudeen Shahul Hameed, Durai, P., Sharmila Gayatri, D. and Backiyarani, S. 2016. DNA profiling of plantain clones using ISSR markers. In: Abstracts of the First International Agro-biodiversity congress held at NASC, New Delhi on 6 - 9 November, 2016. P 211.

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Suresh Kumar, P., Shiva, K. N., Mayil Vaganan, M., Ravi, I. and Marimuthu, N. 2016. Export banana waste as an ingredient for the preparation of resistant starch rich pasta (RSRP). In: 5th International conference on sustainable utilization of tropical plant biomass: bioproducts, biocatalysts and biorefinery (SutB4), Organized by Dept. of Agrl. Microbiology, Directorate of Natural Resource Management, TNAU, held at TNAU, Coimbatore, Tamil Nadu on17 - 18 November, 2016, Pp. 366 - 368.

Thangavelu, R. and Ganga Devi, P. 2016. Biological management of *Eumusae* leaf spot disease using native epiphytic and endophytic microbes in banana cv. Grand Naine (AAA). *Agro-ecological approaches to promote innovative banana production systems* held at Agropolis International - Montpellier, France on 10 - 14 October, 2016.

Thangavelu, R. and Gopi, M. 2016. Field suppression of Fusarium wilt disease (*Foc* race 1- VCG 0124) and plant growth promotion mediated by native microbes and botanicals Zimmu (*Allium sativum* L. × *Allium cepa* L.) in banana cv. Grand Naine. "*Agro-ecological approaches to promote innovative banana production systems*" held at Agropolis International - Montpellier, France on 10 – 14 October, 2016.

Uma, S., Saraswathi, M. S., Backiyarani, S., Udhayanjali, K., Amudha, P., Durai, P. and Anuradha Agrawal. 2016. Success story of rejuvenation of near extinct fragrant banana, cv. Manoranjitham through inter institutional and public private partnership. In: Abstracts of the First International Agro-biodiversity congress held at NASC, New Delhi on 6 - 9 November, 2016. Pp.87.

9.6.2 National

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Backiyarani, S., Uma, S., Maria Doss, A., Saraswathi, M. S., Selvaraj, V., Arun, K. and Durai, P. 2016. Enhancing the seed set in banana using antitoxins. In: National Conference on Fruit Breeding in Tropics and Subtropics - An Indian Perspective. ICAR -Indian Institute of Horticultural Research, Bengaluru. 27 - 29 April, 2016. P. 116.

Ravichamy, P., Nandakumar, S. and Siva balan, K.C. 2017. ICT and media: A powerful communication tool in dissemination of information to banana farming community - A Study. *In:* National Conference on ICT & Communication Development, 5th & 6th January. Manonmaniam Sundaranar University, Tirunelveli. Pp. 14.

Saraswathi, M. S., Uma, S., Bahrudeen Shahul Hameed, Backiyarani, S., Durai, P., Udhayanjali, K. and Udhyavani, U. 2016. DNA profiling of *Musa* wild species of North Eastern India using ISSR markers. In: National Conference on Fruit Breeding in Tropics and subtropics - An Indian Perspective. ICAR - Indian Institute of Horticultural Research, Bengaluru. 27 - 29 April, 2016. P. 79.

Suresh Kumar, P., Dhivya, J., Shiva, K. N., Mayil Vaganan, M. and Jeyabaskaran, K. J. 2016. Development of low glycemic and resistant starch rich flour from dehydrated banana cv. Monthan. In: 8th Swadesh Prem Jagriti Sangosthi - Conference on Perspective of Future Challenges and options in Agriculture, organized by ASM Foundation, New Delhi, Jain Irrigation Systems Ltd., Jalgaon, CHAI and TANS, New Delhi at Jain Hills, JISL, Jalgaon, Maharashtra during 28 - 31 May 2016. P. 103 - 104.

10. CONSULTANCY SERVICES AND COMMERCIALIZATION OF TECHNOLOGIES

Consultancy Services

- The institute has supplied a total of 5747 (2050 + 3697 of TC and suckers) plants of banana cv. Udhayam to banana growers of various districts of Tamil Nadu.
- Under 'Lab Accreditation Facility for Virus Indexing and Genetic Fidelity Testing of Tissue Culture Plants', a total of 17,335 samples were tested for the presence of virus. (Revenue generated - Rs. 93.34 lakhs).
- Polyclonal antiserum produced for CMV, BBrMV and BBTV has been sold to the State agricultural universities viz., KAU, APHU and TNAU. (Revenue generated - Rs. 87,000/-).
- Under 'Lab Accreditation Facility for Virus Indexing and Genetic Fidelity Testing of Tissue Culture Plants', 1250 batches of tissue culture plants (Cvs. Grand Naine, Williams, Robusta, Ney Poovan, Red banana, Quintal Nendran etc.) have been tested for their genetic fidelity using SSR and ISSR markers and reports were issued. (Revenue generated - Rs.21.56 lakhs).
- Mother plants of cvs. Udhayam have been supplied to M/s. Shaanti AgroTech, Bengaluru for mass multiplication purpose.
- Mother cultures of cvs. Udhayam have been supplied to M/s. Hi-Fi Biotech, Salem, Tamil Nadu.
- Manure samples received from M/s. TVS - Srichakra tyres Ltd., Vellarippatti, Melur, Madurai were analyzed and provided the disposal methods.

Commercialization of Technologies

Date	Name of the technology	Address of the client	No. of MOU	Revenue (Lakhs)
4 May, 2016	Banana Fig	1. Mr. Krishnan, V.V., Valiyavalappil, Padiyoor P.O., Iritty, Kannur–670703, Kerala	1	0.10
		2. Mr. Tony Cyriac, Neerakkal, #6B, Ancheril Towers, Kottayam - 686004, Kerala	1	0.10
14 July, 2016	Post-Harvest handling, Packing, Storage and Ripening of Banana for Domestic and Export Markets Tamil Nadu	M/s. Winwal International, No.1, T4, Kgeyes Udita Apartments, 1st cross Street, Besant Nagar, Chennai – 600 090,	2	0.35

Date	Name of the technology	Address of the client	No. of MOU	Revenue (Lakhs)
22 July, 2016	Banana Flower Pickle	G.Viruthambal, No.64, Main Road, S.Pudur, Sathankuppam, Post, CuddaloreTk.,607004, Tamil Nadu	1	0.10
15 September, 2016	Banana Chips and Banana Flour Based Baby Food	Mr. Sandeep Santosh Mahajan, Ad Post, Khamni Thesile, District Burhanpur, Madhya Pradesh – 450 445	2	0.20
25 October,2016	Banana Fig	Mr. Shivaji Lotansing Rajput, Plot No 16, Karwand Naka, Swaminarayan Temple Road, Shirpur District, Dhulia, Maharashtra-425 405	1	0.10
10 November, 2016	Banana Pulp based RTS beverage	Mr. L. Isaac David Benito, 6/49 A, K.Pungampalayam, Marudhur Post, Karamadai-641104,Tamil Nadu	1	0.10
17 February, 2017	Banana Flour Based Health Mix	Mr. Thomas Mattamundayil, Secretary, Malanadu Development Society, Kanjirapally 686512, Kottayam, Kerala	1	0.10
31 January,2017	Contract Research Evaluation on the effect of Pronos and Dormulin treatment for the suppression of post harvest diseases and extension of shelf life of banana	M/s. Nagarjuna chemicals and Fertilizers, Hyderabad	1	3.80
		TOTAL	**10**	**4.85**

11. RAC/ IRC / IMC MEETING

IRC Meeting

The 20th Institute Research Council (IRC) meeting was held on 13 and 14 June, 2016 under the chairmanship of Dr. B. Padmanaban, Acting Director, ICAR – NRCB. Dr. R. Selvarajan, Member Secretary, IRC welcomed the chairman and other members of the IRC. After introductory remarks by the Chairman, research projects, comments of the last IRC, action taken report, salient achievements for the year 2015 - 16 and technical program for the year 2016 - 17 presented by the scientists were reviewed.

The 21st Institute Research Council (IRC) meeting was held on 18 – 20 January, 2017 under the chairmanship of Dr. S. Uma, Director, ICAR – NRCB. Salient research achievements during June – December, 2016 and technical program for the year 2017 presented by the scientists were reviewed.

IRC meeting at ICAR - NRCB

IMC Meeting

The 22nd IMC meeting of ICAR – NRCB was held on 4 September, 2016. Dr. S. Uma, Director, ICAR – NRCB chaired the meet along with the members of the IMC. Various Institute related financial issues were discussed and deliberated.

RAC Meeting

The 18th Research Advisory Committee Meeting of ICAR - NRCB was held on 5 - 6 February, 2017 under the Chairmanship of Dr. S. N. Pandey, Former ADG (Hort.), ICAR, New Delhi. Members of the RAC – Dr. P. Ananda Kumar, ICAR - IIRR, Hyderabad, Dr. T. V. K. Singh, Emeritus Professor, PJTSAU, Hyderabad, Dr. N. Kumar, Former Dean, TNAU, Coimbatore, Dr. A. K. Misra, Principal Scientist & Head, ICAR – CISH, Lucknow, IMC Representatives – Mr. S. Rajendran, Kattuputhur, Tiruchirapalli and Mr. M. N. Vaithianathan, Lalgudi, Tiruchirapalli were attended the meet. Dr. S. Uma, Director, ICAR - NRCB welcomed the RAC Members and presented salient research achievements made by the Centre during last one year. Dr. B. Padmanaban, Member Secretary – RAC, presented the action taken report (ATR) of 17th RAC Meeting followed by the presentation of individual scientists on their research project achievements. After the deliberations, the Committee had made its recommendations. Earlier the team also visited the ICAR - NRCB Farm. The meeting was ended with vote of thanks to the Chair and other RAC Members by Dr. B. Padmanaban, Member Secretary - RAC.

IMC members of ICAR - NRCB

Scientists of ICAR – NRCB with RAC members

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

Human Resource Development

12.1. Trainings / Refresher courses attended by staff of ICAR – NRCB

Name of the Staff	Name of the program	Venue	Date
Dr. I. Ravi Principal Scientist	Formulation of Projects Under Climate Change	Cooperative Training Institute, Hyderabad	5 - 9 September, 2016
Dr. K. N. Shiva Principal Scientist	"Processing Machineries, Value Addition and Entrepreneurship Development in Tuber Crops"	ICAR - CTCRI, Thiruvananthapuram, Kerala	31 August - 9 September, 2016
Dr. S. Backiyarani Principal Scientist	'Agricultural Research Management'	ICAR - NAARM, Hyderabad, Telangana	15 – 26 November, 2016
Dr. P. Suresh Kumar Senior Scientist	Analysis of Experimental Data	ICAR - NAARM, Hyderabad, Telangana	18 - 23 August, 2016
Dr. P. Durai Assistant Chief Technical Officer	'Principles and Production Techniques of Hybrid Seeds in Vegetables'	ICAR - IIVR, Varanasi, Uttar Pradesh	27 September - October 8, 2016
Dr. P. Durai Assistant Chief Technical Officer	'PGR Management in Fruit Crops for the Scientists of ICAR - AICRP on Fruits'	ICAR - NBPGR, New Delhi	22 - 25 March, 2017
Dr. S. Palanichamy Senior Technical Officer	Bio-prospecting instrumentation methods and chemical analysis	IFGTB, Coimbatore, Tamil Nadu	17 – 20 August, 2016
Dr. S. Palanichamy Senior Technical Officer	Experimental data analysis	ICAR - IASRI, New Delhi	20 August - 8 September, 2016
Mrs. T. Anitha Sree Senior Technical Officer	'Good Laboratory Practices'	SRS of ICAR - NDRI, Adugodi, Bengaluru, Karnataka	17 - 22 October, 2016
Mr. P. Ravichamy Senior Technical Officer	'J-Gate@CeRA for Southern region'	Veterinary College, Karnataka Veterinary, Animal and Fisheries Science University (KVAFSU), Hebbal, Bengaluru, Karnataka	27 January, 2017

Name of the Staff	Name of the program	Venue	Date
Mrs. C. Sagayam Jacqueline Technical Officer	Network Basis and Management	ICAR - IASRI, Pusa,New Delhi.	23 – 31 July, 2016
Mrs. C. Sagayam Jacqueline Technical Officer	'Cyber Security' for Technical Personnel of ICAR	ICAR - IASRI, New Delhi	28 September – 6 October, 2016
Mr. N. Marimuthu Senior Technical Assistant	'Technology Management and Business Planning for Entrepreneurship Development'	SRS of ICAR - NDRI, Adugodi, Bengaluru, Karnataka	13 - 18 March, 2017
Mr. R. Pitchaimuthu Senior Technical Assistant	Use and Maintenance of Advanced Instrument in Soil and Plant Analysis	ICAR – IISS, Bhopal, Madhya Pradesh	6 – 15 August, 2016
Mr. B. Sathish Senior Admin. Officer	Roaster and e - procurement	ICAR - NAARM, Hyderabad, Telangana	23 April to 2 May, 2016
Mr. R. Krishnamurthy Asst. Admin. Officer	e - procurement	ICAR - NAARM, Hyderabad, Telangana	25 – 26 April, 2016
Mr. R. Sridhar Personal Assistant	e - procurement	ICAR - NAARM, Hyderabad, Telangana	25 – 26 April, 2016
Mr. R.N.M.S. Kannan Steno Gr. III	ERP, MIS / FMS under HR module	ICAR - IASRI, New Delhi	2 – 11 May, 2016

12.2 Workshop / Seminar / Conference / Symposia / Scientific meet etc. attended by the Scientists

Name of the Staff	Event	Organizer / Venue	Date
Scientists of ICAR - NRCB	Brainstorming Discussion Meet on 'Emerging Pests and Disease Problems in Banana'	ICAR – NRCB, Tiruchirapalli, Tamil Nadu	23 April, 2016
	ICAR – NRCB foundation day cum Kisan Mela	ICAR – NRCB, Tiruchirapalli, Tamil Nadu	21 August, 2016
	Outreach programme for exporters organized by APEDA	Coimbatore, Tamil Nadu	27 April, 2016
	Formulate future mechanization needs for banana	ICAR – NRCB, Tiruchirapalli, Tamil Nadu	28 January, 2017

Name of the Staff	Event	Organizer / Venue	Date
Dr. B. Padmanaban Dr. R. Thangavelu Dr. V. Kumar Dr. K.J. Jeyabaskaran	Banana Farmers' Interface Meeting	ICAR - NRCB and University of Horticulture Sciences, Bidar, Karnataka. Held at College of Horticulture, Bidar, Karnataka	27 April, 2016
Dr. B. Padmanaban Dr. R. Thangavelu Dr. V. Kumar Dr. K.J. Jeyabaskaran Dr. K. N. Shiva	Banana Farmers' Interface Meeting	ICAR - NRCB and HRS, Kovvur, Andhra Pradesh. Held at Dr.YSR Horticultural University, Venkataramanagudem, Andhra Pradesh	28 April, 2016
Dr. V. Kumar Dr. P. Suresh Kumar	National Workshop on Production and Handling of Quality Banana for Export and Domestic Market	Organized by ASM Foundation, New Delhi; Jain Irrigation Systems Ltd., Maharashtra and AIPUB, Tiruchirapalli. Held at Jalgaon, Maharashtra	29 May, 2016
Dr. S. Uma Dr. B. Padmanaban Dr. R. Selvarajan Dr. S. Backiyarani Dr. P. Giribabu	Brainstorming Discussion Meet on 'Problems and Prospects of Banana in North East India'	Organized by DBT, Govt. India. Held at AAU, Jorhat, Assam	3 - 4 June, 2016
Dr. S. Uma Dr. B. Padmanaban Dr. R. Thangavelu Dr. V. Kumar Dr. K. N. Shiva Dr. S. Backiyarani Dr. P. Suresh Kumar	4th Group Discussion of AICRP (Fruits)	ICAR - IIHR, Bengaluru, Karnataka	4 - 7 January, 2017
Dr. S. Uma Dr. R. Thangavelu Dr. V. Kumar	Brainstorming session on 'Innovative approaches in *in-vitro* mass multiplication, production and plant protection for sustainable production in Northern Plains'.	ICAR – CSSRI Regional station, Lucknow, Uttar Pradesh	22 March, 2017

Name of the Staff	Event	Organizer / Venue	Date
Dr. R. Thangavelu Dr. V. Kumar	Workshop on 'Sensitization of stakeholders of Banana on the occurrence of TR-4 of Fusarium Wilt Disease'.	Organized by the DEE, Bihar Agricultural University, Sabour and ICAR - NRCB, Tiruchirappalli, Tamil Nadu. Held at Veterinary College, BAU, Patna, Bihar	24 March, 2017
Dr. S. Uma Dr. V. Kumar Dr. P. Suresh Kumar	National seminar on 'Horticultural education - Present status and future prospects'	ICAR - IIHR, Bengaluru, Karnataka	24 September, 2016
Dr. S. Uma Dr. V. Kumar Dr. P. Suresh Kumar	Review meeting of the AICRP on Fruits - 'Formulation of Future Needs'	ICAR - IIHR, Bengaluru, Karnataka	25 - 27 September, 2016
Dr. B. Padmanaban Dr. K. N. Shiva	National Seminar on Hi-tech Banana Cultivation	Held at Naduveerappattu village, Cuddalore Dist., Tamil Nadu	17 September, 2016
Dr. B. Padmanaban	National Meet of Entomologists	Organized by ICAR - IIHR, Bengaluru. Held at SVC, Bengaluru, Karnataka	7 - 8 October, 2016
Dr. B. Padmanaban	Brain storming meet on rugose spiralling whitefly	Organized by ICAR - NBAIR, Bengaluru. Held at TNAU Coimbatore, Tamil Nadu	24 -25 March, 2017
Dr. R. Thangavelu	Tenth Banana Asia-Pacific Network (BAPNET) steering committee meeting	Organized by Bioversity International, France and Guangdong Academy of Agricultural Sciences, China. Held at Gunagzhou city, Guangdong, China	23 - 26 August, 2016
	Tenth International ISHS / Promusa banana symposium on 'Agroecological Approaches to Promote Innovative Banana Production Systems'	CIRAD, Montpellier, France	10 - 14 October, 2016

Name of the Staff	Event	Organizer / Venue	Date
Dr. R. Selvarajan	9th NABS National Conference on 'New Biological Researches: Opportunities and Challenges for Sustainable Development'	MKU , Madurai, Tamil Nadu	11 - 12 August, 2016
	8th International Geminivirus Symposium and 6th International ss DNA Comparative Virology Workshop	Hotel Taj Vivanta, New Delhi	7 – 10 November, 2016
Dr. R. Selvarajan Dr. C. Anuradha	VIROCON 2016 - International Conference on 'Global Perspective in Virus Disease Management'	ICAR - IIHR, Bengaluru, Karnataka	8 – 10 December, 2016
Dr. M. Mayil Vaganan	Fourth Annual South Asia Biosafety Conference	Hotel Taj Krishna, Hyderabad, Telangana	19 - 21 September, 2016
	Presentation of DBT sponsored New Project proposal on North Eastern Region banana	DBT Office, Defense Colony, New Delhi	8 - 9 February, 2017
Dr. I. Ravi	Workshop on Tuber crops Technology Transfer and Commercialization"	ICAR - CTCRI, Thiruvananthapuram, Kerala	25 June, 2016
Dr. V. Kumar Dr. K. N. Shiva	One-day Awareness Programme on GAP in Nendran Banana	Organized by Dept. of Agricultural Development and Farmers' Welfare, Govt. of Kerala and CII, APEDA, FACE Held at University at State Veterinary Council Hall, Peroorkkada, Thiruvananthapuram, Kerala	10 June, 2016
Dr. V. Kumar	14th Scientific Advisory Committee Meeting	TNAU-KVK, Santhiyur, Salem, Tamil Nadu	29 June, 2016
	7th Scientific Advisory Committee Meeting	TNAU-KVK, Papparappatti, Dharmapuri, Tamil Nadu	29 June, 2016

Name of the Staff	Event	Organizer / Venue	Date
	82nd Scientific Workers' Conference	TNAU, Coimbatore, Tamil Nadu	5 July, 2016
	68th Board Meeting of IICPT	Panchsheel Bhavan, New Delhi	5 August, 2016
	Farmers' Meeting cum Training organized by NABARD and Dept. of Horticulture, Tamil Nadu	Alathur, Pattukottai and Gantharvakottai, Tamil Nadu	16 August, 2016
	39th Scientific Advisory Committee Meeting	ICAR - KVK, Sirugamani, Tiruchirappalli, Tamil Nadu	20 August, 2016
Dr. V. Kumar	7th Scientific Advisory Committee Meeting	ICAR - KVK, Needamangalam, Tamil Nadu	22 September, 2016
	Farmers Field School (FFS) in Banana	Central IPM Centre, Tamil Nadu	29 January, 2017 Tiruchirappalli,
	Scientific Advisory Committee Meeting	KVK –TANUVAS, VC&RI Campus, Namakkal	14 February, 2017
	'Brainstorming session on 'New Crop Diversification Options in Coffee Cropping Systems in South India'	Hill Banana Growers' Federation at Dindigul, Tamil Nadu	28 February, 2017
	'Banana Stakeholders' Meeting' and signing of MoU for the 'Development of Sea Protocol for Trial Shipment for Export on Traditional Bananas'	APEDA and Fair Exports Pvt. Ltd., Kochi, Kerala	20 March, 2017
Dr. K. J. Jeyabaskaran	Workshop on 'Mainstreaming Agriculture in WASH Discourse'	Auroville, Pondichery	17 – 18 June, 2016
	One day training cum workshop for nodal officers of the public authority related to RTI Online Portal of DoPT	ICAR - NAARM, Hyderabad, Telangana	25 October, 2016

Name of the Staff	Event	Organizer / Venue	Date
Dr. K. N. Shiva	Conference on Agricultural Technology of 6th SICCI Agri Summit & Expo 2016	Organized by SICCI and TNAU. Held at PGP College of Agricultural Sciences, Vettambadi, Namakkal, Tamil Nadu	11 June. 2016
	National Seminar on	Organized by Dept. of Horticulture, Banana Kanyakumar Dt. Held at Kalluvilai village, Thuckalay block, Kanyakumari Dist., Tamil Nadu	30 August, 2016
Dr. K. N. Shiva	Processing machineries, value addition and entrepreneurship development in tuber crops	ICAR - CTCRI, Thiruvananthapuram, Kerala	August 31 – 9 September, 2016
	National Seminar on Challenges and Opportunities in Food Packaging	Organized by IICPT. Held at IICPT, Thanjavur, Tamil Nadu	23 September, 2016
	Seminar on 'Value Addition in Food and Agri-Products'	Confederation of Indian Industry at Sona College of Technology, Salem, Tamil Nadu	8 November, 2016
	One day Awareness Training Program for Banana on Good Agricultural Practices and Good Hygienic Practices for Export	Organized by APEDA, CII, FACE, Dept. of Agrl. Marketing and Agri-Business, Govt. of TN,ICAR - NRCB, HC & RI, Periyakulam, TNAU. Held at Hotel Western Ghatz, Theni, Tamil Nadu	29 November, 2016
Dr. K. N. Shiva & Mr. Badhrinath	Horticulture Fair (Totagarike Mela) -2016	Organized by UHS, Bagalkot. Held at UHS Ground, Bagalkot, Karnataka	17 - 19 December, 2016
Dr. S. Backiyarani Dr. M. S. Saraswathi	Workshop on 'Guidelines for access to biological under the biological diversity act, 2002'	UAS - GKVK, Bengaluru, Karnataka	28 July, 2016

Name of the Staff	Event	Organizer / Venue	Date
Dr. S. Backiyarani	Panel discussion on "Opportunities and Challenges in Higher Education-International & National Perspectives"	NIT, Tiruchirapalli, Tamil Nadu	19 September, 2016
Dr. S. Uma Dr. S. Backiyarani Dr. M. S. Saraswathi	First International Agrobiodiversity Congress	NASC, New Delhi	6 - 9 November, 2016
Dr. M. S. Saraswathi	Attended the Brainstorming Meeting on Oil palm tissue culture	ICAR - IIOPR, Pedavegi, Andhra Pradesh	20 September, 2016
Dr. P. Suresh Kumar	Pradhan Manthri Fasal Bhima Yojana meeting	KVK – Sirugamani, Tamil Nadu	28 June, 2016
	Pradhan Manthri Fasal Bhima Yojana & Farmers fair	Organized by Saraswathi Foundation for Rural Development & Training. Held at Prem Mahal, Karur, Tamil Nadu	16 July, 2016
	Brainstorming session on 'Engineering Interventions Required for Horticultural Crops'	CIAE – Bhopal, Madhya Pradesh	24 - 25 October, 2016
	5th International Conference on Sustainable Utilization of Tropical Plant Biomass: Bio-products, Biocatalysts and Biorefinery (SutB4)	TNAU, Coimbatore, Tamil Nadu	17 - 18 November, 2016
	National workshop on 'Environmental Health & Safety Management' (NWEHSM, 2017)	Bharathidhasan University, Tiruchirapalli, Tamil Nadu	10 March, 2017

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

Banana Kisan Mela cum ICAR - NRCB foundation day

ICAR – NRCB celebrated its 23nd foundation day as Kisan Mela on 21 August, 2016. The mela was presided over by Dr. K. Ramasamy, Vice Chancellor, Tamil Nadu Agricultural University, Dr. Prakash Patil, Project Co-ordinator, AICRP – Fruits and S. Uma, Director, ICAR – NRCB.

Brainstorming Discussion Meet at ICAR – NRCB

ICAR – NRCB has organized one day brainstorming discussion meet on "Emerging Pests and Disease Problems in Banana" on 23 April, 2016. The meeting was graced by Dr. N. K. Krishna Kumar, Dy. Director General (Hort. Science), ICAR, New Delhi. Dr. B. Padmanaban, Acting Director, ICAR - NRCB presented the overview of emerging pests and diseases in banana. Dr. Prakash Patil, Project Co-ordinator, AICRP on Fruits, IIHR, Bengaluru; Dr. Sadasakthi, Representative of Commissioner of Horticulture and Plantation Crops, Govt. of Tamil Nadu, Mr. R. Krishnamurthy, Dy. Director of Horticulture, representing Agri. Production Commission and Secretary, Dept. of Agriculture, Govt. of Tamil Nadu; Scientists working on banana from ICAR Institutes, SAUs, Plant Quarantine Departments and representatives of Farmers Association were also participated. In technical session, emerging pest problems viz., Race 1 and other virulent strains of Fusarium wilt disease and banana skipper were discussed in detail and a strategic action plan to contain the spread of dreaded disease in India was developed.

Banana Farmers' Interface Meet at UHS, Bidar

ICAR - NRCB in collaboration with University of Horticulture Sciences, Bidar, Karnataka organized one day "Banana Farmers' Interface Meet" at College of Horticulture, Bidar on 27 April, 2016. The meeting was attended by 80 farmers from Bidar / Kalburgi districts of Karnataka.

Banana Farmers' Interface Meet at HRS, Kovvur

ICAR - NRCB in collaboration with Horticultural Research Station, Kovvur, Andhra Pradesh organized one day "Banana Farmers' Interface Meet" at Dr.YSR Horticultural University, Venkatara managudem on 28 April, 2016. 120 farmers participated in the event.

National Workshop on Production and Handling of Quality Banana for Export and Domestic Market

National workshop on banana was organized at Jalgaon, Maharashtra on 29 May,

2016. The workshop was organized jointly by ASM Foundation, New Delhi & Jain Irrigation Systems Ltd., Maharashtra in collaboration with AIPUB, Tiruchirapalli. 250 progressive farmers from Maharashtra, Madhya Pradesh and Gujarat were attended the workshop. Scientists of ICAR – NRCB have attended the workshop.

World Soil Day

ICAR – NRCB celebrated 'World Soil Day' in collaboration with ICAR - KVK, Sirugamani, TNAU on 5 December, 2016. Dr. S. Uma, Director, ICAR - NRCB inaugurated the exhibition and distributed soil health cards to farmers. Dr. R. Chandrasekaran, Professor and Head, ICAR - KVK, Sirugamani welcomed the gathering. Principal Scientists of ICAR – NRCB, Dr. V. Kumar and Dr. K. J. Jeyabaskaran have delivered lectures on banana cultivation and soil health management respectively. About 500 farmers of Tiruchirapalli, Karur and Thanjavur districts of Tamil Nadu were participated.

14. DISTINGUISHED VISITORS

Name, Designation and Address	Date
Dr. N. K. Krishna Kumar, Deputy Director General (ICAR), New Delhi	23 April, 2016
Dr. Prakash Patil, Project Co-ordinator, AICRP - Fruits, ICAR - IIHR, Bengaluru	21 August, 2016
Dr. K. Ramasamy, Vice Chancellor, TNAU, Coimbatore	21 August, 2016
Dr. S. Devasahayam, Head (Crop Protection), ICAR-IISR, Calicut	4 September, 2016
Dr. N. Bakthavatsalam, Principal Scientist & Head (Division of Insect Ecology), ICAR-NBAIR, Bengaluru	4 September, 2016
Dr. (Mrs.) Anuradha Agrawal, Principal Scientist, ICAR-NBPGR, New Delhi	4 September, 2016
Mr. K. Rajaraman, IAS, Principal Secretary and Director, Entrepreneurship Development Institute, Chennai, Tamil Nadu	27 January, 2017
Dr. S. N. Pandey, Retd. ADG (Hort. Sci.), ICAR, New Delhi	5-6 February, 2017
Dr. P. Anand Kumar, Prinicipal Scientist, ICAR-IIRR, Hyderabad	5-6 February, 2017
Dr. T.V.K. Singh, Emeritus Professor, PJTSAU, Hyderabad	5-6 February, 2017
Dr. A. K. Mishra, Ex. Principal Scientist & Head, ICAR-CISH, Lucknow	5-6 February, 2017
Dr. N. Kumar, Former Dean, TNAU, Coimbatore	5-6 February, 2017

15. EMPOWERMENT OF WOMEN

Exclusive training for women on "Advanced techniques in banana production" was conducted at NEHU, Tura, Meghalaya for 56 tribal women.

16. PERSONNEL

16.1 Staff News

Name	Event	Date
Dr. S. Uma, Principal Scientist	Appointed as Director, ICAR – NRCB, Tiruchirapalli, Tamil Nadu	19 July, 2016
Dr. M. Loganathan, Principal Scientist	Joined ICAR – NRCB from ICAR – DCR, Puttur, Karnataka	9 March, 2017
Dr. D. Ramajayam, Senior Scientist	Joined ICAR – NRCB from ICAR – IIOPR, Pedavegi, Andhra Pradesh	13 March, 2017
Dr. P. Suresh Kumar, Senior Scientist	Promoted to Senior Scientist (RGP Rs. 9000/-)	w.e.f. 25 June, 2015
Dr. P. Durai, Senior Technical Officer	Promoted to Assistant Chief Technical Officer	w.e.f. 3 April, 2016
Mr. P. Ravichamy, Technical Officer	Promoted to Senior Technical Officer	w.e.f. 1 May, 2015
Ms. T. Anitha Sree, Technical Officer	Promoted to Senior Technical Officer	w.e.f. 1 May, 2015
Mr. M. Badrinath, Technical Assistant	Promoted to Senior Technical Assistant	w.e.f. 4 October, 2015
Mr. P. Mohan, Technical Assistant	Promoted to Senior Technical Assistant	w.e.f. 8 July, 2016

16.2 Staff position

Scientific Staff

Sl. No.	Name	Designation
1	Dr. S. Uma	Director
2	Dr. B. Padmanaban	Principal Scientist (Entomology)
3	Dr. J. Poorani	Principal Scientist (Entomology)
4	Dr. R. Thangavelu	Principal Scientist (Plant Pathology)
5	Dr. R. Selvarajan	Principal Scientist (Plant Pathology)
6	Dr. M. Mayil Vaganan	Principal Scientist (Plant Biochemistry)
7	Dr. I. Ravi	Principal Scientist (Crop 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	Dr. M. Loganathan	Principal Scientist (Plant Pathology)
14	Dr. D. Ramajayam	Senior Scientist (Horticulture)
15	Dr. P. Suresh Kumar	Senior Scientist (Horticulture)
16	Dr. P. Giribabu	Scientist (Nematology)

Sl. No.	Name	Designation
17	Dr. C. Anuradha	Scientist (Biotechnology)
18	Dr. A. Thirugnanavel	Scientist (Horticulture)
19	Mr. R. Natarajan	Scientist (Economic Botany)

Technical Staff

Sl. No.	Name	Designation
1	Dr. P. Durai	Assistant Chief Technical Officer (Field)
2	Dr. S. Palanichamy	Senior Technical Officer (Field)
3	Mr. P. Ravichamy	Senior Technical Officer (Journalism)
4	Ms. T. Anitha Sree	Senior Technical Officer (Field)
5	Ms. C. Sagayam Jacqueline	Technical Officer (Computer Programmer)
6	Mr. D. Ramachandramurthi	Technical Officer (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. Badhrinath	Senior Technical Assistant (Field)
13	Mr. P. Mohan	Senior Technical Assistant (Driver)
14	Mr. V. Manoharan	Technical Assistant (Driver)

Administrative, Audits & Accounts and Supporting Staff

Sl. No.	Name	Designation
1	Ms. C. Gomathi	Asst. Finance & Accounts Officer
2	Mr. R. Krishnamurthy	Asst. Administrative Officer
3	Mr. M. Krishnamoorthy	Private Secretary
4	Mr. P. Murugan	Assistant
5	Mr. R. Sridhar	Personal Assistant
6	Ms. S. Durgavathy	Upper Division Clerk
7	Mr. R. Neela Mega Shyamala Kannan	Steno Gr. III
8	Ms. A.V. Suja	Lower Division Clerk
9	Mr. R. Mohanraj	Lower Division Clerk
10	Mr. V. Pandiyan	Skilled Supporting Staff
11	Mr. V. Thangaraju	Skilled Supporting Staff
12	Mr. P. Kamaraj	Skilled Supporting Staff
13	Mr. V. Ganesan	Skilled Supporting Staff
14	Ms. K. Mariammal	Skilled Supporting Staff

17. OTHER INFORMATION

Swachhta Bharath Activities

On the eve of Mahatma Gandhi's birth anniversary, ICAR – NRCB has organized a Swachch Bharath awareness rally with the staff of ICAR – NRCB in association of students from St. Joseph College, Tiruchirapalli and Govt. School, Keerikalmedu, Tiruchirapalli. During the rally, placards and slogans on cleanliness were emphasized to the rural folks. ICAR – NRCB has observed '*Intensive Swachhta Bharath Pakhwara*' from 16 – 31, October, 2016. Cultural events with the theme 'Cleanliness and Pollution' and an exhibition on the theme 'Swatchhta Bharat Mission' were held at ICAR – NRCB. Children from St. Joan of Arc International School and Sivananda Balalaya School were participated.

Mera Gaon Mera Gaurav

Under "*Mera Gaon Mera Gaurav*" scheme, Scientists of ICAR – NRCB have adopted 21 villages of Tiruchirapalli, Tanjavur and Karur Districts of Tamil Nadu and organised interactive meeting with village people and given suggestions for their betterment of livelihood, created awareness about the importance of soil testing in agriculture/ horticulture, given timely recommendations for agricultural activities. A linkage has been established between the Centre and the Central IPM Centre and 'Farmers' Farm School program' was organized with series of lectures by the scientists of the Centre.

Yoga Day celebration

International Yoga Day was celebrated on 21 June, 2016. Members from Isha yoga trust, Coimbatore practiced yoga to ICAR – NRCB staff.

Independence Day celebration

Independence Day was celebrated at our institute on 15 August, 2016. Dr. S. Uma, Director, ICAR - NRCB hoisted the national flag and delivered speech.

Sports meet

ICAR – NRCB participated in ICAR Inter-Institutional Sports meet for south zone held at Hyderabad from 22 – 26 August, 2016. A sport contingent of six members was participated in events viz., Badminton, Table tennis, Chess and Carrom.

Hindi Pakhwara

ICAR – NRCB celebrated '*Hindi Pakhwara*' from 14 – 29 September, 2016. Various competitions *viz.,* singing, quiz, news reading etc. were held and prizes were distributed.

Rastriya Ekta Divas

ICAR – NRCB observed Rastriya Ekta Divas on 31 October, 2016 to commemorate the birth anniversary of Sardar Vallabhai Patel and took pledge for National unity.

Vigilance Awareness Week

ICAR - NRCB observed 'Vigilance Awareness Week' from 31 October to 5 November, 2016. On this eve, staff of ICAR – NRCB took pledge. On this occasion, students from Sivananda Balalaya School, Adavathur, Tiruchirapalli visited ICAR – NRCB and participated in essay writing

competition. Various competitions *viz.*, 'Pick and Speak', 'Essay Writing' and 'Debate' were held on 5th November, 2016. Mr. B. Sathish, SAO organized the competitions and gave vote of thanks.

Communal Harmony Campaign

ICAR – NRCB celebrated 'Communal Harmony Campaign' from 19 to 25 November, 2016. Various competitions *viz.,* singing (Bhajans / patriotic songs), essay writing and painting for children of nearby schools were conducted at this centre and prizes were distributed.

Constitution Day

ICAR - NRCB celebrated 'Constitution Day' on 26 November, 2017 to commemorate 125th birth anniversary of Dr. B. Ambedkar. On this occasion preamble of the constitution was recited.

Agriculture Education Day

ICAR – NRCB celebrated 'Agriculture Education Day' on 9 December, 2016 with students of nearby schools and conducted competitions *viz.*, drawing, essay writing and quiz and distributed prizes. Dr. S. Uma, Director, ICAR – NRCB stressed the importance of agriculture and motivated the students to choose Agriculture as their profession.

National Science Day

ICAR - NRCB celebrated 'National Science Day' on 28 February, 2017 with theme on 'Science and Technology for Specially Abled Children'. On this eve, students suffering from mental disorder from Sivananda Balalaya School, Tiruchirapalli have visited ICAR – NRCB and participated in quiz competitions. Dr. S. Uma, Director, ICAR – NRCB motivated the students and distributed the prizes.

International Women's Day Celebrations

ICAR – NRCB celebrated International Women's Day on 8 March, 2017. Dr. Manimekalai, Professor, Bharathidasan University, Tiruchirapalli was the chief guest of the event. On the eve, cultural events were performed by women college students from HC & RIW, Tiruchirapalli, TNAU.

ANNEXURE – I

I. Institute projects

	Name of the Project	Principal Investigator
	Crop Improvement	
1.	Improvement and management of banana genetic resources in Indian subcontinent	Dr. S. Uma
2.	Improvement of banana through conventional breeding	Dr. S. Uma
3.	Improvement of banana for nematode resistance and marker development	Dr. S. Backiyarani
4.	Development of trait specific markers for fusarium wilt resistancethrough association mapping studies in banana (*Musa* spp.)	Dr. M. S. Saraswathi
5.	Improvement of cv. Grande Naine (Cavendish – AAA) for Fusarium wilt resistance through non-conventional breeding	Dr. M. S. Saraswathi
6.	Improvement of banana for sigatoka leaf spot resistance	Dr. A. Thirugnanavel
7.	Identification and evaluation of superior clones of cv.Ney Poovan (AB) and Grand Naine (AAA)	Mr. R. Natarajan
	Crop Production & Post Harvest Technology	
8.	Studies on nutrient dynamics in banana	Dr. K. J. Jeyabaskaran
9.	Development of clump management technology for enhanced productivity in banana	Dr. V. Kumar
10.	High temperature and soil moisture deficit stresses in banana: Mechanism of high temperature tolerance and management of high temperature and soil moisture deficit stresses in banana	Dr. I. Ravi
11.	Biochemistry of banana fruit ripening and characterization of high value compounds of fruit and flower	Dr. M. Mayil Vaganan
12.	Development of pre and post harvest techniques for leaf production in banana	Dr. K. N. Shiva
13.	Development of modified atmosphere packaging techniques in banana and plantain for domestic and export markets	Dr. K. N. Shiva
14.	Development and refinement of value added products in banana and plantain	Dr. K. N. Shiva
15.	Functions of resistant starch and designer food development from banana flour	Dr. P. Suresh Kumar

	Name of the Project	Principal Investigator
	Crop Protection	
16.	Management of banana weevils	Dr. B. Padmanaban
17.	Pest mapping in bananas and plantains in India	Dr. J. Poorani
18.	Investigation on fungal and bacterial diseases of banana and their management	Dr. R. Thangavelu
19.	Studies on viral diseases of banana and their management	Dr. R. Selvarajan
20.	Host-virus interactions in banana: Molecular mechanisms of resistance and susceptibility, latency, integration and episomal expression of EPRV's	Dr. R. Selvarajan
21.	Molecular approaches to understand the host-virus-vector-environment interactions and RNAi for the management of banana viruses	Dr. R. Selvarajan
22.	Proteomic analysis of host-BBTV interaction in banana	Dr. C. Anuradha
23.	Investigations on *Musa* nematode's diversity, biology, behavior and their interactions	Dr. P. Giribabu

II. ICAR funded projects

	Name of the Project	Principal Investigator
1.	Network project on Transgenic in crops – Banana functional genomics (Sigatoka & Drought component)	Dr. S. Uma
	Consortium Research Projects	
2.	CRP on Agro Biodiversity	Dr. S. Uma
3.	CRP on borers	Dr. B. Padmanaban
4.	CRP on Vaccines and Diagnostics	Dr. R. Selvarajan
	Extra Mural Projects	
5.	A new vision for Quality Planting Material (QPM) Production system in India	Dr. S. Uma
6.	On-site diagnostics for insect pests of selected horticulture crops to enable timely pest management decision making	Dr. J. Poorani
7.	Survey, characterization and management of a most virulent strain of *Fusarium oxysporum* f.sp. *cubense* infecting banana	Dr. R. Thangavelu
8.	Studies on active packaging on extending shelf-life of banana	Dr. K. N. Shiva
9.	Harnessing the potential of *Musa* species in ornamental and leaf industries and screening for better edible flower and pseudostem	Dr. A. Thirugnanavel
10.	Outreach project on *Phytophthora*, *Fusarium* and *Ralstonia* diseases of horticultural and field crops	Dr. R. Thangavelu
11.	Assessment of post-harvest losses in banana	Dr. K. N. Shiva

III. Other externally funded projects

	Name of the Project	Funding Source	Principal Investigator(s)
1.	Bio fortification and development of disease resistance in Banana	DBT - QUT	
	Component - 1: Biofortification and evaluation of Indian banana with pro Vitamin A (PVA) constructs		Dr. S. Backiyarani
	Component - 2: Biofortification and evaluation of Indian banana with Iron constructs		Dr. M. Mayil Vaganan
	Component - 3: Development of efficient ECS for Rasthali and providing authentic virus free IMFC to Indian Partners		Dr. S. Uma
2.	Twinning programme on 'Molecular characterization of *Fusarium oxysporum* f.sp. *cubense* causing Fusairum wilt on banana and its sustainable management'	DBT	Dr. R. Thangavelu
3.	Development of bio-pesticide formulation for reducing post harvest losses and for achieving export quality and increased shelf life of banana fruits	DBT	Dr. R. Thangavelu
4.	National certification system for tissue culture plants	DBT	Dr. R. Selvarajan & Dr. M. S. Saraswathi
5.	Development of non-chimeral mutants with durable resistance to Fusarium wilt in Rasthali through induced mutagenesis	DAE	Dr. M. S. Saraswathi
6.	Framing crop specific DUS guidelines for banana *Musa* spp.	PPV & FRA	Dr. A. Thirugnanavel

ANNEXURE – II

METEOROLOGICAL DATA

Month	Max. Temp. (°C)	Min. Temp. (°C)	Rainfall (mm)
April, 2016	39.93	27.86	-
May, 2016	37.77	26.58	143.2
June, 2016	36.16	26.70	41.5
July, 2016	36.06	26.16	232.7
August, 2016	36.51	26.09	15.5
September, 2016	36.46	25.90	10.5
October, 2016	35.06	24.93	81.7
November, 2016	32.83	23.43	-
December, 2016	31.51	21.87	38.0
January, 2017	31.58	21.38	35.0
February, 2017	33.67	20.35	-
March, 2017	36.48	24.51	-
		Total	1198.1

भाकृअनुप
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तायनूर पोस्ठ तोगमलै रोड
तिरूच्चिरापक्कि ६२० १०२ए तमिल नाडु

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