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ICAR

Vision 2030

National Research Centre for Banana

Tiruchirapalli

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Vision 2030

National Research Centre For Banana
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Tamil Nadu, India

PRINTED : July 2011

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Published by the Director, National Research Centre for Banana, Thogamalai Road, Thayanur Post, Tiruchirappalli. Printed at Sri Sakthi Promotional Litho Process, SF. No. 283, Masaniamman Nagar, Anna Nagar East, Edayarpalayam, Coimbatore - 641 025. Phone : 0422-2450133, 2403500

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FOREWORD

The diverse challenges and constraints as growing population, increasing food, feed and fodder needs, natural resource degradation, climate change, new parasites, slow growth in farm income and new global trade regulations demand a paradigm shift in formulating and implementing the agricultural research programmes. The emerging scenario necessitates the institutions of ICAR to have perspective vision which could be translated through proactive, novel and innovative research approach based on cutting edge science. In this endeavour, all of the institutions of ICAR, have revised and prepared respective Vision-2030 documents highlighting the issues and strategies relevant for the next twenty years.

The National Research Centre for Banana (NRCB), Trichy has given priority to develop varieties and cost effective technologies for achieving higher productivity. The assemblage of largest genetic diversity in banana has given an opportunity to identify the genes for the major biotic and abiotic stress resistance. The Centre is pioneer in developing more than 20 value added products from banana and has commercialized many products.

It is expected that the analytical approach and forward looking concepts presented in the '*Vision 2030*' document will prove useful for the researchers, policymakers, and stakeholders to address the future challenges for growth and development of the agricultural sector and ensure food and income security with a human touch.

(S. Ayyappan)

Dated the 29th June, 2011
New Delhi

Preface

The National Research Centre for Banana (NRCB), Tiruchirapalli is the apex crop based research organization under the aegis of Indian Council of Agricultural Research; New Delhi is actively involved in the basic and strategic research and to improve the production and productivity of banana in India. The Centre has made comprehensive initiatives which has lead to significant achievements in the collection of largest banana germplasm, characterization and evaluation, improved production technologies to increase the input use efficiency, eco-friendly integrated pest and diseases management strategies, development of molecular diagnostic kit for the production of disease free quality planting material has lead to technology driven banana industry, thus maintaining the status of the number one producer in India and also in the world. The transfer of technology and adoption by the innovative banana farmers has shown the fastest growth rate of banana in the horticultural scenario.

The present Vision – 2030 NRC Banana document provides the strategies to overcome the challenges that are emerging due to the climate change and its aftermath and also to trap the opportunities by harnessing the basic and strategic research to resolve the production constraints and to improve the livelihood and nutritional security of the producers and consumers at the national level. This would be achieved by empowering the different stake holders in the banana industry and also have partnership at the national and international level.

I would like to express my sincere gratitude to Dr. S. Ayyappan, Secretary – DARE and Director General – ICAR for his valuable guidance and Dr. H.P.Singh, Dy. Director General (Hort.), ICAR for his constant inspiration and encouragement. I also extend my sincere thanks to the Assistant Director Generals (Hort.), ICAR for their keen interest. I am also thankful to the Scientists of the NRC Banana for their input in bringing out this document.

7th July, 2011
Tiruchirappalli

(M.M.Mustaffa)
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Preamble

India is the home for bananas and plantain and is being grown even before the Vedic times. All social, religious festivals and functions that are adorned with banana plants are considered auspicious, besides providing beauty to the occasion. It is referred as "Kalpatharu" (Plant of Virtue) due to its multifaceted uses.

Banana is an important source of energy and one of the cheapest sources of nutrients for the bulk of our population. In terms of nutritional value, the fruit is rich in carbohydrates, minerals and vitamins. Banana is a food-fruit with medicinal values. It is the quickest source of energy and believed to reduce heart and gastro-intestinal ailments, when consumed regularly. The stem juice is good for reducing kidney stone formation and has diuretic properties. From the pseudostem sheath, fibre is extracted and is used in making handicrafts, other fancy items and fabrics.

Banana is the most important fruit crop in India and accounts for 31.7 per cent of the total fruit production. It is widely cultivated in varying agro-climatic regions under different systems of production. Banana research in India is directed towards increasing the production and productivity. However, banana cultivation continues to face several pests and diseases which affect the production and productivity. Nevertheless, conservation and characterization of genetic diversity, improvement of cultivars with resistance to biotic and abiotic stresses, production technology for high productivity with export quality fruits and better post harvest technology needs more systematic research.

The National Research Centre for Banana (NRCB) was established at Tiruchirapalli, Tamil Nadu on 21st August, 1993 based on the recommendation of a high level task force committee to address the production constraints in banana and to achieve high production and productivity through basic and strategic research approaches in banana. The Centre was started functioning effectively from 1st April, 1994.

Banana industry has witnessed remarkable growth during the last two decades. The area under banana has increased 100% growth during the last two decades and production has witnessed 245% growth, thereby, the banana has become number one fruit crop in India, contributing 32% of the

total fruit production. This significant increase in production and productivity could be achieved through development of novel technologies and creation of awareness about new technologies. Adoptions of these technologies by the banana farmers have lead to the significant growth in the banana industry. Inspite of this success in the banana industry, still there are challenges, especially in the scenario of climate change, increased production cost, increased biotic and abiotic stresses, the banana industry is facing lot of challenges at present. More over, the emerging thrust in the domestic and export market has created an additional opportunity for the banana industry. The new challenges and opportunities has necessitated to revisit the Perspective Plan in 2025 and to formulate new strategies under the emerging new scenario.

Production and productivity in banana is affected by various biotic and abiotic stresses. The production constraints also vary from region to region; however, most of the problems are similar in nature. The complexity of problems demands basic, strategic and adaptive research to attain maximum production and productivity in banana with an interdisciplinary and holistic approach without affecting the existing eco-system.

The Vision 2030 document of NRC Banana identifies the key challenges and opportunities in the banana industry in the next two decades for developing appropriate strategies and road map to envision the role of NRCB in shaping the future of banana research for nutritional and livelihood security of the stake holders.

Contents

Banana Scenario

Banana and plantain, are continuously exhibiting a spectacular growth worldwide. India alone produces 27.01 million tons from an area of 0.765 million ha (2011). India is the largest producer of banana in the world and also in Asia, and contributes 22.15 percent to global production from 7.4 % area (2009) followed by China and Philippines. Although Brazil has the second largest area under bananas (0.49 million ha), the country ranks only fourth in terms of production. Interestingly, there has been an appreciable increase in productivity of banana between 2001 and 2009 in India, owing to technological interventions. Increase in production is more significant in India and China due the technological interventions and adoption, while production in Ecuador, Columbia and Costa Rica has shown a declining trend during this period (Table 1).

Table 1. Area, production and productivity of bananas and plantains

COUNTRY	AREA (000 HA)		PRODUCTION (Million tons)		PRODUCTIVITY (T/HA)	
	2001	2009	2001	2009	2001	2009
India	466	748	14.20	26.99	30.50	35.87
Brazil	513	491	5.74	6.58	11.18	13.41
Philippines	400	415	5.06	7.48	12.65	13.56
Indonesia	285	315	3.60	5.45	8.14	15.49
China	259	269	5.40	8.04	20.84	23.20
Ecuador	298	227	8.03	6.13	26.94	27.07
Cameroon	312	082	2.25	0.79	7.21	9.72
Mexico	074	078	1.97	2.36	26.62	29.99
Columbia	444	062	4.20	1.58	9.45	25.15
Costa-Rica	054	042	2.32	2.22	42.96	52.54
Others	5207	7473	41.79	56.02	---	---
Total	**8310**	**10100**	**94.56**	**121.85**	**---**	**---**

Source: FAO STAT (2001, 2009), NHB (2009)

In the South, South-East Asian and Pacific regions also, a similar trend was observed. India, China, The Philippines and Indonesia are the major banana producers in this region. India is contributing 48% of the total production in Asia from 37% of total area. China contributes almost 17% production from 15% area (Fig.1 and 2). Among various continents, Asia has the lion's share of 60% in global banana production. During the last decade, India remained as the largest producer of bananas in the world. Increase in production is partly due to enhanced area under cultivation and largely due to increased productivity by adoption of high yielding varieties like Grand Naine, Robusta and other Cavendish clones, quality planting material, integrated nutrient and water management, high density planting and ratooning and integrated pests and disease management. Due to wider adaptability, banana is cultivated from humid tropics to subtropics, arid subtropics, and from sea level up to an elevation of 1500 m above MSL. Availability of wider genetic variability, varying production systems, positive response to Good Agricultural Practices have attributed for wider adoption of banana in the country. Also, high productivity, year round demand and higher net returns have attracted many farmers to shift to banana cultivation in the country. Thus, banana has transformed itself from the status of backyard crop to commercial crop across the country.

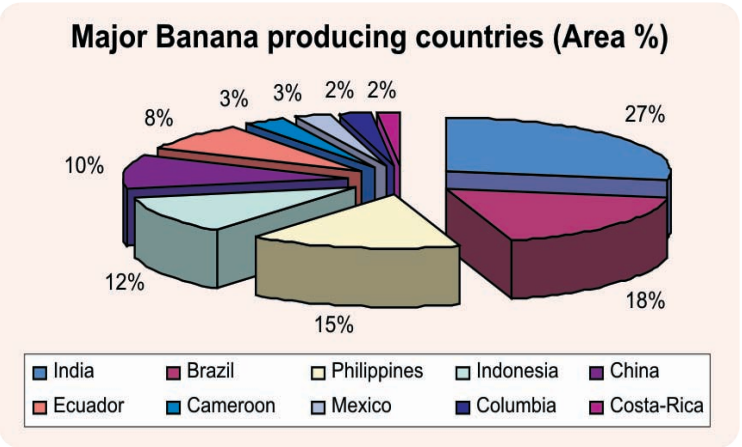


Fig. 1 Banana area in world (2009)

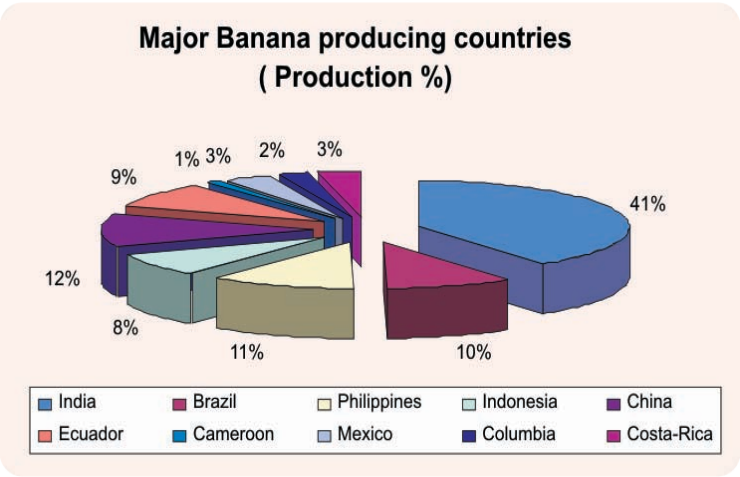


Fig. 2 Banana production in world

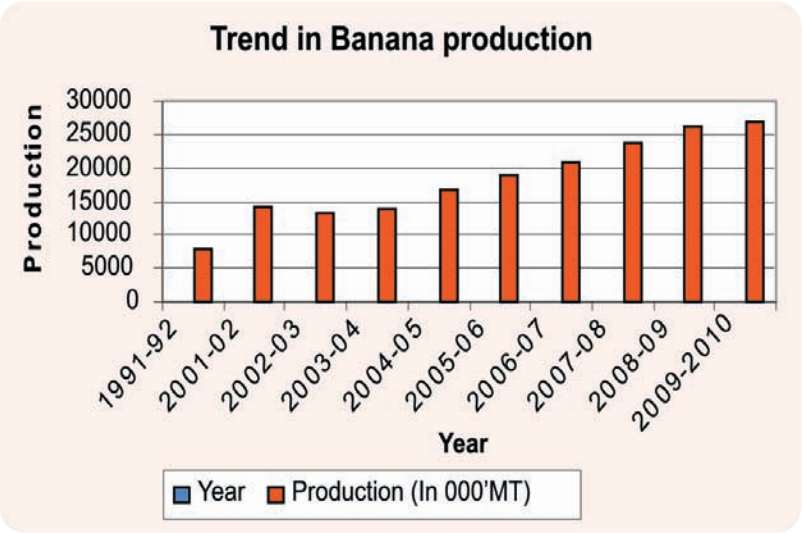


Fig. 3 Trend in banana production in India

The banana industry has witnessed a significant growth during the last two decades. The area and production also has witnessed a spectacular growth indicating an overall 100% increase in area with 250 % increase in banana production during the last two decades (Fig. 3). The significant increase could be achieved due to adoption of improved production technologies.

Table.2. State wise area, production and productivity of banana in India

STATE	2007-08			2008-09			2009-10		
	Area	Production	Productivity	Area	Production	Productivity	Area	Production	Productivity
Tamil Nadu	114.1	6116.5	53.6	124.4	6667.0	53.6	133.4	6368.4	47.9
Maharashtra	80.0	4962.9	62.0	80.0	4960.0	62.0	85.0	5200.0	61.3
Gujarat	57.7	3157.7	54.7	60.9	3571.6	58.7	61.9	3779.8	61.0
Andhra Pradesh	75.2	2631.2	35.0	80.1	2804.0	35.0	80.1	2804.0	35.0
Karnataka	70.5	1793.3	25.4	75.4	1918.8	25.4	81.2	2023.1	24.9
Madhya Pradesh	15.2	788.2	51.9	28.8	1498.0	51.9	36.8	1867.9	50.7
Bihar	30.5	1329.4	43.6	31.3	1373.6	43.9	32.2	1416.8	45.6
West Bengal	37.4	892.2	23.9	39.8	954.1	23.9	41.0	982.2	23.9
Assam	44.1	610.9	13.9	47.9	852.6	17.8	54.0	835.0	15.5
Kerala	61.5	493.9	8.0	59.8	472.9	7.9	59.8	472.9	7.9
Others	71.7	1046.8	14.6	80.4	1144.5	14.2	82.7	1247.0	15.1
Total	657.8	23823.0	36.2	708.8	26217.2	37.0	748.1	26996.6	36.1

NHB 2009-10

The major banana growing states are Andhra Pradesh, Assam, Bihar, Gujarat, Karnataka, Kerala, Tamil Nadu, Madhya Pradesh, Maharashtra, Orissa and West Bengal. Tamil Nadu has the largest area followed by Maharashtra and Karnataka. Tamil Nadu also ranks first in production, followed by Maharashtra (Table 2). However, the highest productivity is recorded in Maharashtra followed by Gujarat, Tamil Nadu and Madhya Pradesh. Maharashtra excels in productivity owing to monoculture of high yielding Cavendish clones coupled with adoption of improved technologies like high density planting, fertigation and growing tissue culture plants.

India is credited as the largest producer and last two decades has witnessed increasing trend recording high growth rate, which has been possible due to adoption of improved production technologies like high density planting, use of in-vitro plants, fertigation and management of insect pest and disease. However, there is a regional disparity in adoption of technologies indicating variation in productivity level ranging from 7.9 to 61.27 tonnes per hectare, but still there is a wide gap between the potential

yield and the average yield obtained in farmers' field. This would need immediate attention so that production could be increased from the same area by increasing productivity. Low productivity is also attributed to local preference for varieties, which has low yield but quality is highly acceptable to fetch higher price than Cavendish.

Interestingly, banana and plantain are grown under different production systems, which have their own merits. Garden land is widely adopted system of production with three crop cycle in many parts of the country. Wetland banana with deep trenches is common in Tamil Nadu and parts of Karnataka and perennial cultivation on hill slopes is practiced in Tamil Nadu, North Eastern states and Karnataka. Banana is grown as subsistence crop in homestead or mixed cropping with areca nut and coconut gardens. Therefore, there is a need for developing production system management strategies addressing regional needs, having focus on yield improvement and also the challenges.

Traditionally, banana has been propagated using suckers but due to the problem of viral diseases and uniformity, in-vitro plants have become success. Currently, 110 million tissue cultured plants are planted every year. To achieve the quality standards of the tissue cultured plants produced by the TC companies, certification standards for T.C. plants and are in place and the NRCB accredited for the testing these plants against genetic fidelity and viruses. Plant health management and extending the use of tissue culture plants for enhancing productivity is essentially required. It is interesting that macro-propagation could be utilized by the farmers for multiplication of plants. The technique developed is simple to adapt.

The research carried out by ICAR Institutes, NRC Banana, AICRP Centers and SAUs have indicated that high density planting has contributed significantly for higher production and productivity especially in Cavendish bananas. A density of 4500 plants ha^{-1} in Maharashtra and 3000-3500 plants ha^{-1} in three crop cycles in other states have contributed for increased productivity. Recent advances like double row planting system with 5200 plants ha^{-1} or modified high density

planting with three suckers per pit with 4500-4600 plants ha^{-1} is becoming popular in many southern states, under drip irrigation and fertigation system. Interestingly, this system has also helped in reducing the water and fertilizer consumption by 30-40 percent as increased the productivity by 50 per cent. Plant architectural management and mat management have to find important place in research to achieve higher productivity of natural resources (soil and water).

Banana being an exhausting crop requires large quantity of fertilizers. Research findings have indicated optimum quantity of fertilizers and time of application for efficient utilization of nutrients. Response of micro-nutrients like Zn, B and Mn has been noted for increased the quality and yield. In this regard, NRC Banana as well as IIHR, Bangalore has developed a micro-nutrient mixtures which has been now commercialized and made available to farmers. Schedule for drip and fertigation has been developed to enhance the water productivity, nutrient use efficiency and to increase the productivity. Due to the advantages of drip irrigation, it has become an integral part in the commercial cultivation of Grand Nain and Robusta varieties in many parts of the banana growing areas. Bunch covering with polythene sleeves to improve the quality and improving the grade of banana has been successful in meeting the demand in niche market and also for export. However, there is ample scope for organic banana production which calls for development of technologies.

Integrated pest and disease management technology have been developed for the effective, eco-friendly management of major pests and diseases, which affect productivity. The major pests like corm weevil and pseudostem weevil cause considerable damage followed by thrips, aphids and scarring beetle. Eco-friendly approaches using pseudostem traps with bio agents like *Beauveria bassiana* and *EPN* Heterohabditis indica are effective. Presence of four types of nematodes is documented from different parts of the country. These could be effectively managed by growing Sunnhemp or Marigold as trap crop and application of bio-agents like *Trichoderma viride, Paecilomyces lilacinus,* and *Pseudomonas fluorescens.* However, there is need for improved understanding about the

phenology which could be predicted utilizing models based on climatic data.

Banana is severely affected by various fungal and bacterial diseases and wilt disease caused by *Fusarium* is of great concern. *Fusarium* race-1 is serious in Rasthali, Ney Poovan, Karpuravalli and Virupakshi varieties, while race-2 is causing damage to cooking bananas. The wilt race 1 to 2 resistant Cavendish group are increasingly infected by tropical race-4 in Asian countries is of great concern and the entry of this race-4 would ruin the banana industry in India. Hence there is a need for preparedness both to avoid entry and have resistant cultivars to tropical regions to safeguard the interest of the banana growers of this country.

Leaf spot diseases caused by *Mycosphearella* are very serious especially in Cavendish bananas which affect the yield and quality. Use of chemicals has been found effective in management. Large scale incidence of Heart rot caused by *Erwinia* in tissue cultured Cavendish banana is a cause of concern. Effective management strategies for the control of these diseases have been developed. Similarly, post harvest disease management schedule have been worked out. However, there is need for studies on dynamics and kinetics of these diseases in different system of management to contain the losses.. Leaf disease caused by *Septoria* has also been recorded. New feature of *Sigatoka* disease noted is that the disease has occurred in devastating proportion in Maharashtra, where it was never considered a problem, which is due to change in climate or there is new biotype need through understanding.

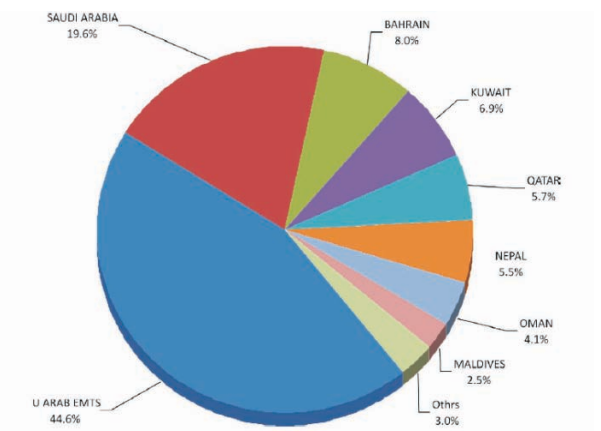
Interestingly, four major viral diseases are of great concern which affects the productivity greatly. Since there is no control measures available, screening of the planting materials viz., sucker and cultured plants has assumes significant. Use of molecular techniques like ELISA, PCR and RTPCR developed at NRC Banana, Trichy helps in identification and elimination of major three viruses simultaneously. An effective molecular technology has been developed. But the diagnostic tests, PCR of Elisa based which cannot be available to farmers. Thus, there is a need to

develop a kit using nanotechnology strip which can even diagnose the problem in the field.

Harvesting time varies depending on the region and the post harvest losses are estimated around 10-15 percent. There is a need to reduce the losses to augment the productivity. Efforts are needed for integrating the processing, storage and export technologies effectively for the maximum output. Bananas could be used as fresh or converted into many value added products viz. frozen puree, juice, slices, powder, fig, wine etc. Many by products have been developed by NRC Banana from wastes like flower, stem core, skin and fibre. Research efforts are needed for integrating product with system management and utilize in a manner which provide maximum profit. Market promotion is needed for better adaptability of the technology.

Bananas after harvest are traded by either private sector or by cooperatives. Grading and sorting are mainly due in the market yard for sales. Though there is no definite yardstick for grading and sorting, size of the bunch and external fruit appearance determine the market price. Efforts are needed for better storage facility with assured marketing and trading. Research efforts are needed in developing better packaging and transportation techniques to avoid the losses.

Banana export status



Interestingly, India is the largest producer of banana and all the produce are consumed domestically with meager export, less than 0.5 percent. Globally, the total volume of export is 16.25 million tonnes valued at US $ 5.7 million. The US is the major importer, followed by European Union and Japan. Latin American countries are the major exporter to US and European Union, while Philippines for Japan. There is a great potential for export of banana and plantains from India to other markets and it will depend, how we harness this potential. After liberalization of world trade, ability to meet the competition in terms of price and quality, will determine the sustainability. Quality of the produce is the key in the emerging scenario, which has been now achieved. Theni in Tamil Nadu produces export quality banana and method have been devised for harvesting and packing without blemishes. With improved knowledge and infrastructure and with enabling environment, the potential is likely to be harnessed for the export of banana. However, more intensive research is needed for understanding physiological process which determines the output in terms of quality of banana available to the consumers.

National Research Centre for Banana

The research initiative on banana was started in the year 1882 with collection of banana local cultivars, wild accessions and landraces. However, systematic collection of clones was undertaken in 1931 with emphasis on description of cultivars from different regions. Subsequently, banana research was started at Aduthurai in Tamil Nadu during 1949 with emphasis on crop improvement by collection and identification of parents for breeding. This initiative was further continued at Tamil Nadu Agricultural University, Coimbatore under All India Coordinated Research Project (AICRP) on Tropical Fruits. The AICRP, for coordinating location and situation research, was established in 1971 under tropical fruits having its centers in banana growing areas, and, work was directed towards nutrition and high-density planting during the 70s. Considering the problems and the need for basic and strategic research, The National Research Centre for Banana (NRCB) was established at Tiruchirapalli in 1993 to meet the challenges. At present, research on banana is directed towards increased production and productivity with emphasis on reducing the cost of cultivation and post harvest losses and value-addition.

Mandate

- To undertake basic, strategic research, developing technologies to address specific constraints and to enhance the productivity in banana.
- To develop improved cultivars through classical and biotechnological approaches.
- To serve as a national germplasm repository for banana and plantain, and to conserve and document the genetic diversity.
- To develop location specific varieties, improved production technology and post harvest technology including value addition for maximizing the profitability.
- To solve major biotic and abiotic production constraints in banana plantain.

- ❖ To disseminate the knowledge for increased production and productivity.
- ❖ To provide leadership, coordinate the network research and to collaborate with National and International agencies in achieving the above objectives.

Banana has expanded well even in the area where banana was not grown before. Adoption of improved technology has contributed profusely for high production and productivity in the last few decades. The production has increased many folds. Banana has emerged as the crop which has highest diffusion of technology and is a clear example of precision farming. Therefore, task before us is to package the technology for sustainable production in emerging challenges and thus following points need consideration.

- ✦ Diversity has been assembled and morphologically characterized which require to be identified for gene source to develop, ideotype of banana having desired characteristics. The conventional breeding needs different approaches utilizing the tools of biotechnology
- ✦ Understanding about genomic of banana has improved, but the knowledge is largely limited to *Musa* a*cuminata.* Genomic information on B genome is not appropriately understood which needs the priority of research for its utilization in improvement of banana.
- ✦ Quality planting material is most critical to ensure freeness from diseases having appropriate fidelity. However, there is still a hope to reduce the cost of improving the technology, thus, needs research & development priorities.
- ✦ A system approach to reduce the cost of production is needed. Covering of soil health, water productivity, fertilizer use efficiency, nutrient budgeting etc..
- ✦ Precision faming could be one of the approaches to improve the productivity through infusion of technology to maximize the productivity and better quality produce to ensure reasonable market support.

- With growing appreciation of organically grown fruits, there is an increasing demand for organically grown bananas. Thus, system approach for organic farming is required.
- Understanding about, Eco-friendly biological control of pests and diseases have improved but there are emerging challenges which needs intensified research.
- Development of infrastructural facilities for better handling, transportation and storage both for domestic and export market are needed, both for Cavendish and indigenous varieties.
- Integration of the efforts of all the stake-holders including NGOs and private entrepreneurs in value addition having participatory mode is needed, which should address all the links in the chain from production to consumption.
- Considering the potentiality of the psuedostem, a waste, there is a need for intensified research to make it commercially viable technologies for banana fibre and to utilize into different products.
- Market promotional activities, market research studies and identifying new markets for export etc. should be taken up on priority.

NRC Banana 2030

The National Research Centre for Banana, Tiruchirapalli is marching ahead with renewed vigour to face the challenges and to harness the opportunities for the economic and lively hood and nutritional security of the farmers and stakeholders.

Vision

- ❖ To increase the production and productivity and to sustain the growth.
- ❖ To stride towards attaining livelihood and nutritional security and welfare of the farmers and stakeholders.

Mission

- ❖ Evolving high yielding varieties with resistance / tolerance to important pests and diseases.
- ❖ Adoption of Improved production technologies with an aim to increase the land, water and fertilizer use efficiency.
- ❖ To mitigate the effects of climate change.

Focus

- ❖ To accomplish the vision and the mission of NRCB, it would focus on the following key areas :
- ❖ Conservation of germplasm in field, *in-vitro* and cryo-preservation.
- ❖ Evaluation and valuation of genes for biotic, abiotic and specific traits.
- ❖ Development of hybrids / cultivars for high yield and resistance to biotic stresses.
- ❖ Development of transgenic plants with targeted gene for improving yield and quality with resistance to biotic and abiotic stresses.

- Development of technology for precision farming and cropping system management.
- Integrated nutrient and water management strategies.
- Standardization of better post harvest handing and packaging of banana.
- Development of new value added products and waste utilization of banana.
- Integrated management of major pest including nematodes.
- Development of eco-friendly pheromone traps for the management of weevils.
- Identification of VCG group of *Foc* and disease management involving bio-control and PGPR agents.
- Development of integrated disease management technology for major diseases.
- Development of molecular diagnostic kit for the identification of major viral diseases.
- Development of transgenic plants against virus diseases.
- Broadening varietal base through exploitation of natural diversity and improvement.
- Resource and evaluation based farming.
- Efficient input management.
- Soil health management.
- Post harvest handling processes and product development.
- Organic farming and Precision farming.
- Development of cost effective plant protection methods.

Harnessing Science

NRCB has initiated many ambitious research programs like broadening varietal base through exploitation of natural diversity and improvement, Resource and evaluation based farming, efficient input management, quality production, organic farming, precision farming, post harvest handling processes for small scale growers and product development, development of efficient tissue culture propagation techniques, development of cost effective plant protection methods, molecular characterization of banana germplasm for identifying the resistant genes and fingerprinting of released varieties, virus as well as pathogen for studying the etiology as well as to develop pathogen derived resistance through genetic engineering and development of effective transfer of technology mechanism.

Banana variability is assembled through the exploration and introductions. Explorations have been undertaken in the areas of natural diversity of Musa covering North Eastern states, Andaman and Nicobar Islands, Arakku Valley of Andhra Pradesh, Kodai Hills, Shevoroy Hill, Kalakkad-Mundanthurai Tiger Reserve Forest area of Tamil Nadu, Western Ghats of Tamil Nadu, Kerala and Karnataka. During exploration on North- Eastern States of Assam and Arunachal Pradesh, a naturally occurring domesticated tetraploid (ABBB) banana cultivar namely *Bhat Manohar* was identified. A new natural mutant of *M.velutina* and an intermediary hybrid have also been identified which exhibit location specific distribution in Indo-China border of Arunachal Pradesh. Three new Musa species viz., *Musa swarnaphalya, Musa kuppiana, Musa saddlensis,* and a new *Ensete sp.* have been collected and named based on the place of collection and morpho-

Musa swarnaphalya

taxonomic traits of the species. Exotic collections have also been introduced through NBPGR especially from INIBAP Belgium.

The National Research Centre for Banana has developed many viable technologies in banana. Udhayam, a superior selection released by NRCB 2005, is a high yielder with 40-50% more yield than the local Karpuravalli and has field tolerance to nematodes and leaf spot diseases. The good quality fruits with good blend of sugar acid ratio are suitable for preparation of many value added products. A farmer friendly and cost effective technology of macro-propagation of disease free planting material of banana has been developed.

Udhayam

By this method, 20 to 25 uniform plantlets per corm can be produced within a short period of 60 to 65 days. In addition, for faster multiplication and cost effective mass production of plants, embryogenic cell suspension technique (ECS) were developed for many commercial cultivars viz., Rasthali (AAB), Nendran (AAB), Ney Poovan (AB), Robusta (AAA) and Grand Nain (AAA).

A modified high density planting system developed with three suckers per pit at a spacing of 1.8 x 3.6 m or 2.0 x 3.2 m, accommodating 4500 plants ha^{-1} is becoming popular in Tamil Nadu, Karnataka and other states. This method increases the productivity by 50% and reduces the cost of production by saving 25% fertilizer and 30-40% water. Fertilizer response curves and

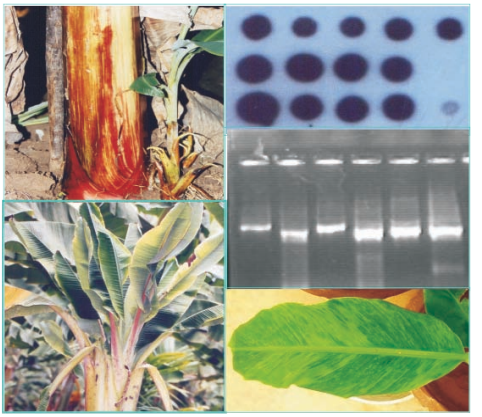
Robusta banana plantation with three suckers per hill

DRIS standards have been developed for banana commercial cultivars to optimize the fertilizer application for maximizing the production and profit and to correct the interactions of nutrients. An effective micronutrient banana mixture, "Banana Sakthi" for soil and foliar application has been developed by NRC Banana. Bunch spraying with 2% Potassium Sulphate increases the fingers size and weight and produces export quality fruits. Pre-harvest spraying of bunches with 2% potassium sulphate with wetting agents immediately after the last hand emergence followed by a second spray after 30 days and covering the bunches with 100 gauge thick polythene sleeves with 6% ventilation enhanced bunch grade, fruit quality and advanced fruit maturity by 5-7 days.

Pseudostem trap applied with *B. bassiana*

Corm weevil *(Cosmopolites sordidus),* pseudostem borer *(Odoiporus longicollis)* and nematodes are the major insect pests threatening banana production and productivity in the recent years. For management of insect pests of banana, eco-friendly approaches using pseudostem traps with bio-agents like *Beaveria sp*. and *EPN* Heterohabditis indica application for controlling the weevils in upland and different systems of cultivation. Swabbing with 0.06 % Chlorpyrifos 20 EC on the pseudostem to a height of 1.2m during 5th and 8th months after planting completely controls banana stem weevil.

Effective local bio-control agents like *Pseudomonas fluorescence, Paecilomyces lilacinus* and *Trichoderma viride* have been identified for the management of nematodes. Use of VAM *(Glomus sp)* also indicated encouraging results in the integrated management of nematodes. Fungicides such as *Propiconazole, Mancozeb* and *Carbendazim* have been found effective in controlling the leaf spot diseases of banana. Effective fungicide and chemical management strategy has been developed for the control of postharvest diseases like cigar end rot, anthracnose, etc.



Many viral diseases have been reported in India and among them BBTV, BBrMV, CMV and BSV are considerably important. Occurrence of BBTV has wiped out large area under hill banana cultivation. BBrMV is another devastating viral disease affecting plantain and many important commercial varieties. CMV occurs in almost all banana growing states. Banana Streak Virus (BSV) is present in every banana-producing region worldwide and its infections can lead to severe decline in yield especially in Poovan varieties. Effective molecular diagnostic techniques like ELISA, PCR and RTPCR techniques have been developed at NRC banana for simultaneous detection of 2-3 viruses

Sl. No	VIRUSES	TEST METHOD			
		PCR / RT-PCR / IC-PCR / DB-PCR / IC-RT-PCR	ELISA / DIBA	Nucleic acid spot hybridization (NASH) using non-radioactive DNA / RNA probes	Southern and northern blots using Non-radioactive probes
1	Banana Bunchy Top Virus (BBTV)	√	√	√	√
2	Banana Bract Mosaic Virus (BBrMV)	√	–	√	√
3	Banana Streak Virus (BSV)	√	–	√	√
4	Cucumber Mosaic Virus (CMV)	√	√	√	√

The viral pathogens are a major impediment in banana tissue culture industry. Diagnosis against viruses has become an integral part in the management of viral diseases in banana. Early and correct diagnosis of viruses is very important in checking for further spread of the disease especially to a new area. So, early detection by sensitive molecular diagnostic methods is the only way to control them. These viral pathogens

cannot be eliminated through shoot tip culture which is adopted by the TC industries for mass propagation. Different molecular diagnostic techniques developed by NRCB have been used to detect the banana viruses in tissue culture plants as well as mother plants used by the tissue culture industries. The Department of Biotechnology (DBT), New Delhi has accredited the molecular biology and virology laboratories of NRC Banana for fidelity testing and virus indexing of the tissue cultured plants of banana for its genetic purity and freeness from viral diseases.

Effective pre and post harvest management technology has been standardized to extend the storage life and also export of banana. Fruits harvested at the appropriate maturity ensure the highest quality. Shelf life could be extended by storage temperature at 13-14°C. NRC Banana has developed better protocols for extending the green shelf life of bananas and plantains for up to 150 days.

Banana Fig

The Centre has also developed technology for 12 value added products like banana chips, fig, powder, RTS, juice, jam, sauce, flower thokku, fruit pickle, health drink, candy and wine, and has commercialised five products, which are available in the market. Scutcher waste from pseudostem after extracting fibre can be used for manufacturing handmade paper; in addition, banana biomass other than fruits can be converted into fuel (briquette), which will be an additional source of income for the banana farming community.

The climate change and associated developments with it like increased atmospheric CO_2 is a concern to discuss. The global circulation model projected that the temperature rise around 1-2°C in the sub-tropical regions of the country may have positive influence on the banana growth in sub-tropical regions of India. This will be favourable especially in Maharashtra, Gujarat, Uttar Pradesh, Bihar, Jharkhand, West Bengal,

Orissa and North Eastern regions. The banana cultivation area may extend in these regions and thereby further augment the production of banana. Central and northern parts of the country will favour banana growth, and, development and yield may increase as compared to present level of production. The average temperatures are expected to increase more near the poles than at equator. The shift in climatic zones will be more pronounced in higher latitudes. In mid latitudes, the shift is expected to 200-300 km for every increase in 1°C. The banana growing states like Tamil Nadu, Kerala, Andhra Pradesh and South Karnataka coming under lower latitudinal regions of the country the temperature rise may be lesser than mid and higher latitudinal regions.

Increasing atmospheric CO_2 has 'fertilizing' effects, because of their perceived beneficial physiological nature. The benefit of C_3 plants would be more pronounced, when the plants grow under enriched CO_2 in the temperature range of 26-28°C. Banana being a C_3 plant, under elevated atmospheric CO_2 conditions, it may perform better in a changed environment. Overall, it may increase the yield or offset the adverse impact of higher temperature during summer, thereby; it may sustain the present rate of yield increase.

Abiotic stresses viz., drought, salinity and temperature extremes are the primary cause of yield loss in agriculture. The reduction of average yields by abiotic stresses for major crop plants by more than 50%. Bananas are a plant of the tropics and subtropics, requiring hot and humid climate and are very sensitive to soil water deficit. In India, banana is cultivated in more than 30% of the area under adverse soil condition with pH >8.5. In such saline-sodic soils, banana suffers from salt injury, and, salinity extends the banana plant's life cycle through increasing days for flowering and fruit development. Salt tolerant cooking type banana like Monthan and Saba can be grown.

Despite excellent progress made in development of technologies for management of stresses, particularly biotic stresses, there are severe shortcomings in research and development for emerging abiotic and biotic stresses. Identifying genes, its functions, gene expression and developing

genetic markers for major traits like biotic and abiotic stresses are underway. Development of pheromones and semio-chemical based kairomones specific to pests of banana are in progress. For management of Fusarium wilt, the available options are limited and developing resistant cultivars is the only sustainable avenue. Development of resistant plant through genetic engineering seems to be the only the possible option. As there are no control measures available for viral diseases, complete characterization of genomes of BBTV, BSV and CMV is paramount for development of PCR based markers for the detection of these viruses at early stages in the nursery. Also, development of transgenic plants resistant to leaf spot and nematodes especially are also paramount. Development of transgenic plants using coat protein for resistance for BBTV is in progress.

Linkages

India being a member in the International Organizations like Bioversity International, Rome and BAPNET, Philippines are involved in formulation of research activities on bananas in South East Asian regions. Being a member in the Bioversity International sponsored Project on "Conserving banana diversity for use in Perpetuity : Strengthening the network of collction to improve access to wider diversity and safeguard threatened banana cultivars" and also member in the PROMUSA working groups involved in breeding, wilt, weevil and nematodes. Effective linkages with Bioversity International have resulted in exchange of germplasm materials and hybrids for testing wilt, Sigatoka leaf spot diseases and nematodes. In addition, linkages also established with other International banana working groups like FHIA, Honduras; IITA, Nigeria; CIRAD, France; QDPI, Australia; TBRI, Taiwan; CNMF, Brazil and CORBANA, Costa Rica. NRCB has linkages with other national institutes like NBPGR, New Delhi; IIHR, Bangalore; BARC, Mumbai; State Agricultural Universities, State Government agencies, commercial tissue culture companies and Private sectors in the areas like germplasm exchange, sharing of materials and know-how, dissemination of information, consultancy and contract research services.

Strategy and Framework

Improvement

- Collection of clean germplasm through explorations.
- Development of varieties resistant to biotic and abiotic stresses through conventional breeding.
- Development of varieties resistant to biotic and abiotic stresses and nutritionally rich through genetic transformation and mutation breeding.
- Development of DNA barcodes for *Musa* spp., wild varieties and indigenous land races.
- Identification of novel genes controlling various biotic and abiotic stresses through genomics and functional genomics approaches.
- Association mapping for drought.
- *Musa* transcriptome analysis.
- *Musa* whole genome sequencing.
- *Musa* EST database.
- *Musa* nucleotide database.
- *Musa* protein database.

Production

- Studies on nutrient dynamics in soil plant system.
- Soil health management for banana based cropping system.
- Development of pesticide residue free fruit production technology in banana.
- Organic Production of banana.

- ➢ Precision farming in banana.
- ➢ Harnessing the production potential of banana based cropping system.

Plant Physiology

- ➢ Mechanisms of drought and salt tolerance in banana.
- ➢ Water Use Efficiency of banana plants.
- ➢ High temperature tolerance in banana.
- ➢ Response of banana plants under CO_2 enrichment studies.

Biochemistry

- ➢ Ripening mechanism of banana fruits.
- ➢ Proteomic and metabolomic studies in abiotic stresses.
- ➢ Characterization of functional compounds of banana.

Post harvest Technology

- ➢ Minimization of post harvest losses for domestic and overseas markets.
- ➢ Product diversification and value addition through processing.
- ➢ Waste utilization.
- ➢ Commercialization of technologies developed under post harvest technology.

Protection

Entomology

- ✦ Developing IPM technology for the management of vectors of banana viral diseases.
- ✦ Developing pheromone and microbial based management strategy for fruit scarring beetle in Eastern and North eastern India.
- ✦ Molecular approaches in host plant defense against insect pests.

Nematology

- ✦ Determining the distribution of plant parasitic nematodes and their pathogenesis variability of nematodes to banana in the country.
- ✤ Molecular variability in nematode species to establish the nematode host relationship.
- ✤ Screening of *Musa* germplasm and identification of resistance gene sources for major banana nematodes.
- ✤ Mass production and commercial formulation of bioagents.
- ✦ Integrated management of nematodes .

Plant Pathology

- ✦ Genetic diversity and development of molecular markers for the early diagnosis of important pathogens of banana.
- ✦ Development of consortium of bio-agents resistant/tolerant to climate change (Temperature, salinity and moisture) for the management of fungal and bacterial diseases of banana.
- ✦ Development and commercialization of liquid formulation for the effective consortium of bio-agents for the management of banana diseases.
- ✦ Development of bio-pesticide formulation for quality banana.
- ✦ Transcriptomics and proteomics approaches for the identification of differentially expressed genes in the bioagents, pathogens and host interaction system.
- ✦ Exploitation of nanotechnology for the cost effective management of important banana diseases.

Virology

- ✦ Development of improved and new diagnostic techniques and kits banana viruses for the use in the certification system.
- ✦ Development of virus resistant transgenic plants.

- Molecular understanding of host-virus-vector interactions.
- Molecular characterization of all banana viruses and diversity analysis.
- Identification of virus resistant gene sources from the germplasm.
- Climate change and its impact on the epidemiology of virus diseases and developing a model for forecasting the disease incidence.
- Integrated management for banana virus diseases.
- RNAi approaches to mitigate abiotic and biotic stresses in banana.
- Computational prediction and validation of novel and conserved miRNA and their targets in banana.
- Deep sequencing of banana short RNAs for the identification of microRNAs targeting various genes.
- Use of cry toxins to develop transgenic banana resistant to nematode and insects.

Epilogue

The National Research Centre for Banana is committed to bring a technology lead revolution in banana production and thereby, increase the productivity in the country to meet the needs of the growing demand for banana due to the changes in the food habits, standard of living and health awareness. The demands of increased consumption of banana and plantain would lead in improving the livelihood of the farmers and for ensuring sustainable cultivation and nutritional security. We envision that innovation in horticulture would transform the agricultural scenario, thereby harnessing untapped opportunities in the domestic and global markets. National Research Centre for banana has developed more than 20 value added products from un-ripe, ripe, and other plant parts of banana and also developed technology for creating wealth from the waste like banana pseudostem. These research findings would generate employment opportunities, encouraging banana farmers and entrepreneurs to conserve natural resources and promote export for higher profitability leading to golden revolution in horticulture. To sustain the benefits of the research and development, NRCB is organizing training programmes and also other extension activities to sensitize and for capacity building of the farmers so as to achieve an inclusive growth.

Concerted efforts would be made to make National Research Centre for Banana to be more sensitive to the needs of the banana farming community especially the small holders and marginal farmers. To achieve these mandates / objectives, NRCB will focus more on the public-private partnership and also empowering the rural women folk through Self Help Groups, thereby, developing clusters for the improvement of the poor living in the villages. It will also develop collaborative mechanisms at the national and international level and will develop strategies to respond to the change for the benefit of the stake holders. It will be done in participatory mode so as to involve all the stake holders for the development of the banana industry in India.

Annexure I : Strategic Framework

Goal	Approach	Performance measure
Genetic Resource Management	Collection, evaluation and utilization of germplasm for direct utilization Identification of new genes for further use through prospection	Conservation of banana gene pool and identification of new genes for exploitation.
Development of elite varieties resistant to biotic and abiotic stresses	Development of synthetic diploids and its use in breeding Development of genetic linkage maps and markers for use in MAS. Development of transgenic bananas. Development of biotic and abiotic resistant commercial varieties through mutation breeding. Application of Bio-Informatics.	Development of new varieties with resistance to biotic and abiotic stresses.
Production system management for enhancing productivity of banana	To enhance the production and productivity of banana through organic farming Nutrient management through recycling in banana based cropping system Soil nutrient and dynamics studies including micro nutrients Precisions Farming for water and nutrient management for location specific Development of organ specific and nutrient specific nano-fertilizers.	Research and development strategies to increase the production and productivity by improving input use and water use deficiency.
Mitigation of climate change	Identification of genotypes and genes responsible for high temperature, salt and CO_2 level	Development of techniques to enhance the productivity.

Plant Health management utilizing diagnosing, and bio-intensive management of pests, nematodes and diseases.	Molecular approaches in host plant defense against insect pests Developing IPM technologies for the management of banana inspect pests and nematodes. Developing pheromone and microbial based management strategy for weevil. To determine the distribution of plant parasitic nematodes and their pathogenis variability in banana Genetic diversity and development of molecular markers for the early diagnosis of important pathogens of banana Development of effective consortium of bio-agents for the management of banana diseases Development of new diagnostic techniques and kits for major banana viruses. Development of virus resistant transgenic plants Climate change and its impact on the epidemiology of virus diseases and developing a model for forecasting the disease incidence	Developed integrated pests and diseases management technologies. Developed technologies for virus diagnostic kits for rapid identification of viral diseases.
Post harvest management and value addition	Ripening mechanism in banana Development of improved post harvest handling and storage techniques Fine tuning/ refinement and popularization of value added products Quantification and characterization of dietary fibre of the fruit	Developed processing technologies and value added products. Commercialization, transfer of technology and product availability.

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