Innovations in Horticultural Science

Mohammed Wasim Siddiqui, Series Editor

Tropical and Subtropical Fruit Crops

Production, Processing, and Marketing

Debashis Mandal | Ursula Wermund
Lop Phavaphutanon | Regina Cronje
Editors

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Abingdon, Oxon, OX14 4RN UK

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INNOVATIONS IN HORTICULTURAL SCIENCE

Editor-in-Chief:

Dr. Mohammed Wasim Siddiqui, Assistant Professor-cum- Scientist
Bihar Agricultural University | www.bausabour.ac.in
Department of Food Science and Post-Harvest Technology
Sabour | Bhagalpur | Bihar | P. O. Box 813210 | INDIA
Contacts: (91) 9835502897
Email: wasim_serene@yahoo.com | wasim@appleacademicpress.com

The horticulture sector is considered as the most dynamic and sustainable segment of agriculture all over the world. It covers pre- and postharvest management of a wide spectrum of crops, including fruits and nuts, vegetables (including potatoes), flowering and aromatic plants, tuber crops, mushrooms, spices, plantation crops, edible bamboos etc. Shifting food pattern in wake of increasing income and health awareness of the populace has transformed horticulture into a vibrant commercial venture for the farming community all over the world.

It is a well-established fact that horticulture is one of the best options for improving the productivity of land, ensuring nutritional security for mankind and for sustaining the livelihood of the farming community worldwide. The world's populace is projected to be 9 billion by the year 2030, and the largest increase will be confined to the developing countries, where chronic food shortages and malnutrition already persist. This projected increase of population will certainly reduce the per capita availability of natural resources and may hinder the equilibrium and sustainability of agricultural systems due to overexploitation of natural resources, which will ultimately lead to more poverty, starvation, malnutrition, and higher food prices. The judicious utilization of natural resources is thus needed and must be addressed immediately.

Climate change is emerging as a major threat to the agriculture throughout the world as well. Surface temperatures of the earth have risen significantly over the past century, and the impact is most significant on agriculture. The rise in temperature enhances the rate of respiration, reduces cropping periods, advances ripening, and hastens crop maturity, which adversely affects crop productivity. Several climatic extremes such as droughts, floods, tropical cyclones, heavy precipitation events, hot extremes, and heat waves cause a negative impact on agriculture and are mainly caused and triggered by climate change.

In order to optimize the use of resources, hi-tech interventions like precision farming, which comprises temporal and spatial management of resources in horticulture, is essentially required. Infusion of technology for an efficient utilization of resources is intended for deriving higher crop productivity per unit of inputs. This would be possible only through deployment of modern hi-tech applications and precision farming methods. For improvement in crop production and returns to farmers, these technologies have to be widely spread and adopted. Considering the above-mentioned challenges of horticulturist and their expected role in ensuring food and nutritional security to mankind, a compilation of hi-tech cultivation techniques and postharvest management of horticultural crops is needed.

This book series, Innovations in Horticultural Science, is designed to address the need for advance knowledge for horticulture researchers and students. Moreover, the major advancements and developments in this subject area to be covered in this series would be beneficial to mankind.

Topics of interest include:

1. Importance of horticultural crops for livelihood
2. Dynamics in sustainable horticulture production
3. Precision horticulture for sustainability
4. Protected horticulture for sustainability
5. Classification of fruit, vegetables, flowers, and other horticultural crops
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10. Horticultural plant physiology
11. Role of plant growth regulator in horticultural production
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ABOUT THE EDITORS

Debashis Mandal, PhD
Assistant Professor, Department of Horticulture, Aromatic & Medicinal Plants, Mizoram University, Aizawl, Mizoram, India

Debashis Mandal, PhD, is Assistant Professor in the Department of Horticulture, Aromatic & Medicinal Plants at Mizoram University, Aizawl, Mizoram, India. He is an academician and research fellow working in sustainable hill farming for the past 12 years. He previously worked as an assistant professor at Sikkim University, India, and has published over 60 research papers and book chapters in reputed journals and books. He has also published books with Apple Academic Press, American Academic Press, and *Lambert Academic Publishing*. He is also working as a member of Workgroup Lychee, Longan and other Sapindaceae Fruits of the International Society for Horticultural Science (ISHS), Belgium, and is also a member in ISHS sections on tropical and subtropical fruits, organic horticulture, and the Commission on Quality And Postharvest Horticulture. Currently, he is working as an Assistant Managing Editor for the *International Journal of Bio Resources & Stress Management* (IJBSM) and as an editorial board member of the *Bulletin Agroteknologi, Research on Crops, Crop Research, Journal of Postharvest Technology, Senhri Journal of Multidisciplinary Studies*, etc. Dr. Mandal is also an editorial advisor in Horticulture Science to Cambridge Scholars Publishing (UK) and regular reviewer of journals including *Fruits, HortScience, ActaPhysiologica Plantarum, African Journal of Agri. Research, Journal of Food Quality*, etc. Further, he is a consultant horticulturist in the Department of Horticulture & Agriculture (Research & Extension), Govt. of Mizoram, India, and Himadri Specialty Chemicals Ltd., and is also handling externally funded research projects. He was convener for the International Symposium on Sustainable Horticulture, 2016, India, and co-convener for the International Conference of Bio-Resource and Stress Management, 2017, Jaipur, India. In addition, he was Session Moderator and Keynote Speaker at the ISHS Symposium on Litchi, India, in 2016; on postharvest technology in Vietnam, 2014 and at South Korea, 2017; and AFSA Conference in 2018, Cambodia. He is recipient of a Best Editor Award (2017) from IJBSM,

Young Achiever Award (2019) from SADHNA, Best Researcher Award (2020) by Scifax, and Young Scientist Award (2020) from the Society of Tropical Agriculture. He has visited countries including Thailand, China, Nepal, Bhutan, Vietnam, South Korea, South Africa, and Cambodia for professional meetings, seminars, and symposia. His thrust areas of research are organic horticulture, pomology, postharvest technology, plant nutrition, and micro-irrigation. Dr. Mandal did his PhD from BCKV, India, and was a postdoctoral project scientist in IIT, Kharagpur.

Ursula Wermund, PhD
Project Manager and R&D Coordinator Greenyard Fresh - Greenyard Fresh Trade International (UNIVEG) GmbH

Ursula Wermund, PhD, is Project Manager and R&D Coordinator at Greenyard Fresh of Greenyard Fresh Trade International (UNIVEG) GmbH, Bremen, Germany. She has marked experience in professional-corporate management, particularly in line with postharvest handling and marketing of fresh fruits and vegetables. She teaches on these subjects as well. She received her doctoral degree in Agricultural Science from Cranfield University, UK, and started her career as a research assistant at Writtle College, University of Essex, Chelmsford, UK. Later, she joined the prestigious Imperial College, Wye, UK, and became the Head of the Post-Harvest Group. During this period, she was actively associated with teaching and research related to temperate fruit production and postharvest management. Subsequently, she started her corporate assignment as head of quality management in Petter Vetter Group, GmbH, Kehl, Germany. Currently, she is a project manager and R&D coordinator for UNIVEG Group (presently known as Greenyard), Bremen, Germany. Her 13 years of corporate affairs led to her dealing with quality assurance and management of Surinamese banana, Madagascar litchi, Italian and Turkish grapes, and Kenyan French bean, etc., in coordination with German and European Fruit Trading Association and Food Safety Working Group. She added thermal pest control and pesticide residue analysis from her experience at working with UNIVEG. She has published 14 research papers in reputed international journals in addition to participating in 11 international meetings, conferences, and symposiums in different foreign countries. Her key areas of work in horticulture are postharvest technology and packaging and marketing of fruits and vegetables.

Lop Phavaphutanon, PhD
Deputy Head and Chief of the Tropical Fruit Research and Development Center, Department of Horticulture, Faculty of Agriculture at Kamphaeng Sean, Kasetsart University, Thailand

Lop Phavaphutanon, PhD, is currently Deputy Head and Chief of the Tropical Fruit Research and Development Center, Department of Horticulture, Faculty of Agriculture at Kamphaeng Sean, Kasetsart University, Kamphaeng Sean Campus, Thailand. He has 30 years of teaching experience at Kasetsart University, Thailand, where he received his MSc. He has published more than 30 research papers, two book chapters, and 24 seminar papers during his active research career. Currently he is handling three research projects related to aromatic coconut and pummelo fruit. He teaches courses on principles of horticulture, physiology of horticultural crops, tropical fruits, orchard management, nutrition of horticultural crops, and research methods in horticultural sciences. He received his doctoral degree from Texas A&M University, USA, and has worked on many tropical and subtropical fruits of Thailand.

Regina Cronje, MSc
Horticulturist, Agricultural Research Council, Institute for Tropical and Subtropical Crops, Nelspruit, South Africa

Regina Cronje, MSc, is a Horticulturist with the Agricultural Research Council of the Institute for Tropical and Subtropical Crops, Nelspruit, South Africa, for the past 13 years. She is actively associated with research of crop production technology of subtropical fruits and is currently focused on litchi and mandarin. She is serving on the Board of Directors of the South African Litchi Growers' Association and is an active member of the South African Society for Horticultural Science and the International Society for Horticultural Science. In addition, she is reviewer of reputed journals, including *HortScience* and the *Agricultural Science Journal*. She has published over 50 research papers and 15 book chapters and was chief editor for book volume published as *Acta Horticulture* (Proceedings of the 4th International Symposium on Lychee, Longan and Other Spaindaceae Fruits). In addition, she was the recipient of the Lindsey Milne Industry Award for outstanding contribution to the South African Litchi Industry.

She earned her MSc in Crop Science at the University of Hohenheim, Stuttgart, Germany.

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CONTRIBUTORS

I. O. O. Aiyelaagbe
Department of Horticulture, Federal University of Agriculture, Abeokuta, Nigeria

Maria Angélica Guimarães Barbosa
Embrapa Semiárido, BR 428, Km 152, PO Box 23, Zip Code 56302-970, Petrolina, Pernambuco State, Brazil

Panchaal Bhattacharjee
Department of Horticulture, Anand Agricultural University, Anand, Gujarat 388110, India

Marcos Botton
Embrapa Uva e Vinho, Livramento Street, 515, PO Box 130, Zip Code 95701-008, Bento Gonçalves, Rio Grande do Sul State, Brazil

Houbin Chen
College of Horticulture, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

Marco Antonio Fonseca Conceição
Embrapa Uva e Vinho, Experimental Station of Tropical Viticulture, Barra Bonita, PO Box 241, Zip Code 15700-971, Jales, São Paulo State, Brazil

Regina Barbara Cronje
Horticulture Department, ARC-Tropical and Subtropical Crops, Private Bag X11208, Nelspruit 1200, South Africa; E-mail: regina@arc.agric.za

Pallab Datta
Department of Fruit Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 735252, West Bengal, India

Bikash Ghosh
Department of Fruit Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia 735252, West Bengal, India

Celito Crivellaro Guerra
Embrapa Uva e Vinho, Livramento Street, 515, PO Box 130, Zip Code 95701-008, Bento Gonçalves, Rio Grande do Sul State, Brazil

Tran Van Hau
Crop Science Department, College of Agriculture, Can Tho University, Vietnam;
E-mail: tvhau@ctu.edu.vn

Tran Sy Hieu
Crop Science Department, College of Agriculture, Can Tho University, Vietnam

Nguyen Van Hoa
Southern Horticultural Research Institute, Long Dinh- Chau Thanh- Tien Giang, Vietnam

Zhouyan Hu
College of Food Science, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

Prashant Kalal
Division of Fruits and Horticultural Technology, IARI, New Delhi, Outreach PhD Programme Centre, IIHR, Bengaluru 560089, India

Venkata Satish Kuchi
MS Swaminathan School of Agriculture, CUTM, Odisha

Sunil Kumar
Division of Fruits & Horticultural Technology, Indian Agricultural Research Institute, Pusa, New Delhi, India

Prasenjit Kundu
Sasya Shyamala Krishi Vigyan Kendra, Ramakrishna Mission Vivekananda Educational and Research Institute, Arapanch, P.O. Sonarpur, Dist.-South 24 Pgs, Kolkata 700150, West Bengal, India

Huynh Ky
Crop Science Department, College of Agriculture, Can Tho University, Vietnam

Noel Lalhruaitluangi
Department of Horticulture, Aromatic & Medicinal Plants, Mizoram University, Aizawl-796004, Mizoram, India

Patrícia Coelho de Souza Leão
Embrapa Semiárido, BR 428, Km 152, PO Box 23, Zip Code 56302-970, Petrolina, Pernambuco State, Brazil

Maria Auxiliadora Coêlho de Lima
Embrapa Semiárido, BR 428, Km 152, PO Box 23, Zip Code 56302-970, Petrolina, Pernambuco State, Brazil; E-mail: auxiliadora.lima@embrapa.br

Sutanu Maji
Department of Horticulture, Babasaheb Bhimrao Ambedkar University, Vidya-Vihar, Rae Bareli Road, Lucknow 226025, Uttar Pradesh, India

João Dimas Garcia Maia
Embrapa Uva e Vinho, Experimental Station of Tropical Viticulture, Barra Bonita, PO Box 241, Zip Code 15700-971, Jales, São Paulo State, Brazil

Debashis Mandal
Department of Horticulture, Aromatic and Medicinal Plants, School of Earth Sciences & Natural Resources Management, Mizoram University (A Central University), Aizawl 796004, Mizoram, India; E-mail: debashismandal1982@gmail.com

Arghya Mani
School of Agriculture, Lovely Professional University, Punjab, India;
E-mail: arghyamani14@gmail.com

George Wellington Bastos de Melo
Embrapa Uva e Vinho, Livramento Street, 515, PO Box 130, Zip Code 95701-008, Bento Gonçalves, Rio Grande do Sul State, Brazil

Loiva Maria Ribeiro de Mello
Embrapa Uva e Vinho, Livramento Street, 515, PO Box 130, Zip Code 95701-008, Bento Gonçalves, Rio Grande do Sul State, Brazil

Dipak Nayak
ICAR-Central Institute for Subtropical Horticulture- Regional Research Station, Malda, West Bengal, India; E-Mail: dipakiari@gmail.com

O. M. Odeyemi
Department of Horticulture, Federal University of Agriculture, Abeokuta, Nigeria

José Eudes de Morais Oliveira
Embrapa Semiárido, BR 428, Km 152, PO Box 23, Zip Code 56302-970, Petrolina, Pernambuco State, Brazil

O. O. Olubode
Department of Horticulture, Federal University of Agriculture, Abeokuta, Nigeria; E-mail: olubodeoo@funaab.edu.ng

Lop Phavaphutanon
Tropical Fruit Research and Development Center, Department of Horticulture, Faculty of Agriculture, Kamphaeng Sean, Kasetsart University, Kamphaeng Sean Campus, Thailand; E-mail: agrlpv@ku.ac.th

Wene Qi
College of Economics & Management, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

M. A. Rahim
Department of Horticulture, Bangladesh Agricultural University, Mymensingh 2202, Bangladesh; E-Mail: marahim1956@bau.edu.bd

Patrícia Silva Ritschel
Embrapa Uva e Vinho, Livramento Street, 515, PO Box 130, Zip Code 95701-008, Bento Gonçalves, Rio Grande do Sul State, Brazil

Henrique Pessoa dos Santos
Embrapa Uva e Vinho, Livramento Street, 515, PO Box 130, Zip Code 95701-008, Bento Gonçalves, Rio Grande do Sul State, Brazil

Sayan Sau
Purba Medinipur Krishi Vigyan Kendra, Bidhan Chandra Krishi Viswavidyalaya, Mulakhop, Dayaldasi, Purba Medinipur, West Bengal 721632, India; E mail: sayan.bckv@yahoo.com

Leonardo Cury da Silva
Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul, General Osório Street, 348, Zip Code 97700-206, Bento Gonçalves, Rio Grande do Sul State, Brazil

Nguyen Minh Thuy
Crop Science Department, College of Agriculture, Can Tho University, Vietnam

Doan Huu Tien
Southern Horticultural Research Institute, Long Dinh- Chau Thanh- Tien Giang, Vietnam

Mai Van Tri
South East Horticultural Research Center, Ba Ria – Vung Tau, Vietnam

Huicong Wang
College of Horticulture, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

Ursula Wermund
Greenyard Fresh Trade International (UNIVEG) GmbH, Bremen, Germany; E-mail: ursula.wermund@greenyardfresh.de

Zhenxian Wu
College of Horticulture, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

Jidong Xian
College of Agriculture, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

Ashok Yadav
ICAR-Central Institute for Subtropical Horticulture- Regional Research Station, Malda, West Bengal, India

Lixian Yao
College of Natural Resources and Environment, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

Tran Thi Oanh Yen
Southern Horticultural Research Institute, Long Dinh- Chau Thanh- Tien Giang, Vietnam

Jovani Zalamena
Instituto Federal de Educação, Ciência e Tecnologia do Rio Grande do Sul, Alberto Hoffmann Street, Zip Code 91791-508, Restinga, Rio Grande do Sul State, Brazil

Biyan Zhou
College of Horticulture, South China Agricultural University, 483 Wushan Rd, Tianhe District, Guangzhou 510642, China

ABBREVIATIONS

ABA	abscisic acid
AC	activated charcoal
ACC	aminocyclopropane carboxylic acid
ACO	aminocyclopropane carboxylic acid oxidase
ACS	ACC synthase
AFB	after full bloom
AFLP	amplified fragment length polymorphism
AI	acid invertase
AMF	arbuscular mychorhizal fungi
AOA	aminooxyacetic acid
ARC-TSC	Agricultural Research Council's Institute for Tropical and Subtropical Crops
ASM	available soil moisture
AVG	aminoethoxyvenylglycine
BB FEI	bulk blend fertilizer
BA	benzyl adenine
BAU	Bangladesh Agricultural University
BBTV	banana bunchy top virus
BOPP	biaxially orientated polypropylene
CA	controlled atmosphere
CARS	China Litchi Research System
CAT	catalase
CEC	cation exchange capacity
CEERI	CSIR-Central Electronics Engineering Research Institute
CI	chilling injury
CND	compositional nutrient diagnosis
CT	continuous trench
CTKs	cytokinins
CVA	critical value approach
DAP	days after pollination
DHF	Dengue Hemorrhagic Fever
DWB	dry weight basis
EMS	ethyl methane sulphonate
EO	essential oils

EPS	expanded polystyrene
EST-SSR	expressed sequence tag-derived simple sequence repeat
EWM	entropy weight method
FAO	Food and Agriculture Organization
FB	full bloom
FBD	flower bud differentiation
FCOJ	frozen concentrated orange juice
FHIA	Fundacian Hondurena de Investigacion Agricola
FJC	frozen juice concentrate
FYM	farm yard manure
Gas	gibberellins
GA	gibberellic acid
GAOs	galacturonic acid oligosaccharides
GDC	Geneva Double Curtain
GDD	growth degree days
GHPS	greenhouse production system
GM	grass mulch
GP	grown panicles
GPS	global positioning system
GIS	geographic information systems
GRAS	generally recognized as safe
GRSPaV	grapevine rupestris stem pitting-associated virus
HDP	high-density planting
HDPE	high-density polyethylene
HLB	huanglongbing
HSP	heat shock protein
HWD	hot-water-dipping
IAA	indoleacetic acid
IARI	Indian Agricultural Research Institute
IBA	indolebutyric acid
IFS	initial fruit set
INM	Integrated Nutrient Management
IPS	integrated production systems
IQF	individual quick freezing
ISSR	inter simple sequence repeat
ITS	internal transcribed spacer
LDP	low-density planting
LDPE	low-density polyethylene
LER	land equivalent ratio

MA	modified atmosphere
MAP	modified atmosphere packaging
MARDI	Malaysian Agricultural Research and Development Institute
MCPG	methylene cyclopropyl-glycine
MD	Mekong delta
MDP	medium-density planting
(M)DRIS	(modified) diagnosis and recommendation integrated system
MIC	minimum inhibitory concentration
MOP	muriate of potash
MSL	mean sea level
MJ	methyl jasmonate
NAA	naphthalene acetic acid
NAD	naphthalene acetamide
NFC	nonfrozen concentrate
NFJC	nonfrozen juice concentrate
NISPRIN	Nigerian Stored Products Research Institute
NO	nitric oxide
NWFP	North West Frontier Province
OM	organic matter
OMF	organo-mineral fertilizer
PAA	peroxyacetic acid
PaLCuV	papaya leaf curl virus
PAR	photosynthetically active radiation
PBZ	paclobutrazol
PC	protected cultivation
PET	polyethylene terephthalate
PFD	postbloom fruit drop
PG	polygalacturonases
PGRs	plant growth regulators
POs	pectic oligosaccharides
POD	peroxidase
PP	polypropylene
PPFD	photosynthetic photon flux density
PPO	polyphenol oxidase
PRSV	papaya ring spot virus
PSDM	Papaya Sex Determination Marker
PVC	polyvinyl chloride

PVP	polyvinylpyrrolidone
QTL	quantitative trait loci
RAPD	random amplified polymorphic DNA
RCTs	rainwater conservation techniques
RFLP	restriction fragment length polymorphism
SBD	soil bulk density
SCAR	sequence characterized amplified region
SMP	Shoemaker, Mc Lean, and Pratt Method
SNA	sodium naphthalene acetate
SNP	single nucleotide polymorphisms
SOC	soil organic carbon
SOP	sulfate of potash
SOPP	sodium ortho-phenyl phenate
SOUR	suppression of uniform ripening
SPS	sucrose phosphate synthase
SRA	sufficiency range approach
SRAP	sequence-related amplified polymorphism
SS	soluble solids
SS	sucrose synthase
SSH	suppressive subtraction hybridization
SSR	simple-sequence repeat
ST	staggered trench
STD	short-term -duration
STMS	sequence tagged microsatellite sites
STS	silver thiosulfate
TA	titratable acidity
TDT	total daily temperature
TSS	total soluble solids
UPD	underpeel discoloration
USDA-APHIS	USDA Animal and Plant Health Inspection Service
UDP	ultra-density planting
VAM	vesicular arbuscular mycorrhiza
VOD	vacuum osmotic dehydration
VSP	vertical shoot positioning
WBR	weed biomass rating
XET	xyloglucan endo-transglucosylase
ZEC	zero-energy evaporative coolant
ZRs	zeatin-ribosides

PREFACE

Tropical and subtropical fruits are known and appreciated for their exotic aromas, textures, and tastes as well as for their nutritional and medicinal value. These attributes and a renewed health consciousness have increased consumer demand for these fruits. Out of the hundreds of tropical and subtropical crops only some 50 are well known and even less are grown on a commercial scale. Most of the best-known ones come from the tropical and subtropical regions of Asia and America. They are important to many developing countries as a contribution toward income and as a source of nutrition. Major tropical and subtropical crops, such as citrus, banana, and mango are extensively cultivated and marketed in local and export markets. Minor tropical and subtropical crops, such as litchi, papaya, and guava, have limited consumption and trade but may have high regional importance.

Despite their increasing popularity, the cultivation of tropical and subtropical fruits is limited to areas with warm temperatures and high humidity throughout most of the year. Due to their highly perishable nature, postharvest handling, transport, and storage has always been a challenge. While tropical and subtropical fruits are still mainly consumed fresh, good advances have been made in processing and value-adding in the past few decades. The commercial success of tropical and subtropical fruits worldwide has also favored the development of agro technology, sustainable crop production techniques, integrated pest management, and, in particular, postharvest technologies and handling techniques. Likewise, biotechnology and molecular biology are increasingly used in breeding programs to develop varieties with improved fruit characteristics, shelf life, and the ability to withstand the adverse effects of climate change.

In this regard, this book volume, *Tropical and Subtropical Fruit Crops: Production, Processing and Marketing*, provides comprehensive information on the latest developments and research efforts in crop production techniques, processing, and marketing, breeding efforts, harvesting and postharvest handling, as well as pest and disease management of banana, citrus, durian, grapes, guava, jackfruit, litchi, mango, and papaya.

Debashis Mandal
Ursula Wermund
Lop Phavaphutanon
Regina Cronje

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CHAPTER 1

BANANA

Sayan Sau[1*], Panchaal Bhattacharjee[2], Prasenjit Kundu[3], and Debashis Mandal[4]

[1]Purba Medinipur Krishi Vigyan Kendra, Bidhan Chandra Krishi Viswavidyalaya, Mulakhop, Dayaldasi, Purba Medinipur 721632, West Bengal, India

[2]Department of Horticulture, Anand Agricultural University, Anand 388110, Gujarat, India

[3]Sasya Shyamala Krishi Vigyan Kendra, Ramakrishna Mission Vivekananda Educational and Research Institute, Arapanch, Sonarpur, South 24 Pgs., Kolkata 700150, West Bengal, India

[4]Department of Horticulture, Aromatic and Medicinal Plants, School of Earth Sciences & Natural Resources Management, Mizoram University (A Central University), Aizawl 796004, Mizoram, India

[*]Corresponding author. E-mail: sayan.bckv@yahoo.com

ABSTRACT

Banana, a member of the Musaceae family, belongs to the genus Musa, which comprises a significant variety of species and hybrids. Though there are over thousand varieties of bananas grown and consumed worldwide, the Cavendish type banana crowned the most commercialized variety tag, accounting for about 47% of global production. In 2018, global banana exports (excluding plantains) are forecast to touch a new high of 19.2 million tons due to ample growth in its supply. Bananas and plantains are the only

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known items under fruits that also constitute a staple food for millions. It is a recommended dietary supplement to lower blood pressure as it contains low salt and high potassium chloride. Bananas are a well-accepted food item in antique medicine in China, India, and ancient Persia due to its effectiveness against obesity, peptic ulcer, infant diarrhea, celiac disease, and colitis. Banana commercially propagated through suckers and more recently for uniform yield and less disease infection plantlets developed through tissue culture are recommended. Seeds are used only in breeding program. Advanced cultivation practices such as sucker management, drip irrigation scheduling, adoption of fertigation, and bunch management lead to achieving higher productivity. Researchers over the world engage in developing new cultivars through several breeding programs like hybridization, selection, mutation to escape the devastating disease like sigatoka, BBTV, and fusarium wilt. In recent times, ripening improvement through standardized ethylene treatment and storing of banana in CA/MA storage makes it possible to store them for a longer duration and safe disposal in targeted market with minimum loss.

1.1 GENERAL INTRODUCTION

Banana belongs to *Musa* genus a member of family Musaceae. The name *Musa* finds its origin to Sanskrit word "*moca*," via its Arabic source, "*mauz*." Banana appeared as "the tree of paradise" in Quran. Bananas were mainly derived from two wild ancestral sources: *Musa acuminata* and *Musa balbisiana* (Lehmann et al., 2002). Present day's bananas and plantains found their native in South-East Asian and western Pacific provinces (Carreel et al., 2002) are seeded, inedible, in the natural forest flora of these regions of diversity, ancestors with diploid set of chromosomes can still be traced (Robinson, 1996). At present, it is nearly ubiquitous in all tropical and subtropical climate zones of the world; it is widely cultivated as one of the important remunerative fruit crops and also serves as staple food commodity in several communities. Bananas at its ripe stage are sweet and easily digestable making them one of the preferred dessert fruits. Gowen (1988) discussed the apparent ambiguity of using the term "plantain." As the fruits ripen, there is a process of conversion of starch to sugar which is relatively slower in cooking varieties (plantains), typical M. *balbisiana* characteristic. Different names are used to address banana in the various countries of the world, as discussed by Uma et al. (2011); this is given in Table 1.1.

TABLE 1.1 Common Names of Banana in Different Countries or in Languages.

Name	Country/ Language	Name	Country/ Language	Name	Country/ Language
banana	Japanese, Italian, Portuguese, Serbo-Croat, Hebrew	*banema*	Guinea	*klue/klui*	Thai
banane	French, German	*Choui*	Vietnam	*mauz*	Turkish, Arabic/ Persian
banaan	Dutch	*Chiao*	Chinese	*maso/ndizi*	Swahili
Banan	Danish	*Futo*	New Caledonia	*pisang*	Malay/Indonesian
banaani	Finnish	*Futi*	West Polynesia	*saging*	Philippines
Banan	Russian/Polish	*hnget-pyaw*	Burmese	*usi*	New Guinea
banbán	Hungarian	*ikindu/ kitoke*	East African	*uch/ut*	Micronesian
mpanána	Greek	*Kela*	India	*vudi*	Fiji

With the progression of technologies in the late 1800s like refrigerated shipping that served as the base of the global banana trade industry, banana exhibits colonial economic nationalism and present-day neoliberal stages of growth and evolution in the world economy (Wiley, 2008). Banana gained reputation for its diversity and skill of adapting into multiple agro-climatic zones, buoyancy to changing climate, fruit yield attribute throughout the year, and large volume per unit yield. The spectrum of cultivar diversity and differential maturity trait allows its adoption and cultivation in more than 155 countries (Uma et al., 2011).

1.2 AREA AND PRODUCTION

Bananas are produced and consumed worldwide, but the Cavendish variety is produced commercially most, which accounts for 47% of global share. Cavendish bananas with their dwarfing and storm-resistant structure can recover quickly from natural disasters and this helps it to attain higher yield. Production scenario depicts that 45–50 billion tons (approx) of Cavendish bananas are produced around the world. The Cavendish variety is preferred for foreign trade than other varieties because it is more resistant to the effects of shipping and thus accounts for the majority of bananas

supplied to the US and European markets. Cavendish bananas are also the most popular variety grown and consumed in China and India (FAOSTAT via Bioversity). A comprehensive figure on global banana production goes untrackable as it comes from small-scale growers with marginal land holding who sell them in informal markets. Available data shows a growth of 3.2% in global production since 2000 (67 million tons) reaching a record of approx. 114 million tons in 2017. According to FAOSTAT, total area in world under banana cultivation in 2017 is 5637,508 ha with total yield of 113,918,763 t and the resulting productivity of 20.21 t/ha. The leading five countries in the world with a higher average banana production (million tons per year) during 2010–17 are India (29), China (11), Philippines (7.5), Ecuador (7), and Brazil (7), respectively (Table 1.2). India is the current top producer of banana with 30,808 (‘000 MT) total yield from acreage of 884 (‘000 Ha) (NHB Database, 2018). Overall, the global banana industry has witnessed improved sign in productivity, with the average yield per unit area shifting from around 14 t/ha (1993) to 20 t/ha in 2017. It has to be mentioned that statistics provided by the FAO do not distinguish between plantain and banana.

TABLE 1.2 Production and Productivity Status of Top Banana Growing Countries in the Year 2017.

Production Scenario			**Productivity Scenario**		
Sl. No.	**Country**	**Unit (million tons)**	**Sl. No.**	**Country**	**Unit (t/ha)**
	India	304.77		Syrian Arab Republic	70.4927
	China	225.93		Nicaragua	65.8088
	Indonesia	71.63		Indonesia	60.1906
	Brazil	66.75		South Africa	59.8494
	Ecuador	62.82		Costa Rica	59.4772
	Philippines	60.41		Turkey	54.099
	Angola	43.02		Israel	52.5692
	Guatemala	38.87		Puerto Rico	50.5256
	Colombia	37.87		Greece	49.2222
	United Republic of Tanzania	34.85		Guatemala	48.4953
	Costa Rica	25.53		Spain	46.4206
	Mexico	22.30		CÃ´te d'Ivoire	46.0917

TABLE 1.2 *(Continued)*

Production Scenario			Productivity Scenario		
Sl. No.	**Country**	**Unit (million tons)**	**Sl. No.**	**Country**	**Unit (t/ha)**
	Viet Nam	20.45		Jordan	44.912
	Rwanda	17.29		Egypt	42.8534
	Papua New Guinea	12.47		Dominican Republic	42.0593

Source: FAOSTAT Database (2019).

India and China both increased their production between 2000 and 2015, nearly doubling their banana harvesting area and increasing yields by 48% and 83%, respectively.

1.3 MARKETING AND TRADE

Considering about the abundant development in provisions, worldwide exports of banana are projected at a record high of 19.2 million tons in 2018, excluding plantains. Ecuador and Philippines are the main patron or contributor in ascent of worldwide banana export market. Ecuador, the chief exporter of bananas worldwide, was expecting a 4% growth in supply to arrive at another raise of 6.7 million tons in 2018, ensued for favorable climate conditions and yield-improving innovations. Booked tax decreases under the EU-Andean arrangements in 2018, which encouraged passages to the EU market at a diminished pace of 96 EUR/t over time will profit Ecuadorian shipments. Ecuador is required to represent a volume portion of almost 40% of worldwide shipments in 2018.

Analyzing India's export market of banana during 2017 through Export Genius (An exim exchange information research firm) report, it has sorted out that however India being number one producer of banana, its export probability is moderately low because of higher homegrown utilization or domestic consumption. India trades most amount of bananas to Middle East nations in which the United Arab Emirates, Saudi Arabia, Oman, Kuwait, and Iran beat out all competitors. UAE and Oman recorded 31.58% and 19.68% share in estimation of banana imports from India, respectively.

1.4 COMPOSITION AND USES

Nutrient contents of tropical fruits found in food organization tables are utilized for the appraisal of nourishing level, connecting diet to wellbeing, dietary arrangement, and food bundle naming and customer awareness. Precise information is required to anticipate dietary energy admission and under nourishment. For tropical organic products like banana, this is significant, as they are regularly viewed as huge wellsprings of minerals, nutrients, and starches (Favier et al., 1993).

Characteristic variation happens in the nutrient contents because of soil and climatic conditions, varieties grown, the phase of development at collect and physiological state when eaten. Generally, food synthesis tables for most nourishment are introduced as mean qualities, overlooking the regular natural inconstancy. It is presumably more helpful to know the scope of qualities found and the standard error or deviation.

The pulp of plantain contains less water than that of banana (Table 1.3). During maturing there is transformation of starch to sugars in pulp, because of respiratory breakdown and peel color is firmly associated with the starch:sugar proportion. Starch declines from about 20–23% at harvest to 1–2% in ripe fruit.

TABLE 1.3 Proximate Composition of Mature Banana and Plantain Fruit Pulp.

Nutritional Content (% Pulp Fresh Mass)	**Banana**			**Plantain**			
Water (%)	71.3–75.7			64.1–66.7			
Energy (kJ)	418			523			
Protein	1.08–1.10			1.10–1.28			
Lipid (g)	0.13			0.03			
CHO (g)	22.2–26.56			31.20–33.39			
Fiber (g)	0.11			0.43			
Ash (g)	0.80–0.90			0.87–0.90			
Minerals content (mg/100 g pulp)	**P**	**K**	**Ca**	**Mg**	**Fe**	**S**	**Na**
Banana	18–27	460–494	5–7	36–40	0.49	34	1
Plantain	21–32	393–440	4–14	32–35	0.54	24	1

TABLE 1.3 *(Continued)*

Vitamin content (mg/100 g pulp)	Vitamin A (IU)	Thiamine (B_1)	Riboflavin (B_2)	Niacin (B_3)	Pantothenic Acid (B_5)	Ascorbic acid (C)
Banana	88	0.044	0.045–0.07	0.69	0.26	5.1–10
Plantain	31	0.038–0.05	0.05–0.064	0.43	0.37	17.5–20

Source: Adapted from Stover and Simmonds (1987), Wenkam (1990), John and Marchal (1995).

Many African nations, Latin America, the Caribbean, and the Polynesian islands consider plantains to be a staple food, where people used to consume banana in different forms like fresh, cooked, steamed, roasted, and brewed (Pillay et al., 2002). The average global per capita consumption of banana and plantain is reported as 5.2 kg/person (Nayar, 2010), but it is significantly much higher in tune of 239 kg/person in Uganda, 223 in Burundi, 180 in Rwanda, 141 in Gabon, and 131 in Samoa where it is revered as fruit equivalent (as per FAOSTAT Database, 2019), with a marginal incremental approach. Besides the fruits, the flower buds and inner core of the pseudostem are also used as vegetables in addition to their wide range of therapeutic uses. Bananas are also processed into puree, juice, fig, jams, canned banana slices (Thompson, 1995), and wine and beer in Africa (Olaoye et al., 2006).

In India's traditional medicine, bananas are believed to be nature's secret to everlasting youth; in China and ancient Persia, banana is considered an ideal diet for obese and geriatric patients due to the low lipid and high energy values (Gasster, 1963). Bananas are low in salt and high in potassium chloride, and thus it is a recommended dietary supplement to lower blood pressure. It is also effective against peptic ulcer, infant diarrhea, celiac disease, and colitis (Seelig, 1969).

Banana can enhance production of hemoglobin in blood which helps anemic persons and banana being rich in tryptophan, which gets converted into serotonin in the body, helps to keep the mind relaxed. For expectant mothers, fruits are considered coolant. Being rich in fiber and pectins, banana helps to improve bowel movement. Benign amino acids that are useful for the kidney and the removal of gall bladder stone are also found in banana. Banana serves as a good source of lectins, which are sugar-binding proteins that can identify foreign invader pathogen and check their entry to the body. Banana roots also possess an antihelmintic effect (Uma et al., 2011).

Banana leaves are considered hygienic dining plates and wrapping material. Nowadays, leaf production is also considered an income source for

small-scale farmers in South India and Africa. The subterranean rhizome is used in a hybrid blend as animal feed. The banana's pseudostem has proven to be a successful substrate for mushroom cultivation either alone or in combination with rice straw. The banana plant saps are also used as an indelible ink in the industry.

Owing to optimum burst, tear, and tensile indices, banana fiber also finds its use in the pulp industry and as a base material in cottage industries for making handicrafts and for making a wide range of handicrafts, also being utilized for treatment purposes of industrial and municipal wastes (Uma et al., 2002). Banana fiber is derived from *M. textilis* having great tear and tensile strength that makes it extensively suitable for printing of Japanese yens and is also blended with cotton in various ratios for use in the textile industry.

1.5 ORIGIN AND DISTRIBUTION

With vast diversity, utility, and spread, banana and plantain is a complex crop and addressing their origin is difficult compared to other crops. After their simultaneous and independent evolution across Asia, Polynesia, and Africa, metamorphosis of the earliest wild banana, a weedy, seeded, nonedible plant into a domesticated, parthenocarpic (nonseeded), edible tasty fruit occurred in a long evolutionary journey.

Banana is one of the primitive crops to be domesticated by man mostly due to its various uses. Current forms of bananas are predicted to have originated in the Southeast Asian and Pacific West areas, where still their inedible, seeded, diploid ancestors habitat in natural forest vegetation. As a wild-seeded plant, banana must have been first recognized for purposes like fiber, roofing, and ropes. The earliest documentary evidence of banana is found in the Vedic period (approx. 1700 BCE).

Buddhist sculptures of central India, *stupas* in Sanchi, carvings in Nalanda, and paintings in Ajantha and Ellora caves act as proofs of early cultivation of banana in human civilization. First mention of the banana in Chinese texts was done by a Chinese official in the T'ang dynasty (618–907), who wrote an *Encyclopedia of Rare Things* that includes the description of the banana plant. Plantains, too, have a long tradition of domestication, their entry to the continent of Africa is reported to be about 1500–2000 years ago and Phytoliths of *Musa* and *Ensete* unearthed in Cameroon are the first

archeological indication of a cultivated crop, dating back 3000 years in Central Africa (Mbida et al., 2000).

At present dessert banana is widely cultivated in warm humid regions of Indian subcontinent, southern America, Caribbean islands, and south-eastern Asia. In case of plantains most cultivars are triploid, 73% of them are grown and eaten in West and Central Africa, and were formed from crosses between *M. acuminata* and *M. balbisiana* (Robinson, 1996).

1.6 BOTANY AND TAXONOMY

The banana plant is a nonwoody tree-like enduring herb. One of the offshoots developing at the foundation of the plant called as the sucker takes over after the aerial parts of the parent plant fade away to the ground after the developing season showing its perennial character. Smaller masse of covering and spirally organized leaf sheath give a trunk the same design known as pseudostem, while the "true" stem is created inside the pseudostem. The variations saw in morphological attributes is utilized to portray or characterize banana plants (Anonymous, 1996). The rhizome is an underground structure creating the roots. It is customarily categorized as a corm, and seldom as a bulb; however, the naturally right term is rhizome (Robinson and Galán, 2010). Primary roots of banana ascend from the outside of the focal chamber of rhizome though optional and tertiary roots start from the primary roots.

In the transition phase from the vegetative to the reproductive stage, the straightened arch formed meristem zone gets curved and transcends the encompassing leaf bases. Bloom bracts supplant the leaves and after the arrangement of the blossom, the aeronautical or aerial stem begins its turn of events and bears the bloom and leaf upward, eventually arising at the highest point of the pseudostem (Skutch, 1932). Individual leaf shows up from the focal as well as the central point of the pseudostem as a rolled cylinder. As indicated by cultivar inclination the distal finish of the extending leaf sheath contracts into a petiole which is pretty much open. Leaf petiole formed into mid rib separates the leaf edge into two lamina parts. The upper and lower surfaces of the leaf are naturally named as adaxial and abaxial, respectively. Scale leaves are the primary rudimentary leaves created from a growing sucker. Foliage leaves are the developed one comprising of sheath, petiole, midrib, and blade, while recently emerged leaf remains rolled as a cylinder termed as "Cigar leaf." Unfurling of moved leaf by and large requires around 7 days under good condition, yet may draw out dependent upon 15–20 days

in bad weather conditions. The white hued new leaves of banana are firmly snaked and for the most part fragile in surface. The tip augmentation of the leaf called as precursory appendage withers and tumbles off after emergence.

Horizontal shoot found in close proximity to the parent plant usually created from rhizome is called sucker, synonymous to keiki (in Hawaii) and pup. Peeper is a kind of sucker which has recently arisen through the soil surface while the "Maiden sucker" is a completely full grown mature sucker having foliage leaves. Morphologically suckers are of two kinds, for example sword sucker with slender leaves and a huge rhizome and water suckers with expansive leaves and a little rhizome. Water suckers are of more fragile association with mother plant and accordingly do not form into strong successive plant. "Follower or ratoon" term indicates a sucker that is chosen for replacing the parent plant in the wake of fruiting.

Botanically, the banana inflorescence is a thyrse, for example, an inflorescence wherein the main axis continuing developing yet the horizontal branches with determinate development propensity or growth habit (Kirchoff, 1992). Banana inflorescence comprises of three sorts of blossoms, at basal bit female blossoms (forms into fruit parthenocarpically, i.e., without fertilization) arranged in two lines, at distal portion cluster of male blossoms (produces pollen of varying degrees of fertility) exist, and in the middle of them there is third kind of flower for example bisexual or hermaphrodite or neutral one (does not form fruit). Inflorescence is upheld by a stalk called as peduncle while the stalks upheld the individual male and female blooms that are named as rachis (Anonymous, 1996). Male blooms encased in bracts have kept themselves secure in male bud that is otherwise called chime having inclination of proceed with development even after the development of the organic product aside from some cultivar. Bunch the spellbinding term means all the fruits in general. The fruits that are arranged into hands are frequently called fingers and the quantity of hands relies on ecological condition, female bloom rate, and sorts of cultivar (Fig. 1.2). Till date the largest bunch, as per Guinness World Records, weighs around 130 kg.

Linnaeus, in Species Plantarum (1753), first allotted logical terminology and scientific nomenclature to bananas by describing *Musa paradisiaca* L. Botanically, the whole entire cultivated bananas are grouped into the class Musa, which—along with two different genera, *Musella* and *Ensete*—are set in the family *Musaceae* and order Zingiberales.

Cheesman (1947) built up a satisfactory and acceptable classification for the genus Musa where he assembled the species in the family Musa into four segments, namely, M. faction. "Eumusa" (M. sect. Musa), M. sect.

Rhodochlamys (Baker), M. sect. Australimusa, and *M. sect. Callimusa*. He demonstrated that "the groups have intentionally been called segments instead of subgenera trying to evade the ramifications that they are of equivalent position." He further mentioned that his distribution may invigorate exploration and recognizable proof monetarily significant undiscovered species of Musa family. Argent (1976) later depicted another Musa sect. Ingentimusa dependent on a single species, *Musa ingens*.

With the assistance of established genomic characters the broadly acknowledged order of edible bananas was formulated by Simmonds and Shepherd (1955). They proposed the theory of banana advancement from wild and seedy ancestors, namely, *Musa acuminata* ($2n = 2x = 22$) and *Musa balbisiana* ($2n = 2x = 22$), originating from South-East Asia, following the development of series of seedless diploid, triploid, and tetraploid bananas. The subsequent genome groups were named AA, AB, AAA, AAB, ABB, AABB, AAAB, ABBB with the letters A and B addressing the commitments of *M. acuminata* and *M. balbisiana*, respectively. Ancestral types of banana and their contributing genome to build up the present genomic classification resemble "A" genome from *M. acuminata* Colla, "B" genome from *M. balbisiana* Colla, "S" genome from *M. schizocarpa*, and "T" genome from *Musa textilis*. Certain quantities of clone developed in Philippine may have come from early hybridization between *M. balbisiana* and *Musa textilis* (T genome). Clones involving A and T genomes or even A, B, and T genomes have been recognized in Papua New Guinea (Robinson and Galán, 2010).

Numerous molecular phylogenetic researches on the genus Musa showed that none of the five sections of Musa characterized by Cheesman and Argent recently dependent on morphology was recuperated as monophyletic. Just two infrageneric clades could be distinguished, which compared well to the basic chromosome numbers of $n = x = 11$ and $n = x = 10/9/7$, individually of which one clade involves species from Eumusa and Rhodochlamys segment, while the other contains species from Callimusa, Australimusa, and Ingentimusa segments (Li et al., 2010; Christelová et al., 2011). Häkkinen (2013) rebuilt Musa species into just two segments thinking about a sum of 70 species, namely, group *Musa* (*Eumusa* and *Rhodochlamys*) and sect. *Callimusa* (consisting of erstwhile *Callimusa*, *Australimusa*, and *Ingentimusa*), in view of the DNA analyses referred to above.

The following 33 species are assigned to section ***Musa*** L. sect. ***Musa*** by Häkkinen (2013); species marked with an asterisk (*) were previously placed in *Musa* sect. *Rhodochlamys*.

1. *Musa acuminata* Colla	12. * *Musa kattuvazhana*	23. *Musa schizocarpa*
2. * *Musa aurantiaca*	13. *Musa lanceolata*	24. *Musa shankarii*
3. *Musa balbisiana* Colla	14. * *Musa laterita*	25. * *Musa siamensis*
4. *Musa basjoo*	15. * *Musa mannii*	26. *Musa sikkimensis*
5. *Musa celebica*	16. *Musa nagensium*	27. *Musa thomsonii*
6. *Musa cheesmanii*	17. *Musa ochracea*	28. *Musa tomentosa*
7. * *Musa chunii*	18. * *Musa ornata*	29. *Musa tonkinensis*
8. *Musa flaviflora*	19. * *Musa rosea*	30. * *Musa velutina*
9. *Musa griersonii*	20. * *Musa rubinea*	31. *Musa yamiensis*
10. *Musa insularimontana*	21. * *Musa rubra*	32. *Musa yunnanensis*
11. *Musa itinerans* Cheesman	22. * *Musa sanguinea*	33. * *Musa zaifui*

The following 37 species are assigned to the section ***Musa*** sect. ***Callimusa*** by Häkkinen (2013); species marked with an asterisk (*) or a plus (+) were previously placed in *M.* sect. *Australimusa* or in *M.* sect. *Ingentimusa*, respectively.

1. * *Musa arfakiana*	14. *Musa haekkinenii*	26. *Musa paracoccinea*
2. *Musa azizii*	15. *Musa hirta* Becc.,	27. * *Musa peekelii*
3. *Musa barioensis*	16. + *Musa ingens*	28. *Musa sakaiana*
4. *Musa bauensis*	17. * *Musa jackeyi*	29. *Musa salaccensis*
5. *Musa beccarii*	18. * *Musa johnsii*	30. *Musa splendida*
6. * *Musa boman*	19. * *Musa juwiniana*	31. * *Musa textilis*
7. *Musa borneensis*	20. *Musa lawitiensis*	32. * *Musa troglodytarum*
8. * *Musa bukensis*	21. *Musa lokok*	33. *Musa tuberculata*
9. *Musa campestris*	22. * *Musa lolodensis*	34. *Musa violascens*
10. *Musa coccinea*	23. *Musa lutea*	35. *Musa viridis*
12. * *Musa fitzalanii*	24. * *Musa maclayi*	36. *Musa voonii*
13. *Musa gracilis*	25. *Musa monticola*	37. *Musa paracoccinea*

Latest additions in the existing edition of banana species occurred in 2016 and 2014, respectively. Two new species, naming *Musa paramjitiana* sp. nov. (Musaceae) close to *Musa balbisiana var. andamanica* with few varying plant characters and *M. indandamanensis*, was described and illustrated, from India's Andaman and Nicobar Islands (Singh, 2014, 2016).

In 2017, it was found in a study that the newly published species of Musa, namely, *M. indandamanensis* and *M. paramjitiana*, are actually synonymized

under *M. sabuana* and *M. balbisiana var. andamanica*, respectively. It was further clarified from the critical study of types and specimens conducted with live samples collected from their natural habitat at the Andaman and Nicobar Islands and Northeast India (Hareesh et al., 2017).

1.7 VARIETIES AND CULTIVARS

By and large for commercial aspects, bananas are classified into two types like dessert and cooking types (Table 1.5, 1.6 and Fig. 1.1). The cooking type bananas are described by starchy fruit and commonly utilized as vegetables as on unripe structure. Cultivars and landraces inside a genome are again assigned with different "Group" and "subgroups." Wild accessions are demonstrated as "types." Diplois are profoundly characterized by their slender pseudostems and more erect leaves, while the triploids are bigger, sturdier plants with increased fruit size. Triploid cultivars are ordered under three genomic groups namely, AAA, AAB, and ABB. Tetraploid cultivars are very few having robust pseudostem and dropping leaves, ordered under AAAA, AABB, AAAB, and ABBB genomic groups. Tetraploids are developed from fertilization of triploid egg cells by haploid pollens.

The genome scoring methods depended on specific explicit of 15 characters of both the ancestral species, for example, *M. accuminata* and *M. balbisiana*. These scoring methods accommodate a value of 15 (15 × 1) for wild *acuminata* and 75 (15 × 5) for wild *balbisiana* species. The scoring technique follows a score value distribution as resemblance to each character of *acuminate,* getting a score value of 1 while this value is 5 for each character matched with balbisiana species. The *acuminata* cultivar should score between 15 and 25 while unadulterated *balbisiana* should range from 70 to 75 and hybrids are between 26 and 69 (Table 1.4).

TABLE 1.4 Genomic Group-Wise Important Banana Cultivars.

Sl. No.	Genomic group	Cultivars belonging to this group
	AA	Mati, Kadali, Anaikomban, Sucrier
	AB	Neypoovan (safedvelchi, chinichampa, Rasagali), Adukkan
	BB	Bhimkol, Attaikol
	AAA	Gros Michel, Dwarf Cavendish (Singapuri, Basrai), Robusta (Harichal, Bombay Green, Giant Governor), Giant Cavendish (Shrimanti, Padarsi, Gandevi), Grand Naine, Red Banana (Agniswar, Anupam, Rathambala, Lalkela, Yeratti)

TABLE 1.4 *(Continued)*

Sl. No.	Genomic group	Cultivars belonging to this group
	AAB	Poovan/Mysore (Champa, LalVelchi, Dudhsagar), Pome subgroup (Virupakshi; syn. Hill banana, Vellavazhai); Silk subgroup [(Rasthali; syn. Amruthapani, Malbhog, Martaman, Rassabale, Sonkel), Amrit Sagar, Chakarakeli]; Plantain subgroup (Zanziber, Moongli)
	ABB	Bulggoe (syn; NallaNontha), Monthan (syn; Kanchkela), Pisang Awak (syn; Karpuravalli)
	BBB	Saba, Cardaba
	AAAA	Bodles Altafort
	AAAB	FHIA-01(Gold Finger), FHIA-18, FHIA-20, FHIA-21
	AABB	Pisang Awak, FHIA-03
	ABBB	Klue Teparod, Swai (synthetic hybrid)

TABLE 1.5 Important Cultivars of Different Countries.

Sl. No.	Country	Cultivars
	Australia	Robusta, Williams, Cocos
	Brazil	Robusta, Santa Catarina Silver, Brazilian
	China	Dwarf Cavendish
	Philippines	Common Dwarf, Lakatan
	South Africa	Dwarf Cavendish, Golden Beauty
	Taiwan	Giant Cavendish
	Thailand	Bluggoe, Maricongo, Common Dwarf
	USA	Dwarf Cavendish, Enano Gigante, Giant Cavendish, Ice Cream, Macho, Orinoco, Pisang masak hijau.

TABLE 1.6 Features of Some Important Banana Varieties Grown over the World.

Sl. No.	Cultivar	Important Features
	Cavendish	It is the most common cultivar in Europe, and it is consumed fresh as well as in smoothies, yogurts, and cakes. Also it is used in sweetening savory dish. It develops balanced sweetness and texture when still yellow with green tips
	Creamily Sweet Reds	Red, short, delicate, and sweet fruits with a light raspberry flavor. Extra vitamin C and beta-carotene can be found in cream-colored fruits. Used as snack, in ice cream as a desert or even in savory dishes

TABLE 1.6 *(Continued)*

Sl. No.	Cultivar	Important Features
	Sweet Babies	Since a baby banana is only a one-third the size of a regular banana but exceptional for its immense nutritional richness. It is different from other bananas for its unique taste and texture. Baby bananas can be eaten raw or used in baby food, cakes, smoothies, and other desserts
	Delicately Apple Manzanos ("Apple banana")	Apple flavored sweet banana, lusciously different and a rich source of fiber, potassium, and vitamin C
	Fabulously Fruity Prata	Most popular in Brazil. Yellow-colored bananas are somewhat square shaped with unique taste. It is best to eat it when it is brown and a little sloppy. Taste of the pulp quiet matches with kiwi fruit and citrus
	Grand Naine	Globally accepted variety of Giant Cavendish subgroup with commercial significance and of premier export market. It gets vast acceptability for both dessert and processing purposes. It has a better pulp-to-peel ratio and has more market acceptability. This one is characterized by medium to tall-stemmed herb, with cylindrical stems. Each plant yields about 25 kg and it may attain a level of 32–35 kg in combination of 8–10 hands with 200–220 fruits/bunch in the crop duration of 11–12 months. The fruit measures 15–21 cm in length and 12–13 cm in circumference
	Robusta	This banana plant has a typical stature and brown-black blotches on the stem, having 8–10 hands/bunch with the weight of around 20 kg. Fruits with thick skin are 15–20 cm in length and 11–12 cm in girth
	Red Banana	Synonymous as Lal Kela, Anupam, Chandrabale, Kembale, Chenkadali, Chevvazhai, Yerra Arati, and Agniswar. This common and expensive variety is grown commercially in different parts of South India. This elite banana cultivar gets its fame for its red peeled luscious flesh and distinctive taste. Robust statured plants are ranged 2.5–3.0 m in height. Fruit, pseudostem, petiole, and midrib are purplish red in color and have a good fragrance. Bunches range between 20 and 30 kg with 6–7 hands under optimum crop management conditions with 16–18 cm lengthy 70–90 robust fruits. Problem identified with this variety is its susceptibility to banana bunchy top virus (BBTV), fusarium wilt and nematodes

TABLE 1.6 *(Continued)*

Sl. No.	Cultivar	Important Features
	Poovan	This cultivar is medium statured and ranges 2.7–2.8 m in height. Characteristic green, shiny pseudostem with uneven pink–purple pigmentation makes it visibly different from other cultivars. Leaf is intermediate in habit, medium green colored with small brown–black blotches at the base of petiole. Peduncle is smooth, green and with very short hairs. Fruit borne in cluster of 12–16 fingers in 14–15 hands each. The bunch is densely arranged and weighed about 16–18 kg with 180–210 fruits
	Monthan	Being moderately tall and robust, it can reach a height of 2.5–3.0 m. It carries a bunch of 18–20 kg within 12 months. Male flower of this variety is highly acceptable as vegetables. Considered one of the leading cultivars suitable for processing. The fruits are light green in color and have a valiant, knobbed, sturdy appearance with green peel. It can grow even under marginal condition having good salt tolerance ability. It is resistant to the Banana Bunchy Top Virus (BBTV), but susceptible to Fusarium wilt

1.8 BANANA BREEDING AND CROP IMPROVEMENT

Bananas having diverse germplasms along with remarkable genetic differences traditionally cultivated in different regions all over the world despite their variations in genomic grouping still exist in the same group. Despite the significance of bananas as far as in terms of trade and commerce, there is exceptionally restricted data on the hereditary qualities for its agronomic significant attributes (Loh et al., 2000). In recent times, banana-breeding objectives are fundamentally limited on some significant viewpoints as portrayed by Robinson (1996):

(1) Resistance against black sigatoka, races 4 of Fusarium wilt, burrowing to nematode and weevil borer and furthermore in decreasing the dependence on chemicals.
(2) Increased dwarfness and stability comparative with "Grand Nain."
(3) Drought resistance to diminish dependence on irrigation.
(4) Low temperature resistance (beneath 16°C) for the subtropical regions.

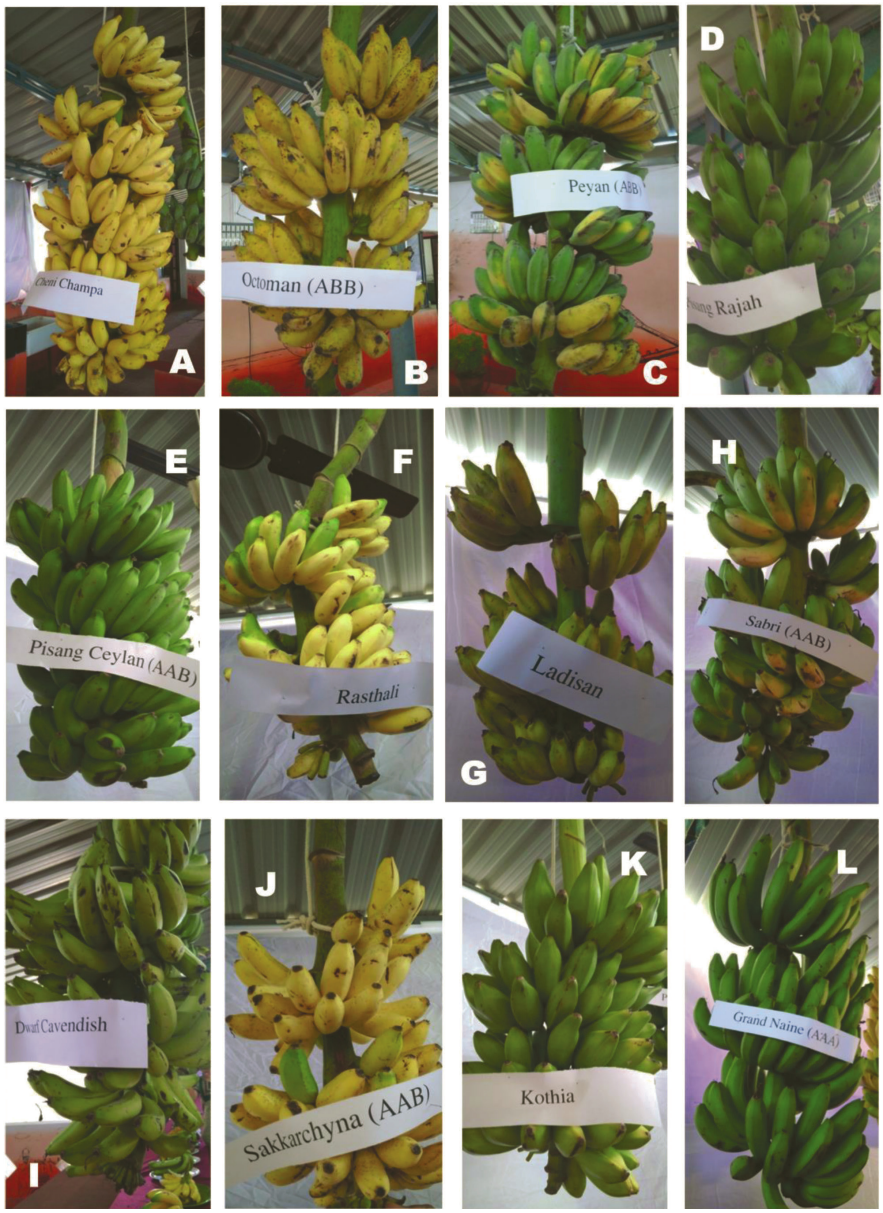

FIGURE 1.1 Glimpses of some important banana varieties. (A) Cheni Champa, (B) Octoman, (C) Peyan, (D) Pisang Rajah, (E) Pisang Ceylan, (F) Rasthali, (G) Ladisan, (H) Sabri, (I) Dwarf Cavendish, (J) Sakkarchyna, (K) Kothia, and (L) Grand Naine.

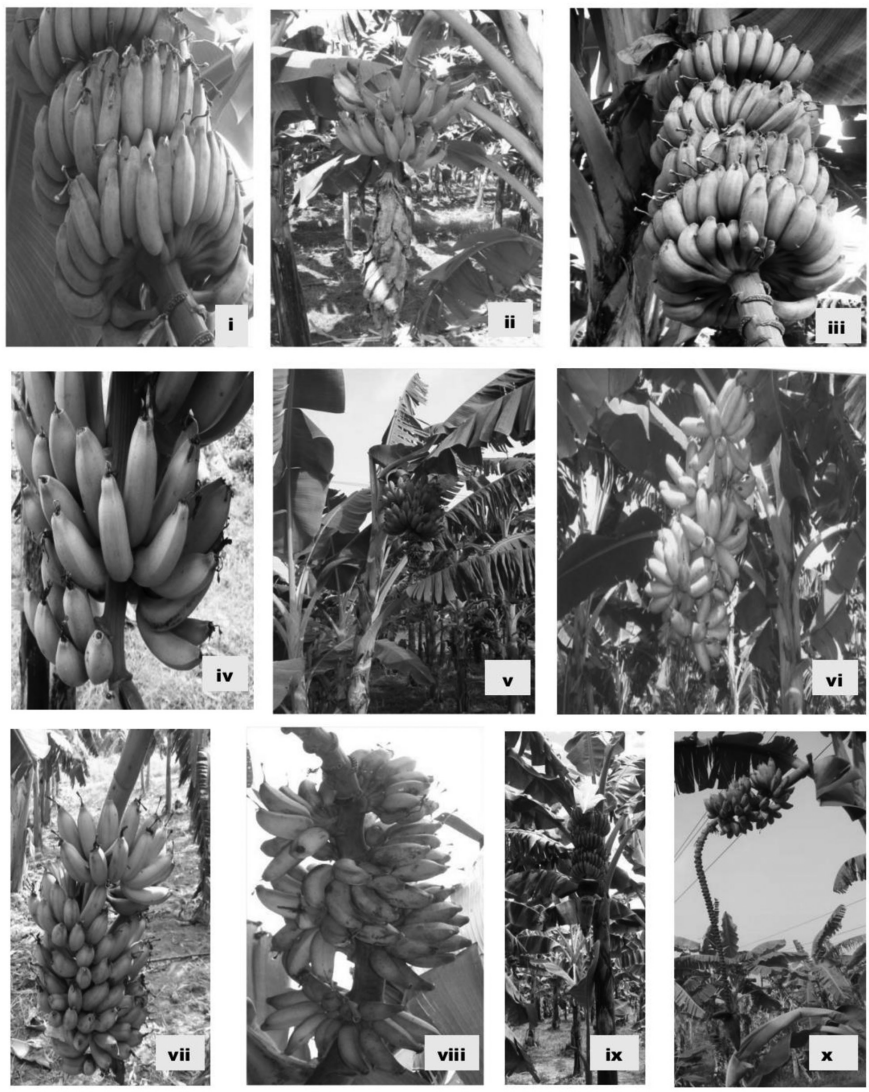

FIGURE 1.2 Characteristic bunch of few important banana cultivars of AAB genomic group grown in India. (i) Poovan, (ii) Nendran; (iii) Champa; (iv) Krishna vazhai; (v) Dudhsagar; (vi) Malbhog; (vii) Martaman; (viii) Chang Monua; (ix) Manohar, and (x) Kanai Bashi.

(5) Yield, harvest index and finger length to be better than "Grand Nain."
(6) Ripening, transport quality, and storability of fruits equivalent to or better than "Grand Naine."

Attempts were made on exotic cultivar assessment and selection at various research institutes working with banana and therefore Popoulu (AAB), Yangambi Km 5 (AAA), Big Ebanga (AAB) selected cultivars were released. Based on the investigation carried out by NRCB, Trichy on three hybrids (FHIA-01, FHIA-03, and FHIA-23) reported that FHIA-01 was substantiated itself as substantially more appropriate for handling alongside high sugar corrosive proportion and low polyphenol oxidation of the pulp which was liable for pulp carmelizing while FHIA-03 had more noteworthy agreeableness as cooking banana (Uma et al., 2006). Unconstrained spontaneous somatic mutants substantial freaks have assumed a critical role in the event of determination of specification (varietal improvement) and domestication of plantain and dessert banana. The wide ranges of bananas as well as the plantains that we cultivate and eat were dominatingly selected in ancient times from unconstrained mutations. From research outcomes it has been reported that more than six mutants have been perceived from the variety Nendran namely, Nana Nendran, Attu Nendran, Moongil, Velathan, Myndoli and Nenu Nendran, etc., while Harichal/Bombay Green, and Pedda Pacha Arati are the semi-tall sport of Dwarf Cavendish. Different examples of other banana mutants are Highate (AAA) and Cocos (AAA) are semi-dwarf mutants of Gros Michel (AAA); Motta Poovan (AAB) is a sport of Poovan (AAB); Ayiranka Rasthah is a sport of Rasthali (or Silk); Barhari Malbhog is a sport of Malbhog (or Silk); Krishna Vazhai is a natural mutant of Virupakshi (or Pome); and Sombrani Monthan (ABB) is a mutant of Monthan (ABB). Hybridization procedure in banana is difficult for its low pollen fertility, complexity in seed set and germination, but tremendous scientific effort and modern breeding techniques help to produce hybrids with three different crossing techniques like:

I. 3N × 2N superior diploids, there is no chromozome decrease in the egg cells in this way yielding tetraploids.
II. 4N reproduced tetraploid hybrids × 2N predominant diploids creating normal triploids
III. 2N meiotic restoring clones × 2N prevalent diploids delivering natural triploids

Another triploid combination namely, NPH-02-01 (AAB) was developed by Krishnamoorthy and Kumar (2005) between the cross of H 201 (AB) ×

Anaikomban (AA) which is not only parthenocarpic pome type yet in addition imperviously resistant to Fusarium wilt (race 1) and nematodes going with attractive yield attributing characters as like better bunch weight (19.00 kg) and hands (11.00).

A fruitful attempt was made by KAU concerning Triploid and Diploid breeding, which prompted to release of two hybrids namely, BRS-1 (Agniswar × Pisang lilin) and BRS-2 (Vannan × Pisang lilin). It has been turned out for homestead cultivation in Kerala as it shows impervious resistant to Sigatoka leaf spot. Significant breeding work at the Fundacian Hondurena de Investigacion Agricola (FHIA) in Honduras is carried out for the development of improved diploids, those are again used as male parents in the crosses with female and fertile triploids for the production of tetraploids (Escalant et al., 2002). Major priority was given to in vitro ploidy breeding program to develop some improved potential diploid cultivars because production of diploid cultivars is not amiable to regular breeding strategies as on account of sterility in any case impervious to numerous stress with a decent yield potential ascribes.

Hamil et al. (1992) achieved enlistment of autotetraploid by utilizing colchicine solution on in-vitro cultured explants of diploid *Musa acuminata* (AA) clone, SH3362. Improvement of commercial triploid cvs. Robusta (AAA), Rasthali Silk (AAB) through sexual hybridization is troublesome as these are female sterile. To resolve the previously mentioned problem, mutation breeding was started in 1995 with such cultivars (Table 1.7). Kumar et al. (2004) detailed the capability of in vitro mutation breeding with cvs. Robusta, Nendran, Poovan, and Rasthali through gamma rays and EMS (ethyl methane sulphonate) and isolated numerous economic mutants.

TABLE 1.7 Putative Mutants Obtained in Banana through Gamma Ray Induction.

Country	Parent Clone	Selected Clone	Selected Traits
Cuba	SH-3436	SH-3436-L 9	Height reduction
	Parecidoal Rey	6.44	Height reduction
Philippines	Lakatan	Lk-40	Height reduction
	Latundan	LT-3	Larger fruit size
Sri Lanka	Embul	Embul-35 Gy	Earliness
IAEA	Grand Naine	GN35-I to GN35-VIII	Tolerant to toxin from *Mycospherella fijiensis*

Somatic hybridization likewise effectively endeavored to tackle the problem of low seed setting in the significant number of the triploid cultivars and diploid crossings during creation of tetraploids. Regenerations of plants by protoplast culture were at first got accomplishment by the Bluggoe (ABB) cultivar (Sagi et al., 1995). Mutation breeding was recommended as a phenomenal elective alternative methodology for banana improvement. Since mutation gives an important valuable source of making variety in plant material, efforts have been made to stimulate it artificially by treating the corms, bits, corm-buds, suckers, and so forth. Lablanc et al. (1995) actuated gynogenesis by irradiating pollen of *M. balbisiana*, *M. ornata*, and *M. becarii*.

Conventional system to characterize banana plants by morphological descriptors has found such countless impediments. Lots of improved assortments/varieties delivered have a complex genealogy which includes several wild species and landraces. Be that as it may, obstructions like immovable treatment, moderate to significant degrees of female sterility, and furthermore triploidy have made the identification of desired cultivars a main point of interest for banana improvement programs (Bhat et al., 1995). In case of developing proficient breeding schemes, extra steady information should be produced on the complex genome structure for hybrids as well as for cultivars. To this end, the characterization of indigenous germplasms will offer an exact method for forming taxonomic, phylogenetic, and heterotic groupings inside the family of Musaceae (Crouch et al., 1998). Cheesman (1948) first recommended that cultivated bananas originated through intra- and interspecific hybridization between two wild diploid species namely, *Musa acuminata* Colla and *Musa balbisiana* Colla, every one of them contributing to the A and B genomes, respectively. The distinguishing proof program of Musa cultivars has generally been based on different combinations of morphological, phenological, and floral criteria. Simmonds and Shepherd (1955) built up a scoring technique typically dependent on 15 diagnostic analytic morphological characters to differentiate *M. acuminata* clones from *M. balbisiana* cultivars and their hybrids into 6 genomic groups. The scientific categorization of developed bananas has for quite some time been an antagonistic issue and in light of the fact that it depends intensely on morphology, the literature shows numerous inconsistencies. For example, in view of molecular data based information, Pillay et al. (2000) recorded that the clones “Monthan Saba” and “Bluggoe” previously classified BBB group based on morphological attributes in any case, later it was demonstrated that really these two clones have a place with the ABB group. Comparative

occasion was found in occurrence of tetraploid "Klue Tiparot" (ABBB) which was again renamed as a triploid ABB (Jenny and Carreel, 1997; Horry et al., 1998). The difficulties related to the utilization of entire plant or botanical morphology have driven researchers to create different procedures for the right identification of Musa species and cultivars. Onguso et al. (2004) revealed that various communities allude to similar nearby cultivars by various names and furthermore absence of clear clonal identity in the crop has brought about unnecessary duplication in cultivation, conservation, and research. But, in recent times, application of modern DNA finger printing techniques is suggested as one of the methods to select banana clones exactly and accurately (Robinson, 1996).

Recommendation made available depicts that different DNA fingerprinting techniques have been utilized as more dependable, reliable alternative choice to study the genetic diversity and scientific classification as well as taxonomy of cultivated bananas which incorporate isozyme investigation (Bhat et al., 1992), restriction fragment length polymorphism (RFLP) (Bhat et al., 1994; Jarret et al., 1992; Kaemmer et al., 1992), rRNA spacer length heterogeneity (Lanaud et al., 1992), inter-simple sequence repeat (ISSR) markers (Godwin et al., 1997), sequence-tagged microsatellite sites (STMS) (Grapin et al., 1998; Kaemmer et al., 1997), and amplified fragment length polymorphism (AFLP) (Loh et al., 2000; Wong et al., 2001). Morphological and molecular characterization of the germplasms is an imperative requisite in the part of making the collection useful from the perspective of plant breeders. According to Nsabimana and Staden (2007) disadvantages of phenotype-based assays can be overcome by direct identification of genotypes with DNA-based markers. Molecular markers have been utilized commonly in Musa genotypes to asses ploidy (Oselebe et al., 2006), phylogenetic relationships (Jain et al., 2007; Nsabimana and Staden, 2007; Uma et al., 2006), and hereditary diversity or somatic diversity because of somaclonal variation (Lakshmanan et al., 2007; Bairu et al., 2006; Ray et al., 2006) or mutation induction (Hautea et al., 2004; Finalet et al., 2000; Toruan-Mathius and Haris, 1999). Polymorphis produced by RAPD analysis has been utilized for fingerprinting as well as classification of the Musa genotype. RAPD markers are typically alluringly liked as the techniques are too simple, extremely clear-cut, multipurpose, adaptable, quite modest, and ready to distinguish minute differences (Williams et al., 1990; Welsh and McClelland, 1990; Howell et al., 1994; Pillay et al., 2000). Linkage of RAPD markers to explicitly specific traits such as disease resistance has been conceivable through this procedure (Damasco et al., 1996) and RAPD-based fingerprinting has

been all the more anxiously, effectively, apprehensively, successfully applied to characterize diverse Musa germplasms (Bhat and Jarret, 1995; Onguso et al., 2004), analysis of Musa breeding populations (Crouch et al., 1999), and furthermore detection of somaclonal variants (Grajal-Martin et al., 1998).

1.9 SOIL AND CLIMATE

Loamy, profound deep friable soil with characteristic of normal drainage and without compaction, is preferred for banana cultivation. Soils with poor permeation, percolation because of abundance of clay, rock, or sand must be avoided. Soils having pH somewhere in the range of 4.5 and 7.5 are vogue, albeit 5.8–6.5 is suggested. Soil textures ranging from sands to heavy clay are utilized. A granular soil structure is liked for better water movement and root development, with high organic matter and fertility guaranteeing significant returns. Most exported bananas are grown on profoundly fertile alluvial loamy top soils. Plantains are likewise best in this kind of soils; however, they will show improvement over the AAA dessert banana in degraded soils. Clearly, the "B" in their genome is liable for this versatility. Soil profundity ought to be around 1.0–1.2 m deep. For better development moist soil with great soil drainage is fundamental; it does not endure standing water. Flooding for 7 days will kill most banana plants (Duarte, 1991). Banana will endure some saltiness: 300–350 mg/L of chlorine and up to 1500 ppm total salts.

Banana accomplished a wide variety during the interaction of development, regarding soil and climatic variation. With regards to world scenario significantly major banana growing territories are lying in between of the Equator and latitudes 20°N and 20°S. Bananas are grown fundamentally in tropical condition; currently it has spread into numerous subtropical environments with gentle winter, with relatively minute temperature variances from day to night and furthermore it proceeds from summer to winter season. The temperature ranging from 15 to 38°C prevails in the vast majority of the banana growing zones with an optimum temperature being ~27°C. The ideal temperature for dry-matter amassing or accumulation and furthermore for fruit ripening is accounted for about 20°C yet for the emergence of new leaves it is recorded about 30°C. Development ceases at 10°C and can lead to "chokethroat" disorders, where inflorescence emergence is hindered and poor fruit development happens. Though banana can survive temperatures under 15°C for short periods but temperatures below 6°C cause serious and

severe harm as well as occurrence of huge damage (Turner, 1994). It has been recorded and demonstrated that the harvest has a high water demand for its appropriate development and about 25 mm/week is viewed as the minimum for acceptable satisfactory growth. It has a good development in territories with 2000–2500 mm yearly precipitation, despite the fact that it can be cultivated easily in the regions with 600–1000 mm yearly rainfall with the assistance of drip irrigation system. Association of several physiological problems observed in colder subtropical environments is chokethroat, winter flower inception (referred colloquially as "November dump" in the southern half of the globe, inseparable from "May bundle" in the northern side of the equator), under peel discoloration (UPD), and growth cessation; these do not happen in the humid tropics. Moreover, the overall lack of wind, dust, storms, hail, or ice in the humid tropics implies that there are not many environment instigated ranch debacles like those much of the time happening in the subtropics (aside from periodic floods and cyclones). This section on specific problems accordingly applies predominantly to banana-developing regions outside the humid tropics (Robinson and Sauco, 2010).

1.10 PROPAGATION

Seeds are generally used in breeding programs. Most of the world preferred cultivars have been confirmed to be female sterile. Suckers are used as planting material for their basal corm or whole corms. A sucker is a lateral shot with a basal corm and a small skewer that comes from the mother corm at the base of a vine. Normally small farmers use sugars or if few plants are required. Their height is difficult for suspenders, which makes it difficult to handle and carry. In comparison, disinfection is also inadequate to prevent the transport of insects, diseases, and nematodes. A young sucker that comes from the ground or a wide sucker with narrow leaves and a large corm is usually planted to the same depth with residual roots, and the excess leaves are cut back.

Banana-exporting companies usually use corms from a plant that has not flowered and grow them in special nursery fields; these corms would weigh 2.5–5 kg. In other instances, 1.6–1.8 m tall sword suckers of 15–20 cm diameters at 20 cm from the soil are used. The suckers are dug out, and 15–20 cm of the pseudostem is held. If propagation material is scarce, large, older corms (bull heads) from flowering plants may be used for planting. Smaller corm bits may also be used. As part of good propagation steps,

pairing of corms to remove dark stains and any sort of root debris is to be done followed by dipping of pared corms in a fungicide, nematicide, and insecticide mixture for 5–20 minutes. A hot water dip at 56–58°C for 15–20 minutes or at 65°C for 12–15 minutes is used by major exporting firms. If pesticides are not available or are not permitted, merely paring the corms will help restrict transfer. Corms for planting should never be left on the field overnight; instead, they should be closely wrapped or transported in a trailer or truck to prevent reinfestation by banana weevil.

1.10.1 IN-VITRO PROPAGATION

Planting material of banana produced following *in vitro* techniques has been used commercially in most countries as a substitute to usual planting material from 1985 onward. In certain Mediterranean and subtropical countries, *in vitro* planting material is now extensively used.

1.10.1.1 ADVANTAGES OF USING IN VITRO PROPAGATED BANANA PLANTS

In case of *in vitro* propagation, 100% establishment rate is found which resulted in that there are no more replacements except somaclonal variants that are discovered after planting. No injury to root system will happen in this system; therefore, steady growth continues immediately after planting. Thus, it has been found that *in vitro* plant will have about 10 functional leaves even prior to their well establishment in field soil. As a result, these types of plants can be established more successfully in the field during each and every month of the year while most of the traditional suckers cannot establish properly during a winter season, and many more deaths occur if planting overlaps with wet summer conditions. *In vitro* plants in bags can be specially chosen for homogeny of size and shape. Uniformity/homogeny in flowering is one of the main characters of these plants and can all be harvested over a very short period making timing of the crop more accurate. Hwang and Ko (1987) opined that *in vitro* plants grow much faster along with larger pseudostems and produce heavier bunches than that of the conventional suckers in first crop cycle. Nematodes, fungal, and bacterial infections are not found in plantlets grown *in vitro*. *In vitro* material, if planted in a treated soil, positively ensures less requirement of use of nematicides and fungicides.

1.11 LAYOUT AND PLANTING

The entire land should be prepared after thorough plowing and leveling done in the month of April–May. Usually, plantation is done in rainy season, that is, in the month of June–July. As well it can be planted in August to November or March to April. Before the plantation the land green manure crops such as dhaincha (*Sesbania aculeata*), cowpea (*Vigna unguiculata*), and others can be cultivated and buried in the soil. The plot must get a minimum of four to six plowing and then subject to weathering for 2 weeks.

Use rotovator or harrow to break the clods and build a fine tilth in the soil. During final land preparation a basal dose of farmyard manure (FYM) should be applied and mixed into the soil. Topsoil mixed with well-decomposed FYM at 10 kg, 250 g of neem cake, and 20 g of carbofuron should be refilled in 45 cm × 45 cm × 45 cm pits. *Azospirillum* and *Phosphobacteria* both are applied in each and every pit with a dose of 20 g of each during planting and after that on 5th month after planting. Pre-emergence weedicide like Fluchloralin at 2 L/ha is sprayed done by a high-volume sprayer. Another alternative method practiced, that is, furrow planting is a form of planting that is done in a row. Depending on the soil strata, the appropriate form, positioning, and depth at which the plant must be planted will be chosen. Before planting Hill Bananas, the jungle must be cleaned and contour stone walls built. Traditionalist banana farmers sow the plant at a high density of 1.5 m 1.5 m; however, plant growth and yields are low due to increased competition for sunlight. The planting distance should be above the range of 2.1 m × 1.5 m in regions such as north India, the coastal belt, and where the humidity is very high and the temperature drops to 5–7°C (Table 1.8).

TABLE 1.8 Standard of Planting Geometry for Different Banana Cultivars.

Varieties	Spacing	Number of Suckers/ha
Grand Naine, Dwarf Cavendish	1.5 m × 1.5 m	4440
Robusta, Nendran	1.8 m 1.8 m	3086
Rasthali, Poovan, Ney Poovan, Karpooravalli, Red Banana, Monthan	2.1 m × 2.1 m	2267
Hill Banana	3.6 m × 3.6 m	771

The planting time plays a pivotal role in banana plantation, so that the time of planting must be adjusted consequently to prevent drought and

high-temperature effect during bunch emergence (i.e., imprecisely 7–8 months after planting).

1.11.1 HIGH-DENSITY PLANTING IN BANANA

High density planting is in a horticultural manner by which plants can be planted in numbers ranging from 4444 to 5555 per hectare, with a yield of 55–60 tons per hectare or even more (Table 1.9). Conventionally, general cultivators used a square or rectangular planting pattern. Planting three suckers per pit for Cavendish varieties at a spacing of 1.8 × 3.6 m (4600 plants per ha) and 2 × 3 m (5000 plants per ha) for Nendran varieties is also practiced.

TABLE 1.9 Comparison between Planting Geometry Followed in Normal and HDP of Important Banana Cultivars.

Varieties	Normal spacing			High density planting		
	Spacing (m)	Population/ ha	Yield (t/ ha)	Spacing (m)	Population/ ha	Yield (t/ ha)
Robusta	1.8 × 1.8	3086	114.36	1.2 × 1.2	6944	174.39
				1.5 × 1.5	4444	145.44
Dwarf Cavendish	1.8 × 1.8	3086	102.34	1.2 × 1.5	5555	166.66
Poovan	1.8 × 1.8	3086	31.50	1.5 × 1.5	4444	37.80

1.12 IRRIGATION

It has been well documented from researches of several scientists that banana plant claims about 900–1200 mm of water in its entire life cycle through natural precipitation (rainfall) as well as from supplementary irrigation. Maintaining optimum moisture level or water retention at all stages of the growth is intensely or severely crucial. But, more crucial thing is to have a good drainage system in banana plantation to remove excess water from the plant's root zone to promote improved growth and productivity. Irrigating the plant every 3–4 days during the hot summer months and every 7–8 days during the cooler months is usually recommended. However, if irrigation is needed during the rainy season, do so; otherwise, do not irrigate cropping land because excessive irrigation or water saturation in the root zone of the

plant can cause root zone congestion or condensation due to the removal of air from soil pores, affecting plant establishment and development. In banana plantations, many methods of irrigation are used, including flood or furrow irrigation, trench irrigation, drip irrigation, and fertilization, each with its own set of benefits and drawbacks. Being a delicious, succulent, evergreen, and shallow rooted crop it requires enormous amount of water for thriving the profitability level up to a stature. Water necessity of banana has been worked out to be 1800–2000 mm for every annum. In all, around 70–75 water systems are allowed to the crop in all its entire life cycle.

Importance and relevance of drip irrigation and mulching techniques has reported to be substantially more beneficial in banana cultivation regarding improvement of water use effectiveness or efficiency. In drip irrigated banana orchard, water is saved up to 58%, maturity advances up to 1 month, and yield expanded by 23–32% which has been verified by a number of scientists (Table 1.10). Next to each other, the drip irrigation likewise empowers effective fertilizer application through the fertigation method. Drip irrigation system might be given in a schedule as like at 15 L/plant/day from the time of planting to fourth month, 20 L/plant/day from fifth month till shooting stage, and 25 L/plant/day from shooting stage to only 15 days preceding harvest. Two sorts/types of drip irrigation system continued in banana are single-line system (pertinent when the planting geometry is followed at 1.5 × 1.5 m spacing and here one horizontal/lateral line and one dripper per plant is used) and double-line system (appropriate when the planting calculation is followed at 1 × 1.5 × 1.8 or 2.1 or 2.4 m spacing as distance between the lines, between two plants, and between two double lines, respectively. Here one lateral and one dripper for two plants are orchestrated).

TABLE 1.10 Drip Irrigation Schedule for Banana.

Sl. No.	Crop growth STAGE	Duration (weeks)	Quantity of water (L/plant)
1.	After planting	1–4	4
2.	Juvenile phase	5–9	8–10
3.	Critical growth stage	10–19	12
4.	Flower bud differentiation stage	20–32	16–20
5.	Shooting stage	33–37	20 and above
6.	Bunch development stage	38–50	20 and above

1.13 NUTRIENT MANAGEMENT

Growth rate of banana is faster than others and it requires generally enormous quantity of nutrients for its higher qualitative yields (Table 1.11). Lahav and Turner (1983) reported, according to assessment, that 50 tons of banana from one hectare of land eliminates 320 kg N, 32 kg P_2O_5, and 925 kg K_2O each and every single year. Application of inorganic fertilizers however increases the yield, probably yet it could not be able to hold up the fertility status of the soil (Bharadwaj and Omanwar, 1994) and have caused a few undesirable consequences and results in the delicate soil eco-system, prompting deliberate decrease in profitability level. In recent times, several researchers directed and suggested coordinated methodology of supplement integrated approach of nutrient management in banana to hasten yield possibility, as RDF100% (200:100:300 g N:P_2O_5:K_2O + 20 kg FYM per plant) + PSB (20 g) + Azospirillum (20 g), as detailed by Pattar et al. (2018). Banana has been found to react well to potash spray provided through muriate of potash (MOP) or potassium dihydrogen phosphate (KH_2PO). The combined impact of these supplements, urea, sulfate of potash (SOP), and cowdung as a post shooting applicant in banana has been evaluated earlier at Indian Institute of Horticulture Research, Bangalore (Adinarayana et al, 2016).

TABLE 1.11 General Fertilizer Recommendations for Orchard Land and Wetland Banana.

Details	N (g/plant)	P (g/plant)	K (g/plant)	Micronutrient
Orchard land				
Varieties other than Nendran	110*	35*	330*	At 3, 5, and 7 months after planting, foliar applications of $ZnSO_4$ (0.5%), $FeSO_4$ (0.2%), $CuSO_4$ (0.2%), and H_3BO_3 (0.1%) help to improve banana yield and efficiency
Nendran	150	90	300	
Wetland				
Nendran	210	35	450	
Rasthali	210	50	390	
Poovan, Robusta	160	50	390	

*Apply 50% more fertilizers to tissue culture bananas at the 2nd, 4th, 6th, and 8th months after planting.

1.13.1 FERTIGATION IN BANANA

Fertigation is the interaction where fertilizers are applied through irrigation system framework. Completely solvent nitrogen and potassium used to feed at the rate of 150 g for every plant is sufficient to meet the nitrogen and potassium for obtaining adequate yield. Use of nitrogen as urea and potassium as muriate of potash (MOP) through this framework system could be profitable. These fertilizers are permeable into the system subsequent to shaping a fertilizer solution in the tank. The fertilizers might be endowed into the system either on a consistent schedule of daily basis or in a customary regular interval of per week and it could be stopped 10–15 days before the harvesting. Several formulations of water-solvent fertilizers are now accessible on the local markets. A very definite determined specified formulation for banana crop indispensably dependent on the crop growth stage can likewise be chosen for fertigation (Table 1.12).

TABLE 1.12 Commonly Followed Weekly Fertigation Schedule for Banana.

Sl. No.	Crop stage	Weeks after Planting	Urea	Total (g/ plant)	MOP	Total (g/ plant)
1.	Establishment stage	9–18 weeks (10 weeks)	15	150	8	80
2.	Vegetative stage	19–30 weeks (12 weeks)	10	120	10	120
3.	Shooting stage	31–40 weeks (10 weeks)	7	70	12	120
4.	Development and harvesting stage	41–46 weeks (5 weeks)	Nil	Nil	10	50
Total			–	340	–	375

1.14 TRAINING AND PRUNING

Training practices to give plants alluring shape is not rehearsed in the case of banana mostly because of its pseudostem-based developing propensity or growth habit and cyclic leaf emergence. Other than the removal of the male inflorescence, no other vegetative pruning is ordinarily followed. Wilted styles and perianths persisting toward the end of the fruit are typically eliminated at the packing station after collection through harvest; however, sometimes these are taken out by hand 8–12 days later of the bunch emergence, to reduce fruit scarring and disease (cigar-end rot). Early evacuation

or removal or expulsion of at least one hand from the distal end of the bunch is politely practiced to expand fruit size by diminishing between finger and hand rivalry. This hand expulsion is done by the export organizations for dessert bananas and plantains to accomplish better calipers (fruit diameter—size) in the remaining fruit. Bunches tumbling from the plant or the entire plant falling over can prompt significant hand damage and can lead to rejection of the affected fruit for trade. Lodging is due to poor corm anchorage, poor planting material, or very large bunches. The issue is decreased if single or double shafts/poles are wedged against the throat of the plant under the curvature of the bunch peduncle or twine guys are stretched out from this equivalent point the other way of the fruit bunch and tied for attachment to bring down positions on close by plants.

1.15 INTERCROPPING AND INTERCULTURAL OPERATION

Intercrops can easily accommodate in the field of the banana plantation at the early stage of growth. Mixed cropping of banana, arecanut, and coconut is generally practiced in some belts, especially in the coastal belts of Tamil Nadu in India. Different types of intercrops like maize, brinjal, colocasia, chillies, turmeric, spinach, bhendi, radish, cabbage, cauliflower can be followed in the banana plantation based on climatic conditions. Banana plays a pivotal role as a shade plant in coffee, cocoa, rubber, young mango, and orange plantation of different parts of the state. For better growth and development of the plant, spade digging should be given at bimonthly intervals and also earthing up should be done periodically. Another thing to do with priority is periodical removal of side suckers at regular interval. The dry and diseased leaves are to be expelled and also burnt to manage the stretch out the severity of leaf spot diseases. Male flowers should be removed 1 week after the opening of the last hand in case of Robusta banana to elude "Cigar end rot." Similarly, flower remains must be removed a week after the last hand's opening. At the flowering stage the plant may be propped. The peduncle should be topped with flag leaf to prevent end rot of main stalk. To protect the plants from sunscald, bunches may also be covered with banana leaves.

1.15.1 DESUCKERING

Evacuation or in terms of removing all of the suckers from the mother plants up to flowering and subsequently keeping only one follower afterward is

the excellent desuckering practice. Desuckering or pruning generally is the practice of removal of unwanted suckers. Here, newly grown suckers have to be cut off or destroyed at their heart position without separating the sucker from the mother one. In some cases, after digging the sucker three to five drops of kerosene is poured into the cavity. Destruction of suckers by using crow bar with a chisel-like end is general practice in South India.

1.15.2 TRASHING

It is the act of expulsion of undesirable material from banana field as dried, diseased, and rotted leaves, pseudo stem after harvest, male bud, last end of inflorescence, and wilted botanical parts especially floral sections.

1.15.3 MATTOCKING

Soon after harvesting of the bunch, the plant stem ought to be cut in stages at any rate following 30–45 days to encourage activation of the supplements basically nutrients from the mother for the growth of ratoon plant. This practice of keeping certain portion of stump about 0.6 m height for nourishment of second-generation crop is generally termed mattocking.

1.15.4 BUNCH COVERING

Covering of the banana bunch isn't just the actual physical protection technique yet additionally it improves the perceptible quality of fruit by advancing skin coloration and diminishing blemishes, anyway it can likewise change the micro-environment for advancement of fruit growth that can have a several gainful beneficial consequences for internal fruit quality. Bunch cover can likewise debase the frequency level of infection, which may arise from insect pest, disease, mechanical damage, sunburn injury to peel, fruit cracking, agrochemical residues on the fruit, and furthermore those sorts of harm brought about by birds (Fig. 1.3). The covering of bunches has now taken place as a huge cultural practice in the arena of commercial banana production. The suggested sort of bunch cover shifts variously as indicated by the natural conditions. Bunch covers specified for banana should have appropriate measurements like made up of low thickness polyethylene (5–40 μm) and are 81.3–91.4 cm wide and of 1–1.5 m long. The slender thin bunch

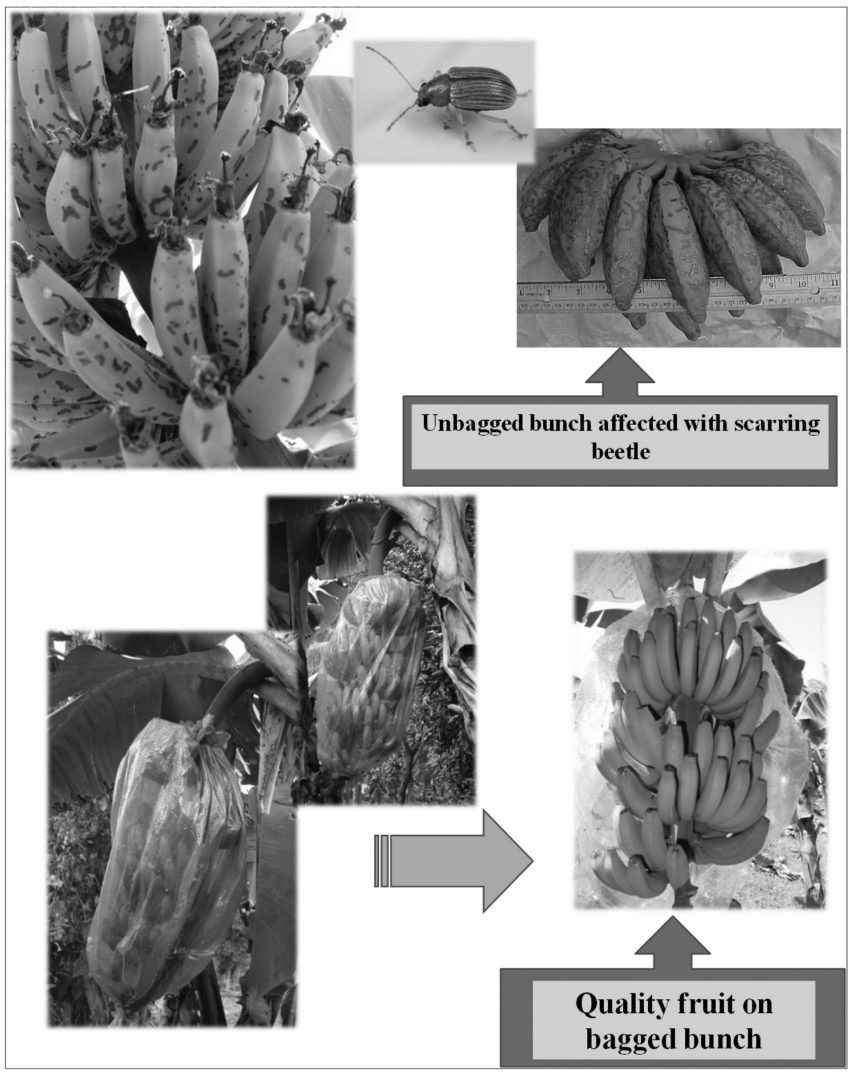

FIGURE 1.3 Difference in resultant banana bunch grown with and without bunch cover.

covers are significantly and logically intended to be utilized just once yet the thicker pack covers can be re-utilized; however, the evacuation cycle of removal process is tedious and it hushes up unwieldy to eliminate it securely without evasion of harming the plastic sheet. Most of the commercially available bunch covers in the market are white colored or translucent blue. Silver-colored plastic may likewise be found in the market which reflects heat (Santosh et al., 2017).

1.15.5 REMOVAL OF MALE BUDS (DENAVELLING)

Removal of male bud after the end of female phase is referred to as "Denavelling" or "Tipping" which aids fruit growth and raises bunch weight. Male buds are taken out from the last one to two small hands with a well put cut together keeping a solitary single finger in the last hand. The infertile male flowers of banana generally protected under reddish scale leaves thus formed a large heart-shaped flower bud, tending to persist even after the fertile blossoms have formed and shaped into a bunch. Along these lines, it is important to eliminate the male bud as and when the bunched is shaped and also formed; or, more than likely it is probably going to go through a portion of the food, which would somehow or another go to the improvement of fruits. This practice is additionally suggested for preventing fingertip disease and thereby improving the appearance of the bunch.

1.15.6 DEHANDLING OF FALSE HANDS OF BUNCH

The incomplete hands of the bunch which are not fit for quality production need to be removed soon after bloom. The false hands are also needed to be removed. Removal of these incomplete hands as well as the false hands helps to improve the weight of the other hands.

1.15.7 PROPPING

Propping is a necessary intercultural operation to give the plant proper shape and size and avoid lodging. It aids in the growth of a bunch in a consistent manner. This could be done by placing bamboos in a triangle against the stem on the leaning direction.

1.15.8 REMOVAL OF FLORAL REMNANTS

The persistent dried floral parts may provide shelter of fungal spores and help in spreading different fungal pathogen, and thus need to be removed from the tip of the fruit or finger.

1.15.9 PEDUNCLE WRAPPING

As peduncle is connected between the developing bunch and the plant for nutrient supplement and water, taking consideration for peduncle is an important activity during the bunch maturation period to evade scorching injury. Immature ripening and falling of bunches is the sign of affected peduncle. Wrapping the peduncle with leaf trash or flag leaf during hot summer days is necessary to avoid the direct effect of heat generated for exposing to scorching sun.

1.15.10 EARTHING UP

Earthing up of banana plantation is done 2–3 months after orchard establishment; it assists with creating uniform establishment of the plant and furthermore assists with dodging water logging at the base of the plant which moreover protects the plant from soil or water-borne infections.

1.15.11 WEEDING

Weed infestation is one of the serious hindrances in banana orchard, periodical weeding is necessary to check the plant weed competition that in return gives optimum productivity of the crop. Application of different pre-emergence and post-emergence herbicides may give better results if manual weeding is not possible. Mulching (jute/plastic) may provide better result to check the weed population as well as to conserve the soil moisture.

1.15.12 REMOVAL OF DEAD LEAVES

Sanitation of orchard is the prerequisite to obtain quality production. As dead leaves serve as a secondary source of infection for different pathogen,

it needs to be ensured to remove all the dead leaves keeping at least 6–8 healthy leaves/plant to ensure maximum bunch development and optimum harvested banana green life.

1.15.13 GROWTH REGULATOR APPLICATION

Application of plant growth regulators (PGRs) like 2,4-D (25 mg/L) during last hand has helped to improve the grade of the bunches. The same spray is also applicable to develop seedless banana in certain varieties like Poovan and CO-1. To increase the yield potentiality CCC @ 1000 ppm at 4th, 6th months after planting and plantozyme @ 2 mL/L at 6th and 8th months after planting may also be recommended.

1.16 FLOWERING AND FRUIT SET

Banana inflorescence starts its development inside the pseudostem and at the end of vegetative stage it comes up as inflorescence from apical meristem, a flattened dome in which the main meristem lies deep inside. Flowering is only possible after the phases of broadening of the apex by both division and expansion of cell. Floral initiation indicates its sign as meristem becomes convex and rises above the surrounding leaf bases. Flower bracts appear as a replacement for leaves. During the initiation of the inflorescence an immense increase in mitotic activity deep in the corpus and thickening of the tunica has happened. As a result of all this activity, finally, we find a stem with elongated internodes, nonencircling bracts in place of encircling sheaths, and a regular system of axillary lateral branches—the flowers (Simmonds, 1966; Stover and Simmonds, 1987). By figure, before floral initiation, the meristem undergoes production of a leaf and a lateral bud (phytomer) every 10 days, but after floral initiation it produces a bract and up to 20 flower initials every 1–2 days.

The axis of the inflorescence, which is terminal on the corm, is located at the distal end of the aerial stalk. Banana inflorescence is typically a raceme or spike comprised of cymose clusters of flowers at nodes enclosed in colored bracts. Three types of flowers are positioned in the same inflorescence in a synchronized way as female flowers are within the basal (proximal) bracts and the male flowers in the apical (distal) bracts; the intermediary clusters or neuters are in transitional position. *Musa* plants are monoecious as they predominantly bear unisexual flowers. Geitonogamous pollination may

take place between inflorescences on the one clump or mat. In the juvenile inflorescence, distinguishing factor for nodes of male and female flowers is characterized by a sharp reduction in ovary length from one node to the next. The principal biochemical processes that ultimately are responsible for the formation of different types of flowers must take place much earlier in the sequence of floral differentiation. Male and female flowers are differentiated on the basis of their ultimate fate as female ovary is larger having a massive style that exceeds the perianth in length, and the stamens are reduced to staminodes whereas in the male flowers the ovary is small and in many cultivars and species they develop an abscission zone at their base and are shed after few days of anthesis. The female flowers are without such abscission zone; however, the style and staminodes may abscise, leaving a calloused scar at the top of the ovary (Stover and Simmonds, 1987).

Depending on genotype, environment, and edaphic condition, the inflorescence bears 1–30 nodes (or hands) of pistillate female flowers, followed by 0–4 hands of neutral flowers or pseudohermaphrodite hands. The remainder of the inflorescence contains staminate flowers, comprising of 150–300 hands. There is a tendency of the apex to produce male flowers continuously long after the female fruits have rotted. Development stops just after the bunch emerges from the top of the pseudostem. It happens in some clones, especially among plantains where the apex is short lived. Exceptionally, the horn plantains are characterized by the absence of male flowers at maturity (Simmonds, 1966; Stover and Simmonds, 1987; Swennen et al., 1995; De Langhe et al., 2005).

Nature of the blossoming upgrade is obscure and stays the subject of significant theory or speculation. It is probably not going to be temperature or photoperiod related, in light of the fact that flowers are initiated in every month all year long in the subtropics, where large temperature and photoperiod gap or fluctuations prevail. Though several conflictions exist, it is presumed that inflorescence can be initiated after the production of 25–50 leaves. There might be a readiness to flower's communication in which the rhizome more likely than not arrived at a basic critical phase of development and a specific "minimum functional leaf area" probably must have been created. The trigger for flower initiation commencement could then be hormonally induced. Recent perceptions (Hernández et al., 2008) demonstrate a buildup of gibberellic acid (GA_3) in the rhizome after emission of leaf 21 (flower inception at leaf 27) on plantain (AAB cv. Hartón). This may demonstrate a job of GA_3 in the cycles of meristematic change and genuine stem elongation; however, this hypothesis actually must be tried and

confirmed. In a new report by Chaurasia et al. (2017) on cvs. Stupendous Nain (AAA genotype) and Hill banana (AAB genotype), it was conceivable to confine the 12 FLOWERING LOCUS T (FT) and two TWIN SISTER OF FT (TSF). This study likewise proposes the expression at any rate of three genes in particular MaFT1, MaFT2, and MaFT5 (and somewhat MaFT7) elevates only before the inception of flowering. These four genes and five others (MaFT3, MaFT4, MaFT8, MaFT12, and MaTSF1) could restrain the deferred flowering imperfectionally defect in the Arabidopsis ft-10 mutant and responsible for actuating early flowering upon over-articulation in the Col-0 ecotype. Connections of relationship of banana FTs vis-à-vis Arabidopsis may likewise be executed through the clues got from the inconspicuous stuble amino acid changes in these FT/TSF-like proteins. Several extraordinary data of this study encourage researchers to work regarding flowering regulation in banana by improved resource management and to decrease misfortunate losses through abiotic stresses and advocated supporting banana flowering is directed by a minimum of three homologues of FLOWERING LOCUS T.

1.16.1 POLLINATION

About 4000 pollen grains are needed to cover the stigmatic surface of the female flower for effective pollination (Dodds, 1945), which is roughly about 20–40 times of the ovules in an ovary. The pollen tubes transverse the entire length of the style after 12 h of pollination. The length of the style is 30 mm, so the rate of development is 0.33 mm/h. Via the micropyle, the pollen tube joins the ovule. The styles abscise about 30 h following the maturation of their receptive surfaces. Fertilization must be done within 24 h of flower opening because after this stipulated time period flowers start to crumble.

1.16.2 POLLEN GERMINATION

Till now, little information is available regarding banana pollen germination. In India, pollen germination of 18 tetraploid (AABB) banana hybrids in in vitro condition was carried out by Krishnamoorthy and Kumar (2005) and their findings concluded that 4–17% germination was noted; however, 84% pollen germination was found in diploid banana (Nyine and Pillay, 2007) in Uganda. Percent germination of pollen is not related to the pollen production

of the plant; thus, amount of germinable pollens could not be predicted based on the amount of pollen production.

1.16.3 POLLINATORS

Several pollinators are associated with banana pollination. Though bird and bats are the key pollinators but several other pollinators are also associated with it which includes tree shrews (*Tupaia* sp.) and bees (*Trigona* sp.). In *Musa* spp. the male flowers have shorter flowering time than female flowers and as bananas produce flowers throughout the year, vertebrate pollinators are attracted by them easily. The timing of anthesis and the crest nectar production by flowers are steady with pollinators being present during the daytime (birds) or at night hours (bats). Seed set in *Musa acuminata* ssp. *halabanensis* (chiropterophily) and *Musa salaccensis* (ornithophily) was pollinator limited (Itino et al., 1991). Equal pollination by birds and bats was noted in *Musa itinerans* in southern China (Liu et al., 2002).

1.16.4 FRUIT SET

The banana fruit can be characterized botanically by a berry, but is produced from a lower ovary. This epidermis and aerenchym coating is created from the exocarp, the mesocarp contains the pulp and the endocarp is contiguous to the ovary cavity and is limited to the inner epithel. For the growth of fruit, pollination is important in wild grain bananas, where mature fruit has an overall black seed surrounded by sweet pulp from ovary and septa areas. It is unlikely to grow seeded bananas if they are shielded from pollination. On the other side, the vegetative parthenocarpy means edible bananas produce where there is no pollination to grow the mass of edible pulp. The ovarian cavity has three locules. Pollen sterility is caused by triploidy and at least three complementary mainstream genes and modifier genes have resulted in female sterility. These sterility genes have been selected for fruit edibility in wild populations.

In banana, ovules are increased by 50% of their initial size within first fortnight after anthesis, and after that they gradually shrink and growth of ovary reduces. In some instances, fruit growth in parthenocarpic bananas with seeds (“Pisang Awak” ABB) has also been observed and it may be due to the stimulus of developing seeds, whereas report is also available on fruit growth only for stimulus of pollination even without development of seed

(Israeli and Lahav, 1986). There are periclinal and anticlinal divisions from about a month and a half (6 weeks) before inflorescence emergence (anthesis) to about a month (4 weeks) after emergence. This division is followed by cell expansion for about 4–12 weeks after rise. Skin mass increases quickly in the initial 40 days in the wake of blooming, with the fruit pulp not starting to create until day 40. Starch amassing parallels finger length and diameter measurement increases (Lodh et al., 1971). The fruit takes 85–110 and 210 days from inflorescence emergence for maturity in the tropics and in the cooler subtropics or under overcast conditions, respectively.

1.17 RIPENING, FRUIT GROWTH, AND DEVELOPMENT

The life span of a banana during its green state is limited to the time between harvest and the visible phase of the respiratory climacteric cycle. From the commercial perspective, main consideration ought to be paid to drag out this period as far as might be feasible and this is accomplished from various perspectives like harvesting at early stage of fruit maturity, providing transportation facility of low temperature control (13°C). It is also possible to increase the preclimacteric phase by hormone therapy (gibberellin) or by storage in a modified/controlled environment (CA) as well as ethylene scrubbing. The respiratory peak (climacteric) is recognized by quick O_2 take-up and CO_2 evolution to a greatest pace of 250 mg CO_2 kg/h from a preclimacteric low of around 30 mg CO_2. Presumption of time prerequisite to touch the pinnacle of preclimacteric state is certainly not a single factor subordinate phenomenon, rather it relies upon temperature, humidity, and ethylene concentration. It is evidenced from different findings that the acceleration of ripening process takes place when the respiratory maximum is attained, whereas the respiration rate diminishes progressively to attain at zero at the physiological demise of the fruit. Once started or just initiated, the climacteric is irreversible.

1.17.1 RIPENING PHYSIOLOGY

Ripening of any fruit is a resultant of several physiological processes. During progression of fruit maturity several conspicuous changes take place concurrently and ultimately make the fruit a ripe one. Out of so many physiological changes, tissue softening commences first in the ripening process, when starch is converted into sugars in both the pulp and the peel, causing

the strength of the cell walls to decrease, cracks to form, and the cells to collapse and degenerate. Furthermore, elevated concentrations of soluble pectic polysaccharides and uronic acid, as well as their associated enzyme activities, are seen. Color changes in the peel of the fruit from dark green to light green and afterward to yellow as chlorophyll is separated or broken down. In course of color change, the pulp becomes more soft and sweet as concentration of sugars tends to be in higher site than starch and in this phase a characteristic aroma developed. All these changes are dependent on several numbers of enzymes. Finally, due to progression of ripening process, the peel becomes spotted brown colored and afterward totally brown colored and the pulp loses its firmness, white surface to get brown colored and thick geltinous.

There is a color graph for ripening bananas in the retail trade that contains seven stages. Here, “Stage 1” denotes hard green organic product with starch content of significant level and “Stage 7” marks delicate yellow fruit with brown-colored specks and high sugar content. The term of “green life” compares to the shading Stage 1 to the furthest limit of Stage 3, though the span of “shelf life of realistic usability” relates to the color Stage 4 (natural product more yellowish than green) to an extended limit of Stage 7. This, thus, relies upon capacity temperature and infectious like disease prevention.

1.17.2 ARTIFICIAL RIPENING

If mature banana fruits are allowed to ripen naturally these will ultimately soften and most of the cases develop dull and unattractive peel. To solve these problems of natural ripening, in commercial aspect bananas are subjected to artificial ripening treatment with exogenous ethylene. These also additionally serve the purpose to get a firm pulp texture, good flavor, bright yellow peel color, and uniform ripening. In recent times, banana traders' expertise was used in ripening the banana in closed chambers with air renewal/recharging, controlled temperature and moistness, ethylene injectors, and outfitted with specialized devices for observing and measuring CO_2, temperature, and relative humidity. The ripening interaction comprises three phases, that is, (i) temperature increase, (ii) ethylene infusion, and (iii) ventilation while diminishing temperature. At a convergence of 1000 ppm and at the optimal beginning temperature, ethylene gas is administered to green fruit. After that, the rooms are fixed for 24 h before the doors are opened, air is re-established/ renewed, and the rooms are ventilated day by day to remove CO_2 that has been collected during the ripening cycle, while temperatures are gradually

dropped. When the fruits reach color Stage 4, the pulp temperature should be at 13–14°C, and the fruits are removed from the chamber. During the whole ripening phase, relative mugginess should be maintained at 95%.

1.18 HARVESTING AND YIELD

After passes through the development and maturation stages, fruits of banana enter into the ripening stage where special experience and care should be needed to judge the optimum harvesting stage. After harvesting if the bunches are handled carefully and transported to the market safely with modern packaging, there is an obvious opportunity for premium return. So, harvesting of banana bunches at optimum stage, proper handling during transport, optimum packaging, and good storage facility are prerequisite to safe disposal of fruit in market.

1.18.1 FRUIT MATURITY STANDARDS

Principles of fruit maturity rely upon a few components like cultivar, agro-ecological circumstance of grouping spot, distance of transport, inclination of the customer, and so on. For instance, fruit could be harvested at completely mature stage for immediate ripening and local business. For on-location showcasing or short-distance transport of green fruit, 90% of complete maturity might be used, whereas 75% maturity is commonly used for medium-distance delivery by truck. Exporters and growers judged the 75% maturity with characteristic "3/4 round" finger, that is fingers still having articulated ridges but with convex planes between them. Banana bunches of under 75% maturity are liked for significant distance transport by ship. This strategically techniques of maturity judgment verifications is required as permitting fruit to get over matured during warm climate can lead untimely premature ripening during transport. Similarly, too soon or early harvesting of immature bunch in cool climate can lead to a few kilograms loss of bunch weight and expanded maturity as well as ripening necessities. Among the developed and tested approaches to determine the optimal harvest stage, majorities are ruinous, harmful, unfeasible, impractical, or subjective. As an example, consider the pulp-to-peel ratio, and an immovability firmless index of fruit skin. Till date the "3/4 round" index continued in numerous subtropical nations is sealed good for the nearby market shipment; however, it is difficult to keep up its precision accuracy and consistency. Be that as it

may, the most adequate functional and target strategy for normalizing harvest maturity is with a mix of phenology (expected bloom rise to harvest duration span (E–H)), shaded strips, and caliper estimation of finger diameter measurement. This strategical methodology, first rehearsed in global organization manors of Central America, is presently regular in many locales where fruits go to top notch trade markets or export market. Bunch coverings made up of colored polyethylene strip or woolen thread are placed 14 days after flowering, affixed to the peduncle. Every week another color tone is utilized on new blossoms, at that point, following 2 months, the shading succession is rehashed. The main benefit of this procedure is that week-by-week bloom checks can be made dependent on the quantity of labels utilized, and these tallies structure the premise of yield anticipating. Second, harvest control and arranging plans are made simpler. In the tropics, normal E–H ranges between 98 and 115 days (Stover, 1979). As a result, 91 days after flowering during the hottest season, bunches with the matching precise color code are tested with a caliper for harvest maturity (finger diameter), and a few of bunches may be cut. As top hands mature snappier than basal hands, caliper estimation is constantly made on the center finger of the external whorl of the second hand to have a normalized standard estimation. As indicated by proper color accomplishment of bunches, consecutive cutting of bunches will be done at 98 and 105 days. Further, the selected bunch as indicated by colored code is checked with the caliper estimation that should be in the range of 31 and 41 mm. During fruit development period, when the cool environment prevails the main caliper estimation might be done following 105 days because of a more extended E–H. Regarding market inclination, the USA market favors marginally more full fruit than the European market, inside the 31–41 mm caliper range.

Another opinion on harvest index fixation by Ganry (1978) stated that prediction of harvest date might be done with the help of calculating "total daily temperature" (TDT) only if we nullify the possibility of occurrence of edaphic and phytopathological constraints. For Cavendish cultivars, TDT is calculated using a 14°C threshold, which is the growth limit of lowest mean daily temperature. TDT is calculated following the given equation:

$$\text{TDT} = \sum [(\text{daily } T\text{max} + \text{daily } T\text{min}/2) - 14$$

where T_{max} = maximum temperature and T_{min} = minimum temperature, for a given day, respectively.

According to findings of several experiments, a TDT temperature of 900°C (measured from the first female hand open to the emergence stage)

is optimal for banana bunch harvesting (three-quarters round stage with a 34-mm caliper measurement), whereas TDT of 1200°C is used as an indicator for the full round stage. In France and West Indies, farmers practice both TDT and caliper measurement for more accuracy (Lassoudiere, 2007). Flawlessness or precision of the TDT relies on the use of a sophisticated digital thermometer or temperature sensor, as well as a weather instrument shelter/cover (Ganry and Chillet, 2009).

In Indian conditions, banana bunches usually take 90–120 days to develop after shoot initiation though a clear difference on time requirement exists for tall and dwarf cultivars for harvesting the bunch after planting; it is 14–16 months and 11–14 months for the first and second categories, respectively. For commercial dessert bananas all through the world, the harvest strategy follows a comparable method example, with minor variations. Exportable bananas like Grand Naine, Cavendish have yield potentiality in the range from 50 to 100 t/ha, though these cultivars generally produce 65–70 t/ha. Otherwise, yield of banana varies in a wide range for difference in cultivars and area of production.

1.19 PACKAGING AND TRANSPORT

First-grade bananas are packed into cardboard containers as entire hands, bunches or singles, and the stuffed container mass can range from 12 to 18 kg, contingent upon nations and markets. In India, CFB solid boxes with 13-kg limit are ordinarily utilized in banana transportation. Containers like cartons should be comprised of required determination of which power-bearing capacity of palletization and arrangement of ventilation to keep a uniform temperature during refrigerated shipment is cared most. Packaging of hands or bunches ought to be done in a perfect, normal example to lessen development and scraping; hence, containers should be full yet not overfull. Cushioning pads (as a rule of general that kraft paper or plastic) are embedded to ensure protection of fruits in between the concerned rows. Polyethylene film liners are regularly utilized in export fruit containers like cartons to limit water misfortune and to give a protected safeguard from scraped area harm during transport. To remove oxygen, air may also be sucked out from the liner. Banana export markets in the EU are particularly demanding in terms of fresh fruit use. EU Directive 2257/94 (EURlex, 2010) is carefully followed with respect to fruit quality, presentation, and stamping, for Cavendish bananas imported to EU markets.

1.19.1 TRANSPORTATION

In major banana-exporting countries, refrigerated trucks are generally used to transport fruit to ships, where pallets are carried to refrigerated holds. Refrigerated transportation is fundamental to keep green fruit from starting the ripening interaction before landing in the destination. Fruits ought to be set into the cold chain inside 24 h of harvesting (generally called the "cut to cool" period), yet the compelling outcomes acquired on the off chance that it is finished within 8 h time span. As concern the varietal reaction, it was seen that 13–14°C is ideal to forestall ripening without causing chilling injury for Cavendish bananas, and 10–12°C might be better for bananas of the "Prata" subgroup. Evidently, the B genome provides better cold resistance both in the field and during transit (Lichtemberg, 2001). Reestablishment of air to dodge ethylene accumulation is fundamental during transport. The recommended rate of air renewal is 30 times the capacity of the container/h (Lassoudiere, 2007). Prior to stacking the refrigerated container (reefer), ventilation and refrigeration should be started. Reefers ought to likewise be stacked in the boats as fast as these could really be expected. While stacking the boat, just as during ocean transport, temperature and ventilation levels should be looked after effectively. On landing in their destiny, palletized containers are quickly moved by street to ripening rooms and afterward to the wholesale dispersing specialist agents in America and Europe or somewhere else.

1.20 POSTHARVEST HANDLING AND STORAGE

1.20.1 DEHANDLING

Dehandling is a process of making a gentle cut close to the stem with the help of clean and sharp banana knife. Not long after dehandling, the fruits are put with the crown confronting topsy-turvy onto a leafy layer for depleting the latex. To prevent the occurrence of crown disease, the hands are dipped in 0.1% solution of Benlate or Thiabendazole.

1.20.2 STOWING

Stowing is characterized as a course of action of banana packs in columns with the cut closures of pedicle confronting upward, expected to clear the spread of microbes conveyed from field in inactive condition or pervasive

under nearby local condition of storage. For the most part Stowing is carried out at two phases, first not long after harvest bunches are restowed in the field over a bed made of banana leaves and afterward they remain stowed in this condition still it is prepared for shipment in a carriage. This process of stowing is also recommended to follow even in transport and at the wholesalers' godown ahead of conveying to ripening room.

1.20.3 ARRANGEMENT OF PACKING

Horizontal arrangement of fruits in the box is made, ideally, in two rows, with the crown end facing the box side and the fruit tips facing the middle of the box, which is said to be the safest place for safe shipping. However, for single-layer packaging, it is best to keep the hands upright by holding the tips up and the crown down. In advanced state of packing to create modified atmosphere inside the box, practice of using cushioning pads or kraft paper at box's bottom and covering of fruit with LDPE liner of 100 gauges should be followed.

1.20.4 PRECOOLING

Precooling assumes a huge part in expanding the storage life of the fruits, where the fruit is bound for the distant and export market. Following bunch harvesting within 10–12 h precooling of the produce ought to be done. Followed by precooling, bunches are subjected to forced air cooling for 6–8 h to bring back the fruit pulp temperature to 13°C from 30–35°C field temperature, at 85–90% RH. For storing reasons the crates ought to be promptly/immediately moved to cold rooms where the shelf-life of the produce could be expanded.

1.20.5 STORAGE

Guaranteeing the rules identified with harvest maturity of bananas could be exported effectively via ocean shipment. To accomplish this, storage conditions of 13°C and 85–95% relative humidity should be given. Failure of maintaining the storage temperature below 13°C leads to chilling injury followed by surface discoloration, dull color, uneven ripening, and browning of flesh of the fruit. Contingent upon the kind of cultivars, storage life at 13°C differs from 3 to 4 weeks or about a month. Low-temperature storage

combined with controlled environment storage shows correlative and complementary benefit for further extension of storage life. By keeping up proper controlled atmosphere storage condition of 5% O_2 + 5% CO_2 at 12°C to 13°C fruits of banana (cv. Robusta) could be stored for almost 2 months, in a green, unripe state.

1.20.6 RIPENING ROOM

To ensure proper ripening, green bananas are first placed into boxes or cushioned plastic crates at the optimal temperature. Any change in the prescribed temperature will harm the fruit during the forced ripening period. The ripening space should be locked, sealed, and airtight, with temperatures ranging from 16 to 180°C and humidity levels ranging from 85% to 90%. The temperature in the ripening chamber is regulated and managed using a thermostat. The ripening room should be supplied with ethylene gas at a concentration of 100 ppm (0.01%). Ethylene acts as a catalyst in the ripening process, kicking off the hormonal process needed for ripening. After 24 h, the ventilation port of the room should be opened to clear the ethylene gas and carbon dioxide emitted during the initial ripening process. After a closed 24 h treatment, the temperature of the ripening drops to 18°C and then steadily drops to 15°C for 3–4 days.

1.21 PROCESSING AND VALUE ADDITION

Bananas and plantains are cultivated in over 130 countries worldwide (in both tropics and subtropics); among them in some of the countries it is considered staple food crops. Countries such as India, Uganda, Brazil, and China, where bananas are consumed locally, do not have significant export opportunities (Pillay and Tripathi, 2007), but they experience huge loss due to improper storage and other marketing-related problems. There exists the opportunity to go for processing and value addition to tackle the postharvest loses. Among different processing options, most recent and must adopting technology may be the production of flour from ripe and unripe fruits and to mix the flour into various innovative processed products such as fiber-rich bread (Juarez-Garcia et al., 2006), cookies that can be digested easily (Aparicio-Saguilan et al., 2007), and fruit's edible films (Sothornvit and Pitak, 2007).

One of the most preferred by-products obtained from banana and plantain is chips which has a widespread acceptability in many banana-growing

countries. In Bangladesh many fast food outlets use chips as their most popular snacks (Molla et al., 2009) and in Nigeria also banana chips get immense popularity (Onyejegbu and Olorunda, 1995). Aseptic canning is used to treat puree derived from ripe fruits of all banana varieties in which peeling, homogenization, centrifugation, air exhaustion, and lastly sterilization are the sequential steps to be carried out. After sterilization, the puree is packaged without contamination into vacuum-sterilized cans that are sealed in a steam environment (Sole, 1996, 2005).

Another by-product resulting from fully ripe banana pulp is banana powder. Pulp is conveyed through a colloidal mill which converts the pulp into a finely grinded paste. To enhance the color of the final product an addition of approximately 1–2% potassium meta-bisulfite solution is advocated. Lastly, the solid recovery is performed through spray or drum drying of finely grinded pulp paste.

Nowadays banana figs as a means of processed product gained huge consumer acceptability and are considered one of the best means of prolonging shelf life of banana. These banana figs were dried or dehydrated pulp having a fig-like sticky consistency and in taste it is on sweeter side. Originally, banana figs were created by sun drying in the tropics; recently hot air circulation in tunnel or cabinet dryers came up as the best means of drying.

Banana flakes and purees are looking similar, but the flakes are prepared by drying the puree in large chrome-plated drum dryers. Among beverages wine, juice, etc. are also processed as value-added products. Bananas and plantains are commonly used as high-fiber sources, with the majority of the fiber concentrated in the dried petioles and leaf sheaths that comprise the pseudostem. Fiber yield ranges from 0.6% to 1.0% depending on the cultivar and method of extraction (Uma et al., 2002). In the main banana-producing countries, the production of starch from discarded bananas generates income side by side creating huge employment possibilities (Zhang et al., 2005). Unripe bananas are rich sources of starch and it quantifies up to 70–80% of its total dry weight (Guilbot and Mercier, 1985; Waliszewski et al., 2003). The starch content of banana is in equivalent range with the endosperm of corn and the flesh of white potato.

1.22 PEST, DISEASE, AND PHYSIOLOGICAL DISORDERS

Banana and plantain are vulnerable to a large extent of insect pests and pathogens. Some insect pests and pathogens are a bit serious and epidemic that can easily spread with the planting materials. After establishment, these

remain persistent and practically difficult to manage. There are several insect pests causing injury to the banana plants at various developmental periods of plant growth, thus reducing the yield potential of successful banana cultivation. Worldwide most prevalent pest and diseases of banana are described in the following tables along with their characteristic symptoms and remedial measure (Table 1.13 and 1.14).

TABLE 1.13 Important Insects of Banana with Their Effective Control Measures.

Pest	Characteristic symptoms	Management	References
Banana rhizome weevil (*Cosmopolites sordidus* Germar)	Larvae of the weevil first start its activity on damaging the rhizome and occasionally the pseudo stem. After hatching, the grubs bore into the rhizome by making tunnels where pupation occurs. During monsoon, plants become weak, ultimately rot and fall down	Addition of cover crop, inclusion of fallow in rotation sequences, mass trapping, use of biological control agents beside sucker treatment, and spraying and drenching around the base of the tree with Chlorpyriphos 20 EC (FP 2.5 mL/L) are the effective measures to control this pest	Gold et al. (2001), Tinzaara et al. (2005)
Giant banana stem borer *Castniomera humboldti* Boisduval and The banana stem weevil *Odoiporus longicollis* Olivier (quarantine pest of Australia)	Stem borer prefers to attack growing tip and kills seedlings and used to tunnel into standing corms and thus damages the corm tissue. Adult stem borer have characteristic nature of feeding on stem and suckers during night while remaining hidden during daytime. Plants that have been infected by the stem borer grow weak and finally decay	Avoidance of infested banana suckers; destruction of places and structure made by the adult borers to hide or shelter; use of borer-resistant varieties like Basrai, Chitti, Kadali, Kunnan, Poovan, Poomkali, Sawaii, etc. for commercial cultivation; sucker treatment with Quinalphos emulsion (0.1%) or Chloropyriphos solution (0.05%) prior to planting and spraying of dimethoate 30 EC or Fenitrothion 50 EC @ 5 mL in 10 L of water around the base of the seedlings are some of the best integrated approach to escape weevil/borer problem in banana	Pinese (1999), Shankar et al. (2016)