PROCEEDINGS

International Symposium on Tropical Fruits (ISTF2017)

"Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruit Industry"

23-25 October 2017, Nadi, Fiji

Edited by:
Christian Anthony Cangao
Dorothy Chandrabalan
Arifurrahman Rusman

FIJI INSTITUTE OF AGRICULTURAL SCIENCE

PROCEEDINGS

International Symposium on Tropical Fruits (ISTF2017)

"Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruit Industry"

23-25 October 2017, Nadi, Fiji

Edited by:
Christian Anthony Cangao
Dorothy Chandrabalan
Arifurrahman Rusman

Symposium organizers:
Ministry of Agriculture, Fiji
International Tropical Fruits Network (TFNet)
Fiji Institute of Agricultural Science

Supported by:
Food and Agriculture Organization of the United Nations

All reasonable efforts have been taken in the compilation and editing of the materials presented in this document. The views expressed herein are those of the presenters, panelists, and facilitators, and not necessarily those of the International Tropical Fruits Network (TFNet) and its members. Any companies, products from manufacturers, and technologies mentioned do not imply the endorsement or recommendation by TFNet.

eISBN 978-983-2532-05-7

Published by:
International Tropical Fruits Network (TFNet)
Box 334, UPM Post Office,
43400 Serdang, Selangor,
Malaysia.
Tel: 603-89416589
Fax: 603-89416591
Website: www.itfnet.org
E-mail: info@itfnet.org

TABLE OF CONTENTS

PREFACE

Following the 2030 Agenda for Sustainable Development, countries have increasingly made commitments towards achieving the Sustainable Development Goals (SDGs). The rise in population and affluence translates to a rise in the demand for well-balanced diets and the need for nutritious food to be made available and accessible to all levels of society for the attainment of food security. Tropical fruits have been well documented to be reliable sources of food, nutrition, and income generation; and the tropical fruit industry has seen an upward market trend in global demand for its production.

However, the tropical fruit industry is facing unprecedented threats due to climate change. The challenge of sustainably intensifying tropical fruit production while improving resilience and reducing vulnerability to the impacts of climate change remains a priority for tropical fruit growing countries. This requires innovative interventions in terms of research, market, and policy coupled with pragmatic actions to be more sustainable and productive.

The 2017 International Symposium on Tropical Fruits (ISTF2017) was a step forward in achieving these SDGs, organized by the International Tropical Fruits Network (TFNet), Ministry of Agriculture Fiji, and Fiji Institute of Agricultural Science with the support of the Food and Agriculture Organization of the United Nations (FAO). Bearing the theme "Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruits," ISTF2017 aimed to provide a platform to discuss the contributions of research and development, the private sector, and policy makers to tropical fruit production and food security in the face of climate change. Specifically, it aimed to:

1. Assemble the latest scientific research, technology developments, best practices, and product innovations that support the transformation of the tropical fruit industry to be resilient to climate change;
2. Discuss how the latest research can contribute towards the adaptation and mitigation of the effects of climate change on tropical fruits;
3. Assess present and future marketing opportunities of tropical fruits;
4. Discuss policies that support the growth and transformation of the tropical fruit industry; and
5. Provide a venue for information sharing among participants from different countries.

The symposium ran for two and a half days, beginning with a keynote presentation by Pascal Liu, Team Leader of FAO's International Investment and Tropical Fruits Team. The keynote was followed by twenty technical presentations divided into five major themes: climate change impacts, adaptation, and mitigation; crop protection and pest and disease management; crop diversification, varietal improvement, and biotechnology; postharvest, product development, and utilization; and farmer support, extension, and policy interventions.

During the wrap-up session, it was concluded that there is a need to incorporate natural disasters into business plans, strategies, and policies. The capacity of farmers to develop production systems that are resilient to climate change should also be strengthened. Lastly, development initiatives should exercise the spirit of *kotahitanga* or "coming together as one" at the local, national, regional, and international levels.

ACKNOWLEDGEMENTS

The 2017 International Symposium on Tropical and Subtropical Fruits (ISTF2017) would not have been possible without the dedicated support and commitment of many individuals.

First and foremost, we would like to thank the Fijian Ministry of Agriculture (MOA) under the guidance of the Honourable Minister Inia Seruiratu. As host, MOA Fiji's heartwarming hospitality and generous funding was vital in the organisation of the Symposium.

We would like to extend our gratitude to the organizing committee chaired by Mr. Jitendra Singh, Permanent Secretary of the Fijian Ministry of Agriculture and co-chaired by Dr. Mohd. Desa Hassim, Chief Executive Officer of the International Tropical Fruits Network (TFNet). A special thank you to Mr. Shalendra Prasad, President of the Fiji Institute of Agriculture Science, as the hardworking point person for the logistics of the event. Other valuable members of the committee from MOA Fiji were Dr. Apaitia Macanawai, Mr. Manoa Iranacola, Ms. Sufuawana Hussein, Ms. Aradhana Deesh, Ms. Olimaipa Tavo, Mr. Shalendra Reddy, Mr. Ajinendra Praneel Pratap, Mr. Jope Waqabaca, and Ms. Diana Nabou. Members of the committee from TFNet were Ms. Dorothy Chandrabalan, Mr. Arifurrahman Rusman, Mr. Christian Anthony T. Cangao, Ms. Hariyatul Asni Abdul Rani, and Ms. Noor Ba'ah Abdol Said. Thank you to the students of Sabeto Sangam School for performing the Fijian National Anthem during the opening ceremony.

Our sincerest gratitude to Mr. Pascal Liu, Senior Economist, Food and Agriculture Organization of the United Nations, for providing the keynote presentation and facilitating the wrap-up session. We would also like to thank our session chairmen: Dr. Mohd. Desa Hassim, Mr. Yacob Ahmad, Dr. Apaitia Macanawai, Dr. Prakash Patil, and Mr. Robert Williams. All paper presenters and audience members are gratefully acknowledged for providing their expertise during the Symposium.

The proceedings was prepared, laid out, and designed by Mr. Christian Anthony T. Cangao. Parts of the report were written by Ms. Dorothy Chandrabalan. Photos used in the cover and chapter introductions were taken by Mr. Arifurrahman Rusman.

LIST OF ACRONYMS

ACIAR	Australian Centre for International Agricultural Research
ACP	Asian citrus psyllid
ANA	Alpha-naphtalene acetic acid
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
BAFS	Bureau of Agriculture and Fisheries Standards
BEA	Beauvericin
BPI	Bureau of Plant Industry
BPI-PQS	Bureau of Plant Industry-Plant Quarantine Services
CAMK2D	Calcium/calmodulin-dependent protein kinase II delta
CBM	Community-based biodiversity management
CBO	Community-based organization
CFFRC	Crops for the Future Research Centre
CPsV	Citrus psorosis virus
CTV	Citrus tristeza virus
CVeV	Citrus vein enation virus
CVPD	Citrus vein phloem degeneration
DA/DOA	Department of Agriculture
EVIARC	Eastern Visayas Integrated Agricultural Research Center
FA	Fusaric acid
FAO	Food and Agriculture Organization of the United Nations
FAVRI	Fruits and Vegetables Research Institute
FIAS	Fiji Institute of Agricultural Sciences
FO	Farmer organizations
Foc/FOC	*Fusarium oxysporum* f. sp. *cubense*
G2G	Government to government
GAP	Good Agricultural Practices
GCTCV	Giant Cavendish Tissue Culture Variant
GDAAS	Guangdong Academy on Agricultural Sciences
GDP	Gross domestic product
GR	Growth regulator
HLB	Huanglongbing
HVCDP	High Value Crops Development Program
HFTA	High-temperature forced air treatment
IAARD	Indonesian Agency of Agricultural Research and Development
IMCHO	Integrated Management for Citrus Healthy Orchard
ICAR	Indian Council of Agricultural Research
ITFRI	Indonesian Tropical Fruit Research Institute
ISTF2017	2017 International Symposium on Tropical Fruits
KANA	Knowledge and Action in Agriculture and Food Security
LSD	Least significant different

MC	Moisture content
MENOPE	Middle East Natural and Organic Products Expo
MFAT	Ministry of Foreign Affairs and Trade
MOA	Ministry of Agriculture
MOU	Memorandum of Understanding
MRL	Maximum residue limits
NBS	Nucleotide binding site
NCRPSC	National Crop Research Development and Production Support Center
NGO	Non-governmental organization
NWC	Nature's Way Cooperative
PAU	Pacific Adventist University
PCR	Polymerase chain reaction
PG2	Polygalacturonase gene class II
PGR	Plant genetic resources
PICT	Pacific Island countries and territories
PNG	Papua New Guinea
PNS	Philippine National Standards
RCBD	Randomized complete block design
RGA	Resistance gene analogs
RQ	Ripley Queen
SCAR	Sequence characterized amplified region
SDGs	Sustainable Development Goals
SIDS	Small Island Developing States
SIPPin	Institution Intranet Genetic Resources Information System
SNAP	Single nucleotide-amplified polymorphism
SSR	Simple sequence repeats
STEC	Samoa Trust Estates Corporation
STG	Shoot tip grafting
TA	Titratable acidity
TC	Tropical cyclone
TCE	Transaction cost economics
TOT	Training of trainers
TSS	Total soluble solids
TFNet	International Tropical Fruits Network
UUC	Underutilised crops
VCG	Vegetative compatibility groups
VSA	Volunteer Service Abroad
VSU	Visayas State University
WBF	World Banana Forum

SUMMARY OF THE SYMPOSIUM

SUMMARY OF THE SYMPOSIUM

The 2017 International Symposium on Tropical Fruits (ISTF2017) was convened in Tanoa International Hotel, Nadi, Fiji on 23-25 October 2017, organized by the Fijian Ministry of Agriculture (MOA), International Tropical Fruits Network (TFNet), and Fiji Institute of Agricultural Sciences (FIAS), with support from the Food and Agriculture Organization of the United Nations (FAO). Bearing the theme *"Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruits Industry,"* the symposium aimed to assemble the latest scientific research, technology developments, best practices, and product innovations that support the transformation of the tropical fruit industry to be resilient to climate change.

The symposium was opened by the Honourable Minister Inia Seruiratu, Fiji Ministry of Agriculture, Rural and Maritime Development and National Disaster Management and Meteorological Services. Welcome addresses were delivered by Deputy Secretary Uraia Waibuta of the Fijian MOA, TFNet Vice Chairperson Dr. Ganjun Yi, TFNet Chief Executive Officer Dr. Desa Hassim, and FAO Representative Pascal Liu.

Eighty-two participants from 11 countries attended the symposium, including Australia, China, Fiji, Indonesia, India, Italy, Malaysia, New Zealand, the Philippines, Taiwan, and Vietnam; in addition to United Nation entities such as the FAO, and organisations such as the Crops for the Future Research Centre (CFFRC), Australian Centre for International Agricultural Research (ACIAR), and the Pacific Island Farmers Organization Network (PIFON). Participants represented various stakeholders such as smallholder farmers, international organizations, government agencies, academic and research institutions, fruit experts, and the private sector.

PRESENTATIONS

Keynote Presentation

Mr. Pascal Liu, Senior Economist and Team Leader of FAO's International Investment and Tropical Fruits Team, delivered the keynote titled *'Socio-economic Impacts of Climate Change on the Tropical Fruit Industry: How can the Industry Address Them?'* He presented key statistics on global tropical fruit production and trade, while highlighting the impact of climate change on the industry. He then cautioned that in the long run, global warming could generate new competitors to traditional tropical fruit producing countries because it alters the productivity of countries differently and therefore modify their relative competitive positions. As a result, tropical fruit producers will need to explore the possibilities for expanding their domestic and regional markets in order to reduce the risks linked to international markets. Mr. Liu urged tropical fruit industry players to increase their preparedness in facing climate change, and laid some practical responses that can be undertaken in terms of adaptation and mitigation. He ended his presentation by reiterating that climate change cannot be addressed by a single entity or country, but will require strong alliances and cooperation at all levels in order to be effective, citing the World Banana Forum (WBF) as an example of multi-stakeholder platform which can be emulated.

Session 1 - Climate Change Impacts, Adaptation, and Mitigation

The first paper was by Mr. Kyle Stice of the Pacific Island Farmers Organisation Network (PIFON) and Nature's Way Cooperative (NWC) with the title *'Integration of Climate Change and Disaster Risk Management in the Agriculture Sector – Case study from the Fiji Papaya Industry'*. Mr. Stice said that agriculture has to be climate, environmentally, and economically 'smart' from this point forward. Current approaches tend to ignore existing threats and focus on ill-defined climate change issues. By improving farmer adaptation to climate extremes in the short and medium term, future generations of farmers will be better prepared for climate change. This can be accomplished through public-private partnerships such as the case of NWC, MOA Fiji, and the Biosecurity Authority of Fiji. Finally, research and extension programmes should focus on problem solving and innovation while supporting industry-led approaches such as spreading of production areas to reduce risk, and inclusion of natural disaster management in crop budgets.

The second presentation was by Dr. Wen'E Qi, an Industrial Economist from the South China Agricultural University, Guangdong, China who elaborated on the *'Impacts of Climate Variations on Litchi Yield in China'.* Dr. Qi stated that because litchi is a very weather-sensitive crop, global warming has significantly narrowed the planting region in China and caused production to become erratic.

The third presenter for the session was Dr. Nguyen Quoc Hung, Director General of the Fruits and Vegetables Research Institute of Vietnam (FAVRI), with a status report on *'Ensuring a Sustainable Tropical Fruit Industry in the Midst of Climate Change: The Vietnam Story'*. Dr. Hung highlighted that drought and flooding in the central provinces have exacerbated the spread of diseases in major banana planting areas. He also presented the case of salinity intrusion in the Mekong River Delta and drought in the Southeast provinces that has caused severe damage to agricultural production. He further described the efforts that have been undertaken to reduce losses due to drought and salinity intrusion.

The fourth presentation was delivered by Dr. Prakash Patil, the Project Coordinator of Fruits from the ICAR-Indian Institute of Horticultural Research entitled *'Ensuring a Sustainable Tropical Fruit Industry in the Midst of Climate Change: The India Story'*. Climate change remains a major threat to the agriculture sector, which contributes more than 30% of India's GDP. Dr. Patil then provided an overall view of climate change trends in India and presented spatial maps indicating that the warming trends are pronounced in North-West India, before narrowing further on the temperature effect on selected fruit crops such as mango, banana, citrus, and papaya. He then dwelled on the impacts of climate change on pests and pollinators in horticultural crops; citing that climate change has altered pollinators and incidence of pests, and shifted production zones of tropical fruits. He recommended growing jackfruit for its resilience and planting multi-species orchards to improve diversity and reduce the incidence of pests and diseases.

The final presenter for the session, Mr. Manoa Iranacolaivalu, Senior Research Officer from MOA Fiji discussed the *'Effects of Three Growth Regulators Induced Flowering on Yield and Quality of Ripley Queen (RQ) Pineapple (Ananas comosus) in Fiji'*. Mr. Iranacolaivalu pointed out seasonality as a key challenge in ensuring sustained availability of pineapples in Fiji. To ensure sustainable production of pineapple all year round, Mr. Iranacolaivalu proposed the use of Growth Regulators (GR). Promising results were obtained, with application of GRs leading to higher yield and shorter fruiting periods as compared to controls.

Session 2 - Crop Protection, and Pest and Diseases Management

Dr. Ganjun Yi presented on the *'Prevention and control of the citrus greening disease also known as the 'Huanglongbing' (HLB)'*. He proposed an integrative application of five key measures: (i) Ecological cultivation system; (ii) Destruction of all diseased trees; (iii) The use of large and healthy seedlings; (iv) High Density Cultivation in moderation; and (v) Rapid and total extermination of psyllids in the orchard.

The second presentation was delivered by Dr. Affandi, Senior Researcher from the Indonesian Tropical Fruits Research Institute (ITFRI) on the current research being done on '*The Infestation Pattern of Scirtothrips dorsalis Hood in Developing Shoot and Flower of Mango Arumanis 143*'. The Arumanis 143 mango is a very sweet and fibreless variety most preferred in Indonesia. Dr. Affandi noted that the quantity and quality of Indonesian mangoes are still low compared to its potential production (25-30 of 55 kg/tree), with insect pest infestation as one of the main reasons. Thrips (*Scirtothrips dorsalis* Hood) has been reported to be one of the most damaging pests of mango. The findings of the study suggested that control tactics should begin early during shoot emergence.

The third speaker, Dr. Chunyu Li of the Institute of Fruit Tree Research, Guangdong presented on the '*Research on Fusarium Wilt of Banana and its Management in China*'. Dr. Li highlighted that the incidences of *Fusarium* wilt of banana in China have been on the incline in the recent years, from 1.4 ha in 1998 to 40,000 ha in 2010. He attributed the increase to large scale monoculture efforts; small scale farming by individual farmers; irregularities in tissue culture production; disregard of quarantine protocols; and unmonitored movement of plants, people and farm equipment. Dr. Li presented the diversity of pathogens and proposed that integrative control measures be adopted.

Session 3 - Crop Diversification, Varietal Improvement, and Biotechnology

The first presenter was Mr. Felix Miller, the Chief Corporate Services of Crops for the Future Research Centre (CFFRC) with the presentation titled '*Social, Economic and Technological Potential of Agricultural Biotechnologies for Crop Diversification – A New Approach in Research*'. Mr. Miller discussed the overdependence of global diets on only four major staples and stressed on the need for agricultural transformation. He proceeded to present CFFRC's current research and work on underutilised crops (UUC) such as the *Moringa* and bambara groundnut, and how the knowledge of genetic resources of UUC can be linked through modelling and geospatial tools for prediction of its potential in new locations. Mr. Miller also informed participants of the recently launched Forgotten Foods Network by CFFRC in response to the vision of FAO for an 'International Year of Forgotten Foods'. The Forgotten Foods Network seeks to create awareness, public contributions, and scientific research on the forgotten foods that are part of common heritage but have been increasingly displaced by a uniform, processed modern day diets.

Dr. Ellina Mansyah of the Indonesian Tropical Fruit Research Institute (ITFRI), Indonesia presented her paper titled '*Breeding and Biotechnology Research Programme of the Indonesian Tropical Fruit Research Institute*'. Dr. Ellina briefed the participants on the responsibilities and activities of ITFRI in breeding and biotechnology research and development of a range of tropical fruits. The activities presented included characterisation, conventional breeding, molecular breeding, and seed production and distribution. Through her presentation, it was highlighted that some local banana varieties such as the Ketan have been showing resistance to Fusarium wilt.

From the Ministry of Agriculture, Fiji, Ms. Kalolaini Colaitiniyara presented the third paper titled '*Breadfruit (Artocapus altilis) Diversity in Fiji*'. She highlighted that breadfruit is a staple in Fiji and holds a cultural significance. It is also a choice fruit crop, known for its hardiness to withstand climate change. Ms. Colaitiniyara enlightened the floor on the status of current characterisation work on 15 varieties of breadfruit and further recommended undertaking a country level breadfruit assessment to reconfirm the distribution of breadfruit varieties.

The last paper for the session was presented by Dr. Arry Suprianto from the Indonesian Citrus and Subtropical Fruit Research Institute, Indonesia on '*Citrus Variety Improvement Programme in Indonesia*'. He reported that 15 years after the citrus improvement programme was initiated, more than 10 million virus-free citrus stocks have been produced and delivered to citrus growers.

Session 4 - Postharvest, Product Development, and Utilisation

The first paper was presented by Prof. Steven Underhill of the University of the Sunshine Coast, Australia on the *'Postharvest Handling of Tropical Fruits in the South Pacific'*. He provided an overview of fruit postharvest handling systems in the Pacific, the key challenges faced, and strategic opportunities present. Prof. Underhill highlighted that high levels of postharvest losses are mostly concentrated at the market-end of the value chain. He elaborated on the: (i) on farm challenges faced such as poor nursery support mechanisms, poor and aging cultivars; (ii) inter-island transportation issues; and (iii) market challenges, presenting case studies on small island developing states. He pointed out that success is not seen yet as most investments go towards addressing agronomic-related issues and tend to ignore the aspect of postharvest loss; thus recommending this as a new area for research investment. He concluded by stressing on the importance of institutional postharvest capacity building for the Pacific Islands.

Associate Professor Dr. Lorina Galvez of Visayas State University, the Philippines presented on the *'Physico-Chemical Qualities of Stored Fresh Cut EVIARC Sweet Jackfruit (Artocarpus heterophyllus Lam.) Pulp as Influenced by Deseeding, Packaging Method, and Storage Condition'*. The study was to investigate the relationship of deseeding, packaging methods, and storage conditions on the physico-chemical properties of minimally processed jackfruit. Amongst the findings of the study was that deseeded jackfruit has a much faster deterioration rate when compared to intact treatments. Jackfruit pulp with seed, vacuum-packed, and chilled was found to have a longer shelf life with better sensory attributes and physico-chemical properties.

Presenting the third paper for Session 4 was by Professor Emeritus Roberta Lauzon of Visayas State University, the Philippines on *'Physio- and Physico-Chemical Property, Sensory Quality and Acceptability of Vacuum-Fried EVIARC Sweet Jackfruit (Artocarpus heterophyllus Lam.) Pulp as Influenced by Fruit Maturity and Other Fruit Conditions'*. The study evaluated the effects of maturity on the quality and acceptability of vacuum-fried jackfruit pulp. Among the important conclusions drawn from the study was that fruit maturity influenced the sensory attributes of vacuum-fried jackfruit, and vacuum fried pulp from 88-day-old fruits were found to be acceptable in 99% of consumers.

Session 5 - Farmer Support, Extension, and Policy Interventions

The first paper for the final session was by Mr. Danilo Dannug, Supervising Agriculturist from the Bureau of Plant Industry – Department of Agriculture, Philippines on *'Government Regulations and Interventions for the Production of High Quality Fruits for Exports in the Philippines'*. Mr. Dannug provided an outlook into the fruit industry of the Philippines and presented on the regulatory activities conducted by the Bureau of Plant Industry. It was noted that accredited plant nurseries for fruits totalled 88 fruit crop nurseries in 2016. A total of 82 farms for various crop commodities covering 22,595 hectares are GAP certified in the Philippines.

For the second paper, Dr. Nick Roskruge of Massey University, New Zealand presented on *'Sustainable Tropical Fruit Production – Farmer Support in the Pacific'*. Dr. Roskruge listed the characteristics of the Pacific production systems which are typically geographically specific, with production often catering for the local markets and lacking value addition. He posed questions such as the type of support required to ensure that tropical fruit production meets the quality and quantity thresholds from local and international markets to guarantee farmer incomes. The future for fruit producers requires ongoing training in crop husbandry and market drivers to optimise production opportunities. Investments in the future could target useful technologies, for example in diagnosing plant health issues or for crop responses to climate change (e.g., through breeding programmes). Dr. Roskruge continued to provide examples of ongoing investments from the aid community in response to climate change, technology advances, and social pressures. He concluded by stating that the spirit of *kotahitanga* or "coming together as one" should prevail amongst stakeholders working around similar issues of interest and initiatives for supporting farmers in the Pacific Islands.

Mr. Atish Chand of the Fiji National University, Fiji elaborated on his presentation titled *'Improving Supply Chain Market Access for Mango Farmers in Fiji: A Transaction Costs Perspective'*. He firstly went on to provide an overview of the mango industry in Fiji which he stated is an active industry. However, production of mangoes in Fiji is very much scattered, thus creating a barrier in accessing the high value chain market and eventually leading to increased transaction costs. He proposed that for Fiji's mango industry, horizontal and vertical coordination could work together to reduce transaction costs and improve farmers' access to the supply chain. He called for the government to play a pro-active role in organising mango producers and initiatives to encourage value addition of mango in Fiji.

The last paper was delivered by Mr. Timote Waqainabete, the Research and Extension Officer for Nature's Way Cooperative (NWC), on '*The Role of Farmer Organisations in Tropical Fruit Research and Development: A Case Study of Nature's Way Cooperative in Fiji*'. Mr. Waqainabete presented the breadfruit orchard model of NWC and some of the major achievements of the NWC research and extension programme. Two note-worthy achievements are the establishment of the Fiji Red certified papaya seed scheme and the development of the Fiji Red brand. He concluded with the statement that "farmer organisations are critical partners to help extend the reach of government and aid agencies to support Pacific Island farmers to adapt to climate change".

THE WAY FORWARD

The wrap-up session was facilitated by Mr. Pascal Liu, Senior Economist and Team Leader of FAO's International Investment and Tropical Fruits Team. He invited all the session chairs to propose recommendations based on the thematic discussions that progressed throughout the their respective session and subsequent discussions. These were then discussed and further refined for finalisation. The target agencies and stakeholders of each recommendations were also identified.

For the first session on *'Climate Change Impacts, Adaptation, and Mitigation'*, session chairman Dr. Mohd. Desa Hassim said that government agencies, farmer groups, international organizations, and implementing agencies should prioritise the welfare of farmers when developing projects because they are the lifeblood of the agriculture industry. On the other hand, farmers should also be adaptive and proactive in addressing issues and not just rely on handouts from the government. The second recommendation calls for the government, farmer groups, implementation agencies, and international organizations to propose holistic critical solutions for extreme weather and changes in temperature that can be applied across multiple sectors. It was also recommended to compile all the proposed solutions in ISTF2017 and develop an action plan that can help climate change adaptation and mitigation for policy makers and governments. Additional recommendations include the need for all stakeholders to incorporate disaster risk management into business plans, strategies, and policies. There is also a need to strengthen the capacity of farmers and farmer organizations in developing production systems that are resilient to climate change.

Mr. Yacob Ahmad, chair for the session on *'Crop Protection, and Pest and Disease Management'*, recommended breeders and researchers to continue their work on developing disease resistant varieties. Meanwhile, extension workers, development agencies, and farmer groups should promote the use of disease tolerant or resistant varieties. The second recommendation calls for extension agencies to conduct capacity building activities to help smallholders identify pests and diseases. Finally, growers, government agencies, and the private sector should implement biosecurity and quarantine measures to prevent the spread of pest and diseases.

The third session on *'Crop Diversification, Varietal Improvement, and Biotechnology'* chaired by Dr. Apaitia Macanawai recommended for government agencies, agricultural universities, and research institutes to develop and promote the diversification of diets with underutilised crops. Second, agriculture ministries of different countries should collaborate by sharing their germplasm to strengthen the genetic diversity of fruits. Finally, research agencies, international organizations, and universities should work closely to collectively improve research and development of tropical fruits. The floor also recommended to develop or support existing databases on underutilised fruit crops.

Chaired by Dr. Prakash Patil, the fourth session was on *'Postharvest, Product Development, and Utilization'*. It was recommended for companies, governments, and farmer groups to build the capacity of smallholders in terms of good postharvest practices. Meanwhile, research agencies and universities should be provided with better institutional capacity in postharvest extension and research. Lastly, research bodies should provide better access to postharvest information. The floor also recommended to increase collaboration among stakeholders in the branding and marketing of tropical fruits.

For the final session, Mr. Robert Williams presented the recommendations on *'Farmer Support, Extension, and Policy Interventions'*. Governments, growers, and donors should promote the adoption of appropriate production, postharvest, and food processing technologies across the supply chain through farmer groups such as cooperatives. Donor agencies should look into the management of sudden impacts of extreme weather and disasters. Third, governments and farmer groups must invest in infrastructure for production, postharvest, food processing, storage, transport, and marketing. Finally, all stakeholders should implement biosecurity protocols.

Before the session came into a close, Mr. Pascal Liu called for the participants to join in the spirit of *kotahitanga* for all initiatives at the local, national, regional, and international levels.

WELCOME ADDRESSES

WELCOME ADDRESS
MR. JITENDRA SINGH
Permanent Secretary, Ministry of Agriculture, Fiji

On behalf of the Hon. Minister for Agriculture, Rural and Maritime Development, National Disaster Management and Meteorological Services, Mr. Inia Seruiratu, I have much pleasure in welcoming you all to Fiji to be part of this important event.

I extend a special welcome to our dignitaries:
1. Dr. Mohd Desa Hassim, Chief Executive Officer, International Tropical Fruits Network (TFNet);
2. Dr. Ganjun Yi, Vice President, Guangdong Academy of Agricultural Sciences (GDAAS), who is also the Vice-Chairperson of Board of Trustees for TFNet; and
3. Mr. Pascal Liu, Representative of Food and Agriculture Organization (FAO) of the United Nations.

This is the second event of the International Tropical Fruit Network (TFNet) to be hosted here in Fiji. The first was a South Pacific Regional workshop held in the Suva, from 26-28 August 2013, focusing on the theme: *"Quality Assurance, Postharvest Management and Processing to Enhance Market Access of Tropical Fruits in the Pacific Islands"*.

We are so grateful to TFNet for choosing Fiji to host a much bigger International Symposium on Tropical Fruits 2017 (ISTF 2017) event. ISTF 2017 provides a platform for TFNet and its partners to discuss the contributions of research, the private sector, and policy makers on tropical fruit production and food security. Furthermore, ISTF 2017 provides a unique opportunity to establish a network to help enhance research and development with a focus on "*Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruit Industry*", the theme of the event.

With rapidly changing climatic conditions around the world, this theme is highly relevant to Fiji as well as other countries. In this respect, I am grateful that this event is being hosted in Fiji. We all look forward to a productive symposium, with enriching discussions so that we can work towards a sustainable and resilient tropical fruit industry around the world.

I hope you will enjoy the friendly Fijian hospitality and wish you well in this week's event.

Vinaka vakalevu and *dhanyavaad*.

WELCOME ADDRESS

DR. GANJUN YI

Vice President, Guangdong Academy of Agricultural Sciences (GDAAS) and Vice Chairperson, International Tropical Fruits Network (TFNet) Board of Trustees

Greetings to the distinguished participants of ISTF 2017!

It brings great pleasure to welcome you to this symposium. On behalf of the Chairperson of the International Tropical Fruits Network and Secretary General of The Ministry of Agriculture Malaysia, I extend my heartfelt appreciation to TFNet, the Ministry of Agriculture Fiji, Fiji Institute of Agricultural Science and the Food and Agriculture Organisation for organising and supporting this important international symposium on tropical fruits with the theme, *'Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruit Industry'*.

The potential of the tropical fruit industry has grown in leaps and bounds over the last two decades, with new markets being developed around the world. The industry serves as a viable option of diversification from the traditional economic commodities, especially in times of uncertainties. Strategic investments in the industry and channelling efforts in the right direction can provide long term benefits not only for economic sustainability, but also in achieving food security. To meet the increasing market demands for tropical fruits and cater to the ever changing trends over the past decade, the industry has to remain relevant by embracing transformation and confronting the roadblocks ahead.

One such challenge is the radical impact of climate change which affects tropical fruit availability and supply, in addition to reducing export capacities, as well as having direct implications to food and nutrition security. A recent WorldBank report states that world hunger is on the rise with the estimated number of undernourished people increasing from 777 million in 2015 to 815 million in 2016. With numerous studies documenting the contribution of tropical fruits in diets of the rural poor, climatic variations which influence tropical fruit production patterns poses a setback to the achievement of the SDGs.

The excellent line-up of experts for the ISTF 2017 reflects the commitment of the organizers in providing an in depth outlook into the future of tropical fruits and the many prospective areas which need to be dealt with.

It is my earnest hope that the outcomes of the ISTF 2017 will spur the development planning for future-proofing the tropical fruit industry and achieving global food sovereignty in the midst of climate change. Therefore, I urge you to share with us your knowledge and expertise through your discussions.

Wishing you all a fruitful ISTF 2017.

WELCOME ADDRESS
DR. MOHD DESA HASSIM
Chief Executive Officer, International Tropical Fruits Network (TFNet)

As the Chief Executive Officer of the International Tropical Fruits Network (TFNet), it brings me great pleasure to welcome all dignitaries, Board members of TFNet, key experts, and participants to the International Symposium on Tropical Fruits (ISTF) 2017. The theme of this year's ISTF: *'Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruit Industry'* recognises the global agenda to tackle the looming threat of climate change and seeks to bring together the latest information, assessments, and research on the impact of climate change on the tropical fruit industry.

Tropical fruits are potent sources of food and nutrition security. The rich genetic diversity of tropical fruits remains an untapped potential for diversifying present day global diets that largely depend on three major crops which are rice, maize, and wheat. The consumption of tropical fruits can become a vital global solution in creating healthy and balanced diets for the population while addressing hunger and malnutrition concerns.

Tropical fruit production and climate change are deeply intertwined. With various efforts taken to support the expansion of the tropical fruit industry, industry players should also be mindful of the perils of climate change. Tropical fruit production has continued to fall and in reality is unable to meet the booming consumption demands of the populace. Concerted efforts are required to increase productivity while identifying adaptation and mitigation strategies to buffer the impact of climate change on tropical fruit production.

Against this background, the ISTF 2017 organised by the International Tropical Fruits Network (TFNet), the Fijian Ministry of Agriculture, and a host of other institutions such as the Food and Agriculture Organization (FAO) of the United Nations serves as an assemblage of researchers, development agencies, researchers, and climate change practitioners. It is hoped that with such a quorum of experts in the ISTF 2017, we would produce a wide spectrum of knowledge and outputs. In unison, we can chart a cohesive direction towards creating a resilient tropical fruit industry.

I take this opportunity to thank the Fijian Ministry of Agriculture for graciously hosting ISTF 2017 in enchanting Fiji. I also acknowledge the relentless efforts of my counterparts both in Fiji and Malaysia, in ensuring the smooth coordination of the ISTF 2017. It is my sincere hope that organising this symposium in Fiji serves as a catalyst to support the commitment of the Fijian Government in addressing climate change, and foster opportunities for future collaboration amongst TFNet member countries.

I hereby encourage you to actively participate and contribute to this important symposium. Thank you.

WELCOME ADDRESS
MR. PASCAL LIU
Team Leader, International Investment and Tropical Fruits Team, Food and Agriculture Organization of the United Nations (FAO)

I would like to thank the International Tropical Fruits Network (TFNet), in particular its Chief Executive Officer, Dr. Desa Hassim, for their kind invitation to FAO to speak in this symposium on *'Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruit Industry'*.

International trade in tropical fruits is significant and has been growing steadily in the past decades. FAO reckons that global trade of major tropical fruits reached a new peak in 2016, with exports estimated at nearly 7 billion tonnes. While tropical fruits play a comparatively small role in global trade in volume terms, their high average unit value of export places them as the third most valuable fruit group. With a total export value estimated at some USD 7 billion, major tropical fruits rank behind bananas and apples. The bulk of tropical fruit trade originates in developing countries. Tropical fruits generate substantial export earning for many of these countries, thereby contributing to their food security.

However, climate change and the associated extreme weather phenomena in tropical areas are threatening the tropical fruit industry. Global production of major tropical fruits experienced significantly slower growth in 2015/2016 than the average over the previous decade. This slowdown is mainly attributable to adverse weather conditions in the main producing regions. Reports from the first half of 2017 point to a continuation of slow production growth in the short to medium term future. According to recent information, production of mangoes, the largest tropical fruit in terms of volume, has been affected by drought in some of the major producing areas in South America and Africa, while pineapple production has seen damage from flooding in Latin America. Drought has also hampered the production of papaya in the largest producing regions in South America, as well as the production of avocado in southern Africa.

Production systems for tropical fruits will have to evolve to become more resilient. In key avocado producing regions in Latin America, which have widely installed more weather resilient systems, output has seen strong growth. This provides food for thought on the potential that climate change adaptation offers. The industry will also need to contribute to global efforts to mitigate climate change by adopting production and trade methods that reduce the emission of greenhouse gases.

Climate change will also exacerbate current challenges including: spreading pests and diseases; the depletion of natural resources; conflicts over these resources; the banning of unsustainable inputs and methods; rising consumer preference for locally-produced foods and pressure on prices by large-scale retailers.

Tackling the many challenges posed by climate change can only be done by the international cooperation of all stakeholders. Gathering key players to discuss possible solutions, as this symposium is doing this week, is very important. Establishing mechanisms for international multi-stakeholder collaboration is the most effective approach to reducing the impacts of global warming on the tropical fruit industry. FAO looks forward to discussing possible collaboration in these areas with TFNet.

SPECIAL MESSAGE

MINISTER INIA SERUIRATU

Ministry of Agriculture, Rural and Maritime Development and National Disaster Management and Meteorological Services

Distinguised Speakers, participants, ladies and gentlemen, I once again welcome you all to the International Symposium on Tropical Fruits (ISTF) 2017, here in Nadi, Fiji. A special welcome to all our overseas friends and partners and I wish you all a pleasant stay in our beautiful Fiji. I commend the International Tropical Fruits Network, Ministry of Agriculture and Fiji Institute of Agricultural Science for organizing this event.

The International Symposium on Tropical Fruits (ISTF) 2017 theme '*Food Security amidst a Changing Climate: Towards a Sustainable and Resilient Tropical Fruits Industry*' is ideal to be hosted in our country. Fiji has been given the responsibility to take up the Presidency of COP23 and we as a nation are very proud of this achievement. The theme of the symposium connects very well with this responsibility. I hope the presentations and discussions during the symposium will address the effects of climate change towards development of sustainable and resilient fruit industry around the world.

The Fijian Government is committed to develop its fruit industry. The Fiji 2020 Agriculture Sector Policy Agenda launched in 2014 clearly identifies the development and agro-processing of fruits such as pineapple, mango, and breadfruit. The policy agenda also mentions the need for exploration of fruits such as mangosteen, rambutan, and durian for the niche tourism market. Production of fruits has a huge potential in this country and we have started to explore this opportunity with our counterparts. This is evident by the current release of a new variety of guava, which we have named Green Pearl for commercial cultivation. This will be the first time for Fiji to start cultivating guava as a commercial crop.

Ladies and gentlemen, fruits are important for nation building because they can provide necessary nutrients for healthy living as well as provide economic support to raise the standard of living of the rural population. The famous saying "an apple a day keeps the doctor at bay" is very true and we therefore need to encourage our communities to consume more and more fruits.

I wish you all successful deliberations and a very pleasant stay in Fiji.

Vinaka vakalevu.

KEYNOTE PRESENTATION

KEYNOTE PRESENTATION

ADDRESSING THE IMPACTS OF CLIMATE CHANGE ON THE TROPICAL FRUIT INDUSTRY

Pascal Liu

Team Leader, International Investment and Tropical Fruits, Food and Agriculture Organization of the United Nations (FAO)

The world still faces the challenge of ensuring food security to a growing population. Some 815 million people suffered from hunger last year, up from 778 million in 2015. This accounts for one person out of nine and is unacceptable. The world's population is projected to increase to 9 billion by 2050, which means that agricultural production should be raised substantially to meet the challenge of feeding everyone. However, there is limited scope for expansion of natural resource use due to the current high pressure on these resources in many areas. The tropical fruit sector can play a role in achieving food security.

International trade in tropical fruits is significant and has been growing steadily in the past decades. FAO reckons that global trade of major tropical fruits reached a new peak in 2016, with exports estimated at nearly 7 billion tonnes. Tropical fruits account for close to 3% of world fruit and vegetable exports in volume. While tropical fruits play a comparatively small role in global trade in volume terms, their high average unit value of export (over US$1000 per tonne) places them as the third most valuable fruit group. With a total export value estimated at some US$7 billion, major tropical fruits rank behind bananas (close to US$10 billion) and apples (some US$8 billion). The bulk of tropical fruit trade originates in developing countries. Tropical fruits generate substantial export earning for many of these countries, thereby contributing to their food security. For example, tropical fruits account for 21%, 6%, and 5% of agricultural export values of Costa Rica, Mexico, and the Philippines respectively.

However, climate change and the associated extreme weather phenomena in tropical areas are threatening the tropical fruit industry. There is global consensus that climate change will generate more extreme weather phenomena in tropical areas. The recent string of devastating hurricanes in the Caribbean and torrential rains in South Asia, which have caused considerable losses of life and damage to the tropical fruit industry, may be viewed as an ominous confirmation of this forecast. Some analysts estimate the total economic costs of hurricane Irma at over US$300 billion. Climate change could increase poverty by between 35 and 122 million people by 2030 according to UN projections. Tropical regions are particularly exposed to its impacts, and adverse effects are expected on tropical fruit production

Indeed, global production of major tropical fruits, which include mango, pineapple, avocado, and papaya, experienced significantly slower growth in 2015/2016 than the average over the previous decade. The slowdown in the pace of production growth is mainly attributable to adverse weather conditions in the main producing regions. Reports from the first half of 2017 point to a continuation of slow production growth in the short to medium term future. According to the most recent information, production of mangoes, the largest tropical fruit in volume terms, has been affected by drought in some of the major producers in South America and Africa, while pineapple production has seen damage from flooding in the major producers in Central and South America. Drought has also hampered the production of papaya in the largest producing regions in South America, as well as the production of avocado in the southern part of Africa.

Trade volumes of major tropical fruits were less affected by the effects of weather changes on a global level as only a small fraction of total production are traded in international markets. On a regional level, however, exporters affected by drought and flooding did report supply shortages and subsequent disruptions to shipments. In terms of the drivers of trade, rising demand in developed markets can be considered the main factor stimulating the expansion in global shipments. Particularly in the United States and the European Union, an increasing health consciousness and more widespread awareness of the nutritional benefits of tropical fruits are contributing to strong demand.

Production systems for tropical fruits will have to evolve in order to adapt to climate change and become more resilient. The industry should increase its preparedness by incorporating the effects of climate change into its strategies and business plans. It should assess and map the risks and vulnerabilities in order to address them in a systematic manner and reduce its vulnerability. The development of early warning systems will be crucial. The industry will need to adopt climate smart agricultural technology and systems. Climate change makes a holistic approach to fruit production even more necessary than before. The sustainable management of natural resources, integrated pest management, and integrated crop nutrition can play a critical role for producers. The selection of heat tolerant and drought resistant plant varieties is essential. Substantial investment will be needed to adapt to climate change. For example, investing in water efficient systems, windbreaks, and drainage infrastructure is critical. Modern technology for precision agriculture can be part of the solution. The development of insurance schemes at national level (e.g., weather related crop insurance systems) could help shield producers from part of the climate risk.

For example, in key avocado producing regions in Latin America where producers have widely installed more weather resilient systems, output has seen strong growth. This provides food for thought on the potential that climate change adaptation offers. The potential of organic agriculture techniques and agro-ecology could be considered, as some studies suggest that such cultivation systems are more resilient.

In addition to adaptation efforts, the industry will also need to contribute to global efforts to mitigate climate change by adopting production and trade methods that reduce the emission of greenhouse gases. Overall, the agriculture sector (including land use change and forestry) accounts for over 20% of greenhouse gas emissions. For example, it will need to reduce the use of inputs whose production and use generate significant quantities of greenhouse gases and to reduce the use of fossil fuels. It will have to increase the use of renewable and clean energy in its cultivation and processing systems. Photovoltaic energy has a considerable untapped potential in tropical countries and its costs have decreased significantly in recent years. The industry will also need to partner with the transportation companies to promote the use of renewable energy in sea transportation and favour maritime over air freight.

Climate change will also exacerbate current challenges including: the spread of new pests and diseases; the depletion of natural resources; conflicts over these resources; the banning of unsustainable inputs and methods; rising consumer preference for locally-produced foods; and downward pressure on prices and carbon-labelling schemes by large-scale retailers. It will accelerate the recent trends observed in major developed markets for promoting ‘low food miles’. A growing share of consumers are reluctant to purchase fruits that have been imported from far away and instead prefer buying locally-produced fruits. Climate change will alter the agricultural productivity and thereby cause a shift of relative competitiveness across producing areas. Some areas will lose competitiveness while others will become more competitive. Producers and exporters must anticipate these shifts and invest in order to maintain or even increase their competitiveness.

In the long run, global warming may also generate new competitors to those countries which have traditionally supplied tropical fruits, as countries which had a temperate climate could become increasingly capable of producing such fruits. As a result, tropical fruit producers will need to explore the possibilities for expanding their domestic and regional markets in order to reduce the risks linked to international markets.

Climate change and all the above challenges are complex, multi-faceted, and global. Consequently, they cannot be addressed by the industry alone or by a single country. They will only be solved through the international cooperation of all stakeholder groups including governments, companies, producer organizations, research and training institutes, worker unions, and other civil-society organizations. Establishing mechanisms for such international multi-stakeholder collaboration is the most effective approach to reducing the impacts of global warming on the tropical fruit industry.

A concrete example of this type of collaborative mechanism is the World Banana Forum (www.fao.org/wbf). FAO facilitated the negotiations of the main stakeholder groups of the global banana sector from 2007 to 2008 and held the conference that led to its establishment in December 2009 in conjunction with the meeting of the Intergovernmental Group on bananas and tropical fruits. The Forum operates through specialized working groups and task forces which reflect its multi-stakeholder composition. Since its creation, the Forum has set up a portal of best practices for sustainable production and trade, produced a guidebook for measuring carbon and water footprints, developed manuals for occupational health and safety and coordinated international activities to limit the propagation of the Fusarium wilt TR4 disease. It has also facilitated multi-stakeholder collaboration on important issues such as costs of sustainable production, decent work, living wages, gender equity, and pesticide reduction.

The Forum held its third global meeting in Geneva on 8 and 9 November 2017. Over 200 persons representing governments, companies, producers, workers, research institutes, and civil society debated the solutions to challenges such as low prices, climate change, combating diseases, reducing the quantities of agrochemicals, improving occupational health and safety, distribution of value along the supply chain, living wages, and gender equity. A global statement was adopted unanimously and practical recommendations will be disseminated to the whole sector worldwide. With its unique multi-stakeholder structure, the World Banana Forum can be a useful model for the tropical fruit sector.

KEYNOTE Q&A

i. There was a query on projected graphs on production and trade of selected tropical fruits in the keynote presentation which showed a trend of increase in output – seemingly indicating the possibility that the effect of climate change was minimal on tropical fruits or due to the industry adapting to climate change. The presenter clarified that this may be due to the fact that the full impact of climate change is still not felt by the industry as though the graphs indicate growth; these are not steep curves, with some curves exhibiting a plateau.

ii. From the keynote, questions were raised on the existing FAOstat database which at present clumps data of selected tropical fruits as aggregated items. This was pointed out as not helpful and could be improved. To this, Mr. Liu agreed on the current limitation in data availability which he attributed "as an issue of resources" and difficulty in obtaining reliable data. Mr. Liu pointed this as an area of potential collaboration between TFNet and FAO on ways of disaggregating the data on tropical fruits.

SESSION ONE

Climate Change Impacts, Adaptation and Mitigation

PAPER 1:
INTEGRATION OF CLIMATE CHANGE AND DISASTER RISK MANAGEMENT IN THE AGRICULTURE SECTOR – CASE STUDY FROM THE FIJI PAPAYA INDUSTRY

Kyle Stice[1] and Andrew McGregor[2]
[1]Pacific Island Farmers Organisation Network, Nadi, Fiji
[2]Koko Siga Pacific

ABSTRACT

Over the past decade, papaya has emerged as a key lead commodity for horticulture development in the Fiji Islands. Currently Fiji exports an average of 800 tonnes of papaya annually to New Zealand and Australia. The development of this industry has been subject to the normal constraints faced by developing countries entering the horticulture export market. In addition to these traditional constraints, the industry is now faced with a new set of challenges that relates to climate change and the likelihood of increasing natural disasters. In recent years natural disasters such as drought, floods and cyclones have had a direct impact on the Fiji papaya industry.

In the face of these traditional and emerging challenges, the Fiji papaya industry led by Nature's Way Cooperative has embarked on a series of initiatives to address the continued threat of natural disasters. These initiatives include both immediate responses to the situation as well as research into new mitigation strategies. This paper examines a selection of these initiatives including: the calculation of natural disasters into papaya crop budgets, reducing the scale of planting and increasing the frequency of planting, the Fiji Papaya Seed production scheme, bulking of seed stocks to quickly recover from natural disasters and research into pre and post-cyclone farm activities.

Keywords: natural disasters, papaya, cyclone, mitigation

PAPER 2:
IMPACTS OF CLIMATE VARIATIONS ON LITCHI YIELD IN CHINA

Wen'e Qi & XiOuyang
South China Agricultural University, Guangzhou, Guangdong 510642, China

ABSTRACT

Climate variations are gradually threatening the production of fresh agro-products especially fruits like litchi which is one of the most demanding tropical fruits for climatic conditions. As China is the largest litchi producer in the world, the yield of litchi in China plays an important role in tropical fruits security in the world. In this paper, two key weather factors — temperature and rainfall were selected as independent variables and a two-way fixed effect model was established to examine the impacts of climate variations on litchi yield in China based on county-level panel data on litchi yields of 39 main producing counties in China and daily weather conditions from 2011 to 2016. The main conclusions are as follows: (1) litchi's yield is negatively related to the days of precipitation during the vegetative and flowering stages; (2) higher daily minimum temperature during the heading stage and maximum temperature during litchi's flowering stage will increase litchi yield; and (3) for different varieties of litchi, there exist some differences between the weather effects on yields.

Keywords: climate, temperature, litchi, yield, China

INTRODUCTION

Litchi is known as "the queen of fruits" due to its unique shape, beautiful color, and mouth-watering taste. Nevertheless, many will miss out on it since litchi's planting region is relatively narrow; mainly in the provinces of Hainan, Guangdong, Guangxi, and Fujian in China. Even in litchi's main producing areas, litchi production tends to be unstable as litchi is one of the most weather-sensitive crops. On the one hand, bitter winters when the temperature is lower than 0°C will lead to freeze injury or death of litchi; while warm winters with high temperatures will have a significant negative effect on litchi's blossoming and fruit.

With global warming, climate is changing more and more frequently in recent years, which is definitely destructive to the growth of agro-products especially tropical fruits that are extremely sensitive to climate conditions such as the litchi. In order to ensure the yield of litchi and reduce the risk of litchi growers, it is of practical significance to study the impacts of climate variations on litchi yield and establish a correlation model between climate variations, phenological period, and litchi yield.

Numerous studies have evaluated the impacts of climate valuations on the yield of agro-products. Some scholars directly established the model between weather variables and the yield of agro-products by controlling other variables that may influence the yield (Anwar et al., 2015; Fang et al., 2017). Others introduced phenological data into the model and examined how meteorological factors during different growth stages affect the final crop yield (Gömann, 2015; Gourdji et al., 2015; Weymann et al., 2015; Liu et al., 2016; Sharma et al., 2016; Lizana et al., 2017) which can reflect the impact of weather on yield more distinctively and exactly since climate variations during different growth stages may generate different effects on the yield.
According to previous empirical researches, meteorological factors that affect the yield of agro-products are mainly temperature and rainfall (Kima et al., 2014; Gömann, 2015; Sarker, Alam, & Gow, 2014; Ma & Maystadt, 2017; Okoro et al., 2017), and there existed differences from the empirical results of the impact of climate variations on the yield of agro-products.

Many studies found that the yield of agro-products is strongly associated with temperature (Campiglia et al., 2015; Vashisht et al., 2015; Lizana et al., 2017; Paul et al., 2017). Some empirical results showed that higher temperatures tended to reduce crop yield. For example, Duncan et al. (2016) found that warmer average temperatures (T_{ave}) have a negative effect on tea yield. Fang et al. (2017) also found that a lower canopy temperature usually produced a higher yield of winter wheat. Similarly, a study by Kim et al. (2017) on marketable tuber also showed that yield would be significantly reduced with a higher temperature between the temperature ranges of 19.1–27.7°C. However, some researchers came to the opposite conclusions that higher temperatures can increase the yield of some kinds of agro-products like early- and late- rice (Liu et al., 2016; Jia et al., 2015). As the climate changes frequently in recent years, some scholars began to pay attention to the impact of extreme weather on crop yield. Zhao et al. (2015) found that higher maximum temperatures (T_{max}) in June would significantly increase the yield of spring maize. However, a study by Conaty et al. (2015) showed that maximum temperature (T_{max}) would correspond to a predicted 23% reduction in lint yield.

Rainfall is another major cause of uncertainty in the yield of agro-products (Campiglia et al., 2015; Nadal-Romero et al., 2015; Zhao, Guo, & Mu, 2015; Shrestha, Chapagain, & Babel, 2017). Most studies showed that rainfall had a negative effect on crop yield such as early- and late-rice (Liu et al., 2016). Nevertheless, some studies showed the impacts of rainfall on the yield are different during different growth stages. For example, Gourdji et al. (2015) found that heavier rains during planting and harvesting would negatively affect bean yield, but the impact would be positive in December and January.

The extents to which different crops are affected by climate are not the same, with some types of crops more susceptible to changes in climate than others (Sarker et al., 2014; Palazzoli et al., 2015; Padakandla, 2016). Even in the same crop, the effects of changes in climate variables vary among the varieties. Although temperature and rainfall have proven to be the major meteorological factors affecting performance of many crop plants, there are a few studies focusing on how weather change influences the production of litchi that is much more vulnerable to climate change and variability than other agro-products. Furthermore, most studies on impacts of weather changes on litchi yield are qualitative researches which cannot reflect the exact impacts. To gain an insight into whether temperature and rainfall influence litchi yield and how they influence the yield, a two-way fixed effect model was established to assess the impacts of climate variations on litchi yield of 39 main litchi producing counties in the provinces of Hainan, Guangdong, Guangxi, and Fujian in China. China is the largest litchi producer in the world with a planting area and annual production accounting for nearly 90% of the world's production and planting area. Variations in litchi yields in the four main litchi producing provinces caused by weather factors will strongly affect the world litchi supply and demand. Therefore, this study provides supportive evidence for litchi producers in adapting to climate change.

RESEARCH METHOD

Data

This paper uses data on litchi's yield, phenological period, and climate variations of 39 main producing counties under the jurisdiction of Hainan Province, Guangdong Province, Guangxi Province, and Fujian Province in China from 2011 to 2016. Litchi's yield was computed as the total production of litchi in a county divided by the total litchi-planted acres in that county. The data on litchi's phenological period, county-specific total litchi's production, and planted acres were obtained from China Litchi and Longan Research System.

Weather data were obtained from the China Meteorological Data Report Network which records daily T_{max}, T_{min} and rainfall for 2290 weather stations of 34 provinces in China. Since county-level data on daily rainfall is not available in public data sources, we used rainy days during each growth period of litchi as the proxy variable for 'rainfall'. This dataset also contained exact coordinates of each weather station of the 39 main producing counties, enabling them to be merged with our county-level litchi's yield data and phenological period data.

Model construction

The panel data model combined information of both cross-section data and time-series data. Therefore, the panel data model not only significantly increased the sample space but also reduced the impact of multicollinearity between explanatory variables on the estimated results, making the estimated results of the parameter more reliable. However, fixed effect model of traditional panel data only considered the individual effect, but not the residual correlation between different regions in different periods, which inevitably lead to the deviation of the results. In order to overcome the bias of model selection, a two-way fixed effect model was used in this paper to examine the impact of climate variations on litchi's yield that could consider both the fixed effect of individuals and the fixed effect of time. The two-way fixed effect model was constructed as follows:

$$y_{it}=x_{it}\beta+\alpha_i+\lambda_t+\varepsilon_{it}$$

Where y_{it} denotes county-average litchi yield in county i and year t. x_{it} represents weather variables, including the means of daily T_{max}, T_{min} and the rainy days during each litchi's growth stage. We also controlled for county-level fixed effects (represented by α_i) and year fixed effects (denoted by λ_t) to remove the effects of unobserved factors that are unique to each county and the effects that are common to all counties in a given year on yield. ε_{it} was the error term. β was the parameter vector that gives the responses of rice yield to weather variations.

EMPIRICAL ANALYSIS

Descriptive statistics

Descriptive statistics of litchi yield are provided in Table 1. From Table 1, we can see that the average litchi yield in all main producing counties is 250.8 kg/mu, with a maximum yield of 1063 kg/mu and a minimum yield of 8 kg/mu.

Table1. Descriptive statistics of litchi yield and meteorological factors

Variables	Obs	mean	sd	min	max
yield	234	250.8	194.4	8	1063
vegetative:T_{max}	234	24.8	3.42	13	37
vegetative:T_{min}	234	7.38	3.65	0	21
vegetative:rainfall	234	8.44	8.02	0	64
heading:T_{max}	234	27.72	3.11	12	37
heading:T_{min}	234	8.51	3.79	-1	21
heading:rainfall	234	14.5	9.6	0	48
flowering:T_{max}	234	30.7	2.51	23	40
flowering:T_{min}	234	21.16	11.7	2	21
flowering:rainfall	234	11.19	6.33	0	30
ripening:T_{max}	234	34.47	2.15	26	41
ripening:T_{min}	234	23.26	2.66	12	27
ripening:rainfall	234	40	5.76	0	88

According to the growth characteristics of litchi, the growing season of litchi can usually be divided into four main growth periods; namely vegetative stage, heading stage, flowering stage, and ripening stage. Temperature varies during litchi's different growth period. For maximum temperatures T_{max}, the average in all main producing counties were 24.8°C during the vegetative stage, 27.72°C during the heading stage, 30.7°C during the flowering stage, and 7.38°C during the ripening stage. For the minimum temperatures T_{min}, they were 24.8°C during the vegetative stage, 8.51°C during the heading stage, 21.16°C during the flowering stage, and 23.26°C during the ripening stage.

As for the rainy days, the average were 8.44 days during the vegetative stage, 14.5 days during the heading stage, 11.19 days during the flowering stage, and 40 days during the ripening stage.

Regression Results: Sample with all varieties of litchi

A two-way fixed effect model was established to examine the impacts of climate variations on litchi yield in China. We included weather variables during each phenological period of litchi, namely T_{max}, T_{min} and rainfall as explanatory variables to examine the variations in litchi yield.

Table 2. The effects of climate variations on litchi yield

Variables	All litchi	Feizixiao	Guiwei	Heiye
vegetative:T_{max}	0.924	5.903	-22.98***	-10.86*
	(3.789)	(6.016)	(5.511)	(6.079)
vegetative:T_{min}	1.011	-0.176	6.188	5.661
	(3.744)	(5.256)	(6.227)	(7.065)
vegetative:rainfall	-3.076**	-4.020**	-0.503	-6.715**
	(1.348)	(1.842)	(2.593)	(3.140)
heading:T_{max}	-2.946	-5.026	-7.935	3.430
	(4.101)	(6.522)	(6.535)	(7.076)
heading:T_{min}	7.112**	14.01**	0.485	-0.373
	(3.587)	(5.536)	(5.753)	(6.720)
heading:rainfall	-0.802	-0.113	1.097	-1.500
	(1.280)	(1.762)	(2.007)	(2.290)
flowering:T_{max}	9.930*	20.83***	-7.864	-3.740
	(5.463)	(7.730)	(9.228)	(11.26)
flowering:T_{min}	0.00234	-0.0383	-0.408	-0.0314
	(0.0825)	(0.103)	(5.307)	(0.0983)
flowering:rainfall	-5.865***	-3.850	-2.620	-7.489***
	(1.821)	(2.565)	(2.879)	(2.832)
ripening:T_{max}	4.356	4.998	39.44***	-53.98***
	(8.109)	(13.54)	(13.67)	(19.67)
ripening:T_{min}	3.578	-3.136	3.743	12.94
	(6.322)	(11.29)	(12.07)	(13.62)
ripening:rainfall	-2.597	-3.535	-4.691*	-4.244**
	(2.069)	(3.057)	(2.605)	(1.825)

Table 2 showed parameter estimates of weather variables for the model specification considered in this study. We found that the responses of litchi yield to temperature and rainfall varied by growth stage. Rainfall had statistically significant impacts on litchi yield during the vegetative stage. T_{min} had significant impacts on litchi yield during the heading stage. Excluding the two variables above, litchi yield was also affected by both T_{max} and rainfall during the flowering stage. However, temperature and rainfall did not have significant impacts on litchi yield during the ripening stage.

Coefficient estimates of weather variables showed that rainfall had negative impacts on litchi yield during both the vegetative and flowering stages, while higher T_{min} during the heading stage and T_{max} during the flowering stage had positive impacts on litchi yield. More specifically, it was observed that a 1°C increase of T_{min} during the heading period caused litchi yield to increase by 7.112 kg/mu and 1°C increase of T_{max} during the flowing period caused litchi yield to increase by 9.930 kg/mu. A day increase of rainy days reduced litchi yield by about 3.076 kg/mu during the vegetative stage and 5.865 kg/mu during the flowering stage.

Regression Results: 'Feizixiao' vs.'Guiwei' vs. 'Heiye'

'Feizixiao', 'Guiwei', and 'Heiye' are the three main litchi varieties accounting for more than 70% in yield and planting area of the litchi varieties. As these three litchi varieties are different in their physicochemical properties and genetic traits, it is necessary to examine whether the weather effects on yield estimated above differed by litchi variety. We divided our samples into several subsamples: 'Feizixiao' litchi-producing counties, 'Guiwei' litchi-producing counties, and 'Heiye' litchi-producing counties; calculated each county's litchi yield of the three main litchi varieties, and then replicated the analysis as the sample with all varieties of litchi.

As shown in the last three columns of Table 2, the weather effects on litchi yield differed substantially by litchi varieties during different phenological periods. For 'Feizixiao', its yield was associated with the germination stage, heading stage, and flowering stage; while the yield of 'Guiwei' was related to the germination stage and ripening stage but not the heading stage and flowering stage. As for 'Heiye', the germination stage, flowering stage, and ripening stage had significant influences on its yield, while the effect of heading stage on its yield was not significant.

Specifically, rainfall had a negative but not the same effect on the yield of different litchi varieties during different phenological periods. During the vegetative stage, one rainfall day increase reduced the yield of 'Feizixiao' by 3.26 kg/mu and 'Heiye' by 10.86 kg/mu. During the flowering stage, the yield of 'Heiye' reduced by 5.76 kg/mu when rainfall increased by one day. During the ripening stage, the yield of 'Guiwei' reduced by 5.23 kg/mu and 'Heiye' by 5.01 kg/mu when rainfall days increased by one day.

Temperature impacts on yield also differed considerably by litchi variety. For 'Feizixiao', its yield was significantly related to T_{min} during the heading stage and T_{max} during the flowering stage. The yield of 'Feizixiao' increased by 12.82 kg/mu with 1°C increase in T_{min} during the heading stage and 26.14 kg/acre if T_{max} increased 1°C during the flowering stage. For 'Guiwei', higher T_{max} during different phenological periods had different impacts on its yield. The effect of higher T_{max} on the yield of 'Guiwei' was negative during the germination stage when the yield of 'Guiwei' decreased by 25.97 kg/mu with T_{max} 1°C higher, which is opposite to the ripening stage when the yield of 'Guiwei' increased by 31.10 kg/mu with T_{max} 1°C higher. As for 'Heiye', its yield was mainly affected by T_{max} during the ripening stage when the yield of 'Heiye' decreased by 66.40 kg/mu with T_{max} 1°C higher. Besides, a 1°C increase in T_{max} during the vegetative stage also decreased the yield of 'Heiye' by 10.86 kg/mu.

CONCLUSIONS

This paper examined the impacts of weather variations on litchi yield by using a county-level panel on litchi yield and weather situations in corresponding counties. The main conclusions are as follows:

1. Meteorological factors affecting litchi yield are not the same during different growth periods. During the vegetative stage, litchi yield was significantly influenced by rainfall. During the heading stage, T_{min} was the major parameter determining litchi yield. During the flowering stage, both T_{max} and rainfall played an important role in influencing litchi yield.
2. Litchi yield was negatively related to rainfall during the vegetative and flowering stages and positively related to daily minimum temperatures during the heading stage and maximum temperatures during the flowering stage.
3. The effects of climate variations on different varieties of litchi are not the same. The yield of 'Feizixiao' was highly related to rainfall during the vegetative stage negatively influencing the yield, T_{min} during the heading stage and T_{max} during the flowering period. For 'Guiwei' and 'Heiye', the yield was mainly affected by T_{max} during vegetative stage and ripening stage and rainfall during the ripening stage. However, T_{max} during the ripening stage increased the yield of 'Guiwei' but decreased the yield of 'Heiye' significantly.

REFERENCES

Anwar, M. R., Liu, D. L., Farquharson, R., Macadam, I., Abadi, A., Finlayson, J., Wang, B., & Ramilan, T. (2015). Climate change impacts on phenology and yields of five broadacre crops at four climatologically distinct locations in Australia. *Agricultural Systems* 132, 133-144.

Campiglia, E., Mancinelli, R., De Stefanis, E., Pucciarmati, & S., Radicetti, E. (2015). The long-term effects of conventional and organic cropping systems, tillage managements and weather conditions on yield and grain quality of durum wheat (*Triticum durum* Desf.) in the Mediterranean environment of Central Italy. *Field Crops Research* 176, 34-44.

Conaty, W. C., Mahan, J. R., Neilsen J. E., Tan, D. K. Y., Yeates, S. J., & Sutton, B. G. (2015). The relationship between cotton canopy temperature and yield, fibre quality and water-use efficiency. *Field Crops Research* 183, 329-341.

Duncan, J. M. A., Saikia, S. D., Gupta, N., & Biggs, E. M. (2016). Observing climate impacts on tea yield in Assam, India. *Applied Geography* 77, 64-71.

Fang, Q., Zhang, X., Chen, S., Shao, L., & Sun, H. (2017). Selecting traits to increase winter wheat yield under climate change in the North China Plain. Field Crops Research 207, 30-41.

Gömann, H. (2015). How Much did Extreme Weather Events Impact Wheat Yields in Germany? - A Regionally Differentiated Analysis on the Farm Level. *Procedia Environmental Sciences* 29, 119-120.

Gourdji, S., Läderach, P., Valle, A.M., Martinez, C. Z., & Lobell, D. B. (2015). Historical climate trends, deforestation, and maize and bean yields in Nicaragua. *Agricultural and Forest Meteorology* 200, 270-281.

Jia, Y., Zou, D., Wang, J., Liu, H., Inayat M.A., Sha, H., Zheng, H., Sun, J., & Zhao, H. (2015). Effect of low water temperature at reproductive stage on yield and glutamate metabolism of rice (*Oryza sativa* L.) in China. *Field Crops Research* 175, 16-25.

Kim, Y., Seo, B., Choi, D., Ban, H., & Lee, B. (2017). Impact of high temperatures on the marketable tuber yield and related traits of potato. *European Journal of Agronomy* 89, 46-52.

Kima, A. S., Traore, S., Wang, Y., & Chung, W. (2014). Multi-genes programing and local scale regression for analyzing rice yield response to climate factors using observed and downscaled data in Sahel. *Agricultural Water Management* 146, 149-162.

Liu, S., Pu, C., Ren, Y., Zhao, X., Zhao, X., Chen, F., Xiao, X., & Zhang, H. (2016). Yield variation of double-rice in response to climate change in Southern China. *European Journal of Agronomy* 81, 161-168.

Lizana, X. C., Avila, A., Tolaba, A., & Martinez, J. P. (2017). Field responses of potato to increased temperature during tuber bulking: Projection for climate change scenarios, at high-yield environments of Southern Chile. *Agricultural and Forest Meteorology* 239, 192-201.

Ma, J. & Maystadt, J. (2017). The impact of weather variations on maize yields and household income: Income diversification as adaptation in rural China. *Global Environmental Change* 42, 93-106.

Nadal-Romero, E., González-Hidalgo, J. C., Cortesi, N., Desir, G., Gómez, J.A., Lasanta, T., Luciá, A., Marín, C., Martínez-Murillo, J. F., Pacheco, E., Rodríguez-Blanco, M. L., Romero Díaz, A., Ruiz-Sinoga, J. D., Taguas, E. V., Taboada-Castro, M. M., Taboada-Castro, M. T., Úbeda, X., & Zabaleta, A. (2015). Relationship of runoff, erosion and sediment yield to weather types in the Iberian Peninsula. *Geomorphology* 228, 372-381.

Okoro, S. U., Schickhoff, U., Boehner, J., Schneider, U. A., & Huth, N. I. (2017). Climate impacts on palm oil yields in the Nigerian Niger Delta. European Journal of Agronomy 85, 38-50.

Paul, S., Das, M. K., Baishya, P., Ramteke, A., Farooq, M., Baroowa, B., Sunkar, R., & Gogoi, N. (2017). Effect of high temperature on yield associated parameters and vascular bundle development in five potato cultivars. *Scientia Horticulturae* 225, 134-140.

Sarker, M. A. R., Alam, K., & Gow, J. (2014). Assessing the effects of climate change on rice yields: An econometric investigation using Bangladeshi panel data. *Economic Analysis and Policy* 44(4), 405-416.

Sharma, L., Priya, M., Bindumadhava, H., Nair, R. M., & Nayyar, H. (2016). Influence of high temperature stress on growth, phenology and yield performance of mungbean [Vigna radiata (L.) Wilczek] under managed growth conditions. *Scientia Horticulturae* 213, 379-391.

Shrestha, S., Chapagain, R., & Babel M. S. (2017). Quantifying the impact of climate change on crop yield and water footprint of rice in the Nam Oon Irrigation Project, Thailand. *Science of The Total Environment* 599–600, 689-699.

Vashisht, B. B., Nigon, T., Mulla, D. J., Rosen, C., Xu, H., Twine, T., & Jalota, S.K. (2015). Adaptation of water and nitrogen management to future climates for sustaining potato yield in Minnesota: Field and simulation study. *Agricultural Water Management* 152, 198-206.

Weymann, W., Böttcher, U., Sieling, K., & Kage, H. (2015). Effects of weather conditions during different growth phases on yield formation of winter oilseed rape. *Field Crops Research* 173, 41-48.

Zhao, J., Guo, J., & Mu, J. (2015). Exploring the relationships between climatic variables and climate-induced yield of spring maize in Northeast China. *Agriculture, Ecosystems & Environment* 207, 79-90.

PAPER 3:
ENSURING A SUSTAINABLE TROPICAL FRUIT INDUSTRY IN THE MIDST OF CLIMATE CHANGE: THE VIETNAM STORY

Nguyen Quoc Hung[1] & Vo Huu Thoai[2]
[1]Fruit and Vegetable Research Institute, Ha Noi, Viet Nam
[2]Southern Fruit Research Institute, Tien Giang, Viet Nam

ABSTRACT

Fruit production has been increasingly playing an important role in agricultural production in Vietnam. In 2016, the area of fruit trees in Vietnam reached 848 thousand hectares with an estimated productivity of over 8 million tons of fruit. Out of the fruit growing areas, the production in the North accounted for about 300,000 hectares, meanwhile the Southern provinces have occupied over 500,000 hectares. Major fruit trees cultivated under large areas include banana, citrus, longan, mango, dragon fruit, pineapple, durian, and rambutan. In the South, provinces along the Mekong River Delta are the main tropical fruit producers of the country with an area of approximately 300 thousand hectares that contributes to 36.5% of the national total fruit production. Vietnam is one of the countries that have suffered most from the effects of climate change, such as great impacts on agricultural production in Vietnam. In the provinces along the Mekong River Delta, salinity intrusion is increasing in terms of both land area and severity. More than 10,000 hectares of fruit trees have been salinated to various degrees. In order to adapt to climate change, the Vietnamese government is making changes in its investment policies for agricultural production. The nation is also concentrating on investing in breeding and selection of fruit tree varieties that are tolerant of drought, resistant to major diseases, and has salt-tolerant rootstocks. The breeders have successfully selected some of fruit varieties/cultivars of good salinity tolerance used for citrus production.

Keywords: Vietnam, exports, climate change impacts

INTRODUCTION

Vietnam has a diversified climatic condition, producing different fruit crops including temperate, tropical, and sub-tropical fruits. The leading fruits in Vietnam are longan, lychee, banana, pineapple, citrus, dragon fruit, mango, rambutan, and durian. The total land area utilized for fruit crop cultivation in Vietnam has reached over 848 thousand hectares. In addition, Vietnam's fruit and vegetable export values have increased rapidly in recent years, reaching USD 2.45 billion in 2016. However, Vietnam is listed as one of the countries that suffer the most from climate change. Annually, floods and droughts frequently occur in the northern and central provinces, and the Central Highlands. Salinisation of the Mekong River Delta has caused serious damage to fruit production and development, chiefly oranges, mandarins, lemon, and pomelo which were classified as relatively tolerant or sensitive to salinity. The current situation demands for solutions to maintain the fruit production under the context of climate change.

FRUIT PRODUCTION IN VIETNAM

Annually, the country produces over 8 million tonnes of fruit. Cultivation area of the major fruits account to three-fourth of the total production. Among the many kinds of fruit, banana takes up the largest production area of over 136 thousand hectares, yielding approximately 2.0 million tonnes per year. Citrus (orange and pomelo) is in the second place, with a total cultivation area of over 128 thousand hectares, with a production of 584.78 thousand tonnes of orange and 474.54 thousand tonnes of pomelo per year. Despite a smaller production area of 44.0 thousand hectares, which is only half of mango's, dragon fruit yields almost 2.5 times higher than that of mango, which was 22.8 and 9.4 tonne/ha, respectively. Southern Vietnam is the main fruit granary of the country, producing various kinds of fruit — most of which are important fruits. Longans can be well cultivated in both the North and the South, while lychee production is available only in the northern provinces. Area and production of longan is 1.2–1.6 times higher than that of lychee.

Table 1. Production of major fruits in Vietnam

Kinds of Fruit	Total area (1,000 ha)	Yield (tonne/ha)	Production (1,000 tonnes)
Banana	136.48	16.2	1,968.71
Mango	84.77	9.4	707.89
Dragon fruit	44.00	22.8	817.80
Pineapple	40.91	16.3	579.98
Orange	72.08	12.4	594.78
Pomelo	54.75	11.7	474.54
Longan	73.94	7.8	504.99
Lychee	64.19	5.0	312.56
Rambutan	26.01	14.9	343.71
Durian	32.30	14.5	336.90
Others	219.21	-	> 1,300.00
Total	**848.64**		**> 8,000.00**

Along with an increase in cultivation area, the export turnover of fruit, vegetables, and flowers has increased from USD 23.1 million in 2000, which doubled in 2010 at USD 471 million, to USD 1.85 billion in 2015 and has currently peaked at USD 2.45 billion in 2016.

Dragon fruit is the leading fruit export in Vietnam. Its export turnover in 2010 reached USD 59 million, USD 483.4 million in 2015, and USD 800 million in 2016 which was one-third of the total export value of fruit, vegetables, and flowers. Many fruits produced in Vietnam including mango, banana, pineapple, pomelo, longan, litchi, and rambutan have been also accepted in numerous countries and territories.

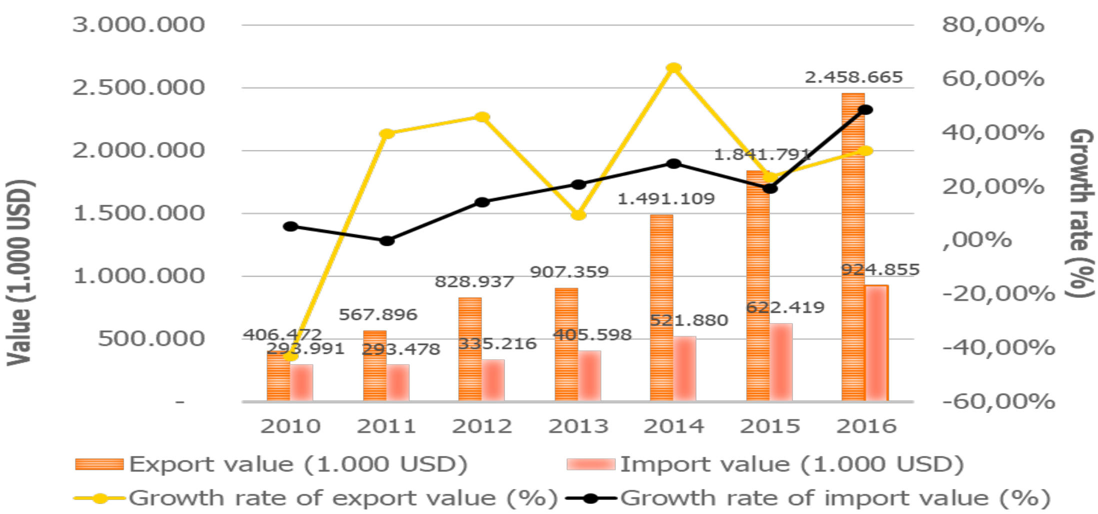

Figure 1: Export and import of fruit, vegetables and flowers in Vietnam (2010-2016)

Vietnam also imports various fruits from different countries in the world, which has seen an increasing trend, specifically since 2010. According to the Ministry of Agriculture and Rural development, Vietnam has recently paid almost half of the amount earned from exports of fruit, vegetables, and flowers for imports of produce. The growth rate of fruit, vegetable, and flower import even closely approached that of export in 2015, which was at 20%, and half as much as that in 2016 at 48.6% and 33.5%, respectively. Most of the imported fruit originates from China, Thailand, America, and Australia.

SALINITY INTRUSION IN MEKONG RIVER DELTA AND SOLUTIONS TO PROTECT FRUIT CROPS

Salinity intrusion in Mekong River Delta

Climate change has already impacted the Mekong River Delta, triggering an increase of sea water levels, annual rainfall amount and frequency, average temperature, and salt water intrusion to the mainland through the net-rivers of the Mekong River Delta. Normally, salinity intrusion appears in early February. The main reason for salinity intrusion is the inability of low upstream water to discharge salt water to the sea through rivers. Moreover, high tides combined with the effects of the northeast monsoon make the situation more severe. In addition, construction of dykes (dams) along the upstream Mekong riverbanks may also be the cause of increasing salt water intrusion. In recent years, it was observed that water levels in the upstream of the Mekong River is lower than the average water levels during dry seasons. This was acknowledged in previous years. Therefore, salt water intrusion has occurred earlier and has moved deeper inland, up to 40–50 km or more.

In fruit crops, the first symptoms of salt toxicity are yellowing and burning at the tip of the leaves which would eventually fall prematurely. In the Mekong River Delta, more than 10,000 hectares of fruit crops have been affected by salt water, including durian, rambutan, and citrus which are classified as relatively tolerant or sensitive to salinity. Salinisation has caused serious damage to the growth and development of fruit crops as well as the fruit production. Various measures such as reclamation, irrigation, and drainage have been used to reduce the salinity of the cultivation soil.

Solutions to protect fruit crops from salinity intrusion

In order to reduce damage of salt water intrusion in the Mekong River Delta, the local government has responded and applied measures to mitigate salt water intrusion as the region faces severe drought during the dry season. Those measures include:

- Pumping water from canals to recover crops along with dredging inland canals for faster and smoother water flow. However, salt water will likely penetrate into the canals soon.
- Building dams in order to prevent salt water intrusion. This measure is ineffective in the long term as hot weather causes the water to evaporate very quickly.
- Storing fresh water in large ponds and small canals in an orchard for months before cultivation. Nevertheless, the water will be insufficient and will run out early.
- Growing crops in areas close to dyke systems or where the water is slightly salty (under 4%) and with short duration of salt water intrusion.
- Growing salt tolerant crops such as coconut, mango, and sugar cane.

However, all the above solutions are only temporary. An overarching strategy for the whole region must be realized in order to cope with salt water intrusion. It is necessary for the Mekong River Delta to redesign cultivation schedules of crops for suitability with the annual intrusion of salt water to avoid its severe damage. Breeding clones/varieties of fruit crops which are tolerant/resistant to adverse environmental conditions is a sustainable measure which should be implemented in the future.

Study on citrus rootstocks for salt tolerance in Mekong River Delta

One recent strategy is to develop new crop cultivars/varieties which are tolerant to salinity. Screening of salt tolerant rootstocks for citrus in particular and other types of fruit crops is a major concern of countries affected by salinity.

Da Xanh pomelo is one of the major horticultural crops in the Mekong Delta and is relatively salt sensitive. Therefore, a study on the selection of the suitable grafted combinations of pomelo (*Citrus grandis* Osbeck) for salinity conditions in the Mekong Delta is necessary. A study on screening natural genetic resources for salt tolerant rootstocks was conducted from 2006–2012. Sixteen clones/varieties of local citrus were collected from the provinces of South Vietnam. Ten clones of citrus hybirds, *Cleopatra mandarin* and *Carrizo citrange* were used as salt tolerant and sensitive rootstocks. The objectives of the study were:

- To select a resistant citrus cultivar/variety as rootstock.
- Identify appropriate combinations of Da Xanh pomelo and rootstocks for salt tolerance, high yield, and fruit quality in saline conditions of the Mekong River Delta.

Results showed that salinity affected the growth and development of citrus clones/varieties and hybrid citrus clones. Salinity reduced chlorophyll content, starch content, and total sugar content while increasing the content of potassium, sodium, and chlorine in the leaves. Under net house conditions, 8 local citrus clones/varieties and hybrid citrus clones were identified as salt tolerant rootstocks such as Bong (Hue), Duong Hong pomelo (Binh Duong), Hong Duong pomelo (Can Tho), Bung pomelo (Ben Tre), Sanh (Ben Tre), Tac (Ben Tre), hybrid of Tac × Long Co Co pomelo, and hybrid of Tac × Da Xanh pomelo. The study suggested that methods for forecasting citrus rootstock-scion compatibility between citrus rootstocks and Da Xanh pomelo scion through ring grafting technique gave fast results and costs less. Five grafted citrus combinations between five salt tolerant rootstocks Bong (Hue), Duong Hong pomelo (Binh Duong), Hong Duong pomelo (Can Tho), Bung pomelo (Ben Tre), and Sanh (Ben Tre) gave good compatibility with Da Xanh pomelo scion under both net house and field conditions. Grafted citrus combinations grew and developed well. The combinations of the above rootstocks with Da Xanh pomelo gave good quality fruits. It is recommended to further evaluate the performance of the combinations to select the best scion-rootstock combination of vigorous growth, development, high yield, fruit quality stability, and good tolerance to saline environment.

Drought tolerance rootstocks for fruit crops in northern and central provinces

Similar to the South, adverse weather conditions have occurred in northern Vietnam with high frequency causing serious damage to the fruit production. Long rainy seasons and heavy storms caused floods to happen at a much higher frequency; long lasting dryness has caused severe drought in the central and central highland provinces; diseases occurring in fruit growing areas are more concentrated causing greater damage. Researchers have proposed various measures to deal with the problem. One of those is to study and develop rootstocks of good flood and drought tolerance. Practical productions revealed several fruit varieties of drought tolerance, especially of citrus. Major citrus varieties which have been used as rootstocks for drought tolerance include: Buoi Chua (sour pomelo), Buoi Do (Red pomelo), and Buoi Thanh Tra (Thanh Tra pomelo). Buoi Chua is the most widely used rootstocks for citrus production in the North. The variety exhibits vigorous growth and development, compatible with various stock varieties rapidly meeting demands for transplanting. However, the variety is of single-embryo and this may influence the stock performance; causing non-identical growth and development thus affecting fruit quality, disease resistance, and tolerance to adverse cultivation conditions.

CONCLUSION

Vietnam has a diversified climate condition, able to produce different fruit crops. The fruit and vegetable export turnover has seen an increase in recent years, contributing to the national agricultural export value. However, Vietnam is one of the countries suffering the most from climate change, causing great impacts on agriculture including fruit production. Floods, long droughts, and saline intrusion have occurred with a higher frequency, severely affecting the industry. The Government of Vietnam has currently established strategies to deal with climate change in future scenarios; gradually transforming the production towards promoting the use of varieties adaptable to drought and saline intrusion. There has been initial success in breeding fruit cultivars and rootstocks resistant to diseases, tolerant to drought and salinity for sustainable fruit production in climate change.

PAPER 4:
ENSURING A SUSTAINABLE TROPICAL FRUIT INDUSTRY IN THE MIDST OF CLIMATE CHANGE THE INDIA STORY

Prakash Patil
Project Coordinator (Fruits), Indian Institute of Horticultural Research (ICAR)

ABSTRACT

India's horticulture sector is one of the main driving forces of the country with more than 30% share in the agriculture GDP. From 2016–2017, it was estimated that production was at 299.85 million tonnes from a planting area of 25.1 million hectares. This has outpaced the production of food grains since 2012–2013. Nevertheless, climate change remains a major threat to the horticulture sector. In the last 35 years (1981–2015), mean temperatures over the Indian subcontinent have indicated warming trends and this is projected to rise. India receives an approximate 75% dependable annual rainfall. However, climatic changes have caused the annual monsoon seasons to be erratic bringing in excess rain as well causing severe droughts in other regions — shifting production zones of tropical fruits. As a result of these fluctuations, fruit crops adapt phenologically, i.e., by altering their vegetative and reproductive stages. For example, in mangos, lower temperatures promote reproductive morphogenesis while high temperatures induce a higher percentage of hermaphrodite flowers. Decreased photosynthetic rates due to water deficiencies would result in stunted growths of papaya trees. These variations will adversely affect the quality and productivity of tropical fruits. Climate change also affects the activity of pests and pollinators. Due to rising temperatures, temperate regions in India have become more favorable to pests such as fruit flies and Bactrocera dorsalis; these pests have been discovered spreading to North India. At higher temperatures, it was observed that the active foraging time of pollinators have reduced by 26%–30%. To ensure sustainability of the agriculture industry in India, the National Initiative on Climate Resilient Agriculture (NICRA) was launched by the Indian Council of Agricultural Research (ICAR). Some of its objectives are to assess the impact of climate change and cultivate adaptive strategies to mitigate its effects across all sectors of agriculture. Proper management of resources as well as employing improved risk management strategies would enhance the resiliency of Indian agriculture amidst the looming threat of climate change.

Keywords: India, horticulture, climate change

PAPER 5:
EFFECTS OF THREE GROWTH REGULATORS INDUCED FLOWERING ON YIELD AND QUALITY OF RIPLEY QUEEN PINEAPPLE (*ANANAS COMOSUS*) IN FIJI.

Manoa Iranacolaivalu & Kalolaini Colaitiniyara
Horticulture Section of the Research Division, Ministry of Agriculture, Fiji

EXTENDED ABSTRACT

Pineapple (*Ananas comosus* L.) is the second major fruit of Fiji, after banana. According to the last Fiji agricultural census (2009), around 445 hectares of planted pineapple are grown by 914 farmers producing about 2,800 tonnes of pineapples annually. The major producing areas (around 75%) lies in the intermediate zone of the Eastern part of the main island and the remaining comes from the dry zone of the Western part of Fiji. Pineapples are sold in hotels and municipal markets worth around FJD 1.8 million to farmers.

The main challenge facing pineapple farmers in Fiji is the seasonality of the crop. However, the availability of growth regulator (GR) chemicals encourage all year round production. The locally available GRs are Ethephon (48% 2-chloroethylphosphonic acid), Floraset (4% 1-naphthalene acetic acid), and EPGR 108 (10.8% 2-chloroethylphosphonic acid).

Table 1. Description of growth regulators

Ethephon (48% 2-chloroethylphosphonic acid)	Alpha-Naphtaline Acetic Acid or ANA
Ethylene, a gaseous plant hormone, is responsible for the initiation of reproductive development in pineapple. Reproductive development can be forced in pineapple throughout the year with ethylene. 2-Chloroethylphosphonic acids or Etyphon, available as “Ethrel”, “Ethephon”, or “EPGR 108”. This is a world-wide used chemical for the harvest control in pineapple.	Available directly under the name ANA or under a range of trade names such as Floraset (4% 1-naphthalene acetic acid), recommended as rooting media as well as flowering hormone. However this chemical is an auxin and is less effective in flower induction than the above mentioned ethephon, with fruiting rates varying over an unacceptable range between 30% to 70% effectiveness, which is too low and unreliable for commercial production. It will be more effective in higher latitudes and can be used during periods with shorter days. As a rooting hormone, this chemical can be useful in the climates with distinct short days during seasonal periods of the year just before the natural season.

The effectiveness of the three growth regulators in inducing synchronized flowering on “Ripley queen” pineapple were evaluated during the 2015 season at the Seaqaqa Research Station (SqRS) in the Northern part of Fiji.

Table 2. Conditions at the Seaqaqa Research Station (SqRS) during the experiment

Soil	WEATHER	EXPERIMENT MAINTENANCE
pH: 5.6 **N**: 0.2% **Olsen P**: 1.0mg/kg **K**: 0.2 me/100g	**Temp**: 18.9 - 29.1 **Rainfall**: 17.5mm **Rainfall days**: 4 **Humidity**: 71%	**BASAL**: Mill Mud 5 tonnes/ha, super phosphate: 250kg. **SIDE DRESS:** Urea: 110kg/ha at 1 month after planting. NPK: 13:13:21 at 250kg/ha at 4 months interval after planting. **Weed Control:** As and when required

The experiment was established in June 2014 using the randomized complete block design (RCBD), and the treatments are four rates of Ethephon, Floraset, and EPGR 108 in 3 levels (recommended rate, level 1 and level 2) and the control in factorial combinations. Ethephon and Floraset use 5ml, 10ml, and 15ml in 10L of water; while EPGR108 uses 30ml, 35ml, and

40ml in 10L of water. Solution mixture includes: chemicals + 10g Borax + 50g Urea + 10L water which is applied at a rate of 50ml/plant. There were three blocks and fifteen plants per plot for each treatment. Fruits are harvested at 85-90% ripeness with results focused on yield and fruit qualities. The collated data were analyzed statistically using CropStat and mean differences were separated for interpretation at 5% level of significance.

Based on the Analysis of Variance (ANOVA) there is significant difference in the treatments based on the crown weight (LSD 5%: 0.0672), total fruit length (LSD 5%: 0.0312) and fruit circumference (LSD 5%: 0.0061). The result showed that the treatments have some effects on the time taken from application of treatment to harvest: i.e. shorter duration for ethephon and floraset especially at Level A. For floraset, level B outweighs the other GRs in terms of highest fruit weight (1127 grams) and the lowest crown weight percentage (13.3%) compared with the control. There is a significant difference in the total fruit length between the treatments and the control. The treatments are showing some effects on the fruit length and circumference compared to the control, especially for floraset and EPGR108. The treatments do not have any effect on the sweetness or total soluble solid (TSS) of the pineapple fruit, however, the control supersedes the treatments.

Results have proven that the 3 growth regulators induce early flowering and better yield in Ripley Queen pineapple variety. EPGR108 and Ethephon showed similar results in terms of number of days taken from GR application to harvest. Floraset, known as a root inducing GR, proved to produce good results in terms of flower induction and yield. Future work needs to focus on expanding the experiment to include other pineapple varieties in Fiji (Smooth Cayenne and Veimama); evaluation of the GRs on ratoon crops (1 & 2); experiment to incorporate monthly planting of pineapple to determine the most appropriate period (month) for off-season production; GRs to be tested on alluvial soil type and in intermediate climatic zone; experiment on postharvest to evaluate shelf life and fruit quality; conduct residual tests on the MRL of the chemical and to conduct economic analysis of the treatments based on the production life of the crop.

Keywords: Fiji, growth regulators, pineapple

REFERENCES

Department of Agriculture. (2009). Fiji National Agricultural Census 2009. Retrieved from: http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_3/FJI_ENG_REP_2009.pdf

SESSION WRAP UP AND Q&A

i. Feedback received included the importance for farmers to plan for disasters. However, for this to take place, the element of 'disaster preparedness' should be incorporated into extension services, which then has a key role in the dissemination of advisory services to the farmers.

ii. For visible success on the ground, more private-public partnerships were urged, as in the case of NWC where focus was given on improving profitability for all actors in the value chain.

iii. Diversification of farming systems was also highlighted as an important adaptation strategy for reducing the impact the climate change, as opposed to mono-cropping.

iv. Recommendations were provided from the floor to incorporate sensory evaluation as a variable for the treatments being used as part of the study on the RQ pineapples.

v. Interest was also noted from the floor on the methodologies used for field trials conducted on salinity tolerance in Vietnam.

SESSION TWO

Crop Protection and Pest and Disease Management

PAPER 1:
PREVENTION AND CONTROL OF HUANGLONGBING (HLB)

Yi Ganjun
Vice President, Guangdong Academy of Agricultural Sciences, Guangzhou, P.R. China

ABSTRACT

Huanglongbing (HLB), also known as citrus greening disease, is caused by a vector-transmitted bacteria *Candidatus* Liberibacter spp. It is transmitted by 2 psyllid species: *Diaphorina citri* and *Trioza erytreae*. All citrus species are susceptible to HLB, irrespective of rootstock with severity varying on cultivars: sweet orange, mandarin, and mandarin hybrids are highly susceptible; grapefruit, lemon and sour orange are moderately susceptible; and lime, pummelo, trifoliate orange are tolerant. Prevention and control of HLB can be summed by into the integrative application of five key and effective measures: (i) Ecological cultivation system; (ii) Kill all diseased trees; (iii) Using large and healthy seedlings; (iv) High density cultivation moderately; and (v) Kill psyllids in the whole orchard rapidly.

Keywords: Huanglongbing, citrus greening, prevention, control

PAPER 2:
INFESTATION PATTERN OF *SCIRTOTHRIPS DORSALIS* HOOD (THYSANOPTERA: THRIPIDAE) IN DEVELOPING SHOOT AND FLOWER OF MANGO ARUMANIS 143

Affandi[1], Celia dela Rosa Medina[2], Luis Rey Ibañez Velasco[2], Pio Arestado Javier[2] Dinah Pura Tonelete Depositario[3], Hardiyanto[4], & Muhammad Syakir[5]

[1]Indonesian Tropical Fruits Research Institute, Jl. Raya Solok-Aripan Km. 8 P.O. Box 5 Solok 27301 West Sumatra Indonesia

[2]Department of Entomology, Crop Protection Cluster, College of Agriculture, University of the Philippines, Los Baños, College, Laguna, Philippines, 4031

[3]Department of Agribusiness Management and Entrepreneurship, College of Economic and Management, University of The Philippines, Los Baños, College, Laguna, Philippines, 4031

[4]Indonesian Center for Horticultural Research and Development, Jl. Tentara Pelajar, No. 3C, Cimanggu, Bogor, Indonesia

[5]Indonesian Agency for Agricultural Research and Development, Jl. Ragunan No. 29, Pasar Minggu, Jakarta Selatan, 12540, Indonesia

ABSTRACT

A research to determine the directional preferences and occupation time of the chilli thrips, *Scirtothrips dorsalis* Hood, associated with flush and flower growth stages of mango was conducted in PT. Trigatra Rajasa, a private mango plantation in Situbondo district, East Java Province, Indonesia from October to November 2015. Yellow sticky traps were utilized to verify the presence of *S. dorsalis* that migrate to the mango canopy. The traps were installed facing all eight cardinal directions during bud break and flower stages for 10 consecutive days. Analysis of variance (ANOVA) with 5 replications was used and significant differences among eight cardinal directions were tested using the Least Significant Different (LSD) test (p=0.05). The results show that *S. dorsalis* preferred the North-East cardinal direction and started to move into the mango canopy during the early shoot emergence, beginning to lean in a certain direction on the second day of observation. During shoot emergence, the highest number of thrips existed on day eight, with a total of 21.00 adults trapped per tree. No preference in direction was observed during the flower growth stage. The highest numbers existed at day three (9.40 adults/per tree) during the flower growth stage. This findings of this research suggest that control tactics should be started during early shoot emergence to prevent initial build-up of population.

Keywords: *Scirtothrips dorsalis*, infestation, pattern, mango

INTRODUCTION

Arumanis 143 is the most prefered mango variety by Indonesian consumers because of its very sweet taste and fiberless texture. However, the production of this variety is still relatively low (25-30 kg/tree) compared to its potential productivity (54.7 kg/tree) (Dinas pertanian kabupaten situbondo, 2004). Pest and disease incursion is one of the major constrains for achieving high yield of Arumanis 143.

One of the most damaging pests for mango is the chilli thrips, *Scirtothrips dorsalis* Hood (Affandi & Medina, 2013). Till recently, there has been little information available about production losses due to *S. dorsalis* incidences for mango. *S. dorsalis* incidences have been reported to reduce fruit production of cashew by 15-25% in India (Gowda et al., 1979). A report by Hoodle et al., (2003) states that in 1998, thrips feeding damage on avocados (which possess a similar fruit morphology with mangos), reduced industry revenues to 12%. *S. dorsalis* alters the leaf color during flush growth from silver to dark brown, which then turns curly and undeveloped, finally falling off. It also decreases fruit set as the young fruit drops. Scarring of the immature and mature fruits are the effects of attack by *S. dorsalis* on flower and fruits.

Basic information on movement of *S. dorsalis* in mango plantation and factors that affect the movement is needed to develop management strategies against *S. dorsalis*. *S. dorsalis* has been reported to prefer buds, tender leaves as well as flowers (Kumar et al., 2013; Mannion et al., 2013). Propensity to a certain direction and time when *S. dorsalis* begins occupying during flush growth and floral induction can be used to determine the type of control strategy for S.dorsalis, whether pre-emptive or reactive management.

The objective of the research is to determine directional preference and time of infestation of *S. dorsalis* associated with mango in flush and flower growth stages.

MATERIALS AND METHODS

The research was conducted in PT. Trigatra Rajasa, a private mango plantation in Situbondo district, East Java Province, Indonesia from October to November 2015. The site is located 30 m above sea level with an average rainfall of 780 mm per year. During the research, the orchard experienced 5.5 wet months and 6.5 dry months.

Arumanis 143 is the only mango variety planted in the orchard. The trees are planted via monoculture with a distance of 8 X 10 m. The mango trees are already 22 years old, reaching 4-5 m in height, with a parabolic-shaped canopy. Good agricultural practices are applied and these include regular prunning, weeding, fertilization, irrigation and pest and disease control. Yellow sticky traps measuring 29.5 x 21 cm were utilized to verify the presence of *S. dorsalis* that migrate from different hosts to the mango trees. The yellow sticky traps were installed facing all eight cardinal directions and were placed 30 cm from the outermost and upper halves of each canopy. The traps was installed during bud break and flower stages of mango. A day after installing the traps, the number of adults caught were recorded daily for 10 consecutive days. Observations were also done during the flowering stage. The counting of thrips trapped in the yellow sticky traps was done in a laboratory using a binocular microscope. The wind direction and speed were also recorded.

The infestation of *S. dorsalis* from different host plants to mango trees was determined by counting the number of *S. dorsalis* adults that adhered to the yellow sticky trap. Analysis of variance (ANOVA) with 5 replications was performed. Hereafter, significant differences among the eight cardinal directions were tested using the Least Significant Different (LSD) test ($p=0.05$).

RESULTS AND DISCUSSION

A total of 379 adults S.dorsalis thrips were trapped during ten consecutive days of observation in the flush growth stage. The thrips started to move in at the start of early shoot emergence and began preferring a certain cardinal direction on the second day of observation. Based on eight cardinal directions, North-East presented as the most preferred direction which was evidenced by the highest average number of trapped *S. dorsalis* (1.74 thrips/trap). Among the 10 consecutive days, the highest number of thrips existed at day eight (21 adults/tree). Analysis of variance and further Least Significant Difference (LSD) based on average trapped population number is presented in Table 1.

The infestation of *S. dorsalis* into the mango trees began soon after the shoot emergence. Mango is one of the trees included as host range of *S. dorsalis* (Aliakbarpour, 2010; Global

Pest and Disease Database, 2011) especially during the flush growth stage, the most preferred food for the S.dorsalis. Various studies have indicated that *S. dorsalis* preferred to feed on the meristem, the terminal and other tender plant parts of the host such as buds and terminal leaves (Seal et al. 2010; Kumar et al. 2013; Mannion et al., 2013; Mannion et al., 2014). It has never been reported to feed on mature host tissues since during the mature stages, leaves contain high lignin content that impair insect feeding and oviposition (Dowd, 2013).

Table 1. *S. dorsalis* daily trap catch in eight cardinal directions during the flush stage of mango.

Direction	Day of Observations (Flush)										
	1	2	3	4	5	6	7	8	9	10	AVR
W	0.80 a	0.20 c	0.00 c	0.20 b	0.80 a	0.20 a	1.40 ab	2.80 ab	0.60 a	0.20 a	0.72 b
SW	0.80 a	0.20 c	0.40 bc	1.20 a	2.20 a	0.60 a	2.40 a	3.20 ab	0.00 a	0.00 a	1.10 ab
S	0.20 a	0.00 c	1.00 abc	0.40 ab	1.80 a	0.80 a	0.60 ab	0.20 b	0.20 a	1.00 a	0.62 b
SE	0.00 a	0.20 c	1.20 abc	0.00 b	0.80 a	0.60 a	0.20 b	0.60 b	0.40 a	0.20 a	0.42 b
E	0.80 a	2.80 ab	1.80 ab	0.20 b	2.20 a	0.40 a	0.80 ab	3.00 ab	1.00 a	0.20 a	1.32 ab
NE	0.60 a	4.00 a	2.60 a	0.20 b	1.60 a	0.20 a	1.20 ab	5.00 a	0.80 a	1.20 a	1.74 a
N	0.40 a	1.00 bc	1.40 abc	0.20 b	0.60 a	0.80 a	0.80 ab	3.20 ab	0.20 a	0.80 a	1.04 ab
NW	1.20 a	0.00 c	0.20 bc	0.00 b	1.00 a	0.40 a	0.20 b	3.00 ab	1.00 a	0.20 a	0.72 b
Total	**4.80 bc**	**9.40 bc**	**8.60 bc**	**2.40 c**	**11.00 b**	**4.00 bc**	**7.60 bc**	**21.00 a**	**4,20 bc**	**3.80 bc**	**7.68**

Note: Means value in each column with the same letter is not significantly different (p = 0.05) based on Least Significant Difference (LSD) test.
W = West SW = South West S = South SE = South East E = East
NE = North East N = North NW = North West

Observations during the flower growth stage showed that a total of 281 adults of *S. dorsalis* thrips were trapped during the 10 consecutive days. It started to colonize the mango trees at the onset of flower emergence. Mango flower is considered as one of the sources of food included in the host range of *S. dorsalis* (Aliakbarpour and Rawi, 2012). Apparently, flowers are preferred due to the non-existence of a meristemal plant parts of mango, especially during the flush stage. *S. dorsalis* has been known to be an opportunistic generalist species that is able to feed on a variety of host plants, depending upon availability of host (Kumar et al., 2013).

Low average population numbers were counted on yellow sticky traps installed in eight cardinal directions. However, *S. dorsalis* did not prefer certain directions based on the average population numbers. In addition, based on Least Significant Different (LSD) test, there was no significant difference among the days of observation (Table 2).

Thrips generally respond to environmental heterogeneity through movement (Dingle and Drake, 2007). Relatively high temperatures during flush growth observation (29.69°C) and low relative humidity (52.85%) can cause the rapid movement of *S. dorsalis*. Derksen et al. (2016) stated that the peak flight of dispersal for *S. dorsalis* occurred when temperatures reach 30°C under low relative humidity.

Table 2. *S. dorsalis* daily trap catch in eight cardinal directions during the flowering stage of mango.

Direction	Day of Observations (Flower)										
	1	2	3	4	5	6	7	8	9	10	AVR
W	0.00 a	0.00 a	0.40 a	0.60 a	0.60 ab	1.00 a	2.40 a	0.20 b	0.60 a	1.00 a	0.68 a
SW	0.20 a	0.20 a	0.60 a	0.20 a	0.20 ab	1.60 a	1.00 ab	0.20 b	0.80 a	0.60 ab	0.56 a
S	0.80 a	1.20 a	2.00 a	2.00 a	2.20 a	1.00 a	0.60 ab	0.00 b	0.40 a	0.00 b	1.02 a
SE	0.20 a	1.00 a	1.40 a	0.40 a	0.80 ab	1.60 a	0.20 b	1.40 a	0.40 a	0.40 ab	0.78 a
E	0.20 a	0.80 a	1.20 a	0.60 a	0.40 ab	0.60 a	0.60 ab	0.60 ab	1.00 a	0.00 b	0.60 a
NE	0.60 a	0.20 a	0.60 a	1.80 a	1.60 ab	0.40 a	0.20 b	0.20 b	0.80 a	0.60 ab	0.70 a
N	0.40 a	0.40 a	1.80 a	1.80 a	0.00 b	0.60 a	0.60 ab	0.20 b	0.80 a	0.20 ab	0.68 a
NW	0.20 a	1.40 a	1.40 a	0.20 a	0.40 ab	0.40 a	1.00 ab	0.40 b	0.40 a	0.20 ab	0.60 a
Total	**2.60 d**	**5.20 abcd**	**9.40 a**	**7.60 ab**	**6.20 abcd**	**7.20 abc**	**6.60 abcd**	**3.20 bcd**	**5.20 abcd**	**3.00 cd**	**5.62**

Note: Means value in each column with the same letter is not significantly different (p = 0.05) based on Least Significant Difference (LSD) test.
W = West SW = South West S = South SE = South East E = East
NE = North East N = North NW = North West

The incidence of *S. dorsalis* trapped on yellow sticky traps was relatively low during the flower growth stage compared to the flush stage. Relatively high temperatures and high humidity during the flower growth stage (29.72°C; 62.85%, respectively) may have reduced the dispersal activity of *S. dorsalis*. Derksen et al. (2016) found that high humidity was negatively correlated with the number of *S. dorsalis* caught in ornamental plants. A study by Affandi et al. (2017) showed the preferential order of adult S.dorsalis to be the flush stage, followed by the flower stage. The dormant stage was the least preferred by the *S. dorsalis*. Similar research on rose informed that *S. dorsalis* densities was found significantly higher on the rose buds than on flowers or on mature leaves (Mannion et al., 2014). A past study by Hansen et al. (2003) found that thrips appeared to prefer the the upper part of the plant canopy and the outer extremities of their hosts. Lewis (1997) suggested that this could be attributed to the nutrient flow in plants towards new growth areas.

Yellow sticky trap observations during flush growth stages exhibited that average wind direction and speed were 203.06° and 1.05 km/hours respectively, indicating the direction of the the wind from between South and South-West to between North and East. The population numbers of *S. dorsalis* tend to clump at North-East. Statistical analysis showed that there was no significant difference in preference among the cardinal directions of North-East, North, East and South-West based on LSD test (Table 1). Similar research on abundance and distribution of *S. dorsalis* in mangosteen confirm that thrips *S. dorsalis* were more abundant in the North and East sides than in the South and West (Pankeaw et al., 2011). Derksen et al. (2016) added that dispersal direction of *S. dorsalis* was correlated with the direction of prevailing winds.

Observations during flower growth stages indicated that average wind direction and speed were 190.50° and 0.75 km/hours respectively, meaning that the wind blew from between South and South-West to between North and East. However, the population of *S. dorsalis* did not tend to clump in a particulardirection. Possibly the low speeds of wind restrained weak fliers to move toward their desired direction. Similar research showed that *S. dorsalis* was distributed homogeneously in roses planted in the green house which was absent at low wind speed (Derksen, 2009). Irwin and Yeargan (1980) added that thrips dispersal or flight depends on wind currents which affect the control of their landing abilities.

The result suggested that the availability of wind direction in high speed strongly influences the movement of *S. dorsalis* to find suitable areas for best reproduction and refuge in mango trees. This information should be considered as basic information in the formulation of effective management strategies.

CONCLUSION

The North-East cardinal direction was the most preferred by *S. dorsalis*. *S. dorsalis* started to move into mango canopy during the early shoot emergence. It began to lean in certain direction on the second day of observation and peak numbers presented at day eight totalled 21.00 adults trapped per tree. *S. dorsalis* did not prefer certain directions during the flower growth stage, with peak numbers at day three totaling 9.40 adults/per tree.

REFERENCES

Affandi and Medina, C.D.R. (2013). Age structure and sex ratio of *Scirtothrips dorsalis* Hood (Thysanoptera : Thripidae) associating with mango agro-ecosystem in East Java, Indonesia. *Agrivita Journal of Agricultural Science*. 35(3), 227 - 236. doi: http://doi.org/10.17503/agrivita.v35i3.

Affandi, Medina, C.D.R., Velasco, L.R.I., Javier, P.A. & Depositario, D.P.T. (2017). Preference of *Scirtothrips dorsalis* Hood (Thysanoptera : Thripidae) on several phenological stages of mango. Unpublished manuscipt.

Aliakbarpour, H. & Rawi, C.S.M. (2012). The species composition of thrips (Insecta: Thysanoptera) inhabiting mango orchards in Pulau Pinang, Malaysia. *Tropical Life Science Research*. 23(1), 45–61. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3799398/.

Aliakbarpour, H., Rawi, C.S.M. & Dieng, H. (2010). Species composition and population dynamics of thrips (Thysanoptera) in mango orchards of Northern Peninsular Malaysia. *Environmental Entomology*. 39(5), 1409-1419. doi: https://doi.org/10.1603/EN10066.

Derksen, A.I., Mannion, C.M, Seal, D.R., Osborne, L.S. & Martin, C.G. (2016). Direction and timing of dispersal of *Scirtothrips dorsalis* (Thysanoptera : Thripidae) on select ornamental host plant species in south Florida. *Florida Entomologist*. 99(4): 710 – 717. doi: http://dx.doi.org/10.1653/024.099.0421

Dinas Pertanian Kabupaten Situbondo. (2004). Standard Operational Procedure (SOP) mangga Arumanis 143 kabupaten Situbondo. *Dinas Pertanian Kab. Situbondo*. p96.

Dingle, H and Drake, V.A. (2007). What is migration? BioScience. 57: 113 - 121. doi: https://doi.org/10.1641/B570206

Dowd, P.F., Sarath, G., Mitchell, R.B., Saathoff, A.J. & Vogel,K.P. (2013). Insect resistance of a full sib family of tetraploid switchgrass *Panicum virgatum* L. with varying lignin levels. *Genetic Resources and Crop Evolution*. 60: 975 - 984. doi: 10.1007/s10722-012-9893-8.

Global Pest and Disease Database (GPDD). (2011). Report on GPDD Pest ID 1276 *Scirtothrips dorsalis* – APHIS. (pp. 1-15).

Gowda, G., Ramaiah, E. & Reddy C.V.K. (1979). *Scirtothrips dorsalis* (Hood) (Thysanoptera : Terebrantia: Thripidae) a new pest on cashew (*Anacardium occidentale* L.). *Current Research*. 8(7):116 – 117.

Hansen, E.A., Funderburk, J.E., Reitz, S.R., Ramachandran, S., Eger,J.E,& McCauslane,H.J. (2003). Within-plant distribution of Frankliniella species (Thysanoptera : Thripidae) and Orious insidiosus (Heteroptera : Anthocoridae) in field pepper. *Enviromental Entomology*. 32(5):1035 - 1044. doi:https://doi.org/10.1603/0046-225X-32.5.1035.

Hoddle, M.S., Karen, M.J. & Joseph, G.M. (2003). The economic impact of *Scirtothrips perseae* Nakahara (Thysanoptera :Thripidae) on California avocado production. *Crop Protection*.

22(2):485-493. Retrieved from http://dx.doi.org/10.1016/S0261-2194(02)00199-0.
Irwin, M. E., & Yeargan, K. V. (1980). Sampling phytophagous thrips on soybean. In *Sampling methods in soybean entomology* (pp. 283-304). Springer, New York, NY.
Kumar, V., Kakkar, G., McKenzie, C. L., Seal, D. R., & Osborne, L. S. (2013). An overview of chilli thrips, *Scirtothrips dorsalis* (Thysanoptera: Thripidae) biology, distribution and management. In *Weed and Pest Control-Conventional and New Challenges*. InTech.
Lewis, T. (1997). Thrips as crop pests. Cab International.
Mannion, C. M., Derksen, A. I., Seal, D. R., Osborne, L. S., & Martin, C. G. (2013). Effects of rose cultivars and fertilization rates on populations of *Scirtothrips dorsalis* (Thysanoptera: Thripidae) in southern Florida. *Florida entomologist*, 96(2), 403-411.
Seal, D. R., Klassen, W., & Kumar, V. (2010). Biological parameters of *Scirtothrips dorsalis* (Thysanoptera: Thripidae) on selected hosts. *Environmental entomology*, 39(5), 1389-1398.

PAPER 3:
A COMPREHENSIVE STRATEGY FOR PREVENTION AND CONTROL OF FUSARIUM WILT OF BANANA BASED ON RESISTANT OR TOLERANT VARIETIES

Chunyu Li, Ganjun Yi, Ou Sheng, Guiming Deng, Chunhua Hu, Huijun Gao, Fangcheng Bi, Qiaosong Yang, Ruibin Kuang, Tongxin Dou & Tao Dong
Fruit Tree Research Institute, Guangdong Acedemy of Agricutural Sciences, China

ABSTRACT

Fusarium wilt of banana is a devastating disease caused by *Fusarium oxysporum* f. sp. *cubense* (*Foc*). Based on virulence to specific banana cultivars, the pathogen can be classified into three races (i.e., races 1, 2, and 4). In 1950s, the export of Gros Michel banana from the Central America to America and Europe dramatically reduced due to *Foc* Race 1. *Foc* subtropical Race 4 reduced the production area in Taiwan from 50,000 ha to 5,000 ha in last 10 years, and nowadays *Foc* tropical Race 4 (*Foc* TR4), the most virulent strain of *Foc*, has been sweeping through banana plantations in Asia and become the major threat to banana industry. The reasons for Fusarium wilt epidemics include six aspects, (1) Large scale growing monoculture of bananas, mostly the Cavendish banana, which decrease the selection pressure for the pathogen. (2) Small-scale farming by individual owners in China, which make it very hard for the goverment to carry out consistent measures to restrict the spreading of the pathogen. (3) Irregular production of tissue clture plantlets, and many factories can't make good seedlings. (4) Pollution of the river water accelerate the spreading of the pathogen. (5) No strict quarantine regulations for the pathogen had been developed. (6) Movement of the plants, labors and equipment also accelerate the spreading of the pathogen. The disease had dislocated the geographical distribution of banana growing districts in China mainland. Ten years ago, banana output from Guangdong province was more than 50% of China, and now is about 20%, and also the growing area decreased from 140,000 to 70, 000 hectares, and ranks third after Guangxi and Yunnan Provinces now. The disease incidence in Guangdong province ranges between 20 to 40%, with individual plantations reaching a rate of 90% (Huang *et. al.*, 2012). Without effective quarantine inspection measures, this disease spread rapidly in new growing areas.

In order to control the spread of *Foc* TR4, we performed comparative genomic analysis on *Foc* by resequencing 80 *Foc* isolates covering three races and 24 vegetative compatibility groups (VCGs). We found that *Foc* evolved very fast, and that exogenous genetic materials had been transferred into linage-specific genomic regions. An effective future disease prevention and control strategy should serve dual roles, both improving host resistance and reducing *Foc* population size. Our group have bred some resistant banana varieties such as Zhongjiao No 3, 4, 6 and 9 against *Foc* TR4, the most virulent race of *Foc*. Experiments in vitro showed that root exudates from these resistant lines inhibited TR4 spore germination and hyphal growth. In addition, field survey over 4 years showed that these resistant varieties limited *Foc* population size. Furthermore, we investigated additional ways to control *Foc* including crop rotation, soil disinfection and biocontrol. The crop rotation involving Chinese leek or rice shows that compared to rice, Chinese leek inhibited or even completely destroyed *Foc* in soils. Soil disinfection using ammonium bicarbonate/lime significantly decreased the *Foc* population in top but not deep soils. Biocontrol applying fermented banana pseudostems with endophytic and antagonistic Trichoderma spp with high cellulose activity in the field limited disease incidence and suppressed the pathogen. In conclusion, we evaluated the feasibility of implementing these control measures in Fusarium wilt of banana diseased regions in Guangdong province, and therefore proposed a comprehensive disease prevention and control strategy integrating multiple measures including planting tissue cultural plantlets, resistant/tolerant banana varieties, crop rotation, designing the banana plantation to prevent *Foc* transmission and reducing population in the soil by biocontrol or soil fumigation.

Keywords: Fusarium wilt of banana, *Fusarium oxysporum* f. sp. cubense, disease prevention and control strategies.

REFERENCES

Huang, Y.H., Wang, R.C., Li, C.H., Zuo, C.W., Wei, Y.R., Zhang, L., & Yi, G.J. (2012). Control of Fusarium wilt in banana with Chinese leek. European Journal of Plant Pathology. doi: 10.1007/s10658-012-0024-3

SESSION WRAP UP AND Q&A

i. During the discussions that followed, recommendations from the floor ranged from the application of pheromone traps for controlling the Asian citrus psyllid (ACP); to ways of organising strategies for pest and disease control, and management amongst smallholder farmers; ensuring biosecurity protocols are in place; to tight border controls. It was observed that integrated pest management strategy was a recurring theme proposed in the session.

SESSION THREE

Crop Diversification, Varietal Improvement, and Biotechnology

PAPER 1:
SOCIAL, ECONOMIC AND TECHNOLOGICAL POTENTIAL OF AGRICULTURAL BIOTECHNOLOGIES FOR CROP DIVERSIFICATION – A NEW APPROACH IN RESEARCH

Sayed Azam-Ali & Felix Miller
Crops For The Future Research Centre

ABSTRACT

Increasing populations, climate change, disparate economic growth and urbanisation constitute major challenges for the ASEAN region. `Business-as-usual' will not be enough. We need fresh ideas and innovative solutions, especially in agriculture which can be a major engine of socio-economic growth. Recent biotechnological advances in major crop species show significant potential for sustainable gains in agricultural productivity, reducing poverty and enhancing food security. However, major staples alone cannot ensure the nutritional security of a growing population or novel sources of livelihoods from marginal landscapes. This presentation shows how knowledge of the genetic resources of currently underutilised crops can be linked with modelling and geospatial tools to predict their potential in new locations. Data driven biotechnology linked with value chains can enhance our understanding of agricultural biodiversity and accelerate selection for suitable crop traits for specific locations and end uses. Using the example of bambara groundnut, this paper presents a case study of crop suitability for soil and climatic conditions of Peninsular Malaysia. Through such an approach, the paper demonstrates how locations and end uses can be identified for particular crops. Comparisons will show potential distributions and uses of underutilised crops in the ASEAN region as an evidence base for agricultural diversification.

Keywords: underutilised crops, crop diversification, South East Asia

PAPER 2:
BREEDING AND BIOTECHNOLOGY RESEARCH PROGRAM OF INDONESIAN TROPICAL FRUIT RESEARCH INSTITUTE

Ellina Mansyah[1], Agus Sutanto[1], Sri Hadiati[1], Hardiyanto[2], & Muhammad Syakir[3]
[1]Indonesian Tropical Fruit Research Institute. Jl. Raya Solok-Aripan Km. 8. PO Box 5 Solok. West Sumatera. Indonesia. ellina_mansyah@yahoo.co.id
[2]Indonesian Center for Horticultural Research and Development. Jl Tentara Pelajar 3C. Kampus Penelitian Cimanggu. Bogor
[3]Indonesian Agency for Agicultural Research and Development. Jl Ragunan 29. Jakarta Selatan

ABSTRACT

Indonesian Tropical Fruit Research Institute (ITFRI) is a part of Indonesian Agency of Agricultural Research and Development (IAARD), Department of Agriculture. The reponsibility of ITFRI is to produce technologies for increasing competitiveness of tropical fruit agribusiness in the global market. The priority commodities are divided into main and potential commodities. The main commodities are banana, mango, mangosteen, and salacca, while the potential commodities are papaya, durian, avocado, watermelon, melon, pineapple, and breadfruit. Research activities of ITFRI are divided into three groups, namely fruit breeding, ecophysiology, and pests and deseases research. This paper explains about the activities in breeding and biotechnology research, concerning management of genetic resources, conventional breeding, molecular breeding, conservation and use of tropical fruits, and seed production and distribution. Management of genetic resources is important in mantaining tropical fruit germplasms. Cultivar improvement is directed to produce superior cultivars for meeting rising consumer demands, high productivity, and resistant to biotic and abiotic stress. Seed propagation, distribution and dissemination are the key factors in developing new cultivars and to increase technology adoption.

Keywords: genetic resources, conventional breeding, molecular breeding, tropical fruits

INTRODUCTION

Fruits are important sources of vitamins, minerals and supplemental food, and play a role in maintaining the body's nutritional balance. Fruit commodities have high economic value and potential to increase family income (Soemarwoto and Soemarwoto, 1984). The need for fruit crops in Indonesia increases from year to year as the population increases and increase of public awareness on nutrition. The efforts to increase production and quality of fruit crops in Indonesia are aimed to fulfill domestic and export demands. Approximately 392 fruit species are found in Indonesia, but only a few have been cultivated. Most of these are still growing wild in the forests (Soedjito and Uji, 1987). Conservation of cultivated and wild tropical fruit species is an urgent need since it provides direct benefit to livelihoods through the development of new products as well as their role in maintaining natural ecosystems (Stolton et al., 2006). On-farm conservation is an effective farming strategy which also provides the answer for improving the quality of life through sustainable local genetic resource management on the basis of traditional farming systems (Maxted et al., 1997).

Indonesian Tropical Fruit Research Institute (ITFRI) is a part of Indonesian Agency of Agricultural Research and Development (IAARD), Department of Agriculture. The reponsibility of ITFRI is to produce technologies for increasing competitiveness of tropical fruit agribusiness for the global market. Research activities of ITFRI are divided into three groups, namely fruit breeding, ecophysiology, and pests and deseases research. This paper explains about the activities in breeding and biotechnology research, concerning management of genetic resources, conventional breeding, molecular breeding, conservation and use of tropical fruits, and seed production and distribution. The contents of this paper are divided into five sections under the following headings: management of genetic resources, conventional breeding, molecular breeding, conservation and use of tropical fruit, and seed production and distribution.

MANAGEMENT OF FRUIT GENETIC RESOURCES

Previous studies have reported that there are 266 species of indigenous fruits encountered in Indonesia and 62 species of them are cultivated. Four genera of indigenous fruits are recommended to be developed in Indonesia such as *Durio*, *Mangifera*, *Garcinia* and *Nephelium*. This study also reported that duku (*Lansium domesticum*), salak (*Salacca zalacca*), matoa (*Pometia pinnata*) have good prospects for being developed in Indonesia (Uji, 2007). Management of genetic resources program in ITFRI consists of exploration, characterization, collection, selection, conservation and use of wild and cultivated tropical fruits.

Exploration, characterization, and collection genetic resources

ITFRI has conducted exploration, characterization, collection and evaluation of tropical fruits. The exploration data includes passport data and plant description can be accessed through http://sdghorti.puslithorti.net which was documented through the Institution Intranet Genetic Resources Information System (SIPPin). In managing fruit genetic resources ITFRI is supported by six experimental stations, i.e. Aripan and Sumani (West Sumatera), Subang (West Java), Cukurgondang, Kraton, and Pandean (East Java). The largest number of tropical fruit collection is found in the Aripan experimental farm. ITFRI has collected 200 accessions of banana (*Musaceae*) from Sumatera, Java, Maluku Islands and Papua. The collections are maintained *ex situ* in the field, *in vitro* in the laboratory and *in vivo* in the screenhouse. Other collections are 3 mango species, 5 durian species, 6 salacca species, 9 *Garcinia* species, and 6 *Ananas* species (Table 1).

Table 1. Collection of fruit genetic resources at ITFRI

Fruit Commodity	Species	Variety/Accessions	Location (Experimental farm)
Mango	3	208 varieties and progenies	Cukurgondang
Mangosteen	1	2 varieties and 73 accessions	Aripan
Banana	2	190 varieties and accessions	Sumani
Durian	5	78 varieties	Aripan and Sumani
Salacca	6	600 progenies from crossing	Aripan, Sumani, and Subang
Ananas	6	150 hybrid progenies	Aripan
Papaya	1	12 varieties and 20 hybrid progenies	Aripan and Sumani
Avocado	1	28 varieties	Aripan, Sumani
Matoa		3 varieties	Aripan
Star fruit		11 accessions	Aripan, Sumani
Dragon fruit		7 varieties	Aripan
Buni		1 variety	Subang
Cempedak		1 variety	Subang
Dewandaru		2 varieties	Subang
Duku		4 varieties	Aripan
Duwet		1 variety	Aripan, Subang
Genitu		1 variety	Subang
Jambu Air		27 accessions	Aripan

Table 1. Collection of fruit genetic resources at ITFRI (continued)

Fruit Commodity	Species	Variety/Accessions	Location (Experimental farm)
Guava		21 accessions	Sumani
Jambu bol		3 accessions	Aripan, Sumani
Citrus		15 accessions	Aripan, Sumani
Kecapi		2 varieties	Subang
Kedondong		2 varieties	Sumani, Subang
Kepel		1 variety	Subang
Kerendang		1 variety	Subang
Kesemek		2 varieties	Subang
Langsat		2 varieties	Aripan, Subang
Leci		2 varieties	Sumani
Lengkeng		9 varieties	Aripan, Sumani
Markisa		2 varieties	Sumani, Subang
Garcinia species	9		Aripan, Subang
Namnam		2 varieties	Subang
Nangka		10 varieties	Aripan, Subang
Rambutan		37 varieties	Aripan, Subang
Sarikaya		3 varieties	Cukur Gondang, Aripan
Sawo		7 varieties	Aripan, Sumnai, Subang
Sour Sop		14 varieties and accessions	Aripan, Sumani, Subang
Bread Fruit		3 varieties	Aripan, Sumani, Subang
Water melon		4 varieties	Aripan, Sumani

CONVENTIONAL BREEDING

Crossing and selection from indigenous population

Almost all Indonesian tropical fruit varieties were obtained from conventional breeding through selection of indigenous population and hybridization. ITFRI's genetic resource collection has been utilized as a parental source in breeding programs of new varieties of pineapple, salacca, durian, banana, mango, papaya, watermelon and melon (Table 2.)

Conventional hybridization of banana has started with the identification of resistant genotypes of male parents. For this, five accessions, namely, Kole (AA), Klutuk (BB), Jaran (*M. acuminata* spp. burmanica), BKT-11 (AAw) and Calcutta-4 (AAw) were obtained. These male parents were crossed with commercial varieties (female parents). The hybrid seeds were obtained when Calcutta-4 crossed with Kepok Kuning (ABB), Raja Siem (ABB) and Ketan (AAB). The hybrid plants are now being evaluated in the field. Selection of mango germplasm at Cukurgondang experimental farm has been released, totalling 14 varieties with some of these having red skin, namely Marifta-01 and Ken Layung, Red Garifta, Garifta Kuning, Garifta Gading, and Garifta Orange (Rebin and Karsinah, 2010)

Table 2. List of ITFRI varieties from conventional breeding

Fruit Commodity	Variety	Main characteristics	Breeding Method
Salacca	Sari Intan 295	Thick pulp, very sweet (19-21 ° Brix), good aroma, well adapted at low to medium altitude	Hybridisation
Salacca	Sari Kampar	Thick pulp, very sweet without astringent (20 – 22°Brix), good aroma, crispy, well adapted at low to medium altitudes	Hybridisation
Papaya	Merah Delima	Fruit weight: 0,8-1,9 kg, cylindris with star hole, thick (2,5 to 4,5 cm) and orange pulp, chewy, sweet taste (11-14,50°Brix), 43,40 to 98,25 mg Vit. C/100g, Fruiting 2 to 3 months after planting and first harvesting at 7 to 8 months after planting, 45 to 60 cm in height. Productivity 70 to 90 ton/ha/six months.	Hybridisation
Papaya	Dapina Agrihorti	Fruit weight (150 to 2500 g), thick pulp and red-orange in colour, sweet taste (11 to 13°Brix), productivity 60-100 ton/ ha/year, shelf live: 8-10 days	Hybridisation
Papaya	Agrisolinda	Medium fruit (500-1000 g), thick and yellow bright pulp, sweet taste (12-13 ° Brix), slightly chewy texture, edible portion 75-85%, good aroma, high productivity 80 ton / ha / year, well adapted to drought stress, hard soil texture and high rain fall.	Hybridisation
Papaya	Carvita Agrihorti	Fruit weight 400-1100 g, yellow-green skin, red-orange pulp and 2-4 cm in thickness, sweet taste (10-14 ºBrix), high productivity, high vitamin C, and first harvesting at 220-230 days after planting	Hybridisation
Guava	Piraweh Ampalu	High productivity (250-280 kg/ton/year, 1,45 - 1,74 cm in thickness, yellow-green skin colour, red pulp, sweet taste (7,67-10,07 Brix), sugar and acid ratio 9,61-20,74, and edible portion 72,16-86,09%	Hybridisation
Watermelon	Serif Saga Agrihorti	Oblong fruit, light green, skin thickness 1,10-1,25 cm, fruit weight 4,33-5,55 kg, sugar content 10-12 ºBrix, sweet taste, red flesh colour, adapt well on lowland in the dry season.	Hybridisation
Mango	Agri Gardina 45	Oblong fruit, pointy fruit tip, red at the base and yellow tip, harvesting at 90 to100 days after flowering, adapting at dry and low to medium altitude, flowering to harvesting period 90-100, high productivity (136-273 fruits / tree / year at 3 years to 4 years), attractive fruit peel (red base, yellow tip), sweet flavor (TSS 15-18 ºBrix), medium aroma	Hybridisation
Mango	Mangga Gadung 21	Large fruit (350-650 g/fruit), thick flesh (7.26-8.8 cm), low fiber content, high starch content (10.27%). low water content (75-77%) and sweet taste (TSS 15-21 ºBrix).	Hybridisation
Mango	Garifta Orange	Sweet- sour flesh (16,8,0 ° Brix), Vitamin C 58.1 mg / 100 g, fruit length 8.5-11.5 cm; width 6.5-8.5 cm; thick pulp 2.4-3.2 cm; first flowering at 5 years old, flowering until harvest period 105-110 days. Productivity 135.4 kg /tree/ year; fruit weight 235-365 g, resistant to antrhracnose and fruit flies	Hybridisation
Mango	Garifta Merah	Sweet flesh (15.5° Brix), vitamin C 45.0 mg / 100 g; fruit length 14.0-16,5 cm; width 6.8-8.3 cm, thick pulp 2.8-13.6 cm; first flowering 5 years after planting, productivity 62.28 kg/tree/year; fruit weight 220-320 g; strong aroma, resistant to anthracnose and fruit flies.	Hybridisation
Mango	Garifta Kuning	Fruit weight 190-230 g/fruit, sweet (17,5 ° Brix), vitamin C 61,10 mg/100 g; fruit length 10.5 cm; width 8.8-10.3 cm, thick flesh (3.0-3.8 cm); first flowering 5 years after planting, productivity 76.76 kg/tree/year; fruit weight 320-400g; good aroma, and resistant to anthracnose and fruit flies	Hybridisation

Table 2. List of ITFRI varieties from conventional breeding (continued)

Fruit Commodity	Variety	Main characteristics	Breeding Method
Mango	Garifta Gading	Sweet taste (18.0 ° Brix), Vitamin C 45,1 m/ 100 g; thick flesh (2.8-3.4 cm); first fruiting 5 years after planting, productivity on 64,42 kg / tree/year; good aroma, and resistant to anthrachnose and fruit flies.	Hybridisation
Mangosteen	Ratu Kamang	Long pedicel (more than 2.5 cm). Round and pointed base (height/diameter ratio 0.93-0.94), number of fruit segments 5-8, round stigma lobe, water content 81.54-84.73%, fruits with gamboge disorder less than 8%, edible portion 32.67%, smooth skin.	Selection from indigenous populatiom
Mangosteen	Ratu Tembilahan	Short pedicel (< 1.5 cm), elliptic fruit (heigt/ diameter ratio 0.78–0.80), ellip stigma lobe, number of fruit segment (4-11), moisture content 78-82%, crunchy, slightly sour taste, edible portion 27.5%, firmly flesh, suitable for processing and for swamp land.	Selection from indigenous populatiom
Durian	Tambago Sungai Tarab	Ovoid flower buds, yellow Orange flesh, sweet taste, high productivity (820 -1220 kg/tree/ year).	Selection from indigenous population
Durian	Sambeng	Fruit shape oval-obovoid, thick and yellow flesh, medium to thick, sweet taste, smooth and sligthly fiber.	Selection from indigenous population
Durian	Kalumpang Sijunjung	Fruits shape globose, very sweet, thick pulp (1,18-1,98 cm), and high edible portion (35,33-43,18%).	Selection from indigenous populatiom
Banana	Raja Kinalun	Plant height 2,25 – 2,55 m, 4-5 suckers/plant, 8–9 hands / bunch, 12–14 finger/hand,100–105 fruits/bunch, 95–120 g/fruits, 32,6 mg vitamin C/100g, sweet taste (TSS 23,5–24,0o Brix), edible portion 80-85%. dessert banana, shelf live 15-24 days, productivity 15–20 ton/ha/year.	Selection from indigenous population
Banana	Kepok Tanjung	Plant height 3,5-4 m, 3–5 suckers/plant, 15 - 25 kg/bunch, 9–17 hands/bunch, 13–18 fingers/hand, 150–250 fruits/ bunch, yellow-orange pulp, 125–170 g/fruit, 23,0 mg vitamin C/100g, sweet taste (29–30 0Brix), dessert banana, shelf live 15-21 days, productivity 20-30 ton/ha/year resistant to blood deseases. Origin: Seram Island (Maluku Province)	Selection from indigenous population

BREEDING FOR WILT RESISTANCE

Selection of seedling populations of four Indonesian wild *Musa* to *Fusarium* wilt resistance

The experiment was conducted by using the seeds of four wild *musa* species *M. Balbisiana* from Nusa Tenggara Timur, *M. acuminata* ssp. Sumatrana, *M. acuminata* ssp. Halabanensis, *M. acuminata* ssp. Microcarpa. The seedlings was then transfered to small pots prior to fusarium inoculation with VCG 01213/16 [TR4] and VCG 0124-5 [TR1]. Resistant plantlets will be transferred to the soil for further evaluation.

Evaluation candidate of superior banana cultivar resistant to *Foc*

The research was conducted at the Aripan Experimental Farm to test the resistance of two new varieties INA-03 and INA-02 to *Fusarium oxysporum* f. sp *cubense* (*Foc*). The variety was observed for vegetative and generative growth, and registered as a resistant variety to *Foc*. In the year of 2017, INA03 is being processed for release as a new variety resistant to *Foc*.

MOLECULAR BREEDING

Conventional breeding has been shown to improve quality of fruit crops. However, this method has many weaknesses, such as the long breeding time and the morphological character evaluation that is strongly influenced by the environment. Molecular breeding can serve to accelerate the breeding program, shorten the selection process, and eliminate the effect of environmental factors and plant growth.

Application of molecular markers for genetic variability study

Identification of genetic diversity of fruit crops has been done on mangosteen, mango, salacca, papaya, durian through the Random Amplified Polymorphic DNA (RAPD), Intersimple Sequence Repeat (ISSR), and Simple Sequence Repeat (SSR) techniques. Population genetic structure of mangosteen (*Garcinia mangostana* L.) was studied using 8 RAPD and 5 ISSR primers. A total of 106 samples from seven mangosteen populations in Purwakarta (West Java), Kerinci (Jambi), Tembilahan (Riau) and Bulukumba (South Sulawesi) were used in this study. Genetic diversity was analyzed using the GenAlex 6.2 program. The results showed the highest level of genetic diversity within populations found in Purwakarta population (Na=1.32 ,Ne=1.32, and I=0.28) and the lowest in Kerinci ((Na=1.00, Ne=1.17, and I=0.15). Pairwise populations of Kerinci and Bulukumba showed the closest genetic distance (D=0.08) with the highest uniformity (Nei I = 0.92). In contrast, the couple of Bulukumba and Tembilahan populations shows the furthest genetic distance (D= 0.164) with the lowest genetic uniformity (Nei I = 0.85). Analysis of Molecular Variance (AMOVA) showed that genetic diversity within population equal to among populations, i.e., 50%. Each of Purwakarta and Tembilahan populations were divided into two distinct genetic groups (Mansyah et al., 2012).

Application of microsatellite markers on mango was conducted to identify varieties, and genetic similarity of Gadung and Arumanis which are known as commercial mango cultivars. Past mango experts have claimed the Gadung cultivar to be synonymous with the Arumanis. Thirty microsatellite markers were used to discriminate the cultivars. The results showed that Gadung-21 was similar to Arumanis-135 (Tasliah, 2016). Molecular research on banana is used to determine somaclonal variation in tissue culture propagation. The observation showed the variation of DNA banding patterns occuring on the sixth and tenth sub culture plantlets (Sutanto, 2015). Molecular analysis of salacca was used to support the release of a new variety, Sari Intan 48. The results indicate that Salaca var. Sari intan 48 is genetically different with its comparable variety (Hadiati, 2015). Molecular analysis of pineapple obtained the specific bands of Cayenne and Queen groups. It can also provide information on the presence of somaclonal variation in ananas tissue cultured plants (Hadiati, 2015).

Application of molecular genetics for specific traits

The utilization of molecular markers for specific traits at ITFRI was for selecting banana varieties resistant to the fusarium wilt, selecting mango varieties based on fruit size and resistance to fruit drop, selecting mangosteen non gamboge disorder genotypes, and identification of SSR markers specific for yellow pulp color, and small seeds for durian.

Isolation and characterization of Resistance Gene to Fusarium Wilt on Indonesian Wild *Musa* Species

Genomic DNA was isolation from two banana cultivars (one suceptible cultivar: Barangan and one resistant cultivar: Rejang), and four wild species (*M. balbisiana, M. acuminata* ssp. sumatrana, *M. acuminata* ssp. halabanensis, *M. acuminata* ssp. microcarpa). Degenerate primers were used to isolate RGA fragments, and then the PCR product was cloned, sequenced and analyzed using BLASTN, BLASTP, multiple alignment and phylogenetic analysis. Isolation and characterization of resistance genes from local banana cultivars were important in order to support the development of *Foc* resistant banana cultivars. Resistance gene analogues (RGAs) were isolated and characterized form three fusarium resistant banana cultivars using degenerate primers based on NBS domains. From 91 fragments sequenced, 17 fragments were positively NBS-type sequences and encoded as MNBS1-MNBS17. Phylogenetic analysis of MNBS deduced amino acid classified into three groups. The first group consisted of 14 members (MNBS1-MNBS14) with 97.4% identity, and the other three groups consisted of one member (MNBS15, MNBS16 and MNBS17, respectively) with 28.5% identity. All MNBS sequences were categorized as non-TIR-NBS-LRR. Comparison and phylogenetic analysis of MNBS with other known RGA and R genes showed that deduced amino acid MNBSs shared 91.7-98.8% identity with *Musa* NBS-LRR and 19.9-35.5% identity with known R genes. Among them, MNBS17 shared 50.5% identity with RGC2 (ABY75802) that was assosiated to *Foc* race 4 resistant *Musa* species (Sutanto et al., 2014)

Identification of molecular marker for selecting mango variety based on fruit size and resistancy to fruit drop

The research comprised of two subactivities : 1) Evaluation of SCAR markers for selection mango varieties based on fruit size, 2) Development of SNAP markers for fruit size and resistancy to fruit drop on mango. The research steps including design degenerate primers for polygalacturonase gene class II (PG2) and JOINTLESS and specific primers for geneFas (Yabby - like TF), sequencing of PCR products, sequence analysis and identification of SNP sites, and development and evaluation of SNAP markers. The research is still in progress.

Development of molecular markers for selecting non gamboge disorder mangosteen genotypes

The research consists of two activities namely sequencing specific PCR products from RAPD analysis and microsatellite analysis of gamboge disorder and non gamboge disorder genotypes. The results obtained 69 sequences of polymorphic and monomorphic DNA fragments on mangosteen. Among the sequences found was a DNA fragment similar to the enzyme suspected to be associated with the calcium/calmodulin-dependent protein kinase II delta (CAMK2D). This enzyme works for regulation of calcium ions and xyloglucan galactosyltransferase for cell wall physiology mechanisms allegedly related to mangosteen damage by yellow latex. Other sequences obtained indicated that the mangosteen individuals were different in molecular characters of microsatellite DNA fragment or transposon which is known as non coding region (Mansyah et al., 2015). Microsatellite analysis showed variation of IGMP 012 SSR locus of non gamboge disorder and gamboge disorder genotype of mangosteen (Mansyah et al., 2016).

Identification and characterization of SNP markers for selecting non-astrigent genotypes on salacca

The activities including DNA extraction, DNA amplification with specific primers for gene*LAR* and *ANR*, and sequencing PCR product. The observations including analysis and identification of *non-synonymous* SNP situs, design specific primers for SNAP marker, and evaluation of SNAP primers efectivity. The research is still in progress.

Identification of SSR markers for yellow pulp and small seeds on durian

The research was conducted by a bulked pseudo-segregant analysis (BpSA). The results obtained showed 3 loci suspected as potential marker for identification of yellow flesh of durian, mDz3G731, mDz2E9, and mDz6F06; 2 loci as a marker for the identification of large seed characters, mDz1G3 and mDz03A31; as well as 2 locus for small seed character, mDz1G102 and mDz1C41. The three loci of mDz3G731, mDz2E9, and mDz6F06 should be tested for use as a specific identification for yellow flesh, large seeds and small seeds (Santoso, 2015).

CONSERVATION AND USE OF TROPICAL AND WILD TROPICAL FRUIT

Conservation of five Indonesian bana local cultivars on farmers orchard

Planting of five Indonesian banana local cultivars Ambon Hijau (AAA), Kepok Tanjung (ABB), Barangan (AAA), Bile (AB), Libod (AA) were conducted at Kecamatan Situjuh Kabupaten Lima Puluh Kota, West Sumatera. It is necessary to introduce local cultivars to farmers, as well study the acceptance of farmers and the market to the cultivars in addition to know the adaptability of the local cultivars to be developed by farmers. Activities that have been implemented are coordination with farmer groups, banana seed production, training of banana cultivation and pest and deseases control. The next activity is the distribution banana seedlings.

Planting banana var "Kepok Tanjung" at Nagari Salayo, Kabupaten Solok

The activity started in 2017 by the planting of banana var Kepok Tanjung at Selayo, the main production area of bananas. Kepok Tanjung is a banana variety which has no heart and naturally avoids the incursion of the banana blood desease.In this location, banana was wiped off by the banana blood disease. The objective of this program is to rejuvenate the banana production in this location. The local goverment of Solok district strongly supports the program and will develop Selayo as a Banana village.

Conservation and use of *Garcinia* species based on Community Based-Biodiversity Management (CBM)

This activity has been developed on the basis of Bioversity International's activities from the "Conservation and Sustainable Use of Cultivated and Wild Tropical Fruit Diversity: Promoting Sustainable Livelihoods, Food Security and Ecosystem Services", project's priority on *Garcinia* species. This underutilized species grows on buffer zonse in the forest of Sijunjung district-West Sumatra, is not well maintained and in danger of extinction by rapid genetic erosion due to habitat destruction, agricultural expansion, conversion of land for settlement, and uncontrolled exploitation. These can be addressed by managing *Garcinia* genetic resources through conservation and utilisation by implementation of the 'Community Based-Biodiversity Management' (CBM) strategy which includes: 1) Documenting the agreed procedures for managing community-based knowledge among key stakeholders; 2) Identification of local community-based organizations (CBOs) for implementing farmers information database; 3) Nursery community development; 4) Recognizing and promoting diversity through diversity fairs; and 5) Supervising planting material multiplication and added value to support conservation. In the third year of activities, the local community has successfully produced 'Garci-tea', a unique product of *Garcinia atroviridis*. These activities are successful in creating new income generation opportunities in rural areas and bringing the local genetic resources, *Garcinia* atroviridis, from the forest to the international market. Further activities are needed for ensuring the sustainability of the CBM in collaboration with the local goverment. In the long run, the conservation activities will contribute to ecosystem services and in reduce negative impacts of climate change. Before this activity the community was not aware of the diversity of genetic resources they possessed and did not utilize the local genetic resources to improve economy. Instead they were cutting down the rare fruit trees, the plants grown in the forest, and had lack of local government participation. In the third year of the activity, several benefits arose such as the community recognizing their genetic resources, they begun utilizing the asam gelugur (*Garcinia atroviridis*) in bioindustry (dry leave and fruits), availability of plant materials for planting in conservation locations increasef, and the local governments started to participate in conservation. These conservation activities need to be mantained and facilitated by infrastructure to initiate the development of bioindustry products. Another important activity is the promotion of processed products and linking farmers to the market. Collaboration of governments, communities and the private sector is required through the management and utilization of local genetic resources for ecological, economic and social benefits.

SEED PRODUCTION AND DISTRIBUTION

One of the problems in fruit crop development in Indonesia is the limitation of plant materials (seedlings) to be distributed, due to: 1) Limited number of parent trees as a source of seeds; Most of the new varieties are released as single trees; 2) Slow seedling growth; 3) Limited propagation techniques; 4) The seed availlability is dependant on fruit season; and 5) Plant tissue culture technology is still limited.

The availability of good quality seedlings is required to increase fruit production. The Indonesian Agency for Agricultural Research has developed a Tropical Fruit Seed Production Unit to produce and distribute tropical fruit seeds. The seed production program consists of: 1) Increasing the number of parent trees through determination of duplicate trees, DNA analysis, registration of parent trees, and developing Foundation Blocks of scion; 2) Accelerate the growth of seedlings; and 3) Provision of seed production facilities and infrastructure. These activities complement and support the Indonesian Ministry of Agriculture's program, the 'Year of Horticulture 2018'. For the year 2017, a total of 971,000 tropical fruit plant seedlings consisting of mango, mangosteen, durian, banana, salacca, papaya, and breadfruit will be produced for distribution to farmers and growers.

REFERENCES

Hadiati S. (2015). Karakterisasi, konservasi, dan sumberdaya genetik tanaman buah tropika. *Laporan Hasil Penelitian*. 2015.

Maxted, N, J G Hawkes, B V Ford-Lloyd & J T Williams. (1997). A practical model for in situ genetic conservation, in Maxted, N., Ford-Lloyd, B.V., Hawkes, J.G. (Eds.), *Plant Genetic Conservation: the In Situ Approach*, Chapman and Hall, London

Mansyah, E & Edison Hs. (2015). Pendugaan Keragaman *Garcinia* sp dan Nephelium sp di Propinsi Sumatera Barat dan Jambi serta Potensi Pemanfaatannya dalam Pertanian Bioindustri. *Seminar Nasional Buah Nusantara II,* 22-24 Agustus 2014.

Mansyah, E. (2012). Struktur genetik Manggis (*Garcinia mangostana* L.) berbasis marka morfologi dan molekuler. Disertasi. Institut Pertanian BogorRebin dan karsinah

Mansyah, E, Deden D. Matra. & Eichii Inoue. (2016). Microsatellite and Flowcytometry analysis on the genetic diversity of mangosteen (*Garcinia mangostana* L.). *Laporan hasil penelitian.* Ibaraki University.

Rebin & Karsinah (2010), Varietas unggul baru mangga merah dari Kebun Percobaan Cukurgondang, *Iptek Hortikultura*, No. 6, Hlm. 24-29.

Santoso, P.J. (2015). Identifikasi marka SSR terpaut karakter daging buah warna kuning dan biji kempes pada durian. Laporan Hasil Penelitian. *Balai Penelitian Tanaman Buah Tropika*

Stolton S, Maxted N, Ford-Lloyd B, Kell S, & Dudley N. (2006). Arguments for Protection Food Stores: Using Protected Areas to Secure Crop Genetic Diversity. A research report by WWF, Equilibrium and the University of Birmingham, UK Written. Published August 2006, *WWF – World Wide Fund for Nature*

Soemarwoto, O. & I. Soemarwoto. (1984). The Javanese Rural Ecosystem, Pp 254-287 in *An Introduction to Human Ecology Research on Agricultural Systems in Southeast Asia*,

Soedjito H & Uji T, (1987). Potensi flora hutan yang kurang dikenal. *Prosiding Diskusi Pemanfaatan Kayu Kurang Dikenal*. Badan Penelitian dan Pengembangan Kehutanan.

Cisarua, Bogor, 15–43
Sutanto, A, D. Sukma, C. Hermanto, & Sudarsono. (2014). Isolation and characterization of Resistance Gene Analogue (RGA) from *Fusarium* resistant banana cultivars. Emir. J. *Food Agric.* 2014; 26(6): 508-518. doi: 10.9755/ejfa.v26i6.17219
Sutanto, A. (2015). Perbanyakan pisang dan nenas secara kultur *in vitro*. *Laporan Hasil* penelitian tahun 2015.
Tasliah, Karsinah, & J. Prasetiyono. (2016). Keragaman Sebelas Klon Mangga Komersial Indonesia. *J. Hort*. Vol. 26 No. 1, Juni 2016 : 31-40
Uji T. (2007). Diversity, distribution and potential of genus *Garcinia* in Indonesia. *Hayati* 12:129-135.

PAPER 3:
BREADFRUIT DIVERSITY IN FIJI

Manoa Iranacolaivalu & Kalolaini Colaitiniyara
Horticulture Section of the Research Division, Ministry of Agriculture, Fiji

EXTENDED ABSTRACT

Breadfruit (*Artocarpus altilis*) is an important crop in Fiji as a staple food as well as its traditional significance. The tree crop is tolerant to climate extremes and recovers early especially during the post cyclone rehabilitation phase as a source of food for the communities. This is evident for the people of Natewa, known as the breadfruit hot spot in the Northern part of Fiji, who consumed breadfruit all year round due to the wide genetic diversity with its overlapping cropping season.

A breadfruit survey conducted in 2015 found 15 varieties in four villages, Natewa, Muana, Sese, and Naboutini. These varieties were identified, characterized, and 8 varieties were analyzed in the laboratory. The breadfruit descriptor developed by Diane Ragone, 2003, was used in the characterization of 10 fruits for each variety: mainly on the leaves and fruit morphological features. The varieties were divided into two categories: seeded (12 varieties) and non-seeded (3 varieties).

Table 1. Fruit characteristics of non-seeded varieties

VARIETY	KARO-KARO	BALEKA-NA DINA	UTO VATU	BALEKA-NA SAMOA	BOKASI	COKA	VIROA-SOLA	LASA-WA	UTO DINA	VUNI-DAWA	OQO	UTO VULA
FRUIT SHAPE	Round	Round	Round	Oblong	Round	Round	Round	Round	Oval	Oval	Round	Round
FRUIT SKIN TEXTURE	Rough – sand papery	Smooth	Rough	Smooth	Rough sand papery	Smooth	Rough, sand papery	Rough	Rough skin	Smooth	Smooth	Rough irregular raised.
FRUIT WEIGHT (grams)	396	422	475	758	1223.5	1434	1517.4	1733	1774	1904.7	2080.2	2458
FRUIT CIRCUMFERENCE (cm)	30.5	29	46	35.14	40	45	51.2	47.4	45.5	50	54.2	55
FRUIT LENGTH (cm)	10.25	10.625	12.3	13.75	14.75	16	18.7	17.3	19	18.93	17.3	19.5
FRUIT DIAMETER (cm)	9.5	10.5	10	10.75	14	14.5	12	15.25	14.25	15.2	16.25	17
FRUIT COLOR	Light Green	Light Brown	Green	Light Yellow	Light Yellow	Light Green	Light Green	Light Green	Light Green	Greenish Yellow	Light Green	Light Green
LENGTH OF PEDUNCLE (cm)	7.25	4.625	6.75	6.25	7.75	5.5	7.5	8.7	8	7.83	8.7	8.5
COLLAR NECK (cm)	2.25	4.5	2.55	4.5	3.25	4	2.5	2.5	2.25	3.5	4	4
PEDUNCLE INSERTION (cm)	1.5		1	1.75	2.25	2	1.5	1.5	1.5	2.1	1.75	2
LATEX (No latex, light, heavy)	light	none	none	light	heavy	heavy	Light	Light	Light	heavy	Light	Light
WIDTH AT MIDPOINT (cm)	5	5.5	4.4	5	7.25	7	6.25	7.5	7.25	8	8.75	8.75
WIDTH AT SHOULDER (cm)	6.5	5	6.7	5	10	9.5	7.25	7	7.75	8.6	9	8.25
LENGTH OF CORE (cm)	5.5	7	4.25	9	8.75	9	8.5	6.75	11.25	10	7.25	10.25
WIDTH OF CORE (cm)	2.25	3	2.75	2.75	4.5	4	2.75	3.25	3.25	2.83	3	3.25
FLESH COLOR (white, creamy, light yellow, yellow)	Light yellow	Light Yellow	Creamy	Light Yellow	Light Yellow	Light yellow	Light yellow	Light yellow	Light yellow	Creamy	White	Light yellow

Table 2. Fruit characteristics of seeded varieties

VARIETY	SAVISAVI	LIVA	WELESI
Fruit shape	Round	Oval	Oval
Fruit skin texture	Smooth	Smooth	Rough, sand papery
Fruit weight (grams)	672	700	1831.5
Fruit circumference (cm)	36.5	46.6	52.5
Fruit length (cm)	12	15.8	18
Fruit diameter (cm)	11.25	10.5	15.75
Fruit color	Light green	Light yellow	Light green
Length of peduncle (cm)	4.75	7.25	8.5
Collar neck (cm)	3.25	2.5	3.5
Peduncle insertion (cm)	1.75	1.75	2.25
Latex	Light	Light	Light
Width at midpoint (cm)	3	5.5	8.25
Width at shoulder (cm)	8.25	7.25	9.75
Length of core (cm)	6.25	6.25	11.5
Width of core (cm)	3.25	3.25	5.25
Flesh color	Light yellow	Light yellow	Light yellow

Table 3. Laboratory Analysis

Varieties	Total Ash (%)	Nitrogen %	Protein %	Brix %	Iron (mg/kg)	Manganese (mg/kg)
Balekana ni Samoa	1.6	0.21	1.29	12	38.5	14.4
Uto Vula	1.29	0.17	1.03	8.5	52.8	12.1
Viroasola	1.74	0.14	0.87	23.8	44.1	7.54
Lasawa	1.64	0.16	1	13.4	47.3	8.86
Uto Karokaro	0.7	0.3	1.89	9.1	56.9	12.8
Oqo	1.63	0.17	1.06	12.5	68.2	5.64
Liva (seeded var)	1.79	0.18	1.14	10	71.8	9.04
Balekana Dina	1.5	0.18	1.1	10.4	69	8.28

Characterization data showed that majority of the varieties are non-seeded. There are also variations within the categories in terms of fruit sizes and weight, which can be classified into three categories: i.e. small (396 to 758g) with 6 varieties; medium (1223.5 to 1904.7g) with 7 varieties; and large (2080.2 and 2458g) with 2 varieties. Fruit characteristics showed that small varieties generally has short fruit circumference, length, and diameter, followed by medium fruits and large fruits, except for Liva and Bokasi varieties.

The laboratory analysis showed an interesting data on the nutrient content of the varieties, especially the high iron content of the Liva variety with 71.8mg/kg. The characterization data also showed that there are similarities on the leaf characteristics amongst the categories as well as diversity within the categories.

Future activities will focus on the following:

- Tissue culture – conservation purpose and production of planting materials
- Yield mapping of each variety
- DNA fingerprinting of varieties
- PGR conservation - Establishment of formal orchard at the village
- National breadfruit survey – Reconfirmation of the distribution of varieties
- Awareness and promotion on food and nutrition security

Keywords: Fiji, breadfruit, morphology

PAPER 4:
CITRUS VARIETY IMPROVEMENT PROGRAM IN INDONESIA : VARIETIES, PRODUCTION AND DISTRIBUTION VIRUSES FREE OF CITRUS NURSERY STOCKS

Arry Supriyanto[1], Muhammad Taufik Ratule[1] & Muhammad Syakir[2]

[1]Indonesian Citrus and Subtropical Fruit Research Institute. Jl. Raya Tlekung no 1, Batu 65301, Jawa Timur, Indonesia. Tel./Fax. +62-341-592683/593047,

[2]Agency for Agricultural Research and Development, Jl. Raya Ragunan 24, Pasarminggu, Jakarta

ABSTRACT

Indonesia is rich in local citrus varieties that are mainly grouped into mandarin, tangerine, pummelo and other groups. The citrus variety improvement program was initiated in 1987 to produce virus-free propagation materials especially for the Huanglongbing (HLB), Citrus Tristeza Virus (CTV) and the Citrus Vein Enation Virus (CVeV). Activities consisted of the selection of mother trees, shoot-tip grafting and indexing, and technology improvement in production systems, distribution process and seed certification regulation; all with the ultimate aim of producing virus free citrus stocks. A typical process for the distribution of virus-free citrus propagation material in Indonesia can be described as follows: (i) Foundation Blocks where individual pots are planted in an insect proof screen house; (ii) Multiplication Blocks consist of densely planted bud-produced plants in an insect proof screen house; and (iii) Commercial Nursery Blocks produce labelled citrus nursery stocks in the fields. Despite the technical and regulatory issues faced in implementation, at present citrus Foundation Blocks have been established in 19 provinces, while Multiplication Blocks have been built at 29 provinces out of the total 34 provinces in Indonesia. Most nurserymen in Indonesia produce budded citrus trees in the field, while some new nurserymen have started to produce labelled citrus nursery stock in polybags. Good management practices combined with synchronized production of rootstock seedlings, and timely pruning at Multiplication Blocks are key for producing good quality citrus budsticks at the most appropriate time for budding. These strategies enable nurserymen to produce citrus stocks within one year. So far more than 10 million virus-free citrus stocks have been produced under this program.

Keywords: *Citrus* sp, variety, Huanglongbing (HLB), shoot-tip grafting (STG), foundation, block, multiplication blocks, certification program

INTRODUCTION

The citrus growing areas in Indonesia amounts to almost 70,000 ha, and production has been estimated to be around 1,500,000 tons. Harvesting seasons fall during the periods of January-April (19% of total national production); May-August (56% of total national production) and September-December (25% of total national production). Indonesia imports a lot of citrus especially mandarins from citrus producing countries such as China, Pakistan, Thailand, USA and at times from Argentina and South Africa. These imports reach less than 10 % of the national production.

In the 1980s, most citrus plantations in Indonesia were infected by the Huanglongbing (HLB), also known as the Citrus Vein Phloem Degeneration (CVPD) disease, which is caused by the *Liberibacter asiaticum* (Jagoueix et al.,1994) and transmitted by a vector known as the *Diaphorina citri* Kuw. The disease also infected material for propagation, reducing productivity to approximately 10tonnes/ha and significantly denting the citrus agribusiness in Indonesia. Despite the bleak outlook for the citrus industry due to the widespread effect of the disease, citrus growers were eager to continue planting citrus trees because for economic reasons. Efforts to curb the spread of the disease in the past yielded unsatisfactory results. In 1987, the Indonesian Citrus Rehabilitation Program for production of virus-free citrus nursery stocks was initiated (Supriyanto & Whittle, 1992). By 1992, the program was successful in producing and distributing HLB and other virus-free citrus stocks in several places, notably in North Bali. The success of the program was then strengthened with the initiation of the Indonesian citrus certification program.

At present time, the Multiplication Blocks which serve as the primary source of scions for nurserymen have been established at 29 provinces out of the total 34 provinces of Indonesia. The establishment of country-wide Multiplication Blocks signify potential for the production of virus-free citrus stocks or labeled citrus stocks almost anywhere in Indonesia. Based on this system, more than 10 million virus-free citrus stocks have been produced in Indonesia, although the production of certified nursery stocks are still not enough to fulfill the national demands because of various reasons. Although the program was successful, the performance of citrus plantations again fluctuated due to the recommended technology was not implemented by citrus growers properly

Citrus agribusiness in Indonesia is located in more than 25 provinces mainly in the provinces of East Java, North Sumatera, West Kalimantan, West Sumatera and Bali. The citrus plantations are spread throughout varied agro-climatic conditions such as lowlands and highlands, dry and humid areas, and sometimes in swampy area. These areas host a wide range of varieties, and various forms of cultivation are often times practiced.

CITRUS VARIETIES

Indonesia is rich in local citrus varieties that can be grouped into mandarin, tangerine, pummelo and others including lime, lemon, *Citrus hystrix*. Almost 80% of the citrus production area at lowland were planted with tangerine cultivars Siam Pontianak, Banjar, Madu, Gunung Omeh and Kintamani. Those varieties have narrow different in morphological site except the rind color will be green and yellowish when planted at lowland while in the high land the color became yellow-orange. Mandarin group varieties were planted at high land area mainly with local variety e.g. Keprok Batu 55 are being become Indonesia mandarin because they are going to be planted in most provinces in this country. Gayo mandarin from Aceh with smooth texture of the flesh and the best mandarin of Soe come from West Timor-NTT (Figure 1) which have rind color of deeply orange-red because while during ripening at the area the temperature amplitude is relatively high caused by cool wind breezed from Australia continental. These mandarin of Tejakula, Madura and Borneo Prima have yellow-orange rind color although planted at lowland area. Pummelo such cultivar Nambangan grow well at lowland while planted at highland, the bitter taste will be appeared. Borneo lime were planted by citrus growers at the lowland area and even in East Kalimantan, growers planted the seedless lime at swampy area.

Figure 1. The Gayo or SoE mandarin, has been touted as the best mandarin variety in Indonesia from East Nusa Tenggara. The variety is commonly found in traditional markets

For the purpose of improving the citrus fruit quality in Indonesia and fulfilling the demand for seedless citrus fruits, a hybridization research program has been conducted through conventional breeding, irradiated gamma ray and fusion protoplasm at the Indonesian Citrus and Subtropical Fruits Research Institute (ICSFRI). A notable achievement of this research was the production of a seedless pummelo variety (Pamindo or Pamelo Indonesia), and a mandarin variety (SoEIndo or SoE Indonesia) induced via gamma irradiation. Research in finding a citrus variety tolerant to HLB is still ongoing.

Figure 2. Pamindo (Pummelo of Indonesia) : A seedless new variety of pummelo induced by gamma ray irradiation

PRODUCTION OF VIRUSES FREE OF CITRUS MOTHER TREES

The rich citrus diversity in Indonesia and the increasing market demand for local citrus varieties create a necessity for all varieties that are distributed to citrus growers to follow a certification program. A labeled citrus nursery stock ensures that the citrus stocks are free from viruses, with true-to-type scions and rootstocks, and are in good condition to be delivered to citrus growers. Once a single desirable citrus tree is located in a particular area and identified as a new potential citrus variety, it is then sent to the Indonesian Citrus and Subtropical Fruit Research Institute (ICSFRI). The option of hybridization is also considered for the production of the new prior variety.

The plant materials of new prior of citrus varieties are cleaned from viruses such HLB, CTV, CVEV, CEC and CPsV by Shoot-tip Grafting (STG) based on protocols described by past studies (Murashige et al., 1972, Navaro et al., 1975; Triatminingsih et al., 1992 & Devy et al., 2015). For promotion of STG plantlet regrowth, re-grafting is performed onto 4-6 month old rootstock seedlings which are grown in an insect proof screen. After three to five months, the grafted plants are ready to be indexed. The absence or presence of pathogens are verified through indexing conducted using PCR, Elisa kit and citrus indicator plants for comparison (Muharam and Whittle, 1992; Devy et al., 2015).

Based on the research and experiences thus far, there is still need for improvement in several aspects in order to produce virus-free citrus mother trees. For shoot-tip grafting, the percentage of successful grafts varied depending on the varieties, with averages of 40-60% reached. Pummelo faces a high difficulty level in STG results due to the presence of trichrome at its apical dome. However when successful, re-grafting percentages reached 60-90% for pumelo. A negative indexing result meant the plant is free from viruses or systemic pathogens. Subsequently, the plants are vegetatively propagated and maintained in an insect proof screen house as a mother plant source and indexed periodically.

DISTRIBUTION OF VIRUSES FREE OF CITRUS PROPAGATION MATERIAL

The distribution of virus-free citrus propagation materials from mother tress in ICSFRI to the citrus growers follows the path described (Supriyanto et al., 1992): Foundation Blocks – Multiplication Blocks – Citrus Nursery Blocks (Nurserymen) - Citrus Growers. This is then ensued by a certification program. Foundation Blocks house plants from mother trees in ICSFRI. The plants are grown in individual pots under insect proof screen house with indexing and true to type checks performed periodically in order to remove mutation sprouts. Multiplication Blocks are where plants are grown in a high planting density of 50cm x 25 cm, under insect proof screen houses, and harvesting is done after 3-5 years. At the Citrus Nursery Blocks, plants are produced on the field or in the polybags following the regulations of the certification program. Once the process is complete, plants are ready for citrus growers who are entitled to receive premium certified nursery stocks, with specific varieties during the planting season.

Table 1 shows the distribution of viruses free of citrus propagation material via Foundation Blocks and Multiplication Blocks through nurserymen to the citrus growers in Indonesia. Foundation Blocks so far have been established in 19 provinces while Multiplication Blocks have been built at 29 provinces of 34 provinces existing in Indonesia. From those more than 10 million of viruses free of citrus nursery stocks has been distributed to the citrus growers in this country

Table 1. Distribution of viruses free of propagation planting material to Foundation Blocks and Multiplication blocks in Indonesia

Mark	Foundation Blocks	Multiplication Blocks
Number of provinces	19	29
Number of plants	786	43.713
Number of varieties :		
Mandarin	12	21
Tangerine	4	6
Pummelo	1	5
Others : lime, lemon	2	5

TECHNOLOGY RECOMMENDED

The mission to produce virus-free citrus nursery stocks or labeled citrus nursery stocks within one year (Hardiyanto et al., 2011; Supriyanto et al., 2017) is a priority of the institute, with daily activities being undertaken at the Experiment Garden of Punten – ICSFRI towards this. Research has been conducted to improve the technology for producing citrus budded trees. Polybags measuring in diameter x height of 10 cm x 30 cm, filled with sand as a big portion of mixed media are used. For monitoring purposes, it is of importance to remove yellow leaves from seedlings of 'Japansche citroen' rootstock and curving roots of seedlings. Most importantly is for the selection of nucellar seedlings, leaving out off – types (Andriani et al., 2013). This is usually conducted before transplanting of seedling to the polybags. Budding height is 20-25 cm above media surface. The key for the success in producing labeled citrus nursery stock within one year is synchronizing the scion harvesting time with the time when seedlings are ready to be budded. This recommended technology has been implemented in several provinces and widely adopted in East Nusa Tenggara (Supriyanto et al., 2015). Based on the experiences of the research team, the improved quality of the nursery stocks planted by citrus growers has led to better fruit quality especially in terms of fruit homogeneity (Supriyanto & Zamzami, 2014).

Once virus-free citrus stocks are planted in the field, the risk of being re-exposed and re-infected by vectors especially the HLB and CTV diseases increases. For maintaining the health and vigor of the new plants, citrus growers are advised to implement the Integrated Management for Citrus Healthy Orchard (IMCHO) technology package which consist of the following components: (1) Using virus-free citrus nursery stocks; (2) Vector control; (3) Eradication of infected trees; (4) An optimum maintenance; and (5) Consolidation of orchard management between growers in the Citrus Grower Group, and among Citrus Grower Groups under the Citrus Association in the area of citrus agribusiness (Supriyanto, 1996; Supriyanto et al., 2001; 2012).

ISSUES AND RECOMMENDATIONS

Twenty years of experience in producing virus-free citrus mother trees and distribution of the material propagation to almost all provinces in Indonesia have revealed various observations and issues that have to be addressed.

Issues include: (1) Existing Multiplication Blocks are not well maintained, leading to the insufficient number of scions produced. (2) It is a common complaint among Citrus nurserymen that they are unable to obtain the bud sticks during the budding period in a timely manner. The current practice is for bud sticks to be harvested in Multiplication Blocks selectively, instead of pruning all simultaneously. This creates an uncertain pattern in growth flush, reducing the production of bud sticks or scions. (3) Broken screens are not promptly repaired, leaving Multiplication Blocks in deplorable conditions, and causing healthy plants in the screen house to be infected by viruses through the introduction of vectors. (4) The limited number of bud sticks has led nurserymen to look elsewhere for another sources of scions of which the health status is unknown. (5) Many nurserymen still prefer prolonging the lifespan of plants grown in Multiplication Blocks under insect proof screen houses for 5 years instead of 3 years. (6) Many small-scale citrus nurserymen are finding it difficult to implement management practices recommended by citrus certification program.

Observations and recommendations include: (1) The success using the STG protocol is species and variety-specific, with each citrus species exhibiting different levels in success, hence protocols should be tailor-made accordingly; (2) The method of indexing has to be consistently improved; (3) Five years has been recommended as the optimal time to produce bud woods in multiplication blocks, instead of the current three years as suggested; (4) In order to increase the bud stick production from Multiplication Blocks, some form of training has to be conducted. Areas of training include Multiplication Block management, and enforcement of implementing the certification regulation program; and (5) Establishing an 'Indonesian Citrus Nursery Information System' to ensure all the activities of citrus nurserymen in this country are well coordinated.

CONCLUSION

Twenty years after the Citrus Variety Improvement Program started in Indonesia, more than 10 million virus-free citrus stocks have been produced and delivered to citrus growers throughout the whole country. Future research and activities are geared towards the improvement in management of Foundation Blocks and Multiplication Blocks; technology improvement to produce labeled citrus nursery stocks within one year; enforcement for the better implementation of the citrus certification program; as well as establishing the National Citrus Nursery Information System.

REFERENCES

Andriani, A., Suharsi, T.K., & Surahman, M. (2013). Studi Poliembrioni dan Penentuan Tingkat Kemasakan Fisiologis Benih Japansche Citroen Berdasarkan Warna Kulit Buah. *J.Hort.*, 23(3), 195-202.

Devy, N.F., Hardiyanto, and Dwiastuti, M.E. (2015). Teknologi Shoot-top Grafting dan Indeksing, aplikasinya pada perbenihan jeruk bebas penyakit. AARD PRESS. p80.

Hardiyanto, Supriyanto, A., Sugiyatno A., Setiono & Mulyanto H. (2011). Panduan Teknis Teknologi Produksi Benih Jeruk bebas Penyakit. Balitbangan: Kementerian Pertanian. p89.

Jagoueix, S., Bove, J.M., and Garnier, M. (1994). The phloem-limited bacterium of greening disease of citrus is a member of the alpha subdivision of Ptoteobacteria. *Int. J. Syst. Bacteriology*, 44: 397-86.

Muharam, A. & Whittle A.M. (1992). Indexing of citrus for major systemic pathogens in Indonesian Citrus Variety Improvement Program. In Proc. Asian Citrus Rehabilitation Conf.

Murashige,T., Bitters,J.M., Rangan,T.S., Naurer,E.M., Roistacher,C.N., & Hollyday P.B. (1972). A technique of shoot apex grafting and its utilization towards recovering virus free citrus clones. Hort. Sci. 7:118-119.

Navarro, L., Roistacher, C.N., & Murashige, T. (1975). Improvement of shoot-tip grafting in vitro for virus free citrus. *J. Amer.Soc. Hort. Sci*. 100:471-479.

Supriyanto, A. (1996). Pengelolaan Terpadu Kebun Jeruk Sehat. Trubus no. 324 Tahun XXVII. Yayasan Sosial Tani Membangun. p. 32-45.

Supriyanto, A., & Whittle, A.M. (1992). Citrus Rehabilitation in Indonesia. In Proc. 11th Conference of the International Organization of Citrus Virologists. Riverside, CA (pp. 409-413).

Supriyanto, A., Dirgantara, D.S., & Purbiati,T. (2016). Sinkronisasi penyediaan semaian batang bawah dan mata tempel dalam produksi bibit jeruk bermutu premium. In Prosiding *Perhorti dan Peragi: Peningkatan Produksi Pangan dan Hortikultura yang beradaya saing mendukung*. (pp.230-236). MEA.

Supriyanto, A., Utomo, J.S., Hanif, Z. & Silva, H.D. (2015). Adopsi teknologi anjuran Produksi Bibit Jeruk Keprok SoE (*Citrus reticulata* Blanco) berlabel biru dalam polibag dalam Soemargono cs. In Prosiding Seminar Buah Tropika Nusantara II. (pp. 1167-1176).

Supriyanto, A., Subijanto, P.B., & Whittle, A.M. (1992). The Indonesian Citrus Improvement Programme. In Proc. *Asian Citrus Rehab. Conf. Puslitbang Hortikultura*. (pp. 50-58).

Supriyanto, A. & Zamzami, L. (2014). Memperkuat daya saing jeruk di pasar domestic dan global. In Daya saing *Produk Hortikultura.* IAARD Press. pp 195-204.

Triatminingsih, R., Purbiati, T. & Widayati, E. (1992). Citrus Shoot-tip Grafting and its application in Indonesia. In Proc. *Asia Citrus Rehabilitation Conf. Indonesia*. (pp. 77- 88).

SESSION WRAP UP AND Q&A

i. Scaling up some of the research outputs through institutional collaboration or G2G projects should be encouraged and considered as the way forward.

ii. The session illustrates that the 'Business as Usual' approach will not succeed in addressing climatic uncertainties and alternative approaches need to be sought after.

iii. It was also highlighted that though numerous activities are undertaken on breadfruit, currently there exist no central strategy (i.e., a national breadfruit development plan) for streamlining breadfruit research in Fiji. At present the breadfruit is grown "wild" in forests and home gardens. A more organised approach is required if breadfruit is to become a major commodity for export in Fiji.

iv. The session chair, Dr. Apaitia Macanawai pointed out on a recent signing of an memorandum of understanding (MOU) between the Fijian Ministry of Agriculture and the Indonesian Ministry of Agriculture to strengthen agricultural cooperation between the two countries on the exchange of technical information, exchange of specialists, transfer of technology, and promotion of joint ventures in the marketing of agricultural commodities. He welcomed discussions between the national agencies to pursue activities of mutual interest under the MOU in the future.

SESSION FOUR

Postharvest, Product Development and Utilization

PAPER 1:
POSTHARVEST HANDLING OF TROPICAL FRUITS IN THE SOUTH PACIFIC

Steven J.R. Underhill[1,2] & Salesh Kumar[3]
[1]University of the Sunshine Coast, Locked bag 4, Maroochydore DC 4558, Queensland Australia.
[2]Queensland Alliance for Agriculture, Food and Innovation, The University of Queensland, St Lucia, Brisbane, 4000, Queensland, Australia.
[3]College of Agriculture, Fisheries and Forestry, Fiji National University, Koronivia, Fiji Islands. Email: salesh.kumar@fnu.ac.fj

ABSTRACT

While tropical fruits represent less than 20% of the net horticultural productivity in the South Pacific, they experience disproportionally high levels of postharvest loss. Much of this loss is concentrated at the market-end of the value chain. Inter-island fruit value chains and those associated with transient and opportunistic fruit harvesting practices are particularly vulnerable. When losses occur they are often significant (20% to 80%), but can also be unpredictable. Postharvest loss has been attributed to the combination of low-input fruit production systems, poor postharvest practices, unpredictable transport, and short product shelf-life. Highly seasonal production with ensuing sporadic market over-supply and resultant prolonged storage further elevates postharvest loss. Mitigating postharvest loss within fruit value chains has become increasingly important in recent years as Pacific Governments and donors seek to enhance horticultural exports and improve industry resilience.

In this paper, we discuss the current postharvest challenges facing fruit value chains in the Pacific, with a specific focus on small island developing states. We highlight the interconnectivity between pre-harvest and postharvest handling remediation, the implications of semi-commercial fruit value chains, and the importance of transport and market system contributors to loss. Further, we discuss strategies undertaken to remediate postharvest loss, highlight the need for increased institutional capacity building and conclude by proposing a series of targeted interventions aimed at better supporting Pacific fruit value chains.

Keywords: fruits, Pacific, postharvest, horticulture, food loss, food security

INTRODUCTION

Postharvest handling of tropical fruit crops has historically received little attention in the South Pacific. Much of the effort in support of Pacific fruit value chains has focused on improving agronomic productivity, environmental sustainability, genetic resource management, and improving natural disaster resilience (Chung, 1987; Taylor & Tuia, 2007; Stice et al., 2010; Nath, 2014). Given endemic production challenges, the nascent stage of many fruit industries in the region, and cyclic risks due to natural disasters, such an approach is justified. For the majority of fruit crops and markets in the Pacific, there is little information as to current levels of postharvest loss, which fruits are most vulnerable, or the critical contributing factors.

In the last ten years, there has been an increased awareness of the need to improve postharvest handling systems as Pacific Island countries and donors seek to enhance and diversify the horticultural sector. The emergence of several important fruit export industries (i.e., Fiji papaya and breadfruit) has seen many larger horticultural enterprises progressively adopt better postharvest handling practices (Stice et al., 2007; 2010; Sole et al., 2014). Similarly, smallholder farmers accessing expanding domestic market opportunities, particularly those associated with the tourism sector, have started to improve their postharvest handling and food safety compliance (Berno, 2011; Underhill, 2013a). Most Pacific Island Government fruit and vegetable strategies now make implicit reference to the need for improved postharvest handing practice (AAACP, 2009ab; Solomon Islands Ministry of Agriculture and Livestock, 2015; Vanuatu Department of Agriculture and Rural Development, 2017). With many Pacific small island developing states also facing the added burden of high rates of non-communicable diseases and food security risks, improving postharvest fruit handling systems is now considered essential to developing resilient and nutritionally sensitive Pacific food systems (Hazelman & Pilon, 1997; FAO, 2017; Underhill & Singh-Peterson, 2017).

In this paper, we provide a commentary on the broad postharvest challenges facing the development of sustainable fruit value chains in the Pacific, with a special focus on small island developing states. We further discuss the effectiveness of strategies to remediate postharvest loss, and conclude with a series of targeted and country-specific postharvest research and development priorities.

CHALLENGES TO IMPROVING FRUIT POSTHARVEST VALUE CHAINS

On-farm practice

Given the profound effect that pre-harvest practices have on fruit quality (Arpaia, 1994; Hofman et al., 1997; Sams, 1999; Rehman et al., 2015), any effort to reduce postharvest loss needs to be inclusive of wider efforts to improve fruit production systems. Pre-harvest practices often have the greatest impact on postharvest quality, when product is grown under low-input and low-intensity production systems, or when production is based on species or cultivars that are poorly suited to local conditions. For much of the fruits grown in the South Pacific, such conditions are the norm. In tree fruits (such as mango and citrus) there is limited or no tree pruning, little pre-harvest disease control, inconsistent fertiliser application, and limited site selection or cultivar evaluation. While temporary fruit (such as pineapple, papaya, and melon) production practices are more consistent with other broad acre crops, they are still far from ideal.

Low-input production practices not only results in poor and highly variable fruit quality entering the value chain, but also shapes underlying smallholder farmer attitudes and behaviours. Having produced fruits on the basis of minimal farm-inputs, fruit farmers are often resistive to adopting better postharvest handling practices that necessitate added input costs (such as improved packaging). This attitude is particularly prevalent in fruit value chains sourced from village or community-based plantings involving sporadic or opportunistic harvesting. Unlike vegetable crops which necessitate a greater investment in time and resources, much of the fruit production in the Pacific still remains semi-commercial in nature. We are not implying that all Pacific fruit value chains are semi-commercial, there are numerous examples of large fruit-based enterprises (>10 ha) throughout the region (i.e., papaya, pineapple, and citrus). Rather, the disparity between commercial vegetable value chains and the predominance of semi-commercial fruit chains, means it is often more difficult to improve postharvest handling practice amongst fruit farmers.

Dysfunctional fruit production systems in the South Pacific can also create critical obstacles to improving postharvest handling efficiency. In Tonga, limited access to new fruit cultivars coupled with few commercial plant nurseries has resulted in much of the domestic tree fruit production being sourced from aging trees, leading to declining fruit supply, reduced product quality, and elevated postharvest loss (Underhill & Singh-Peterson, 2017). In Samoa, domestic fruit production is based on a limited number of cultivars creating a concentrated seasonal market supply, resulting in significant market loss, and economic disincentives for wider industry participation (Underhill et al., 2017). This inter-connectivity between pre-harvest and postharvest value chain efficiency is particularly prevalent in the Pacific. Low supply volumes and few commercial-scale farmers mean that there are few options for markets to compensate for the implications of poor pre-harvest practices.

Improved postharvest practices alone cannot be expected to undo the implications of poor pre-harvest practice. Similarly, poorly adapted cultivars, aging trees, or seedling-sourced planting material, translate into lower fruit quality, a greater risk of postharvest diseases, and reduced fruit shelf-life. The critical first step in reducing postharvest loss within Pacific fruit value chains must involve the introduction of elite or better adapted fruit genetics and improved local capacities to smallholder farmers.

Transport

Most Pacific fruit value chains, excluding those associated with PNG, involve comparatively short intra-island transport distances. Inter-island and inter-regional fruit value chains do exist and involve substantial transport challenges (i.e., inter-island supply of pineapples from Luganville to Port Vila, Vanuatu can take up to seven days), but they only represent a small percentage of product sold into Pacific fruit and vegetable markets. A recent study by Underhill et al. (2017), noted that much of the domestically-sourced fruits in the municipal markets in Samoa travelled less than 20 km from farm to market. The main fruit production regions on Efate Island, Vanuatu are less than 30 km from the Port Vila markets. In Fiji, the Sigatoka Valley, a key horticultural center is only 170 km from the Suva markets. The comparative close proximity of many intra-island production regions means product commonly arrives within twelve to twenty-four hours. As municipal markets across the region tend to be based on small vendor trading space and limited in-market storage capacity, commercial value chains are further forced to supply small quantities of product but on a regular basis. Collectively, fruit value chain logistics involve small volume consignments being transported over short distances with comparatively rapid market through-put. The emphasis here is on transport speed and predictability. The implications of poor on-farm postharvest handling practice are lessened through rapid transport logistics and limited market storage. In Pacific horticultural value chains, anything that slows the supply chain down, adds increased complexities to the supply chain logistics, or reduces transport predictability, will have a disproportionally adverse impact on the level of postharvest loss.

While horticultural transport distances may be short they are often comparatively expensive. Accessibility to affordable transport is commonly mentioned as a key concern amongst all smallholder farmers. For more remotely located farms or value chains that require multiple modes of transport, high transport costs can be sufficient to impede smallholder farmer market participation. For example, it is not uncommon for fruit farmers on the island of Espiritu Santo, Vanuatu supplying the municipal market in Luganville to incur 60% of the net consignment value in transport costs.

Creating more cost effective horticultural logistics has been a particular focus of donors, with various potential strategies being articulated in recent Pacific fruit and vegetable strategies (AAACP, 2009ab; Solomon Islands Ministry of Agriculture and Livestock, 2015; Vanuatu Department of Agriculture and Rural Development, 2017). Much of the recent attention has centered on promoting various farm-cooperative models, an approach considered by Duncan and Sing, (2009) and Veit (2009) to be difficult to implement in the Pacific. We believe more could be gained if an alternative approach based on targeted support of nascent outer island and regionally remote fruit value chains was considered. Creating more viable inter-island fruit value chains often only necessitates better at wharf storage facilities or more cost efficient wharf to market transport. For example, in Vanuatu it can cost more to transport fruit consignments from the Port Vila wharf to the Port Vila municipal market (approx. 2.5 km), than it does to transport product from Espiritu Santo Island to Port Vila, Efate Island (approx. 350 km). Further, inter-island fruit supply chains into Port Vila often cease during the Christmas period as family members based at the markets relocate back to their village, leaving few options to coordinate supply.

Markets

Once at the market, rapid market throughput is vital if postharvest loss is to be minimised. While there have been few studies to explore the implications of market vendor handling practice, Underhill and Kumar (2014) and Underhill et al. (2017), reported proportionally higher levels of postharvest loss of fruits (compared to vegetables) in Fijian and Samoan municipal markets due to prolonged market storage. The implications of market operations and consumer purchase behaviour as potential additional contributors to postharvest loss are also poorly understood. There is some preliminary evidence to suggest that efforts to improve municipal market infrastructure in some Pacific Island countries may have actually increased the amount of postharvest loss, due to poor market design, reduced consumer accessibility, and disconnects with consumer purchase behaviour trends (Underhill et al., 2017). We believe, how and where fruits and vegetables are sold in the Pacific, has a profound effect on the level of horticultural postharvest loss. It is interesting to note that while Pacific fruit and vegetable markets and the consumer-end of the value chain have received little attention by researchers, there have been disproportionally large infrastructure investments by Pacific Island Governments and international donors to “improve” them.

STRATEGIES AND APPROACHES TO REMEDIATION OF POSTHARVEST LOSS

Postharvest institutional capacity building

The need to strengthen local institutional postharvest capacity to better support farmers in the Pacific has long been recognised (Cocker, 2000; Rolle, 2006). A review of postharvest research, extension, and education capacity in the South Pacific highlighted ongoing critical failures and the need for increased investment to support local postharvest research, development, and extension capacity (Underhill, 2013b). In subsequent years, there has been some notable improvements, with the Fiji National University, the Scientific Research Organisation of Samoa (SROS), and the Ministry of Agriculture Samoa now having dedicated postharvest specialists. SROS is starting to emerge as a possible important regional leader in postharvest research and development in the South Pacific based on strong support by the Samoan Government and significant investments by international donors. In spite of these recent gains, wider postharvest institutional capacity in the region remains poorly developed.

It is impossible to over-state the importance of nurturing strong and enduring institutional postharvest capacity in the Pacific. To be effective, extension officer capacity and resources in postharvest horticulture need to be enhanced. To be enduring, the horticultural curriculum at key Pacific universities and colleges needs to be strengthened to incorporate relevant sub-tropical and tropical postharvest handling content, supplemented with postharvest resource material. We believe that any initiatives to enhance fruit value chains in the Pacific that do not include postharvest institutional capacity are unlikely to be enduring.

Translating Government strategies and policies

While many countries in the South Pacific have developed fruit and vegetable sectoral plans and strategies that place strong emphasis on improved postharvest handling practices (AAACP, 2009ab; Solomon Islands Ministry of Agriculture and Livestock, 2015; Vanuatu Department of Agriculture and Rural Development, 2017), most have struggled to translate this intent into practice. The reasons for this are four-fold:

1. With the exception of Samoa and Fiji, Pacific Island countries tend to lack appropriate technical postharvest expertise or associated postharvest infrastructure. The capacity to identify, prioritise and respond to technical postharvest challenges, risks, or opportunities simply does not exist. For many Pacific Island countries, this is symptomatic of limited undergraduate or postgraduate training in postharvest horticulture at the various regional universities and agricultural colleges. Unless greater emphasis is given to enhancing postharvest content of existing agricultural curriculum, the challenge of poor postharvest capacity and awareness will remain.
2. Remediating postharvest loss increasingly involves the development of robust private sector-government partnerships. This is particularly relevant when it comes to key investments in postharvest infrastructure such as refrigerated storage, export disinfestation equipment, and fruit and vegetable markets. To date, inconsistent engagement with the private sector has led to resultant infrastructure not being fit-for purpose, built in the wrong location, lacking critical human resources to operate, or being operated or ulitised in a manner inconsistent with private sector benefit. This is particularly relevant in the case of export market access, where Pacific governments are often economically unable to sustain disinfestation infrastructure, but equally unwilling to disinvest ownership or enter into public-private partnerships to resolve.
3. Tackling postharvest loss often requires a coordinated and multi-government agency approach. Unlike horticultural production challenges which normally fit neatly within the mandate of the Ministry of Agriculture, strategies to improve postharvest handling practices necessitate a multitude of government and non-government stakeholders, many of which have little pre-existing collaborative contact. Given the close connection between postharvest loss and food security, initiatives such as the recently proposed Tonga Food Security Council may provide a pathway forward.
4. In many Pacific Island countries, there is a declining trend in agricultural participation coupled with increased urban drift. For those that persist with farming, ongoing access issues to critical farm inputs, land access, affordable transport, and limited market opportunities create powerful disincentives for increased investment. These challenges can be particularly acute for fruit farmers. Morgan (2014) noted that farmers commonly perceived local consumers to be high-price sensitive, a view likely to further compound farmer resistance to added postharvest input costs.

Inappropriate postharvest remediation

In seeking to improve postharvest handling practice in the Pacific there has been an ongoing tendency to default to postharvest remediation strategies that have proven highly successful elsewhere (such as sub-Sahara Africa and Southeast Asia). To do so, overlooks the fact that Pacific horticultural production systems possess many unique bio-physical and socio-economic attributes that can negate or undermine the effectiveness of such approaches (Duncan & Sing, 2009). This is not to say that getting the postharvest basics right is not important, but rather the introduction of any technology or strategy to address postharvest loss needs to be tailored to the local situation, sympathetic to socio-cultural considerations, and respond to the real contributors of loss.

Socio-networks and relationships within Pacific value chains are often overlooked, replaced instead with the perception that smallholder farmers in the region are disconnected from markets and are impeded by poor market connectivity. While this is true in many fruit value chains especially those associated with inter-island trade, we need to be cautious in assuming this situation is the norm. Kumar (2017) in his assessment of Fiji farmer and market vendor relationships observed that many smallholder farmers have been supplying the same market vendors for at least 15 years and that they retain close and enduring relationships with a very small and select number of vendors. In many cases, these deep farmer-to-vendor relationships are based on ethic or geographic commonality. There are also complex and sometimes transient socio-cultural issues at play within Pacific agri-food value chains (Eti-Tofinga et al., 2017). Overlooking potentially long-standing value chain relationships on the premise that they don't exist is a common mistake amongst donors and researchers. It is essential to first understand the existing value chain operations from the bio-physical and socio-economic level before seeking to introduce perceived best-practice.

Given the multitude of postharvest challenges along Pacific fruit value chains, interventions that seek to solve postharvest problems that do not really exist would seem improbable. Low-input postharvest fruit value chains should benefit from even the most basic level of remediation. However, just because there is poor practice within a postharvest value chain, does not mean that it leads to tangible levels of postharvest loss or reduced product quality. For example, introducing improved packaging into value chains with low levels of in-transit loss, providing on-farm cool rooms where there are few reasons to promote farm storage, or exploring regional collection centres in locations where existing transport systems are well established. In the right context, such strategies can revolutionise fruit value chains in the Pacific. However, when applied inappropriately, these same technologies can inadvertently erode smallholder farmer profitability or disrupt existing value chain operations.

Postharvest research and development priorities to support Pacific fruit value chains

We believe that to enhance postharvest handling practice in support of Pacific fruit value chains necessitates:

1. Raising awareness of good postharvest practice
2. Better institutional capacity in postharvest extension and research
3. Better postharvest information access
4. Enhancing availability of elite fruit cultivars

One of the strategic advantages that the South Pacific has to achieving this outcome is the extensive international research already undertaken in support of sub-tropical and tropical fruits. The challenge now is to create an effective pathway to communicate, value-add, and build-on this knowledge and expertise. What has been lacking to date has been effective regional postharvest discipline leadership and coordination, a network of suitably trained postharvest extension staff, better regional access to practical postharvest extension resource material, and enhanced farmer access to new and elite planting material. In terms of more specific details, we propose:

1. The horticultural curriculum at the University of the South Pacific, Fiji National University, Solomon National University, and the Hango Agricultural College (Tonga) be reviewed with the aim of improving postharvest horticultural content.
2. The Scientific Research Organisation of Samoa becomes a Pacific Postharvest Centre.
3. Research and extension officers in Vanuatu, Fiji, Samoa, and Tonga receive further training in postharvest handling practice.
4. Fiji National University and the Fiji Ministry of Agriculture receive donor funding to establish a joint fruits, vegetables, and root crops postharvest laboratory.
5. Current and historical fruit varietal trial plots at the various Pacific Government research stations are audited and information made regionally available.
6. The Pacific Community's web portal expanded to provide better online postharvest resource information to Pacific extension officers.
7. Pacific Island Farmers Organisation Network receives funding to provide training and awareness of good postharvest practice.

CONCLUSIONS

The challenges facing Pacific fruit value chains are not dissimilar to those associated with Pacific vegetable or roots crops. However, high-seasonal production, the prevalence of low-input semi-commercial production systems, and a short product shelf-life makes fruit value chains particularly vulnerable to high postharvest loss. In many cases, we know how to resolve the multitude of postharvest handling issues observed. The issue is how to do so in a way which translates into economic benefit for farmers and creates an enduring impact. In this paper, we have highlighted the critical need for targeted institutional postharvest capacity building, the need for donor investment to be more responsive of local conditions, the importance of first understanding the operations and dynamics of fruit value chains before seeking to improve them, that little is going to be achieved in the absence of a more holistic approach to horticultural productivity, and emerging opportunities to assist outer-island fruit value chains.

REFERENCES

AAACP (2009a) Fruit and vegetables sector strategy for Samoa. Retrieved from http://www.intracen.org/uploadedFiles/intracenorg/Content/Exporters/Sectoral_Information/Agricultural_Products/Fruits_and_Vegetables/Samoa%20Strategy%20launch%20final%20aug.pdf

AAACP (2009b) A sector development strategy for the fruits & vegetables and roots & tubers industry in Fiji. Retrieved from https://www.yumpu.com/en/document/view/41902129/fiji-sector-strategy-for-fruits-amp-vegetables-and-roots-amp-tubers-aaacp

Arpaia, M. L. (1994). Preharvest factors influencing postharvest quality of tropical and subtropical fruit. *HortScience*, 29 (9), 982-985.

Berno, T. (2011). Sustainability on a plate: Linking agriculture and food in the Fiji Islands tourism industry. *Tourism and Agriculture: New Geographies of Consumption, Production and Rural Restructuring*, 87-103.

Chung, J. (1987). Fiji, land of tropical cyclones and hurricanes: A case study of agricultural rehabilitation. *Disasters*, 11(1), 40-48.

Cocker, E. (2000). Postharvest handling status and problems of the Pacific Island countries. In G.I. Johnson, Le Van To, Nguyen Duy Duc & M.C. Webb (Eds.) *Quality assurance in agricultural produce*, (pp. 57-59). Canberra, ACIAR Proceedings 100.

Duncan, R. & Sing, Y. W. (2009). The failure of agricultural policymaking in Fiji. *Pacific Economic Bulletin*, 24(2), 168-184.

Eti-Tofinga, B., Douglas, H., & Singh, G. (2017). Influence of evolving culture on leadership: a study of Fijian cooperatives. *European Business Review*, (in press).

FAO. (2017). Global action programme on food security and nutrition in small island developing states, Rome, pp. 73.

Hazelman, M., & Pilon, B. (1997). The Importance of Fresh Fruit and Vegetables in the Pacific Region. *In ACIAR Proceedings* (pp. 15-18).

Hofman, P. J., Smith, L. G., Meiburg, G. F., & Giles, J. E. (1997). Production locality affects mango fruit quality. *Australian Journal of Experimental Agriculture*, 37(7), 801-808.

Kumar, S. (2017). Postharvest handling practices and losses of tomato along value chains in Fiji. (Doctoral dissertation). *University of the South Pacific*, Fiji.

Morgan, E. H. (2014). *Value chains for nutrition: the applicability of value chain approaches to address low fruit and vegetable consumption in Fiji (Doctoral dissertation)*. London School of Hygiene & Tropical Medicine, UK.

Nath, P. (2014). Horticulture Potential in Fiji Island. Progressive Horticulture, 46(2), 175-183.

Rehman, A., Malik, A. U., Ali, H., Alam, M. W., & Sarfraz, B. (2015). Preharvest factors influencing the postharvest disease development and fruit quality of mango. *Journal of Environmental and Agricultural Sciences*, 3, 42-47.

Rolle, R. S. (2006). Improving postharvest management and marketing in the Asia-Pacific region: issues and challenges. *Postharvest management of fruit and vegetables in the Asia-*

Pacific region, 23-31.
Sams, C. E. (1999). Preharvest factors affecting postharvest texture. *Postharvest Biology and Technology,* 15(3), 249-254.
Sole, D., Henriod, R., Diczbalis, Y., Stice, K. N., & Tora, L. (2014). Modified atmosphere packaging effects on the postharvest quality of papaya fruit. In *XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscape*s (IHC2014): IV 1111, (pp. 119-124).
Solomon Islands Ministry of Agriculture and Livestock. (2015). *Solomon Islands agriculture and livestock sector policy* 2015–2019. Retrieved from https://pafpnet.spc.int/images/articles/policy-bank/solomon/Solomons-Islands-NALSP_Final%20Draft_151118.pdf
Stice, K. N., McGregor, A. M., & Kumar, & S. N. (2007). A review of fresh breadfruit exports from Fiji." In *I International Symposium on Breadfruit Research and Development*, 757, 243-249.
Stice, K. N., McGregor, A. M., Kumar, S. N., & Konam, J. (2010). Fiji Red papaya: progress and prospects in developing a major agriculture diversification industry." *Acta Horticulturae*, 851, 45-52.
Taylor, M. B. & Tuia, V. S. (2007). Breadfruit in the Pacific region. In *International Symposium on Breadfruit Research and Development*, 757, 43-50.
Underhill, S. J. & Kumar, S. (2014). Quantifying horticulture postharvest wastage in three municipal fruit and vegetable markets in Fiji. *International Journal of Postharvest Technology and Innovation*, 4(2-4), 251-261.
Underhill, S.J.R. & Singh-Peterson, L. (2017). Improving non-communicable disease remediation outcomes in Tonga: the importance of domestic fruit production systems: an analysis. *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 118(1), 91-103.
Underhill, S.J.R, Zhou, Y., Sherzad, S., Singh-Peterson, L., & Tagoai, S.M. (2017). Horticultural postharvest loss in municipal fruit and vegetable markets in Samoa. Food Security, (in press).
Underhill, S.J.R. (2013a). Improving the effectiveness of small-holder farm postharvest practices in Fiji. *Acta Horticulturae*, 1011, 41-48.
Underhill, S.J.R. (2013b). An overview of postharvest research, extension and education capacity in the Pacific with a focus on Western Samoa, Tonga and the Fiji Islands. *Acta Horticulturae,* 1011, 425-432
Vanuatu Department of Agriculture and Rural Development. (2017). *Vanuatu National Fruit and Vegetable Strategy.* Retrieved from http://www.nab.vu/sites/default/files/documents/F%20%26%20V%20Strategy.pdf
Veit, R. (2009). Assessing the viability of collection centres for fruit and vegetables in Fiji: a value chain approach. *FAO All Acp Agric. Comm. Program.* Ser. paper, 7. Retrieved from http://www.fao.org/fileadmin/templates/est/AAACP/pacific/FAO_AAACP_Paper_Series_No_7_1_.pdf

PAPER 2:
PHYSICO-CHEMICAL QUALITIES OF STORED FRESH CUT EVIARC SWEET JACKFRUIT (*ARTOCARPUS HETEROPHYLLUS* LAM.) PULP AS INFLUENCED BY DESEEDING, PACKAGING METHOD AND STORAGE CONDITION

Lorina A. Galvez[1], Anne Gellie P. Pablo[1], Roberta D. Lauzon[1], & Yan Diczbalis[2]
[1]Visayas State University, Visca, Baybay City, Leyte, Philippines
[2]Queensland Department of Agriculture Fisheries and Forestry, Australia

ABSTRACT

Processing method is noted to play a significant role in the physico-chemical properties of the food product. This study was conducted to evaluate the effects of deseeding, storage condition, and packaging method on the physico-chemical properties of fresh-cut jackfruit during the 8-day storage period. A 2x2x2 factorial experiment was used in the study making a total of 8 treatments. All of the treatments were subjected to physico-chemical analysis following standard protocols. Data were subjected to single factorial Analysis of Variance (ANOVA) and multi-factorial ANOVA for the interaction of dependent variables. Jackfruit pulps which are deseeded have shown significant decrease in the physico-chemical attributes of the product which is an indicator for product quality. Deseeded products have much faster deterioration compared to treatments with seeds. Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TSS, pH, browning and firmness during the storage period compared to those stored at ambient temperature. Packaging method protects the product from contamination of the product but it does not solely dictates the pH and TA reading during storage. Treatments packed in vacuum have slower deterioration compared to treatments which are conventionally packed.

Keywords: fresh-cut, jackfruit, physico-chemical, low-temperature, vacuum packed

INTRODUCTION

Jackfruit is a huge fruit, which is becoming more popular in the market due to its unique flavor and the health benefits offered to the consumers. One way of producing this fruit into a high value product is through minimal processing which can also reduce its weight.

Fresh-cut products are highly perishable due to the disruption of tissue and cell integrity, with a concomitant increase in the enzymatic, respiratory and microbiological activity, which reduce the shelf-life of these products (Olusola, 2002 as cited by Fagundes et al., 2013). These products generally have higher respiration rates than the corresponding intact products. Higher respiration rates indicate a more active metabolism and usually a faster deterioration rate. Also, higher respiration rates can result in more rapid loss of acids, sugars and other components that determine flavor quality and nutritive value.

In general, fresh-cut fruit should be rinsed just after cutting with cold (0 to 1°C, 32 to 34 °F) chlorinated water at pH 7.0. This may help extend product shelf-life by reducing microbial load, removing cellular juices at cut surfaces that may promote cut surface discoloration, and actually inhibiting the enzymatic reactions involved in fruit browning (Brecht et al., 1993; Hurst 1995). However, post-cutting washing or dipping may have negative consequences regarding increased water activity and "washing away" of desirable flavor attributes.

Cantwell and Suslow (2013) also mentioned that the physical damage or wounding caused by preparation increases respiration and ethylene production within minutes, with associated increases in rates of other biochemical reactions responsible for changes in color (including browning), flavor, texture, and nutritional quality (sugar, acid and vitamin content). The degree of processing and the quality of the equipment significantly affect the wounding response.

Strict temperature control is required to minimize the increased respiration rates of fresh-cut products. Low temperature storage is also essential to retard microbial spoilage on cut surfaces. Cantwell and Suslow (2013) cited that the increased oxygen demand due to the higher respiration rates of fresh-cut products dictates that packaging films maintain sufficient permeability to prevent fermentation and off-odors. Hence, this study was conducted to investigate the relationship of deseeding, packaging method and storage condition to the physico-chemical properties of minimally processed jackfruit.

METHODOLOGY

Procurement of Materials

EVIARC Sweet jackfruit was procured from the farm of Job Abuyabor in Mahaplag, Leyte, Philippines. The chemicals namely, sodium hypochlorite, calcium chloride, and ascorbic acid, as well as other materials were procured from commercial sources in Cebu City, Philippines.

Preparation and Processing of Fresh-Cut Jackfruit

The jackfruits were washed with soap and water, scrubbed until visually clean from adhering organic matter such as leaves, soil, and stems. The whole fruit was sanitized with chlorine solution of 100 ppm concentration equivalent to 0.01% solution and was sliced longitudinally for ease of handling. The pith was removed and fruit pulps were segregated from the seed and other jackfruit by-products. The jackfruit pulps were trimmed and only those that are undamaged were used. Food grade sodium hypochlorite (NaOCl) solutions with concentrations of 0.04374% w/v, calcium chloride (CaCl2) solutions (w/v) at 0.74% and ascorbic acid solutions (w/v) at 0.65% (Patindol, 2016) were prepared. The product was soaked to pretreatment solutions (NaOCl, CaCl2, ascorbic acid) for 2 minutes. The product was put into sanitized hanging baskets to remove excess water.

After draining off the liquid, treatments were packed in respective containers. For vacuum packaging, polyethylene bags with 0.003 mm thickness were used. The product was vacuumed for 25 seconds and sealed at medium heat for 3 seconds. For conventional packaging, plastic tray and cling wrap was used. Treatments 1, 3, 5, and 7 were stored at the refrigerator (crisper) (4-6°C), and the remaining treatments (2, 4, 6, and 8) were stored at ambient temperature (30 °C) (Table 1). The process flow of fresh-cut jackfruit production is shown in Figure 1 and 2.

Experimental Design

A 2x2x2 factorial design was employed to compare the different responses of physico-chemical properties to the variables. Table 1 shows the different treatments with their corresponding variables.

Table 1. Experimental combinations of jackfruit pulp preparation, packaging method and storage condition in preparation of the treatments

TREATMENTS	JACKFRUIT PULP PREPARATION	PACKAGING METHOD	STORAGE CONDITION
T1		Vacuum	Chilled
T2	With seed		Ambient
T3		Without vacuum	Chilled
T4			Ambient
T5		Vacuum	Chilled
T6	Without seed		Ambient
T7		Without vacuum	Chilled
T8			Ambient

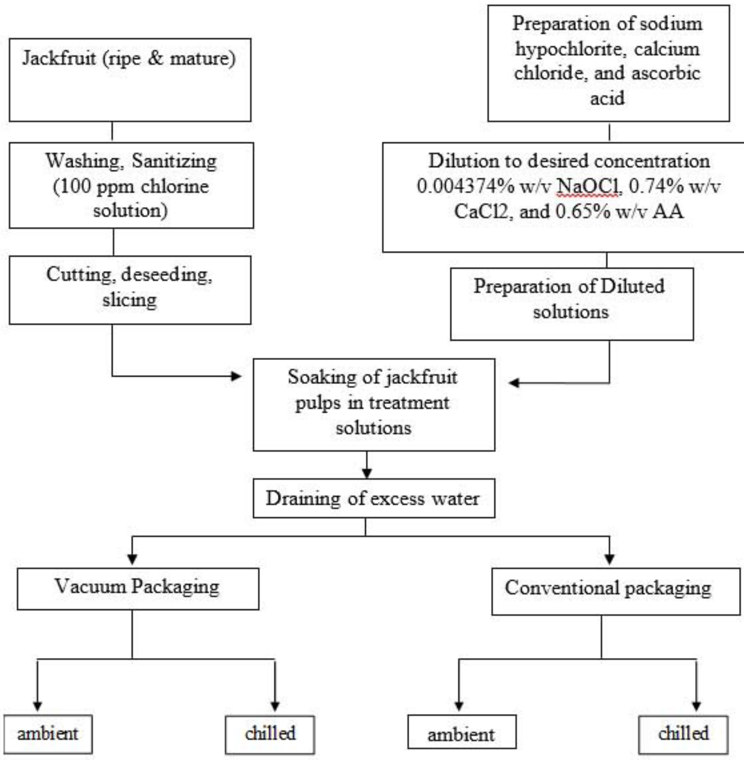

Figure 1. Process flow for fresh-cut jackfruit preparation

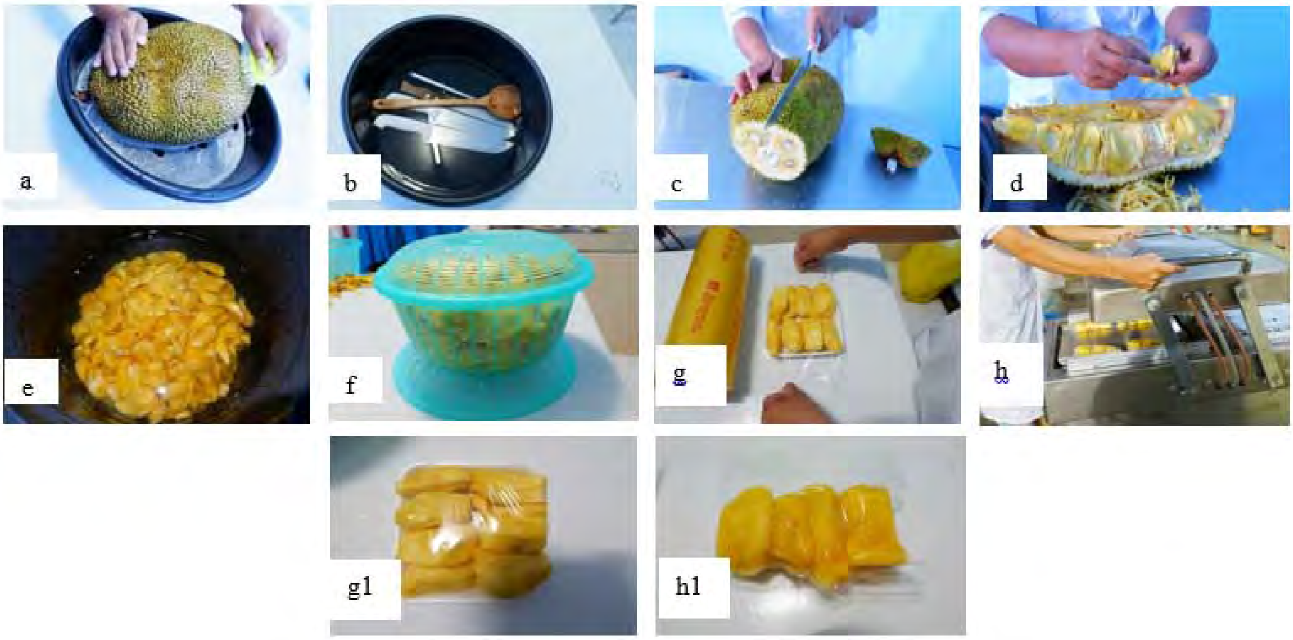

Figure 2. Preparation of fresh-cut jackfruit. (a) cleaning and sanitizing of whole fruit, (b) sanitizing of utensils for cutting and dipping, (c) opening of fruit, (d) depulping/deseeding, (e) pretreatment soaking, (f) draining of pretreatment solution, (g) (1 conventional packaging) (2 vacuum packaging), (g1 & h2) product

Physicochemical Analysis

Evaluation of all physico-chemical properties of fresh-cut jackfruit was done on the first until the eighth day of storage for every packaging method and storage condition.

Total Soluble Solids (TSS)

The total soluble solids were measured using a hand refractometer (Atago ATC-IE model Japan). It was calibrated by placing a drop of distilled water on the prism of the refractometer. Then the percent of dry substance from the reading was obtained as the correction factor. After calibrating, a drop of pure juice from squeezing the sample was placed on the prism.

Titratable Acidity (TA)

The TA was determined by employing the standard titration method using a standardized 0.1N NaOH solution. Five grams of the blended sample was diluted with 25 ml distilled water in a volumetric flask. Then 2-3 drops of phenolphthalein indicator was added. It was titrated with the standardized 0.1N NaOH solution until stable pink color was observed. This acidity was calculated according to following formula:

$$\%TA \text{ (citric acid)} = V \times N \times M / W \times 100$$

Where:
V = volume of NaOH added, mL
N = concentration (N) of NaOH,
M = milliequivalent weight (meq/g) of predominant acid,
W = weight (g) equivalent of aliquot, g

W=(weight of sample (g))/(vol.aliquot) x vol.of water added

pH

The pH of sample was determined using a calibrated digital pH meter (pH-Pen PT-70). The pH of the sample was determined by dipping the pH meter electrode into a five gram pureed sample. Reading was done in three replications.

Color Measurement

For color measurement, colorimeter (Lovibond Colorimeter) was used to determine the color of all the treatments. Hunters L and b value were measured. Hunters L represents the lightness of the color. The b value represents the yellow/blue opponent where blue was at negative b values and yellow is at positive b values.

Degree of Browning

The modified method proposed by Baloch et al. (1973) as cited in Mahayothee et. al. (2009) was used to evaluate the accumulation of the formation of brown pigments. The chopped sample (5g) was soaked in 50 ml of 2% (v/v) acetic acid solution for 2 hrs. Subsequently, the sample was placed in the plastic centrifuge tubes (50 ml capacity) then centrifuged at 3,000 ppm for 1 hr. The supernatant was obtained and the absorbance was read at 420 nm with UV-Vis double beam spectrophotometer (Genesys™ 10S, USA). Two percent acetic acid was used as a blank. Three readings was done and the results was expressed as absorbance per weight of sample in dry basis.

Firmness Measurement

Firmness was measured using a fruit penetrometer to get the numerical rating of the pulps. Flat tip plunger was used. The values were reported in kg/cm^2 force.

The sample was put in levelled surface to ensure stability of both the sample and the reading. The penetrometer was tared to zero, slowly plunged into the sample until it touched the very surface of the sample. The plunger was slowly pressed into the sample until a consistently firmness value appeared on the screen. Five readings were obtained and the mean was used in reporting the result.

Statistical Analysis

Data gathered from the physicochemical analysis were subjected to single factorial Analysis of Variance (ANOVA) for the readings of each treatment per day and multi-factorial ANOVA to determine the interaction of dependent or response variables on the physico-chemical properties of fresh-cut jackfruit. Interval as well as interaction plots were generated through factorial plots and time series plots using Minitab Express Software.

RESULTS AND DISCUSSION

Physico-Chemical Quality

Total Soluble Solids

The initial Total Soluble Solids of the product during day 0 has a mean of 25±1. It was observed that there is no significant difference ($p \leq 0.05$) on the TSS readings between treatments during

0 and 1 day, but apparent changes occurred during day 2 onwards. The analysis of variance of the TSS of treatments during the 8th day storage period indicates that observed changes were mainly due to the storage temperature since it has the higher percentage of variance explanation (Table 2).

Table 2. Analysis of variance of TSS of fresh-cut jackfruit stored for 8 days

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A: preparation	0.00	0.11	0.01	0.07	0.10	0.04	0.09	0.09
B: packaging method	0.73	0.06	0.49	0.34	1.19	29.75**	0.28	0.19
C: storage condition	1.11	4.32	5.95*	61.04**	54.64**	92.99***	22.48**	11.04*
Interaction								
A x B	0.72	0.17	0.55	0.04	0.14	0.06	0.09	0.28
A x C	1.91	18.91**	3.89	0.28	0.05	0.01	0.13	0.47
B x C	0.04	0.24	0.37	11.35*	6.30	19.17*	4.53	3.53

NS: not significant. *,**,*** Significant to P≤0.05, 0.01 and 0.001, respectively.

Ambient temperatures caused increase in biochemical reactions in pulps. Fruit pulps which have living tissues, continue the respiration process, consuming sugars and varying TSS levels, as mentioned by Lamikanra et al. (2000). Suslow and Cantwell (2013) mentioned higher respiration rates indicate a more active metabolism and usually a faster deterioration rate in fruit tissues. Also higher respiration rates can result in more rapid loss of acids, sugars and other components that determine flavor quality and nutritive value.

Another observation noted was treatments with intact fruit pulps stored at chilled condition also exhibit increase in their TSS at the early stage of storage. The chilling condition helps decrease the rate of respiration thus allowing senescence to take place slowly and makes the fruit pulp sweeter (Figure 3).

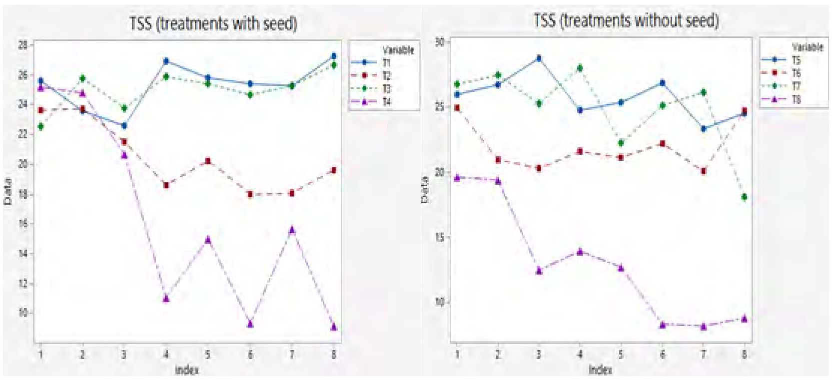

Figure 3. TSS of different treatments at different storage period *T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient

During storage, it was observed that TSS of the product is affected by storage condition and preparation method. Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TSS (24.6, 24.32, 25.03 and 24.23) during the storage period compared to those stored at ambient temperature (20.26, 16.64, 21.66, and 13.61). Again, with longer storage time within treatments with the same type of preparation and packaging method the mean TSS decreased to minimum values after 8 days, with differences among them, and with significant differences from the initial TSS (Figure 3). It was further observed that treatments which have intact fruit pulps (with seed) have slight decrease in TSS during the 3-day storage of period (±1.84) compared to treatments which are deseeded that shows abrupt decrease in TSS (±4.35). This can be explained by the fact that as a fruit tissue is ruptured, the rate of biochemical reactions increases thus consuming sugars in the process. Fresh-cut processing increases respiration rates and causes major tissue disruption as enzymes and substrates normally sequestered within the vacuole, become mixed with other cytoplasmic and nucleic substrates and enzymes. Processing also increases wound-induced ethylene, water-activity and surface area per unit volume, which may accelerate loss and enhance microbial growth since sugars also become readily available (King & Bolin, 1989; Watada et al., 1990; Wiley, 1994; Watada & Qi, 1999). This drop in TSS content might also be explained by the fact that this early period (after minimal processing) would be characterized by an intensive respiration during which this sugar would be rapidly used as substrate in the metabolic process. The increase of TSS at the early stages of the chilled treatments might be due to metabolism of the cell wall polysaccharides producing sugars (Fennema, 1985).

Titratable Acidity

The increase in TA as storage period increases may be affected by the fermentation in the product due to increased microbial activity. In a study of Aneja et al., (2014), fresh fruit juices were spoiled due to high levels of molds and yeast attributable to the increase in acidity of the product. The presence of microorganisms especially yeast can cause fermentation which converts sugars into organic acids.

In Figure 4, fermentation in the product is evident as the packaging materials bloat (vacuum packed treatments) as storage period increases especially those stored at ambient storage condition. It was also observed that T1 (with seed at chilled storage condition) have maintained its vacuum throughout the storage period.

Figure 4. Vacuum packed fresh-cut jackfruit at (left) chilled and (right) room temperature storage (3 days)

A significant increase in TA was observed in all treatments as storage time increases. It was observed that treatments stored at ambient temperature establish a higher increase in TA relative to the initial TA reading (0.0016 ±0.50%). TA and TSS reading established a relationship. As initial TSS decreased by ≤10.23 during storage period, TA also increases by ≤0.007888 (Figure 5). Table 3 shows the ANOVA of TA during the 8-day storage. It was observed that storage condition as well as packaging method greatly affects the TA of the product. And the interaction of factors: packaging method and storage temperature is highly significant starting day 3.

It was further observed that TA of treatments stored at room temperature rapidly increased compared to refrigerated samples which show decrease in TA during early days of storage and increased during late days of storage (Figure 5). This rapid increase in TA at treatments stored at ambient condition may be contributed to the fast respiration rate as well as increased microbial activity in the product. Treatments stored at chilled condition, established a slow change in TA compared to treatments stored in ambient condition during the storage period. As mentioned by Cantwell & Suslow (2013) low temperatures minimize differences in respiration and ethylene production rates between the fresh-cut and the intact product. Low temperatures are also essential to retard microbial spoilage on cut surfaces.

Table 3 and Figure 5 show that rapid increase in TA was observed in treatments which were deseeded and stored at ambient temperature. This implies that fresh-cut jackfruit's TA quality can be retained or variation from the produce can be minimized when the pulps' tissue is not ruptured due to deseeding and when it is stored at chilling conditions.

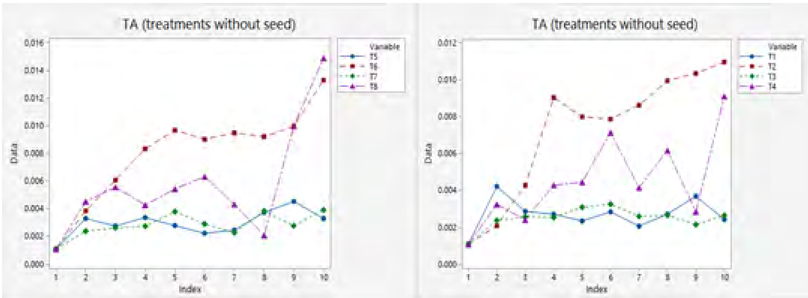

Figure 5. TA of different treatments for 8-day storage period (T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient).

Table 3. Analysis of variance of TA of fresh-cut jackfruit stored for 8 days

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparationns	0.44	1.10	0.00	0.17	2.21	0.01	0.07	0.06
B:packaging method	0.08	0.36	95.84***	8.01*	0.06	81.86***	1.21	3.42
C:storage condition.	0.36	14.80	219.39***	53.20**	146.43***	279.08***	10.60*	2.51
Interaction								
A x Bns	0.02	0..11	0.00	0.00	0.03	0.02	0.10	2.15
A x C	2.62	6.62*	0.06	0.07	0.21	0.02	0.76	1.10
B x C	3.77	0.28	66.59***	20.02*	8.20*	94.39***	6.08	0.04

NS: not significant. *,**,***   Significant to P≤0.05, 0.01 and 0.001, respectively.

pH

As expected, general trend in pH readings showed that during the 8-day storage period, pH decreases at different treatment by ≤1.4. The decrease in pH corresponds to the increase in TA during the storage period (Figure 6) but they are not directly correlated.

As mentioned by Lea (1991), the pH is a logarithmic measure of the concentration of free hydrogen ions in a chemical or biological system while titratable acid, is a simple measure of the (related) amount of acid 'anions' in a juice. There is no direct relationship between titratable acidity and pH, although generally the pH goes up as the acid goes down and vice-versa. The exact relationship differs from sample to sample and depends on esoteric concepts like 'buffering capacity' which will vary for a whole host of reasons. In general, titratable acid (TA) relates well to the 'acid taste' of a juice while pH relates more to microbial stability and susceptibility to mold and bacterial spoilage.

Figure 6 shows that treatments stored at ambient condition have higher decrease in pH compared to treatments stored at chilled conditions. As per mentioned in the previous statement, pH change is also an indicator of microbial quality. It was expected that treatments stored at ambient conditions will exhibit increase in fermentation because environment for microbial activity is very favorable for microbial growth. Period of handling of the pulps may also contribute to microbial contamination thus deseeded samples (T1-T4) exhibit lower pH reading compared to sample with intact pulps (T5-T8) during the last day of storage period.
Table 4 shows the Multifactorial ANOVA of pH readings. It was observed that interaction between factors is not significantly different while preparation method is significant during day 4, packaging during day 2 and storage condition during day 5 and 7. It was observed that treatments which are deseeded have more significant decrease in pH compared to intact fruit pulps. As the fruit tissue ruptures, surface area of the pulp increases thus contributed to the higher respiration rate of the product. When cells are ruptured by cutting during minimal processing, wound-induced biochemical reactions are initiated that shorten storage life (Cantwell & Suslow, 2002).

Packaging method does not directly affect the pH of the product. According to Aneja et al. (2014) fruit juices have pH in the acidic range (<4.5) serving as important barrier for microbial growth thus even at different packaging condition, change in pH is dictated by the natural physico-chemical properties of the fruit as well the method of how it's handled.

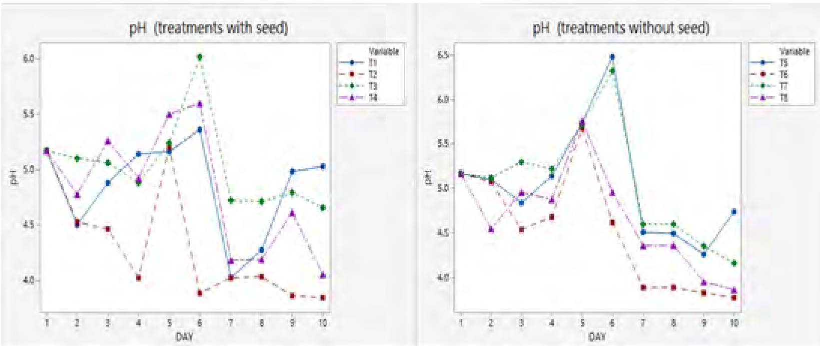

Figure 6. pH of different treatments for 8-day storage period (T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient)

Table 4. Analysis of variance of pH of fresh-cut jackfruit stored for 8 days

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparation	2.06	0.00	0.58	43.55**	0.30	0.24	0.03	2.05
B:packaging	0.28	22.23**	0.53	2.60	0.85	2.75	12.05*	0.37
C:storage con.	1.13	0.70	6.39	0.09	11.39*	6.45	22.59**	4.02
Interaction								
A x B	4.17	0.02	0.08	1.38	0.63	0.12	0.00	0.07
A x C	0.13	0.17	0.08	0.99	0.49	0.14	00.91	0.54
B x C	1.13	2.16	2.96	0.12	1.06	0.08	0.07	0.84

NS: not significant. *,**,***Significant to P≤0.05, 0.01 and 0.001, respectively.

Color Evaluation

The analysis of variance of the color parameters (Tables 5 & 6) shows how the interaction of the three factors was significant for lightness (Hunter L* value), and yellowness (Hunter b*value). As observed the percentage of variance explanation is very low at all parameters due to the fact that even though the product has undergone fermentation and other quality degradation, the yellow color of the fruit is retained. According to Chichester et al. (1965), the stability of various carotenoid pigments is a function of their association with cellular proteins and other substances. Thus, 3-carotene in commodities are relatively stable pigments which persist through prolonged storage.

Table 5. Analysis of variance for color parameter (*L) of fresh-cut jackfruit for 8-day storage period**

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparation	2.53	0.26	0.02	0.00	0.01	1.84	0.13	6.38*
B:packaging method	2.79	6.26*	2.53	7.19*	0.41	1.83	11.15**	5.21*
C:storage condition	2.31	8.80**	0.09	26.45***	0.00	0.50	11.88**	3.43
Interaction								
A x B	1.46	0.70	5.65*	0.69	1.80	2.82	0.19	0.00
A x C	0.44	3.87	0.04	3.64	0.94	5.20*	0.21	0.04
B x C	4.75	2.14	3.20	3.64	5.59*	2.12	43.88***	10.68**

NS: not significant. *,**,*** Significant to P≤0.05, 0.01 and 0.001, respectively.

Table 6. Analysis of variance for color parameter (b*) of fresh-cut jackfruit

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparation	1.95	0.04	0.05	0.05	0.37	0.05	0.00	0.03
B:packaging method	0.27	1.78	0.04	1.35	1.12	10.27*	5.77	1.42
C:storage condition.	1.19	3.30	1.45	1.88	2.84	3.65	0.06	19.45*
Interaction								
A x B	0.47	0.80	0.23	2.03	0.08	0.02	0.15	0.02
A x C	0.66	1.17	1.52	0.17	0.33	0.38	0.30	0.22
B x C	0.54	4.37	6.29	8.85	6.19	6.34	0.39	35.38**

NS: not significant. *,**,*** Significant to P≤0.05, 0.01 and 0.001, respectively.

Figure 7 shows the Hunter *b. Positive *b indicates yellowness of the product. It can be observed that treatments stored in ambient conditions (T2, T4, T6 & T8) have observable lower b* than those stored at chilled conditions (T1, T3, T5 & T7). It can also be observed that deseeded pulp have lower Hunter b* during the late day of storage compared to intact samples. This may be due to the browning of the pulps as tissues deteriorated during storage. This is in agreement with the findings of Galvez (2015) with dehydrated jackfruit pulps. Wounding increases rates of water loss, softening, and browning. Using very sharp tools to peel fruits and cut their flesh limits cellular damage and reduces leakage of cellular contents and enzymatic browning mediated by the enzymes polyphenol oxidase and phenol oxidase (Kader, 2008).

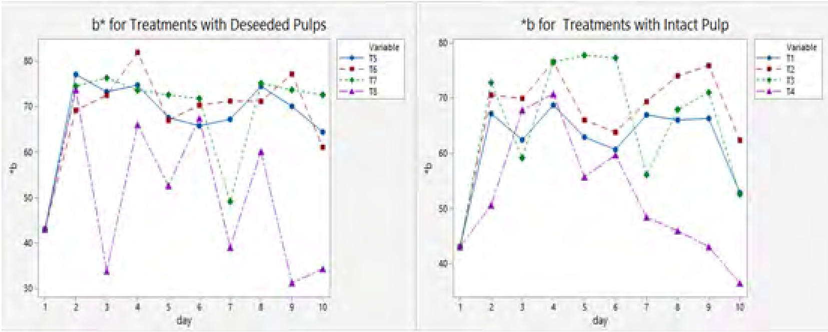

Figure 7. Hunter b*of different treatments at different storage period *T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient

Degree of Browning

Accumulation of the formation of brown pigments will dictate the degree of how physical property of the pulp has deteriorated in terms of firmness and color. As shown in the plots in Figure 8, deseeded pulp has a very significant increase in absorbance compared to intact pulps. As cited by Watada et al. (1990), the practice of fresh-cut processing causes wounding, increases metabolic activities and decompartmentalizes enzymes and substrates. This may cause browning, softening, decay, and off-flavor development.

Storage temperature greatly affects the degree of browning. Treatments stored at room temperature have higher degree of browning compared to those chilled (Figure 8 & Table 7).

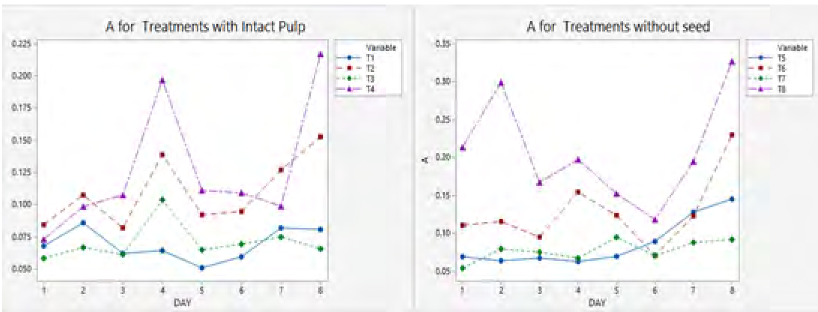

Figure 8. Absorbance of different treatments at different storage period *T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient

Table 7. Analysis of variance for absorbance parameter of fresh-cut jackfruit

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparation	0.96	0.60	0.72	0.01	1.46	0.05	1.62	0.85
B:packaging method	0.16	0.43	0.93	13.33*	0.75	0.52	0.00	0.10
C:storage condition	2.65	2.17	8.75*	96.13***	10.10*	6.92	2.54	12.95*
Interaction								
A x B	0.42	1.19	0.26	0.06	0.04	0.00	0.32	0.0
A x C	2.62	1.61	0.49	0.43	0.30	0.73	0.14	0.56
B x C	0.66	0.94	2.08	2.06	0.02	3.24	0.72	2.32

NS: not significant. *,**,***Significant to P≤0.05, 0.01 and 0.001, respectively.

Biochemical reactions such as respiration speed up at higher temperatures. The increase in absorbance could be explained by nonenzymatic browning reactions such as the assumption that high temperature accelerated the carotenoid isomerization, which led to the loss of yellowness (Chen et al., 1995). Another factor is the favorable environment for increase in microbial quality that causes the degradation of the tissues those results to browning.

Firmness

Firmness of the fruit pulp was measured using a fruit penetrometer (GY-3 fruit sclerometer). As expected, as time of storage increases, fruit pulp becomes softer thus readings in all the treatments decrease by approximately ≤0.77. During fruit ripening, cell wall polysaccharides are extensively modified by a variety of ripening-related enzymes secreted from the symplast into the cell wall space. This process continues even after cutting open the fruit pulp. The changes affect the structure and strength of the wall, and ultimately bring about fruit softening (Brummell, 2006).

It was observed that packaging method and storage condition significantly affect the firmness of the pulps with storage (Table 8). As cited by Bruwell (2006), firmness is determined largely by the physical anatomy of the tissue, particularly cell size, shape and packing, cell wall thickness and strength, and the extent of cell-to-cell adhesion, together with turgor status.

Table 8. Analysis of variance for firmness parameter (kg/cm^2) of fresh-cut jackfruit

Main Effects	STORAGE PERIOD (DAY)							
	1	2	3	4	5	6	7	8
A:preparation	0.31	0.31	0.13	0.42	0.96	0.05	0.21	0.00
B:packaging method	16.41*	1.64	0.13	0.01	4.29	0.12	0.30	11.16*
C:storage condition.	1.78	0.13	9.93*	22.95**	4.64	80.57***	47.04**	21.13*
Interaction								
A x B	1.22	3.30	0.13	0.06	1.44	0.03	0.01	0.12
A x C	0.01	0.26	0.64	6.07	0.28	0.02	0.47	0.31
B x C	0.15	0.60	2.77	0.01	0.02	14.33*	5.49	0.22

NS: not significant. *,**,*** Significant to P≤0.05, 0.01 and 0.001, respectively.

It was observed that treatments stored at ambient temperature have very significant decrease in the firmness of the pulp (Figure 9). While treatments stored at chilled condition and with intact pulps showed minimal changes in their firmness. For treatments stored at chilled condition, the firmness of the pulp was mostly retained or were only changed slightly, this implies that, the optimum condition for the storage of fresh-cut is in chilled conditions. Processes of plant senescence increase as tissue is harvested from the plant and involves degradative changes in membranes, cell walls, subcellular organelles, proteins and texture. Wounding (fresh-cut processing) activates not only ACC synthase and ethylene production (Yu & Yang, 1980). For best quality retention of fresh-cut fruits, the preferred storage temperature is not higher than 5oC, which is considered a chilling temperature for chilling sensitive tropical fruits (Dea et al., 2010).

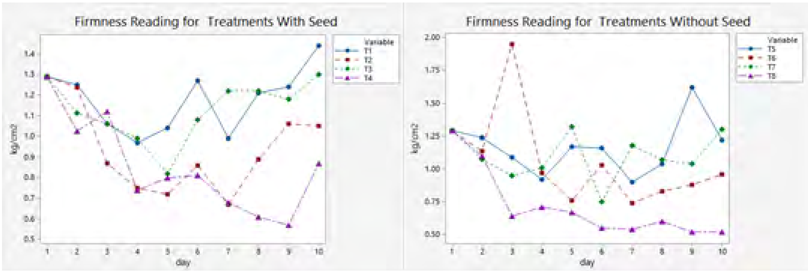

Figure 9. Firmness of different treatments at different storage period (T1-vacuum and chilled, T2-vacuum and ambient, T3- without vacuum and chilled, T4- without vacuum and ambient, T5-vacuum and chilled, T6-vacuum and ambient, T7- without vacuum and chilled, T8- without vacuum and ambient)

CONCLUSIONS

Processing method plays a significant role in the physico-chemical property of the product. Jackfruit pulps which are deseeded have shown significant decrease in the physico-chemical attributes of the product which is an indicator for product quality. Deseeded products have much faster deterioration compared to intact treatments.

Treatments stored in chilling (4-6°C) condition exhibited lesser variation in TSS (24.6, 24.32, 25.03 and 24.23) during the storage period compared to those stored at ambient temperature (20.26, 16.64, 21.66, and 13.61).The chilling condition helps decrease the rate of respiration thus allowing senescence to take place slowly and makes the fruit pulp sweeter. Treatments stored in chilled condition also have minimal change in pH (±0.59), TSS (±1.84), browning (±0.28) and firmness (±0.025) compared to treatments stored in ambient conditions (±0.855), (±4.35), (±0.2214) and (±0.44) respectively. Low temperature storage minimizes differences in respiration and ethylene production rates between the fresh-cut and the intact product. Low temperatures are also essential to retard microbial spoilage on cut surfaces.

Packaging method protects the product from contamination of the product but it does not solely dictates the pH and TA reading during storage. Treatments packed in vacuum have slower deterioration compared to treatments which are packed with cling wrap. Limitation of oxygen as well as protecting the product from contaminants helps reduce the physico-chemical changes in the product.

ACKNOWLEDGEMENTS

The researchers would like to thank ACIAR & DOST for funding this research.

REFERENCES

Aneja, K.R., Dhiman, R. Aggarwal, N.K., Kumar, V. & Kaur, M. (2014). Microbes Associated with Freshly Prepared Juices of Citrus and Carrots, *International Journal of Food Science,* Volume 2014, Article ID 408085 pp. 1-7.Retrieved from www.hindawi.com/journals on May 29, 2017

Brumwell, D.A. (2006). Cell wall disassembly in ripening fruit. Funct. *Plant Biol*. 33, 103–119.

Cantwell, M. & Suslow, T. (2013). Fresh-cut fruits and vegetables: aspects of physiology, preparation, and handling that affect quality, *Technology Horticulture*, Products, Chapter 36, Section 5, pp. 1-8.

Brecht, J.K, Dea, S. Nunes, C., & Baldwin, E.A. (2010). Occurrence of chilling injury in fresh-cut 'Kent' mangoes, *Postharvest Biology and Technology*: 57 (2010) 61–71 , www.elsevier.com/locate/postharvbio

Fagundes, C. Carciofi, B.A.M, & Monteiro, A.R. (2013). Estimate of respiration rate and physicochemical changes of fresh-cut apples stored under different temperatures. *Food Sci. Technol*, Campinas, 33(1): 60-67.

Fennema, O.R. (1985). *Food Chemistry.* 2nd ed., Marcel Dekker, NY, pp 857-911.

Galvez, L.A. (2015). Variety & Sulfite Levels Affect Microbiological & Sensory Properties of Dehydrated Jackfruit (*Artocarpus heterophyllus* Lam) During Storage. *Annals of Tropical Research*. 37(2): 93-103.

Kader, A.A. (1986). Biochemical and physiological basis for effects of controlled and modified atmospheres on fruits and vegetables. *Journal Food Technology*, 5, 99-104.

Lamikanra, O. Chen, J.C., Banks, D. & Hunter, P.A. (2000). Biochemical and microbial changes during the storage of minimally processed cantaloupe. *Journal of Agricultural and Food Chemistry*, 48(12), 5955-5961.

Lea, A.G.H. 1991. Enzymes in the production of beverages and fruit juices, *Enzymes in food processing* Tucker, G. A.; Woods, L. F. J. (Editors) Blackie & Son Ltd.Glasgow; (pp. 194-220, 36 ref.) Retrieved from http://www.cider.org.uk on May 29, 2017.

Makayama, C. O. & And T.O.M.1965. Pigment changes in senescent and stored tissue. In: T. W. Goodwin, ed. *Chemistry and Biochemistry of Plant Pigments*. Academic Press, London.

Mahayothee, B. Udomkun P., Nagle, M., Haewsungcharoen, M., Janjai, S., & Mueller, J., (2009). *Effects of pretreatments on colour alteration of litchi during drying and storage.* Eur Food Res Technol 229: 329-337.

Olusula, L. (2012). Fresh-cut fruits and vegetable: *Science and technology and market*, CRC Press

O' Connor-Shaw, R.E., Roberts, R., Ford, A.L., & Nottingham, S.M. (1994). Shelf-life of minimally processed honeydew, kiwifruit, papaya, pineapple, and cantaloupe. *Journal of Food Science*. 59 pp. 1202-1206, 1215.

Patindol, M.R. (2016). Process optimization of minimally processed fresh-cut jackfruit (*Artocarpus heterophyllus* Lam.) M.S. Thesis, VSU pp 1-98.

Ponting, J.D., Jackson, R., & Walters, G. (1971). Refrigerated apple slices: effects of pH, sulfites and calcium on texture. *J. Food Sci*. 36:449-450.

Ponting, J.D., Jackson, R. & Watters, G. (1972). Refrigerated apple slices: preservative effects of ascorbic acid, calcium and sulfites. *J. Food Sci*. 37:434-435.

Watada, A. E., Abe, K., & Yamauchi, D. (1990). Physiological activities of partially processed fruits and vegetables, *Food Technology Journal,* Volume 44, pp 116-122.

Whitaker, J.R. & Lee, C.Y. (1995). Recent advantage in chemistry of enzymatic browning: an overview. In C.Y. Lee and J.R. Whitaker, eds., *Enzymatic browning and its prevention,* Washington, ACS Symp. Ser. 600, pp. 2-7.

Wiley, R.C. 1994. *Minimally processed refrigerated fruits and vegetables*, Chapman and Hall, London, UK.

PAPER 3:
EFFECT OF MATURITY, FRUIT AND PULP LOCATION AND PULP SIZE AND THICKNESS ON THE QUALITY OF VACUUM-FRIED JACKFRUIT (*ARTOCARPUS HETEROPHYLUS*) PULP FROM EVIARC SWEET VARIETY

Roberta D. Lauzon[1], Lorina A. Galvez[1], Jennlyn F. Vinculado[1], Felix J. Amestoso[1] & Yan Diczbalis[2]
[1]Visayas State University, Visca, Baybay City, Leyte, Philippines
[2]Queensland Department of Agriculture Fisheries and Forestry, Australia

ABSTRACT

The study was undertaken to evaluate the effect of fruit development and conditions of the quality and acceptability of fresh and vacuum-fried jackfruit pulps from EVIARC Sweet jackfruit variety. Four maturity periods; 85, 88, 91, and 94 days after bagging of fruits were considered in the study. The effects of fruit location on the tree and pulp location in the fruit, as well as size and thickness of the pulps were the conditions evaluated. Physico-chemical properties such as pH, TTA, TSS, thickness, and pectin of fresh ripe pulp were evaluated while sensory attributes of vacuum-fried jackfruit pulps were determined. Color, aroma, texture, oiliness, and general acceptability of vacuum-fried jackfruit pulps were the attributes evaluated by semi-trained panelists. Consumer acceptability was determined by subjecting the product to consumer evaluation employing students, faculty, staff, housewives, and guests of the Visayas State University. Fruit maturity significantly affected the quality of vacuum-fried jackfruit pulps. Eighty-eight days after bagging is the ideal maturity of jackfruit for vacuum-fried pulp production. Fruit location on the tree and pulp location in the fruit had significant influences on pH, TSS, and TA. Fruit location on the tree, location of pulp in the fruit, and pulp size and thickness had no significant effects on the sensory attributes of the vacuum-fried jackfruit pulps; the products were acceptable among consumers.

Keywords: EVIARC Sweet, vacuum-fried jackfruit

INTRODUCTION

Jackfruit (Artocarpus heterophyllus, Lam.) is one of the most widely grown fruit crops in the Philippines (Coronel, 1983) and one of the most famous in the world owing to the largest tree-borne edible fruit that may weigh as much as 50 kg. It is known for its large edible bulbs of yellow, very sweet smelling, pineapple and banana-flavored flesh that enclose a smooth, oval, light-brown seed. Jackfruit is nutritious owing to its vitamins and minerals (Morton, 1987) as cited by Lauzon et al. (2013).

Green jackfruit is usually used as vegetables while ripe jackfruit is usually consumed as fresh fruits. Other regions used the ripe jackfruit bulb as an ingredient in native delicacies like guinataan, the filling of banana turon or banana roll, and as flavorant for ice cream and other frozen desserts.

The Visayas State University (VSU) through the Department of Food Science and Technology developed vacuum-fried jackfruit pulps from ripe bulbs of jackfruit, specifically the EVIARC Sweet variety. The product was highly acceptable among consumers of all ages and even among foreign guests of the university. The high acceptability of vacuum-fried jackfruit encouraged the Department of Food Science and Technology to commercialize the product. The current vacuum frying technology for jackfruit operated at the Visayas State University has shown great potential for the conversion of jackfruit pulps into a commercial product. Diamante (2007) pointed out that commercialization of vacuum-fried jackfruit provides a way of adding real value to the crop and reinforces its promotion as a viable crop for farmers. The popularity and high demand for vacuum-fried jackfruit encourages a number of processors to adapt the vacuum frying technology. However, the current vacuum frying technology has some constraints yet to be addressed.

Uneven color, occasional browning, bland taste, less aromatic, and a less crispy texture in some fried pulps are some identified problems in the current vacuum-fried jackfruit technology which is believed to be influenced by fruit maturity. Pale color, bland taste, and absence of jackfruit aroma are noted in vacuum-fried pulps from underripe jackfruits while brownish yellow color and a less crunchy texture are perceived in vacuum-fried pulps from overripe fruits.

Standardization of fruit maturity and pulp quality are necessary in order to achieve and maintain product quality. This study was conducted to determine the effects of fruit maturity, fruit location on tree, location of pulp in fruit, and pulp size and thickness on the quality and acceptability of vacuum-fried jackfruit pulps.

METHODOLOGY

Procurement of Materials

The fruits were procured from the farm of *Magsasakang Siyentista* or Farmer Scientist from Mahaplag, Leyte. Arrangements were made with the *Magsasakang Siyentista* to provide dedicated jackfruit trees as source of fruits for the study. The freshly harvested jackfruit with identified maturity was carefully harvested from the farm and brought to the Department of Food Science and Technology for evaluation.

Physico-Chemical Properties

Moisture content, pH, titratable acidity (TTA), total soluble solids (TSS), and pectin content of jackfruit pulps from 88-, 91-, and 94-days-old fruits were analyzed following the method set by AOAC (1980).

Moisture Content (MC). Five grams of jackfruit pulp from different fruit maturity was separately weighed and placed into previously tared crucibles The crucibles were dried for 24 hours or until the weight of the sample became constant for 3 consecutive readings. The moisture content of the samples was computed following the formula below:

$$\% \text{ MC} = \frac{W1 - W2}{W1} \times 100$$

Where: W1 = initial weight; W2 = final weight of sample; 100 – constant figure

pH. Ten grams of homogenized sample was weighed and added with 10 mL distilled water and mixed well. The mixture was centrifuged and the supernatant was collected and used in the determination of pH of the sample. The evaluation was conducted three times and the average of three readings was used in reporting the data.

TTA. The TTA of the sample was determined employing the methods set by AOAC (1980). Five grams of finely crushed sample was diluted with 25 mL disltilled water and mixed well. Three to four drops of phenolphthalein indicator was added into the mixture and properly mixed. The mixture was titrated with 0.1N NaOH until a pale pink color appeared. The percent age of TTA (% ascorbic acid) was computed using the given formula.

Total Soluble Solids (TSS). The TSS of the sample was determined using a laboratory hand refractometer. A drop of the sample was placed on the prism of the instrument. The lid was closed and the instrument was directed towards a light source to get a clear sight of the reading. The TSS was calculated and computed based on the following formula:

$$TSS = \text{diluted factor (DF)} \times {}^{\circ}B$$

$$DF = 1 + \frac{\text{volume of hundred (10 added (mL))}}{\text{Weight of sample (g)}}$$

Assume: 1 mL water = 1 g water

Pectin. Jackfruit pulps from fruits of different maturity was separately collected and placed in separate containers. One hundred grams of fruit pulp was chopped and separately placed into sauce pots. An equal amount of water was added and the mixture was boiled for 3 minutes. Fifteen milliliters of the extract was collected in a clean flask. Denatured alcohol (50 mL) was added into the flask and the mixture was slowly stirred with a glass rod and allowed to stand undisturbed to allow for the formation of pectin lumps. Pectin was collected by allowing the mixture to pass through a pre-weighed filter paper. It was then allowed to dry on the filter paper and re-weighed. The weight of pectin was determined by subtracting the weight of the filter paper and recorded as gram pectin per 100 g pulp.

Fruit Preparation and Evaluation

Effect of Fruit Maturity. Fifteen fruits of the same age were harvested from the trees dedicated for the project. The fruit age was 85 days after bagging as identified by the *Magsasakang Siyentista*. The fruits were grouped into four with 5 fruits per group. Each group was considered a treatment; T1 – 85 days, T2 – 88 days, T3 – 91 days, and T4 – 94 days. The fruits were allowed to ripen at ambient conditions.

The fruits of different maturity; 85, 88, 91, and 94 days were washed with diluted dishwashing solution, rinsed with tap water, and dipped into 10 ppm chlorinated water. The fruits were split opened and separately depulped and deseeded. The pulps from different fruit maturity were separately blanched, drained, packed, and frozen. The frozen pulps were vacuum-fried employing the vacuum frying schedule set by Diamante (2007). The vacuum-fried pulps were spun-dried to remove the excess frying oil, packed, sealed, and kept in closed containers ready for evaluation. The process of producing vacuum-fried jackfruit is presented in Figure 1.

The identified fruit maturity suitable for vacuum frying was the maturity of fruits used in the succeeding fruit quality evaluation.

Effects of Fruit Location on Tree. Nine fruits of the same maturity (88 days) were used in the study. Fruit selection was based on their location on the tree. Three fruits from the upper part, three from the middle portion, and three fruits from the lower part of the tree were selected. The fruit location namely upper, middle, and bottom parts were considered as treatments of the study. Upon harvest, the fruits were brought to the laboratory to ripen at room conditions. The pulps of ripe jackfruits were separately collected and processed into vacuum-fried jackfruit following the method of Diamante (2006) with modifications.

Effect of Pulp Location on Fruits. Five fruits of same maturity (85 days) were harvested and allowed to ripen at laboratory conditions. After three days of storage, the fruits were separately washed with a mild detergent, washed with potable water, sanitized in 10 ppm chlorinated water, and split opened. Pulps were separately collected from three fruit locations; the upper, middle, and bottom portions of the fruit. The pulps were separately deseeded, blanched, and frozen ready for vacuum frying. The pulp locations in the fruit were considered treatments of the study.

Effect of Pulp Size. Fruits were washed with a mild dishwashing solution, rinsed with tap water, and dipped into 10 ppm chlorinated water. The clean fruits were split opened, depulped, and the fruit pulps were arbitrarily grouped into small, medium, and large. Twenty five pieces of fresh bulbs were collected from each size categories and separately placed into clean containers. The pulps were deseeded, blanched, drained, and allowed to cool before being packed, and frozen. The frozen pulps of different sizes were separately vacuum-fried, spin-dried, packed, and kept ready for evaluation.

Pulp Thickness. Fruit pulps from fruits with identified maturity were collected and deseeded. The pulps were split opened and seeds were removed. The fruit pulps were sorted and arbitrarily grouped as thin, thick, and thicker. The thickness was determined using a vernier caliper. The pulp with different thickness were separately blanched, drained, allowed to cool, and frozen. The frozen jackfruit pulps with different pulp thickness were separately vacuum-fried, spin-dried, packed, and kept ready for evaluation.

SENSORY EVALUATION

Sensory evaluation of the different treatments was carried out employing a laboratory test panel composed of thirty two fourth-year students, faculty, and staff of the Department of Food Science and Technology of the Visayas State University, Visca, Baybay City, Leyte, Philippines. Sensory evaluation was carried out using the method set by Mabesa (1986). Samples were randomly coded with three digit numbers and presented to the panelists and they were asked to evaluate the vacuum-fried jackfruit according to their color, aroma, taste, texture, oiliness, and general acceptability using quality scoring in combination with the 9-Point Hedonic scale.

CONSUMER EVALUATION

The samples with the highest mean acceptability rating based on the result of sensory evaluation were subjected to consumer acceptability evaluation employing one hundred consumers consisting of students, faculty, staff, and guests of the university. Consumers were individually given samples of the most acceptable vacuum-fried jackfruit pulps together with the control samples. They were asked to rate the product based on their own judgement. Each consumer was given a scorecard for them to write their answers. The percentage of consumers who liked or preferred the product was determined by dividing the total "like" responses by the total number of consumers who evaluated the product and the answer was multiplied by one hundred.

$$\%\ \text{acceptability} = \frac{\text{No. of like of prefer answers}}{\text{Total no. of consumers who evaluated the product}} \times 100$$

RESULTS AND DISCUSSIONS

Physico-Chemical Properties

The physico-chemical properties of EVIARC Sweet jackfruit as influenced by fruit maturity is presented in Table 1. Results revealed that fruit maturity significantly influenced the physico-chemical properties of fresh jackfruit pulps.

Table 1. Physico-chemical properties of fresh jackfruit pulps as influenced by fruit maturity.

Maturity (Days)	Moisture Content** (%)	Pectin* (g)	pH*	TTA** (% AA)	TSS** (°Bx)
85	5.89 d	3.63 a	4.4 c	0.0596 d	16.93 d
88	6.62 c	2.67 b	4.9 b	0.1357 c	33.88 a
91	8.60 d	2.66 b	5.0 b	0.1603 b	30.33 b
94	12.82 a	2.62 c	5.3 a	0.2334 a	27.35 c

* - significant; ** - highly significant

Moisture Content. Pulps from fruit harvested 85 days after bagging had significantly lower moisture content at 5.89%. Increasing the fruit maturity to 88, 91, and 94 days increased the moisture content to 6.62%, 8.60%, and 12.82% respectively which were significantly different from each other. The significantly higher moisture content of pulps from the 94-days-old fruit can be attributed to some enzymatic activities that result in the conversion of pectin to free D-galacturonic acid, a water soluble compound which makes the overripe fruit watery (Raymundo, 1989). This finding can be supported by the result in pectin determination as shown in Table 2 wherein pulps from the 94-days-old fruit had significantly lower pectin content and higher moisture content.

Pectin Content. Fruit maturity had a significant effect on pectin content of the pulps. Pectin content was significantly higher in fruit pulps from 85-days-old fruit. As the maturity period increased to 88, 91, and 94 days, there was a significant decrease in pectin content from 3.63 g, 2.67 g, and 2.66 g, respectively and a significantly lower pectin content of 2.62 g in fruit pulps from the 94-days-old fruit. Pectin content was indirectly proportional to the fruit maturity period and moisture content of the pulps. The significant decrease in pectin content of pulps from the 94-days-old fruit was due to the action of enzymes on pectin that resulted in The production of soluble pectic substances. As pointed out by Meyer (1971) soluble pectic substances in some fruits increases as it passes the ripening stage..

pH. The pH value of jackfruit pulps was significantly influenced by maturity. Our results have shown that as fruit maturity increased from 85 days to 88, 91, and 94 days; pH values of the pulps significantly increased from 4.6 to 4.9, 5.0, and 5.3, making the pulps slightly acidic.

TSS. The total soluble solids of jackfruit pulps from 85 days of maturity had the lowest TSS value of 16.93°Bx. Increasing the fruit maturity to 88 days resulted in a significantly higher TSS of 33.88°Bx. Increasing it further to 91 and 94 days resulted in significantly lower TSS values of 30.3°Bx and 27.35°Bx, respectively. It is possible that upon maturity, sugar in the fruit pulp was converted into fruit acid as exhibited by the increasing value of titratable acidity (Table 1). Of the fruit maturity evaluated, pulps from the 88-days-old fruit had a significantly higher TSS value of 33.88°Bx, significantly higher than its counterpart.

TTA. The TTA of 85-days-old pulps was 0.0596%, significantly lower than its counterparts. Increasing the maturity period to 88 days significantly increased the TTA of fresh pulps to 0.1357%. A significant increase in TTA was noted as maturity periods increased to 91 and 94 days. TTA of pulps from 94-days-old fruit was 0.2334%, significantly higher than the TTA of all samples evaluated (Table 1).

Effect of Maturity on Sensory Attributes

Quality Description. The description of quality attributes of vacuum-fried jackfruit from EVIARC Sweet variety as influenced by fruit maturity is presented in Table 2. The color of vacuum-fried pulps from 85- and 88-days-old fruits was described as "light yellow" to "dark yellow". Increasing the maturity period to 91 and 94 days resulted in a "golden yellow" to "brownish yellow" color. The darkening in color of vacuum-fried pulps from 91- and 94-days-old fruits can be attributed to the increase of sugar in the pulps as shown in Table 2; sugar caramelizes upon frying of the pulps. The more sugar caramelized, the darker the color of the product. As observed, sugar leached out from the fruit upon frying and the caramelized sugar adhered to the surface of the fried pulps, resulting in the browning of the product. The aroma of vacuum-fried pulps from 85-days-old fruit was described as "slightly perceptible jackfruit aroma", while a "very perceptible jackfruit aroma" was perceived in fruits processed from 88-, 91-, and 94-days-old fruits. For taste, a "slightly sweet taste" was noted in products from 85-days-old fruit. Increasing the fruit maturity to 88, 91, and 94 days resulted in a "moderately sweet" to "very sweet taste" of the vacuum-fried pulps. Ripening of fruits increased the sugar content which contributed to the sweetness of the fruit. The texture of vacuum-fried jackfruit was perceived as "very crispy" regardless of fruit maturity. The oiliness of vacuum-fried pulps was influenced by fruit maturity. Vacuum-fried pulps from 85-days-old fruit was perceived as "not oily". However, the oiliness description of vacuum-fried pulps from 88-, 91-, and 94-days-old fruits ranged from "not oily" to "slightly oily".

Table 2. Quality description of vacuum-fried pulps from AES1 variety as influenced by fruit maturity.

Treatment	Days	Color	Aroma	Taste	Texture	Oiliness
1	85	Light yellow to dark yellow	Slightly perceptible jackfruit aroma	Slightly sweet	Very crispy	Not oily
2	88	Light yellow to dark yellow	Very perceptible jackfruit aroma	Moderately sweet	Very crispy	Not oily to slightly oily
3	91	Golden yellow to brownish yellow	Very perceptible jackfruit aroma	Moderately sweet	Very crispy	Not oily to slightly oily
4	94	Golden yellow to brownish yellow	Very perceptible jackfruit aroma	Moderately sweet	Very crispy	Not oily to slightly oily

General Acceptability. The mean general acceptability ratings of vacuum-fried jackfruit pulps as influenced by fruit maturity are tabulated in Table 3.

Table 3. Mean[1] acceptability ratings[2] of the sensory attributes of vacuum-fried jackfruit from pulp of AES 1 variety as influenced by fruit maturity.

Treatment	Days	Color**	Aroma**	Taste**	Texture^{ns}	Oiliness**	Gen. Acc.**
1	85	8.08a	7.00c	6.39c	7.80	7.44a	7.27b
2	88	7.77b	8.05a	8.14a	7.85	7.06b	8.11a
3	91	5.94c	7.52b	7.83b	7.47	6.66c	7.21b
4	94	4.91d	6.71d	6.82c	7.38	6.14d	6.16c

[1]N = 24 * - significant ** - highly significant ns – not significant

[2]Range of scores:

9 – like extremely
8 – like very much
7 – like moderately
6 – like slightly
5 – neither like nor dislike
4 – dislike slightly
3 – dislike moderately
2 – dislike very much
1 – dislike extremely

Results showed that fruit maturity significantly influenced product acceptability. The color of vacuum-fried pulps from 85-days-old fruit had significantly higher mean acceptability rating of 8.05, equivalent to "like very much". This was significantly higher than vacuum-fried pulps from the fruit that was left to mature for 88 days with a mean rating of 7.77 which corresponded to “like moderately” and significantly higher than the 91- and 94-days-old fruits with mean acceptability ratings of 5.94 and 4.91; leaning towards “like slightly” and “neither like nor dislike” category of the 9-point Hedonic scale.

For aroma, vacuum-fried pulps from 88-days-old fruit had an average mean of 8.05 equivalent to “like very much” , a significantly higher value than pulps from 85- and 91-days-old fruits with mean acceptability ratings of 7.00 and 7.52, respectively; under the “like moderately” category of the 9-point Hedonic scale. The same observation was noted in taste attributes wherein vacuum-fried pulps from 88-days-old fruit had a mean rating of 8.14 corresponding to “like very much” and significantly higher than vacuum-fried pulps from 91-days-old fruit whose mean rating was 7.83 equivalent to “like moderately” category of the scale. Of the treatments evaluated, vacuum-fried pulps from 88- and 94-days-old fruits had significantly low mean acceptability ratings of 6.39 and 6.82, which corresponded to “like slightly” category of the scale. Fruit maturity had no significant influence on textural quality of the vacuum-fried pulps. Regardless of fruit maturity, the product had a mean acceptability rating ranging from 7.38 to 7.80 and did not differ significantly from each other. Oiliness in vacuum-fried pulps was significantly affected by fruit maturity. Vacuum-fried pulps from 85-days-old fruit had the highest mean acceptability rating for oiliness which was at 7.44 and fell between “like moderately” to “like very much”. This was significantly higher than vacuum-fried pulps from 88-, 91-, and 94-days-old fruits with mean acceptability ratings of 7.06, 6.66, and 6.14, respectively. For general acceptability, vacuum-fried pulps from 88-days-old fruit had the highest mean acceptability rating of 8.11 corresponding to “like very much” and considered the suitable maturity age of EVIARC Sweet jackfruit for vacuum-fried pulp production. The highest acceptability rating of vacuum-fried pulps from 88-days-old fruit can be attributed to the sweet taste and perceptible jackfruit aroma of the product which was influenced by the high TSS and TTA of the pulps (Table 4).

Table 4. Consumers* acceptability towards vacuum-fried pulp from 88-days-old fruit compared with the existing product.

Sample	Consumers Response			
	Like	Dislike	No Comment	Total
Sample A	99	-	1	100
Sample B	92	2	6	100

* Students, faculty and staff of VSU, guests of the university

Consumer Evaluation. The result on consumer evaluation is presented in Table 4. It was revealed that vacuum-fried pulps from 88-days-old fruit were acceptable among 99% of the consumers, higher than the existing vacuum-fried products with a consumer acceptability of 92%. The high consumer acceptability of vacuum-fried jackfruit from 88-days-old fruit pulps was due to its attractive uniform color, sweeter taste, distinct jackfruit aroma, and thicker pulps. Non-uniformity in color was observed in sample B.

Influence of Fruit Location on the Quality of Jackfruit Pulps

Physico-Chemical Properties. Location of fruit on the tree had significant effects on pH, TSS, and TA of jackfruit pulps but not on pulp thickness. Pulps from the fruit located at the lower part of the tree had a pH value of 4.80, significantly higher than the pulps from fruits located from the top and middle portion of the tree with pH values of 3.92 and 4.11, respectively. Fruit obtained from the top of the tree had a significantly higher TSS value of 31.0°Bx, higher than the TSS of pulps from fruits located at the middle and bottom portion of the tree with TSS values of 26.4 and 27.0, respectively; and the values were not significantly different. For TTA, pulps from fruit taken from top part of the tree had a TTA value of 0.57% which was significantly higher than the TTA of pulps from the fruit located at the middle part of the tree with a TTA value of 0.44%. Pulps from fruit located at the lower part of the tree had significantly lower TTA of 0.26%. In terms of pulp thickness, the fruit's location on the tree had no significant effect on the thickness of the pulps. Regardless of the fruit's location, pulps from the top, middle, and bottom had a thickness of 3.12 mm, 3.02 mm, and 3.40 mm, respectively (Table 5).

Table 5. Physico-chemical properties of pulps as influenced by the fruit's location on the tree.

Pulp Location	pH*	TSS* (°Bx)	TTA* (%)	Thickness^{ns} (mm)
Upper	3.92 b	31.0 a	0.57 a	3.12
Middle	4.11 b	26.4 b	0.44 b	3.02
Lower	4.80 a	27.0 b	0.26 c	3.40

Sensory Quality of Vacuum-Fried Pulps. Results from the sensory evaluation of vacuum-fried jackfruit pulps as influenced by the location of fruit on the tree are summarized in Table 6. The fruit's location on the tree did not significantly affect the sensory attributes of the vacuum-fried pulps. The mean acceptability ratings of the product ranged from 7.10–7.90 and fell within the "like moderately" category of the 9-point Hedonic scale. Results implied that regardless of the location of the fruit on the tree where the pulps were taken, the vacuum-fried pulps were acceptable.

Table 6. Mean[1] acceptability ratings[2] of vacuum-fried jackfruit pulp as influenced by the location of fruit on tree.

Fruit location	Sensory Attributes^{ns}						
	Days	Color**	Aroma**	Taste**	Texture^{ns}	Oiliness**	Gen. Acc.**
Top	7.20	7.13	7.90 a	7.10	7.50	7.8	7.27
Middle	7.18	7.10	7.67 b	7.13	7.54	7.7	8.11
Lower	7.10	7.11	7.60 b	7.09	7.50	7.7	7.21

[1]N = 24
[2]Range of scores:
9 – like extremely
8 – like very much
7 – like moderately
6 – like slightly
5 – neither like nor dislike
4 – dislike slightly
3 – dislike moderately
2 – dislike very much
1 – dislike extremely

Consumer Acceptability. Results from the consumer evaluation are presented in Table 7. Out of 100 consumers who evaluated the product, 97% liked sample A; 96% for sample B; 93% for sample C; and 90% for the control sample. These results implied that the vacuum-fried jackfruit, regardless of the location of the fruit on the tree was acceptable among consumers.

Table 7. Consumers[1] acceptability toward vacuum-fried pulp from fruit located at the top, middle and lower portion of the tree.

Sample	Consumers Response		
	Like	Dislike	No Comment
A (Top)	97	-	3
B (Middle)	96	-	4
C (Lower)	93	-	7
D (control)	90	-	10

[1]N = 100 consumers student, faculty, staff, and employee

Effect of Pulp Location in Fruit. The location of the pulp in the fruit had significant influences on the pH, TSS, and pulp thickness but not on TSS of the pulp. The pH value of pulps located at the upper part of the fruit was 4.22 and significantly lower than the pH value of pulps located at the middle and bottom portion of the fruits which were 4.47 and 4.45 respectively, and were not significantly different. In terms of TSS, pulps from the bottom part of the fruit had the highest TSS value of 26.98°Bx which was significantly higher than the TSS value of pulps taken from the middle and upper parts of the fruit with TSS values of 24.63 and 24.41°Bx, respectively; significantly lower than the TSS values of pulps from the bottom of the fruit. For pulp thickness, pulps from the middle part of the fruit had an average thickness of 5.30 mm which was significantly higher than pulps from upper and lower parts of the tree with thickness values of 3.62 mm and 3.56 mm; and were not significantly different.

Table 8. pH, TSS, TTA and thickness of pulp as influenced by their locations in fruit.

Pulp Location	pH*	TSS* (°Bx)	TTA (%)	Thickness* (mm)
Upper	4.22 b	24.41 b	0.68	3.02 b
Middle	4.47 a	24.03 b	0.56	4.00 a
Lower	4.45 a	26.95 a	0.65	3.56 b

Sensory Evaluation. Results in sensory evaluation of vacuum-fried jackfruit pulps as influenced by location of pulps in the fruit are presented in Table 9. Results showed that pulp location in the fruit had no significant influence in all sensory attributes evaluated except on taste. In terms of taste, pulps from the upper part of the fruit had a mean acceptability rating of 7.81, closer to "like very much" and significantly higher than samples from middle and lower parts of the fruit with mean acceptability ratings of 7.35 and 7.0; which were not significantly different and fell under the "like moderately" category of the 9-point Hedonic scale. The high mean acceptability rating of pulps from the top portion of the fruit can be attributed to the high TSS value of the pulps which contributed to the sweetness of the product.

Table 9. Mean[1] acceptability ratings[2] of vacuum-fried pulp as influenced by the location of pulp in the fruit

Fruit location	Sensory Attributes^{ns}					
	Color^{ns}	Aroma^{ns}	Taste*	Texture^{ns}	Oiliness^{ns}	Gen. Acceptability^{ns}
Upper (top)	7.30	7.50	7.81 a	7.15	7.57	7.60
Middle	7.28	7.19	7.35 b	7.14	7.60	7.61
Bottom (lower)	7.25	7.17	7.00 c	7.10	7.55	7.61

[1]N = 24
[2]Range of scores:

9 – like extremely	4 – dislike slightly
8 – like very much	3 – dislike moderately
7 – like moderately	2 – dislike very much
6 – like slightly	1 – dislike extremely
5 – neither like nor dislike	

Consumer Evaluation. Results from the consumer evaluation ratings revealed that the location of the pulp in the fruit had no influence on consumer acceptability towards the product. All samples evaluated regardless of their location in the fruit had high consumer acceptability ratings. Sample A received 97% consumer acceptability; sample B, 98%; sample C, 98%; and the control sample received 90%. These results implied that regardless of pulp location, the product was acceptable among consumers.

Table 10. Consumer[1] acceptability towards vacuum-fried pulp taken from different locations in the fruit.

Sample	Consumers Response		
	Like	Dislike	No Comment
A (upper/top)	97	-	3
B (middle)	98	-	2
C (bottom/lower)	98	-	2
D control	96	-	4

[1]N = 100 consumer composed of students, staff, and faculty of VSU.

Effect of Pulp Thickness

Quality Description. Quality description of the sensory attributes of vacuum-fried jackfruit as influenced by pulp thickness is presented in Table 11. In terms of color, "brownish yellow" color was perceived in vacuum-fried pulps from thin and thicker pulps, and "golden yellow to brownish yellow" color was noted in vacuum-fried products from thick pulps. For aroma, regardless of the thickness, the products were perceived to have "perceptible jackfruit aroma". For taste, a "sweet taste" was perceived in products from thin and thicker pulps while moderately sweet taste was described in products from the thick pulps. For texture, a "very crispy" texture was perceived in vacuum-fried products from thin and thick pulps, and "crispy texture" was perceived in thicker pulps. Thick pulps were described as "moderately oily" while thin and thicker pulps were perceived as slightly oily.

Table 11. Quality description of vacuum-fried jackfruit as influenced by the thickness of pulp used.

Pulp Thickness	Sensory Attributes				
	Color	Aroma	Taste	Texture	Oiliness
Thin	Brownish yellow	Perceptible jackfruit aroma	Sweet	Very crispy	Slightly oily
Thick	Golden yellow to brownish yellow	Perceptible jackfruit aroma	Moderately sweet	Crispy to very crispy	Moderately oily
Thicker	Brownish yellow	Perceptible jackfruit aroma	Sweet	Crispy	Slightly oily

General Acceptability. Table 12 summarizes the mean acceptability ratings of the sensory attributes of vacuum-fried jackfruit as affected by pulp thickness. Results revealed that pulp thickness did not significantly influence the mean acceptability ratings of the sensory attributes of the products. Regardless of the pulp thickness, the vacuum-fried products had a mean acceptability rating that corresponded to "like moderately". Although the mean acceptability rating for texture attributes of vacuum-fried products from thin pulps was significantly higher than thick and thicker pulps, their ratings did not significantly differ from each other.

Table 12. Mean[1] acceptability ratings[2] of the sensory attributes of vacuum-fried jackfruit as influenced by pulp thickness.

Thickness	Sensory Attributes^{ns}					
	Color^{ns}	Aroma^{ns}	Taste^{ns}	Texture^{ns}	Oiliness^{ns}	Gen. Acc.**
Thin	7.40	7.38	7.50	7.47	7.78	7.27 b
Thick	7.38	7.58	7.68	7.38	7.75	8.11 a
Thicker	7.63	7.63	7.63	7.45	7.35	7.21 b

[1]N = 32
[2]Range of scores:

9 – like extremely
8 – like very much
7 – like moderately
6 – like slightly
5 – neither like nor dislike
4 – dislike slightly
3 – dislike moderately
2 – dislike very much
1 – dislike extremely

Consumer Acceptability

Consumer acceptability towards vacuum-fried jackfruit as influenced by pulp thickness is presented in Table 13. Of the 100 consumers, 90% liked the vacuum-fried jackfruit from thin pulps, 93% liked the thick pulps, 96% liked the thicker pulps, and 92% liked the control products. The common comment on their likings preference toward the products is was the unique taste and crunchiness of the products. Those who did not give comment said that they cannot detect any differences between the sample and the rest of the samples evaluated.

Table 13. Consumer[1] acceptability towards vacuum-fried jackfruit as influenced by pulp thickness.

Samples	Consumer Response (%)		
	Like	Dislike	No Comment
Thin (A)	90	-	10
Thick (B)	93	-	7
Thicker (C)	96	-	4
Control (D)	92	-	8

[1]N = 100 respondents composed of students, faculty, staff and guests of VSU.

Pulp Size

Quality Description. The quality description of the sensory attributes of vacuum-fried jackfruit as influenced by pulp size is presented in Table 14. In terms of color, "golden yellow" to "brownish yellow" was discerned in vacuum-fried pulps from small bulbs, "brownish yellow" was noted in medium pulps, while "golden yellow" was used to describe the color of vacuum-fried pulps from large bulbs. For aroma, a "perceptible jackfruit aroma" was perceived in vacuum-fried pulps regardless of the size of pulp used. The same observation was noted in terms of taste and oiliness wherein "sweet taste" and "slightly oily" was perceived in the product regardless of the pulp size used. For texture, a "crispy" description was given to products from small bulbs while "very crispy texture" was perceived in medium and large jackfruit pulps. For oiliness, results showed that regardless of pulp size, the products were perceived as "slightly oily".

Table 14. Quality description of the sensory attributes of vacuum-fried pulp as influenced by fruit pulp size.

Pulp Size	Sensory Attributes				
	Color	Aroma	Taste	Texture	Gen. Acc.
Small	Brownish yellow to brownish	Perceptible jackfruit aroma	Sweet	Crispy	Slightly oily
Medium	Brownish yellow	Perceptible jackfruit aroma	Sweet	Very crispy	Slightly oily
Large	Golden yellow	Perceptible jackfruit aroma	Bland	Crispy	Slightly oily

General Acceptability. Table 15 summarizes the sensory attributes evaluated; only taste was significantly affected by pulp size. Of the sizes evaluated, small- and medium-sized pulps had mean acceptability ratings of 7.67 and 7.50, respectively corresponding to "like moderately" and did not significantly differ from each other. Large-sized pulps had a mean acceptability rating of 6.60, equivalent to "like moderately" and was significantly lower than small- and medium-sized pulps. The mean acceptability ratings of other attributes like color, aroma, texture, and general acceptability were not significantly influenced by the pulp size used.

Table 15. Mean[1] acceptability ratings[2] of the sensory attributes of vacuum-fried jackfruit as influenced by pulp size.

Pulp Size	Sensory Attributes^{ns}					
	Color^{ns}	Aroma^{ns}	Taste**	Texture^{ns}	Oiliness^{ns}	Gen. Acc^{ns}
Small	7.40	7.73	7.67 a	7.77	7.57	7.57
Medium	7.28	7.68	7.50 a	7.87	7.67	7.55
Large	7.78	7.58	6.60 b	7.80	7.65	7.17

[1]N = 32 ns – not significant ** - highly significant at p<0.005.
[2]Range of scores:
9 – like extremely
8 – like very much
7 – like moderately
6 – like slightly
5 – neither like nor dislike
4 – dislike slightly
3 – dislike moderately
2 – dislike very much
1 – dislike extremely

Consumer Acceptability

Table 16 present the results in consumer evaluation of vacuum-fried jackfruit as influenced by pulp size. Of the 100 consumer panelists, 98% signified a preference on vacuum-fried products from small fruit pulps, 95% preferred the medium-sized pulps, and 92% preferred the large-sized pulps, while 89% preferred the control. Comments of their preference towards the vacuum-fried products from 88-days-old pulp were the attractive color and dominant jackfruit taste.

Table 16. Consumers[1] acceptability towards vacuum-fried jackfruit pulp as influenced by pulp size.

Samples	Consumer Response (%)		
	Like	Dislike	No Comment
Small	98	-	2
Medium	95	-	5
Large	92	-	8
Control	89	-	11

[1]N = 100 respondents composed of students, faculty, staff and guests of VSU.

CONCLUSION

Fruit maturity has significant influences on the sensory qualities of vacuum-fried jackfruit pulps. Vacuum-fried pulps from 91-days-old fruit has a golden yellow color, perceptible jackfruit aroma, moderately sweet taste, and moderately oily. Maturity is critical in the production of vacuum-fried jackfruit. A period of 88 days after fruit bagging is the ideal fruit maturity period and the product was acceptable among 98% of consumers, higher than its counterpart.

Fruit location influenced the values of pH, TSS, and TTA but not on pulp thickness. It had no significant effect on the mean acceptability ratings of the vacuum-fried pulps as all the samples were highly acceptable among consumers. Fruit location had significant effects on pH, TSS, and thickness of the pulp but not on the percentage of TTA of the pulp. Fruit location had no significant influence on the mean acceptability ratings of the sensory attributes of the vacuum-fried pulps. Regardless of the pulp's location, the vacuum-fried pulps were acceptable among consumers. Pulp size and thickness had no significance influences on the sensory attributes of the product. Regardless of size and thickness of the pulps, the product was acceptable. Vacuum-fried jackfruit was acceptable among consumers regardless of size and thickness of the pulps used.

ACKNOWLEDGEMENTS

The researchers would like to thank ACIAR & PCAARRD for funding this research.

REFERENCES

AOAC. (1980). Official Methods of Analysis of the Association of Official Analytical Chemists (13th ed.). W. Horvitz (Ed.). Washington, D.C.: Association of Official Analytical Chemists.

Coronel, R.E. (1983). *Promising Fruits of the Philippines.* UPLB. College of Agriculture, Laguna. 508 pp.

Diamante, L. M. (2009). Vacuum fried jackfruit: Effect of maturity, pre-treatment and processing on the physico-chemical and sensory qualities. In *Proceedings of the Nutrition Society of New Zealand* (Vol. 33, pp. 138-142). Massey University Press, Palmerston North, New Zealand.

Lauzon, R. D., Amestoso, F. J., Galvez, L. A., & Varron D. A. C. (2013). *Processing of High Value Product from Jackfruit* (PCAARRD Funded Research Terminal Report).

Mabesa, L. M. B. (1986). *Sensory Evaluation of Foods: Principles and Methods.* Laguna, Philippines: DRL Printing Press.

Meyer,L.H. 1971. Food Chemistry (Ninth printing)Reinhold Publishing Corporation,N.Y. 385 pp.

Morton, J. F. (1987). Jackfruit and Related Species. In *Fruits of Warm Climates.* Retrieved from https://hort.purdue.edu/newcrop/morton/jackfruit_ars.html

Raymundo,L.C. 1985. Lecture Paper on Food Biochem. Unpublished.IFST, UPLB

SESSION WRAP UP AND Q&A

1. Clarifications were sought from the floor on the use of the terminology of postharvest losses versus postharvest waste. In a related discourse, consumer preference, income strata, and market segregations were other factors noted to influence postharvest losses.

2. Interest was also generated on the vacuum fry methodology used for the EVIARC Sweet Jackfruit, for which the presenter clarified that the machine was developed by the students of the Faculty of Engineering at the Visayas State University. Participants also expressed hope that the products developed for the jackfruit will be scaled-up.

SESSION FIVE

Farmer Support, Extension and Policy Interventions

PAPER 1:
GOVERNMENT REGULATIONS AND INTERVENTIONS FOR THE PRODUCTION OF HIGH QUALITY TROPICAL FRUITS FOR EXPORT

Danilo T. Dannug
Bureau of Plant Industry, Department of Agriculture, Philippines

ABSTRACT

The Philippines has a rich diversity of tropical fruits wherein more than 20 different species are cultivated in the entire archipelago. Production system ranges from backyard to highly integrated operation with the latter catering to the export market. In 2016, the total production of selected fruit crops reached 10,961,730.73 MT with a total area of 811,618 hectares. For export, the top four (4) fruit crops for 2015 are: Banana (2,663,230.041 MT), Pineapple (407,205.331 MT), Mango (14,563.7056 MT) and Papaya (2,287.5839). The High Value Crops Development Program (HVCDP) now under the Bureau of Plant Industry (BPI) has a major role in the implementation of programs and projects pertaining to fruit crops activities. Highlights and support for the industry were focused of Banana Fusarium Wilt, carabao mango exports, technology demonstrations for different pineapple varieties, distribution of good quality seedlings from accredited plant nurseries, and development of fruit standards for minor fruit crops.

Keywords: Philippines, fruit exports, government projects

INTRODUCTION

The Philippines has a rich diversity of tropical fruits wherein more than 20 different species are cultivated in the entire archipelago. Production system ranges from backyard to highly integrated operations with the latter catering to the export market. Farms are generally small in size ranging from 1 to 5 hectares.

Major fruit species grown in the country are: a) banana (*Musa* sp.); b) pineapple (*Ananas comosus*); c) mango (*Mangifera indica*); d) papaya (*Carica papaya*); e) calamansi (*Microfortunella microcarpa*); f) durian (*Durio zibethinus*); g) jackfruit (*Artocarpus heterophyllus*); and h) lanzones (*Lansium domesticum*).

In 2016, the total production of selected fruit crops reached 10,961,730.73 MT with a total area of 811,618 hectares. For export, the top four fruit crops for 2015 are: banana (2,663,230.041 MT), pineapple (407,205.331 MT), mango (14,563.7056 MT), and papaya (2,287.5839).

The High Value Crops Development Program (HVCDP) now under the Bureau of Plant Industry (BPI) has a major role in the implementation of programs and projects pertaining to fruit crops activities. Highlights and support for the industry were focused on banana Fusarium wherein DA-HVCDP RFOXI organized Task Force Fusarium to make an action plan for information awareness campaign, mapping, and training of banana growers. Banana Giant Cavendish Tissue Culture Variant (GCTCV) 218 and 219 resistant varieties were developed.

The US Government declared the Philippines as mango pulp and seed weevil free on February 8, 2013. Export of mango can now be sourced from any province except Palawan. A trial shipment of carabao mangoes to Dubai, UAE was done by DA RFO 12 (AMAD and HVCDP) in 2015. This is one of the outputs of the DA’s participation to the Middle East Natural and Organic Products Expo (MENOPE).

A techno demo for different varieties of pineapple particularly MD2, Ulam Pine, and local variety were conducted in the following areas: Lucena, Quezon; Daet, Camarines Norte; Calauan, Laguna; and Silang, Cavite. Ulam Pine, however is a variety that is protected under the Republic Act 9168, otherwise known as Plant Variety Protection Act of 2002.

In collaboration with the Bureau of Product Standards, PNS for rambutan and guava was approved by Secretary Proceso J. Alcala and submitted to DTI for registration aside from the seven fruit standards that were developed: avocado, breadfruit, dragon fruit, marang, soursop, and sugar apple.

BPI distributed a total of 333,943 pieces of assorted fruit seedlings to beneficiaries, farmers, walk-in clients, and students while certified parent, foundation, and scion trees totaled 2,423 and 172,585 certified seedlings for 2016, which is an increase of 186.48% from 2013 which was at 93,845 seedlings. Accredited plant nurseries for fruits totaled 88 fruit crop nurseries.

The BPI completed researches on fruits particularly banana, mango, and citrus conducted from BPI-Davao NCRPSC (15), Baguio-NCRPSC (3), and BPI-GNCRPSC.

Table 1. Production volume (in metric tons) of fruits (2012-2016)

CROP	YEAR				
	2012	2013	2014	2015	2016
Cashew (ripe fruit with nuts)	132,541	146,289	170,853	205,531	216,398
Pili Nut (with shell)	7,933	8,243	7,316	7,362	7,291
Banana	9,226,768	8,646,417	8,884,857	9,083,929	8,903,684
Banana Cavendish	4,694,655	4,230,089	4,448,460	4,566,907	4,638,328
Banana Lakatan	942,938	930,032	954,856	970,496	898,515
Banana Saba	2,645,893	2,557,109	2,567,495	2,627,129	2,474,199
Calamansi	178,549	164,091	160,740	162,676	118,248
Durian	85,961	91,212	80,334	87,382	71,444
Lanzones	14,190	35,207	13,899	20,814	17,160
Mandarin Orange	16,755	15,287	14,045	14,064	13,243
Mango	768,410	816,378	885,038	902,739	814,055
Mango Carabao	630,596	671,929	730,140	740,239	659,014
Mangosteen	3,209	3,303	2,686	3,400	2,522
Orange	3,827	3,513	3,325	3,219	2,861
Papaya	164,913	166,336	172,628	172,650	162,481
Pineapple	2,397,745	2,458,528	2,507,098	2,582,699	2,612,474
Rambutan	7,189	7,440	6,479	8,723	7,668
Tamarind Fruit	7,921	7,782	7,558	7,436	7,128

Source: PSA, 2017

Banana is the number one fruit commodity in the Philippines, both in production and hectarage. The industry is divided into two distinct sectors namely those for the domestic market and those for the export market. For the former, the cultivars being grown are 'Lakatan', 'Latundan', 'Bungulan', and 'Saba'/'Cardaba'; while for the latter, it is the Cavendish-type cultivars ('Umalag', 'Grand Nain', 'Giant Cavendish', 'Dwarf Cavendish', etc). Pineapple production in the country is concentrated in a few provinces namely Laguna, Cavite, Camarines Norte, Southern Leyte, Bukidnon, Davao, and South Cotabato. The farms are generally small in size (1-2 ha) which caters to the local market except for the farms managed by two multinationals (Del Monte and Dole) situated in Bukidnon, Davao, and South Cotabato, both for fresh fruit and processed products.

Mango cultivars grown are 'Carabao', 'Pico', and 'Katchamita' or popularly known as Indian. The latter cultivar is generally consumed as green mango. The industry is anchored on large backyard trees scattered in the various farms/regions of the country wherein minimal care is being done by farmers.

Papaya is grown in small farms (1-5 ha) with a productivity period of 3-4 years. The major varieties grown are 'Cavite Special', 'Sinta', and 'Solo' (yellow and red flesh). 'Sinta' is a popular variety being grown by farmers due to its moderate resistance to papaya ringspot which is prevalent in the growing areas in Luzon.

EXPORTS

Banana, pineapple, mango, and papaya are the major fruit export commodities of the country both in fresh and processed forms.

Table 2. Major fruit exports from 2011 to 2015 (in metric tons)

Fruits	2011	2012	2013	2014	2015
Banana (Cavendish)	1,818,393.173	4,062,408.312	2,940,410.633	2,543,172.217	2,663,230.041
Pineapple	201,011.368	345,564.663	349,887.073	388,277.192	407,205.331
Mango	14,818.6554	15,316.7164	16,026.0025	14,366.7526	14,563.7056
Papaya	2,334.2060	4,208.2575	3,795.0515	18,294.2244	2,287.5839

Source: BPI-NPQSD

A. BANANA

- In 2014, Giant Cavendish Tissue Culture Variant (GCTCV) 218 and 219 resistant varieties were developed by Bioversity International. These variants were found to be resistant against Fusarium wilt under Philippine conditions thus the mass production of such variety is continuously conducted. The distribution of planting materials is still on-going.

- DA-HVCDP RFO XI organized the Task Force Fusarium which came up with an action plan to addresses the following:
  - » Advocacy for the issuance of provincial/ municipal/ barangay ordinances for quarantine measures of the diseases
  - » Information awareness campaign
  - » Trainings for the prevention of the spread of Fusarium.
  - » Provision of disinfectants to affected small growers/ farmers
  - » Crop Rotation (corn after banana)

- Developed mapping of Fusarium wilt infestation in Region XI

- *"Mitigating Banana Fusarium Wilt TR4 through a Farmer Participatory Approach of Developing Disease Management Strategies"* A funded research activity on Fusarium was conducted in Davao Region. The activity was a three year project conducted with the Bureau of Agricultural Research and Biodiversity International.

  - » Established 20 farms planted with GCTCV 219 and Grand Naine as the control variety;

» Results showed positive response wherein GCTCV 218 and 219 resistant varieties developed by Bioversity International were found to be resistant against Fusarium wilt under Philippine conditions thus the mass production by the BPI of such variety will be continuously conducted and the seedlings produced distributed

» For 2015, the DA allotted funds to step up control measures of Fusarium wilt in Region XI. The following were the activities:
  - Eradication of disease thru the production of GCTCV 219
  - Crop shifting (cacao-coffee-cassava-corn-vegetables)
  - Trainings (GAP banana, GCTCV 219 production and management of Fusarium wilt)
  - IEC campaign
  - Reward dystem
  - *Trichoderma* production and utilization
  - Monitoring (Ten plant pathologists were deployed in different provinces to work with LGU technicians for the implementation of the Fusarium Management Program)

- In 2012, when several restrictions were imposed on the exportation of Philippine horticultural products due to the scale insect which was found during inspection for China market, DA-HVCDP XI has identified the need to upgrade banana packinghouses to meet the requirements for accreditation of affected small banana exporters and conform with the standards of the General Administration of Quality Supervision, Inspection, and Quarantine of the People's Republic of China. The upgrading of these facilities did not only address this problem but also serves as a long term strategy to expand the markets for Philippine Banana thus, HVCDP provided ₱20M for the following:

- Two units of standard packinghouses for Cavendish banana were established at Brgy. M. Guinga, Tugbok Davao City and Brgy. Casig-ang, Sto. Tomas, Davao del Norte

- Four units of standard packinghouses were rehabilitated wherein the Mindanao Banana Farmers Exporters Association (MBFEA) are the beneficiaries located at the following :
  » Brgy. New Bantayan, Asuncion, Davao del Norte
  » Prk. 3 Brgy. Kimamon, Mun. of Sto. Tomas, Davao del Norte
  » Brgy. Mamacao, Mun. of Kapalong, Davao del Norte
  » Brgy. Tamugan, Calinan District, Davao City

- Exportation: Philippine highland bananas to reach US shores. Eight years after requesting for market access for Philippine bananas, the Department of Agriculture (DA) through the Bureau of Plant Industry-Plant Quarantine Services (BPI-PQS) exported the country's initial shipment of 6.561 metric tons of highland bananas to the United States of America at the Mindanao International Container Terminal in Tagoloan, Misamis Oriental in September 2013.

B. MANGO

- Developed module and conducted trainings regarding mango classifiers. This training ensures that mangoes heading for both international and domestic markets are properly classified to meet existing quality standards for mango. These trainings were conducted in Abra, Ilocos Norte, Nueva Vizcaya, Zambales, Tarlac, Antique and Iloilo, Pangasinan, La Union, Batangas, Davao del Norte, and Davao del Sur

- Exportation: The US Government declared the Philippines as mango pulp and seed weevil free on February 8, 2013. Exportation of mango can now be sourced from any province except Palawan. Trial shipment of carabao mangoes to Dubai, UAE was done by DA RFO 12

(AMAD and HVCDP) in 2015. This was one of the outputs of the DA's participation to the Middle East Natural and Organic Products Expo (MENOPE).

C. PINEAPPLE

- In partnership with BPI, an on-going techno demo for different varieties of pineapple particularly MD2, Ulam Pine, and local variety were conducted in the following areas: Lucena, Quezon; Daet, Camarines Norte; Calauan, Laguna; and Silang, Cavite. Ulam Pine and MD2 are varieties planted in Mindanao. Ulam Pine however, is a variety that is protected under the Republic Act 9168 otherwise known as the Plant Variety Protection Act of 2002. The project aims to:
  - » Identify and document agronomic/horticultural characteristics of different varieties of pineapple particularly MD2 and Ulam Pine;
  - » Identify farmers/co-operators who will venture into planting new varieties
  - » Introduce and commercialize 2 varieties that can be planted in Luzon

  BICOL
  - » Planted in a research outreach station of the Department of Agriculture in Daet, Camarines Norte
  - » Pineapple fruits were harvested in March 26, 2015
  - » Three varieties were planted: Ulam Pine, MD2, and Queen (farmers' variety)
  - » A taste test was undertaken and the results were: 70% preferred the taste and texture of Ulam Pine; the local variety was the least preferred variety in terms of taste and texture

  LAGUNA
  - » Planted in Calauan, Laguna through a Farmer co-operator scheme
  - » Pineapple fruits are to be harvested this April 24, 2015.
  - » Three varieties were planted: Ulam pine, MD2 and Calauan variety (farmers' variety)

  QUEZON
  - » An area of approximately more than 2,000 square meters in Domoit, Lucena City was planted with 3 varieties of pineapple
  - » The pineapple fruits were harvested in January 14, 2015
  - » A taste test was undertaken and the results were: 75% preferred the taste and texture of Ulam Pine; the local variety was the least preferred variety in terms of taste and texture
  - » Planting materials augmentation of Ulam Pine variety through micro section planting was undertaken

D. OTHER FRUITS

- Development of Philippine National Standards (PNS)
  - » PNS for rambutan have been approved by the Secretary on November 18, 2013. The approved standards have been forwarded to the Bureau of Product Standards of the Department of Trade and Industry, as the national repository agency, for registration as "Rambutan for PNS/BAFS 124:2013".
  - » PNS for guavas have been approved by the Secretary on November 18, 2013. The approved standards have been forwarded to the Bureau of Product Standards of the Department of Trade and Industry, as the national repository agency, for registration as "Guavas for PNS/BAFS 122:2013".
  - » This is in addition to the previously developed PNS for high value crops, seven PNS were developed for CY 2012 namely : PNS for avocado, breadfruit, dragon fruit, marang, soursop, and sugar apple

E. CUT ACROSS COMMODITIES

- » HVCDP supported the conduct of the supply/value chain study (benchmarking) for the 11 selected agricultural commodities (mango, chili-red/hot, green mongo beans, peanut, shallots, tamarind, saba banana, garlic, lanzones, and mangosteen). The study aims to support and strengthen the development of competitive agricultural products that meet specific market demands and identify ways and means to improve the local value/supply chain of selected agricultural commodities.
- » Assisted in the certification of GAP farms for fruits. There are fourteen approved GAP certified farms: three for banana; two for pineapple; two for dragon fruit; six for mango; and one for other types of fruits.

REGULATIONS

The Bureau of Plant Industry is also mandated to undertake regulatory activities for the fruit crop plant nursery operators to produce quality planting materials for distribution to our stakeholders. The first regulatory activity is the plant nursery accreditation program wherein plant nurseries will apply and if the requirements are met, they will be given certificates and they are given priorities in government procurements.

The other activity is the Plant Material Certification program wherein foundation trees, scion trees, clonal trees, and budwood trees are subject for certification to ensure that all are of true-to-type of the varieties and of clean material. There are a total of 172,585 seedlings certified and 2,924 trees certified.

The GAP certification program is administered by the Department of Agriculture-Bureau of Agriculture Fisheries Standards (DA-BAFS) since 2005. Pursuant to the Food Safety Act of 2013, the PhilGAP certification program is currently on transition period to the DA-Bureau of Plant Industry (DA-BPI) with the full implementation starting 2017. The standards, guidelines, protocols, and code of practices are developed and aligned to the international norms and best practices. The elements of the PhilGAP program are anchored to the ASEAN GAP. It contains four modules, namely on: (1) food safety; (2) produce quality; (3) environmental management; and (4) workers' health, safety, and welfare. Among the relevant developed PNS are code of practices for fruits and vegetable farming, corn, mango, onion, banana, rice, papaya, coffee, and cassava. As of July 2016, there are a total of 82 GAP certified farms for various crop commodities covering 22,595 hectares.

MAJOR ACCOMPLISHMENTS OF BPI-NATIONAL PLANT QUARANTINE SERVICES

1. The Australian Government recognized the Philippines as a country free from mango pulp and seed weevils.
2. DA-BPI exported the initial shipment of 6.561 MT highland bananas to the U.S.A. at the Mindanao International Container Terminal in Tagoloan, Misamis Oriental in September, 2013.
3. BPI-Davao NCRPSC under the leadership of Dr. Lorna E. Herradura recommended resistant somaclones for planting in Fusarium-infested areas. This came from selections out of the field trials conducted in Davao region. Selections were based on good horticultural characteristics, early maturation, and with high to moderate resistance to Fusarium disease.
4. BPI-Davao remains to be the source of disease-free pummelo plant materials and pre-immunized budlings primarily for the use of the citrus rehabilitation program of the region and of the country as well.

PAPER 2:
SUSTAINABLE TROPICAL FRUIT PRODUCTION; FARMER SUPPORT IN THE PACIFIC

Nick Roskruge
Institute of Agriculture & Environment, Massey University, Palmerston North, New Zealand.

ABSTRACT

In recent years the impacts from climate events, technology advances, and social change have affected tropical fruit producers across the Pacific. Cyclones have devastated longstanding plantations; cocoa in Samoa, mango, coconut, and banana in the Fiji Islands. Technology has bypassed many traditional producers in economies such as Papua New Guinea where investment from offshore producers now impacts local production. More noticeably however, the succession of the next generation as producers is becoming fraught from the impact of urbanisation and crop issues such as pest and disease vulnerability, biosecurity threats, and changing consumer expectations. What support is needed to ensure tropical fruit production meets the quality and quantity thresholds from local and international markets to guarantee farmer incomes?

A number of farmer support programmes exist across the Pacific, essentially as aid programmes. Whilst often driven by political altruism, they all compete for the farmer's time and skills. The future for fruit producers requires ongoing training in crop husbandry and market drivers to optimise production opportunity, and also through investment in the future — technology for example in diagnosing plant health issues or for crop responses to climate change; e.g., through breeding programmes. Examples of producer support through external programmes can be seen in recent work funded from New Zealand with the fresh produce sector in Papua New Guinea to support existing producers to grow their presence in the local market despite competition or disease pressure, cocoa plantation restoration in Samoa to meet a burgeoning international market demand, and cyclone response work in Fiji where farmers are rebuilding following Tropical Cyclone Winston. These programmes all draw from international experience in tropical fruit related work to help Pacific economies evolve as reliable contributors of food and nutrition to their consumers.

Keywords: Pacific horticulture, food security, Papua New Guinea, Fiji, Niue, Samoa

INTRODUCTION

In recent years a series of compounding impacts from climate events, technology advances, and social change have affected tropical fruit producers across the Pacific. The most visible impacts derive from extreme weather events such as cyclones which have devastated longstanding plantations in many of the Pacific islands; cocoa in Samoa, mango, coconut and banana in the Fiji Islands. Other climatic factors such as drought or flooding also impact directly on communities. Technology has bypassed traditional producers in many ways. The development of new products from locally grown fruits, gene technology for crop development, or food safety assurance are often missing or marginalised in local economies such as Papua New Guinea or Fiji. In addition the investment from offshore investors in regional production opportunities further impact on local farmer systems and returns. More noticeably however, the succession of the next generation as producers is becoming fraught from the impact of urbanisation and crop issues such as pest and disease vulnerability, biosecurity threats and changing consumer expectations.

The recently published Framework for Resilient Development in the Pacific (2016) summarises the present situation in the Foreword as follows:

'Pacific Island countries and territories (PICTs) are extremely vulnerable to climate change and natural hazards which are major challenges for the development aspirations of the people of the Pacific and their environment. The experience of the region to Tropical Cyclone Winston in 2016, Tropical Cyclone Pam in 2015 and numerous other events have all reinforced that the actions on climate change and disaster risk management have to be better understood, planned for, funded and coordinated at the local, national, regional and international level. The Framework seeks to place sustainable development, that is resilient, front and centre. It recognizes the importance and critical role of political leadership and commitment, and the central government agencies as key actors. It also embraces the role of the private sector and civil society in building resilience. The discourse should continue to shift: from stating the business case to implementing the opportunities to build resilience. Small Island Developing States (SIDS) in the Pacific, are leading this work, but more support is needed.' (Foreword, p. 7)

This also highlights the growing concern in the Pacific related to climate change and natural hazards – and the impacts they are having on the food production sector among others. Food production is an attractive target for a variety of different aid projects by donor countries (e.g., New Zealand, Australia, EU), development organisations (e.g., World Bank), as well as NGO's (e.g., World Vision, Save the Children). Many of these international aid programmes are consistent contributors to Pacific fruit production sectors, providing investment in development and supporting research or infrastructure to support growers and economies. Recent examples which draw from New Zealand expertise can be found in Papua New Guinea, Fiji, Niue, and Western Samoa. These are examples of ongoing investment from the aid community of the response to climate and climate change, technology advances, and social pressures. NZAid refers to the aid programme which is administered through the New Zealand Ministry of Foreign Affairs and Trade (MFAT).

PAPUA NEW GUINEA FRESH PRODUCE SECTOR

New Zealand through the NZAid partnership programme is supporting Papua New Guinea to achieve sustainable economic and social development so it can reduce poverty and become a more secure and prosperous nation . Within this programme is an NZAid-Massey University (NZ) collaboration alongside the Pacific Adventist University (PAU), 14 mile, Port Moresby. The opportunity exists for PAU Farm to increase food security and replace the import of expensive fresh food, whilst contributing to the development of the local economy and community. PAU farm development goals also align with the Papua New Guinea strategy '2050 PNG Vision' (Treasury Department, 2011) where food production is projected to form the basis for socioeconomic growth. As the farm is part of a PNG-based University, PAU Farm development also aligns with the intent of collaboration between research and higher education institutions and industry in order to add value to local knowledge and enterprise, building knowledge of the processing and downstream management of agricultural products that may yield attractive returns to PNG (PNG Vision 2050 sections 1.17; 1.17.4; 1.20.21). Several challenges for the farm have been identified for immediate action: climate change issues, e.g., recent drought conditions; retaining market share for produce; depleting soil fertility; crop health issues; water security; and farm staff training and development (Roskruge & Semese, 2017).

PAU will only be able to achieve a vibrant and sustainable production system if the strategic industry drivers are either established, or where they already exist, have improved effectiveness and efficiency. Advanced land management practices in their food production systems including up-to-date plant/tree husbandry practices, and application of up-to-date post-harvest handling and management of produce needs to be applied. Furthermore, crop decision systems need to respond to market intelligence on consumer demands and needs, be informed by regular and effective extension services, all of which will contribute to a skilled and diverse workforce.

Papua New Guinea is rich in natural resources, however; logistical, climatic, and geographic challenges continue to reduce the availability of local fresh produce around the capital, Port Moresby. Farming is based on subsistence agriculture and lack of local production causes residents to rely on expensive imports for their basic food needs. The development of modern agriculture offers urban residents access to regular supply of fresh and healthier food, while diversifying the local economy and providing much needed employment.

Port Moresby and the nearby Central Province has a population of around 365,000 (2011 census). Recent figures further indicate the city accounts for around 18% of the total PNG population of close to 8 million people. Chang et al. (2015) found that limited options exist in close proximity to Port Moresby for commercial fresh produce production because of issues of land capability and land tenure. However, farmers from more distant areas (>30km) were working in groups to supply supermarkets. Other areas in PNG have high agricultural potential and fertile soils, but poor transport infrastructure is a serious challenge for agricultural development generally. Further, Chang et al. (2015) defined the market situation in Port Moresby as being in a state of flux, on both the demand and supply front, thus considerable opportunity still exists to meet supply needs.

The project scoping exercise identified three key areas for development of the complete produce supply chain as a system. These are: upgrading the cool chain system; brand development based on quality and supply factors; and postharvest handling, i.e., transportation, packaging, hygiene, and presentation. Value addition and branding, market choices, and customer relationships are important factors to maintain the brand going forward. This project will consolidate and build the supply chain of fresh produce into Port Moresby district and therefore create more opportunity for small farmers, many who are women and who are distant from the city to also supply through a recognised entity (Roskruge & Semese, 2017). A particular emphasis is the move from subsistence vegetable production to longer-term fruit production plantations which although presenting higher risk, offer strong market returns if done well.

The alignment of the project outputs to the PNG 2050 vision enhances the drivers for success in working to attaining the PNG nation's dream to be a 'smart, wise, fair, healthy, and happy society' (Ambang, 2012). This project is in its infancy and will be watched with interest as the burgeoning demand for fresh produce from the Port Moresby district continues and local producers are challenged with meeting that demand.

FIJI

Another project currently in its evolutionary stage is the *KANA : Resilience through knowledge and action in agriculture and food security* based in Fiji. This project also comes under the auspices of the NZAid programme. The NZAid programme in Fiji particularly invests in developing agriculture, achieving a more highly skilled, and educated workforce. Rural communities have traditionally relied on home gardens for food and income. Fijian households (78.9%) grow food for home consumption with many households in rural areas obtaining all their food from their garden (NFNC, 2007).

After Tropical Cyclone (TC) Winston in February 2016, many communities were affected with fishing, farm, and plantation activities damaged or destroyed. The cost of Winston in loss of agriculture and horticulture has been estimated at FJ$ 208.3 million (excluding the sugar sector) and in the worst affected areas, 100% of crops were destroyed. As these communities recover, it is essential to develop food security and family incomes that will build resilience. The worst affected areas were identified as, Vanuabalavu, Lomaiviti, Cakaudrove, Bua, Tailevu

North, and Ra (Naleba, 2016).

The current project being established by NZAid with Save the Children (NZ and Fiji) will focus on two regions, Ra and Koro Island, where the impacts of TC Winston on the agriculture sector are expected to last for several years due to continued production losses and associated higher production costs. High winds, flooding, and storm surges have imposed substantial damage to permanent plantations for fresh produce (mangoes, banana and coconut and others) which will need to be replanted. The regrowth of the mangoes 12 months and later is now evident but production capability is still affected.

Some villagers have been forced to look for alternative sources of income through jobs in the private sector or have migrated to other provinces for income generation opportunities. This has put an additional strain on food security, and left some productive farm land unattended. There is an increasing domestic market for fruit and vegetable crops in Fiji (ITC, 2017) especially in the tourism and urban markets.

In Ra, coastal region communities had relied almost solely on coconut production for their livelihoods prior to TC Winston. However, the cyclone destroyed most of the coconut trees. It will be at least three years before coconut production recovers and communities are struggling to earn much needed cash. This presents an opportunity to encourage diversification of land use for both food security and increased income. Dalo (taro) and cassava are the main crops grown, but there are opportunities for bee keeping and some different crops such as cocoa and ginger. The project is planned to assist the selection of crops where local farmers can learn from demonstration areas or field days and benefit from access to expertise.

On Koro Island, each village is at a different stage of cyclone recovery. With the relocation of housing and other activities unique to each village following TC Winston, the actual agricultural/horticultural activities have relocated, often to relatively steep slopes or on plateaus quite a distance from the road. Plantations of dalo, cassava, coconuts, and papaya are evident as they are being replanted. The farmers were confident around these crops — but to achieve crop security, they will need to diversify to crops with a better income opportunity and market demand such as vanilla, ginger, passion fruit, citrus, and others. This island has considerable potential and the most to gain from development opportunities aligned to landuse and cropping.

It is early days for this project but huge potential exists to optimise the food production activity in susceptible regions within Fiji, especially in local fruit production which can supply the local and tourist markets.

WESTERN SAMOA COCOA DEVELOPMENT PROJECT

This project also fits under the NZAid programme and is a collaboration between The Agrichain Centre (NZ), Samoan Chamber of Commerce, and Massey University; also New Zealand. This current (2017–2022) project looks to restore cocoa production in Samoa to strong export levels. Samoa has grown cocoa since 1883 when it was introduced during the period of German colonisation. Since then the loss of markets in the post-war period, changing national priorities, and climate disasters have greatly influenced the shape and nature of the Samoan cocoa industry. In recent years, the Samoan cocoa industry has tried to take advantage of the strategic window for cocoa export supply through building singular cocoa bean supply chains into specific chocolate manufacturers in New Zealand and Australia (PHAMA, 2015).

There are five factors currently causing change in the regional and global cocoa market, which provide opportunities for Samoa: as the world population grows, the demand for cocoa is increasing, there are current harvest shortfalls in the West African cocoa producing countries due to political unrest, and adverse climatic conditions in Africa affecting production volumes. The Pacific Island nations are beginning to be recognised by New Zealand and Australia as desired cocoa suppliers as long as they can meet quality standards. New Zealand and Australian markets are beginning to understand that relying on one or two African countries to meet cocoa demand presents an unnecessary risk and that a degree of diversification is available. Over the years, cocoa has also become part of the Samoan culture, represented by the liberal consumption of Koko Samoa. Domestic Koko Samoa production is firmly in the hands of smallholders and subsistence farmers, meeting an important need in the income generation mix of that population segment. Samoan cocoa producers range from smallholders with 10 plus trees, to the state-owned Samoa Trust Estates Corporation (STEC) established under the Samoa Trust Estates Corporation Act 1977 to develop and maintain plantations, and other agricultural activity on Upolu Island.

Samoa has natural constraints in the availability of suitable land for fruit production affecting any push to increase production volumes and improve quality. The opportunity to differentiate Samoan cocoa as an indigenous crop and optimise the outcomes for Samoa from increased supply if traditional knowledge of cocoa is able to be combined and aligned with international best practice as understood by cocoa buyers. The cocoa plantings in Samoa will benefit from improved crop husbandry practices on many farms, a replanting programme with particular emphasis on stock quality to replace the current plantation rejuvenation approach which is based on planting seedlings rather than grafted plants. Seed selection does not currently follow good agricultural practice and as a result, the next generation of cocoa trees currently accessed are variable and will not deliver consistent enough quality attributes to rebuild a sustainable export industry. The national cocoa tree stock can be significantly improved through the introduction of grafting of young plants in the nurseries as well as healthy low yielding trees in the field. Further improvements will come on stream with the introduction of nurseries working to Good Agricultural Principles, which includes taking a systematic and documented approach to the selection of seed material, rootstock, and scion wood. From the producer perspective, this will also require extension services focused on crop husbandry, planting and preparation, harvest techniques, and field grafting.

The project is in its infancy but has committed to developing the sector through farmer support and training, nursery development for new plantings, and processing plants for the harvest produce. The fruit sector generally has much to learn from the continued development of cocoa as a tropical system in Samoa.

NIUE

One of the smaller nations in the Pacific, Niue has a number of projects focused on land-use, fruit production, and agricultural training. The Food and Agriculture Organization of the United Nations (FAO) currently supports a number of initiatives which draw on New Zealand's expertise through NGO organisations (VSA) and universities (Massey University, NZ). In 2016, a two year project called the Niue Household Fruit and Nut Trees Integrated Replanting Project was launched by FAO and the Government of Niue to increase local fruit production as a means to improve food and nutritional security, and increase employment (FAO, 2017). The development of the fruit tree demonstration area at the Vaipapahi Agricultural Research Farm has been the main area for demonstrating the management techniques to farmers and interested growers. The primary focus is to increase domestic production of fruits and nuts through a selection of fruit species and varieties, and the adoption of improved production techniques and management practices (FAO, 2017). The project also includes supporting farm demonstrations with selected village farmers and schools to adapt technologies to local conditions. Parallel to this is another project where training opportunities were identified for various levels on the island and Massey University experts undertook the initial workshop events in July 2017.

This emphasis on horticulture in Niue has progressed through their partnership with FAO since the island country joined the organization in 1999, with cooperation focusing on food and nutrition security, and natural resource management. FAO technical assistance has ranged from support to the formulation of agricultural policies and legislation to capacity strengthening in data collection, agri-processing and value addition of agricultural products, and scoping for artisanal and traditional fisheries development (FAO, 2015).

DISCUSSION

These examples highlight a number of farmer and sector support programmes which exist across the Pacific, essentially as aid programmes. Whilst often driven by political altruism, they all contribute to the skill development and experience of producers. The future for fruit producers requires ongoing training in crop husbandry and market drivers to optimise production opportunity. This can be supported also through investment in the future; technology for example in diagnosing or responding to plant health issues or for crop responses to climate change, e.g., through breeding programmes.

The opportunities to grow a skilled and diverse workforce for fruit and horticultural development in the Pacific are necessary to contribute to existing skills and demographic trends. Young people are needed to sustain and grow the horticultural economy, but they need to have a perspective of their future. Fruit and fresh produce are the focus of a variety of different aid projects by donor countries, development organisations, as well as NGOs. Programmes need to be attractive to the emerging generation to consciously work towards building confidence in them as future managers, to retain them in the rural situation, and to upskill them for decision making systems suited to the contemporary marketplace. This attractiveness will be driven by the fact that food security and climate change responses by Pacific communities will gain in a positive manner from the support of a production mix in tropical gardens. Markets exist and continue to grow, both local and export; however, the need to develop production systems to meet the demands of these markets through Good Agricultural Practises also exists and needs to be achieved for the future to be better secured.

SUMMARY

A range of support mechanisms are needed to ensure tropical fruit production meets the quality and quantity thresholds from local and international markets to guarantee farmer incomes in the Pacific. The examples cited all draw from regional expertise and contribute to sector and farmer development in Papua New Guinea, Fiji, Niue, and Western Samoa. These are examples of ongoing investment from the aid community as a response to climate and climate change, technology advances, and social pressures. Food security is a popular catch phrase at this time but it will only ever be achieved if local responses to the pressures on food production in the Pacific are realised through investment in the producers themselves and in the systems they manage through education, technological advances, and market alignment.

REFERENCES

Ambang, T. (2012). Progress and the challenges of implementing PNG Vision 2050: Reflections from Human Development Index ranking for 2011–2012. *Contemporary PNG Studies*: DWU, 17.

Chang, C., Bonney, L., Griffith, G., & Maino, G. (2015). Assessing the potential for expanding vegetable production in Central Province, Papua New Guinea. *Australasian Agribusiness Perspectives*, Paper 103.

FAO. (2015). Niue and FAO; Partnering to improve food security and income-earning opportunities (Information brochure). FAO Subregional Office for the Pacific Islands, Apia, Western Samoa

FAO. (2017). Fruit and nut trees project flourishes in Niue. Retrieved from: http://www.fao.org/asiapacific/news/detail-events/en/c/884768/

ITC. (2014). Supporting Fijian farmers and agrifood enterprises. *International Trade Centre Annual Report* 2013.

MFAT. (2017). Our aid partnerships in the Pacific. Retrieved from: https://www.mfat.govt.nz/en/aid-and-development/our-work-in-the-pacific/

Naleba, M. (2016). TC Winston costs agriculture sector $208.3 million. The Fiji Times, Page 1, March 17 2016.

NFNC. (2007). *2004 Fiji National Nutrition Survey Main Report*, National Food and Nutrition Centre Suva, Fiji, September, 2007

Pacific Community (SPC), Secretariat of the Pacific Regional Environment Programme (SPREP), Pacific Islands Forum Secretariat (PIFS), United Nations Development Programme (UNDP), United Nations Office for Disaster Risk Reduction (UNISDR) and University of the South Pacific (USP). (2016). *Framework for Resilient Development in the Pacific: An Integrated Approach to Address Climate Change and Disaster Risk Management* (FRDP) 2017-2030.

PHAMA. (2015). *Increasing the export capacity of Samoan Agriculture* (Factsheet), Pacific Horticultural & Agricultural Market Access Programme, Suva, Fiji.

Roskruge, N., & Semese, S. (2017). Pacific Adventist University Farm Project, unpublished

Treasury Department. (2011). PNG Vision 2050. Retrieved from: http://www.treasury.gov.pg/html/publications/files/pub_files/2011/2011.png.vision.2050.pdf

PAPER 3:
IMPROVING SUPPLY CHAIN MARKET ACCESS FOR MANGO FARMERS IN FIJI: A TRANSACTION COSTS PERSPECTIVE

Atish Chand and Salesh Kumar
College of Agriculture, Fisheries and Forestry, Fiji National University, Koronivia Campus, Fiji

ABSTRACT

Mango industry is significant to the economy of Fiji. Even though mango being recorded as scattered plants in agricultural census 2009, these scattered plants form the basis of the mango industry. The industry consists of various supply chain evolved in Fiji. These supply chains are driven by transaction costs affecting the mango producer's choice of trade in the open market. Since transaction costs have significant impact on mango industry, it is important to understand the effect of transaction costs in the Fijis mango industry. Therefore, this study is aimed at improving the supply chain access for mango farmers by studying transaction costs and ways to improve farmer access to the lucrative mango markets. This study reviews wider literature on transaction costs and supply chains models of mango and fruits in Fiji and other similar countries. The outcome of this study will identify the major supply chain models in Fiji and the effect of transaction costs on mango industry.

Keywords: transaction costs, vertical coordination, horizontal coordination, supply chain

INTRODUCTION

The popularity of mango is increasing in the global market as fresh and processed product (McGregor, Gonemaituba, & Stice, 2009). Over 90 percent of mango is grown by smallholder farmers with low investment capacity (Vayssieres et al, 2008). Due to trade liberalisation, the opportunity for many developing countries has opened up in the export of traditional crops including mangoes (Van Melle & Buschmann, 2013). Fiji being a developing country has also been tapping the locked potential in this industry.

Major important constraints facing the access of these supply chains are inconsistency in supply, the scattering of production, lack of coordination, information asymmetry and lack of quality produce (Brown, 2008; United Nations Industrial Development Organization & World Bank, 1983). Moreover, Young and Vinning (2007), find that there is a definite supply chain for the mango markets in Fiji but farmers are not able to take advantage of the high return markets. This can be due to constraints which lead to high transaction costs. defines Transaction costs are costs of economic exchange or in simple terms costs of participating in the market Williamson (1998). The issue of transaction costs has always been highlighted in the agricultural markets (Assuncao & Wander, 2015). Transaction cost economics (TCE) has influenced the agricultural supply chains and has been a considerable theory in explaining missing markets (Pingali et al., 2005). These are transaction costs in form of missing markets such as credit (Besley 1994), labour markets (Bardhan, 1984), and land production markets (Stiglitz, 1989; Holden & Binswanger 1998) which are seen in developing countries.

Transaction costs in mango industry in Fiji has resulted producers transacting in spot markets. In spot markets, small farmers have an advantage of low transaction costs, family labour and intensive local knowledge (Pingali, Khwaja, & Meijer, 2005) but it is important to understand the transaction costs in accessing input and output market, traceability of product and quality assurance.

Furthermore, there has been no efforts made by individual growers to improve fruit quality for tourist or processing markets and this has prevented hotels, resorts and processors directly dealing with local producers (Young & Vinning, 2007). This has given rise to the middleman in mango supply chains (Brown, 2008; Kumar & Palanivel, 2016; Veit, 2009). These middlemen bear the transaction costs of these high earned supply chains and benefits from better returns whereas the mango producers are presented with lower prices. Farmers are considered price takers here as they are discouraged to anticipate in higher lucrative markets due to transaction costs (Fischer & Qaim, 2012).

On contrary, as noted from farmer producing for exporters, the success of export market can be contributed due to the vertical coordination within the supply chain. There is a use of market contracts which stipulates the price paid to the farmer, the quality of the product and the quantity specifications (Veit, 2009).

From the discussion, above, it can be noted that transaction costs can be a major limiting factor for the smaller mango producers to capitalise on high-value markets (Aphane, 2011). Therefore, the question arises on how these mango producers can access to markets with higher economic gains to improve their living.

Based on the above evidences, firstly this paper will classify the supply chains existing in Fiji mango market and secondly examine the effect of transaction costs on the mango producers in Fiji.

METHOD

The conceptual framework used in answering the research question uses analysis of theories and dimensions of supply chain models. To understand the mango market of Fiji, the supply chain market model is based on research from mango value chain analysis based in Benin, Faso and Ghana (Van Melle & Buschmann, 2013). This model was then adjusted to Fiji's mango supply chains based on evidence from literature on Fiji mango supply chains. These mango supply chain markets identified in Fiji was studied to identify the governance, transaction costs, and institutional arrangements. To add, rapid survey was conducted with the supply chain actors including farmers, Nature's way and exporters. Literature used to identify transaction costs in these supply chain include Coase (1937), Hobbs (1996) and Williamson (1979). Furthermore, the transaction costs in accessibility of supply chain for scattered mango farmers in Fiji will be examined to determine its impact.

MANGO SUPPLY CHAIN MODELS IN FIJI

In developing countries, there are three common market segments emerging as defined by its supply chain; traditional, modern and export markets (Swinnen, 2007; Van Melle & Buschmann, 2013). To make classification of mango supply chains in Fiji, different types of mango chains have been studied to the targeted end market and its main characteristic to define the typology of mango supply chain models. These models has been adapted as per Fijis supply chain markets to resemble the actual actors and transactions involved.

Fiji mango supply industry in this study has been identified into different supply chain markets based on literature. Fiji mango industry has evolved into the three major supply chains which are traditional, modern and export markets (Brown, 2008; Kumar & Palanivel, 2016; & Veit, 2009).

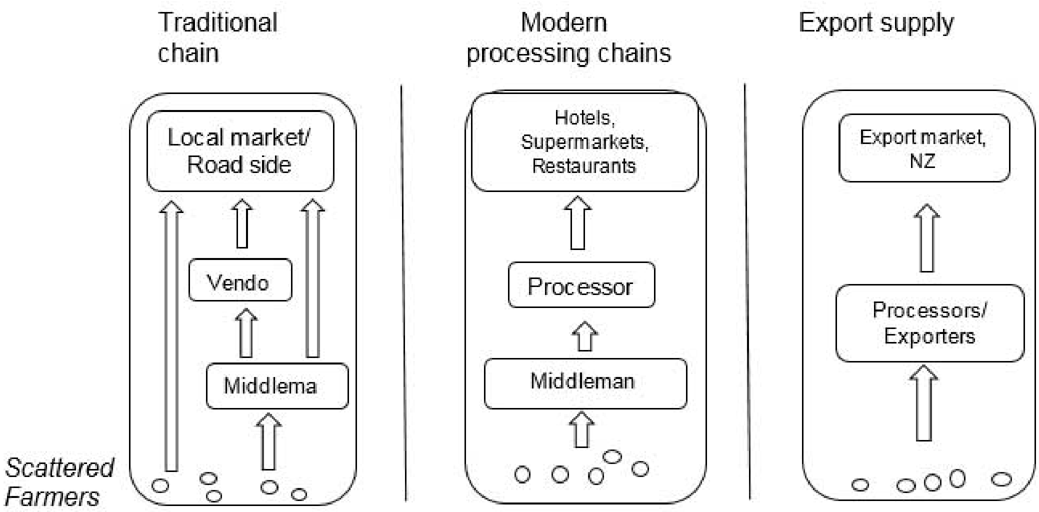

Figure 1: Diagrammatic representation of three mango supply chains model in Fiji (Adapted from Van Melle and Buschmann, 2013)

TRANSACTION COSTS ASSOCIATED WITH SUPPLY CHAINS

Traditional supply chains

There has been a significant increase in road side sellers in past 10 years and market vendors who sometimes are also middleman (McGregor et al., 2009). In this market chain farmers or middleman pick mangoes to be sold along the road side or in the local market (Kumar & Palanivel, 2016). The transactions occur in the spot market with minimum transaction costs. A total of 1380 tonnes of fresh mangoes ranging from green to ripening stage is estimated to be available annually in municipal markets and roadside stalls throughout the two major islands of Fiji (Brown, 2008).

Famers facing transaction costs in spot market are in the form of searching information for market prices, bargaining, and negotiation with the unknown buyers or middleman. Most mango farmers in Fiji are seen transacting in the spot market in traditional supply chain due to lower transaction costs. In the spot market, mango farmer's transaction costs are low and farmers may get a good price for their produce if they directly deal with consumers. Despite this, transacting in spot market also increases the risk of selling mangoes in open market which exposes vendors to price uncertainty and wastage of the produce due to no fixed market.

Apart from farmers selling directly to consumers middleman play an active role in this supply chain. According to Kumar and Palanivel (2016), it found that the wholesale price of mangoes at the farm gate paid by middleman was FJD 10 per 30 kilogram bag which means farmers only get FJD 0.33 cents per kilogram for the produce. The reason for this low price as explained by Pingali et al. (2005) is that farmers seek lower transaction costs and are therefore accept price they receive from the sales.

Modern processing chains

In this type of supply chains a new type of transaction costs has arisen due to demand in improved product quality (Pingali et al., 2005). The three major end markets, processors (Kumar & Palanivel, 2016) supermarkets and tourist market (hotels and resorts) creates demand in this supply chain (Young & Vinning, 2007). Modern supply chains have coordinated vertically but this is only noted between the middleman and the processors (Kumar & Palanivel, 2016). Mango producers in this supply chain are not able to directly deal with the processors, hotels or supermarkets due to high transaction costs. These transaction costs can be due to information asymmetry, increase in quality requirement and consistency in supply (Pingali et al., 2005).

The involvement of intermediaries removes the burden from farmers of meeting the transaction costs and standard requirements of fruits for the domestic supply chains (Mushobozi & Santacoloma, 2010) The relationship between the farmer and the middleman is based on spot market where the middleman buys the mango while still on the tree and uses his own labour for harvesting. The farmer receives FJD 0.33 per kilogram from the middleman for the mango produced which is similar for those dealing with middleman in traditional supply chain.

Export supply chain

Currently, there is a small network of farmers in this supply chain consisting of 12 major exporters (Kumar & Palanivel, 2016) and 39 registered growers (South Pacific Trade Commission, 2000). The producer and exporter have developed strategic alliance through vertically coordinating and the relationship is guided by market contracts in this supply chain.

Strategic alliances are relatively informal agreements between two parties to cooperate in the vertical marketing chain by sharing information while maintaining their formal separate identities (Worley & McCluskey, 2000).

In this supply chain, the role of intermediary or the middleman is played by the exporter who sells the fresh mango and its processed product to the high earned markets. The stakes are high in this market due to some asset specificity, opportunism and requirements of product quality. Therefore, marketing contracts are used to guide this relationship which increases the transaction costs. Ministry of Agriculture and Biosecurity play an important role in regulating the contract between farmers and the exporters. This leads to transaction costs of negotiating and monitoring contracts outweighed by the benefits which both parties get from this relationship. In addition, there is also minimum transaction cost involved in this relation to search for trading partners and bargaining for better prices since contract guides the transaction. The price paid farmers are FJD 40 - FJD60 per 35 kg bag of mango depending on the size and quality (Kumar, 2017). This gives farmers FJD 1.14 - FJD 1.71 per kilogram of mangoes.

Apart from price and market certainty there can be vertical integration along the supply chain so that the farmers are able to get the direct benefit of the export prices. The price received by exporters in this market is a major motivator for the coordination of this supply chain. The price of the mango received is FJD 1 - FJD 3 each which is less than other major exporters due to inferior quality (South Pacific Trade Commission, 2000).

DISCUSSION

In Fiji, the transaction costs to some extent determines farmer's choice of transacting in various supply chains. As noted in the traditional supply chain, the transaction cost is low therefore farmers prefer transacting in the spot market. This includes farmers who are selling at municipal markets and road sides. There are also some farmers in this supply chain who are unable to meet the transaction costs therefore relay on middleman for sales of their produce. The transaction costs involved in the mango supply chain can be in related to inconsistency in supply, lack of information, poor market price indicators, demand for high quality products, arranging of transportation, assessing finance for adequate facilities (Young & Vinning, 2007) and negotiation costs with the buyers. This has resulted in farmers being presented with lower prices in this supply chain.

A new type of transaction costs has arisen due to improved product quality in modern agriculture market (Pingali et al., 2005). This is due to improvement in living standards of the consumers. Apart from the increase in transaction costs due to product quality, other reasons for an increase in transaction costs can be due to search, negotiation and monitoring costs (Hobbs & Young, 2000). As noted in the traditional and modern supply chains mango market in Fiji, these mentioned transaction costs are affecting mango producers from vertically coordinating. Especially for modern processing and export supply chains, transaction costs increases with stringent product quality requirements (Anon, 1985; Young & Vinning, 2007). Therefore, an increase in product differentiation is notable development associated with closer vertical coordination (Young & Hobbs, 2002). Vertical coordination can be achieved with the use of contracts as seen from the export supply chains success in Fiji. The use of contracts in vertical coordination must be considered to improve farmer access to these supply chains. According to a study, most growers feel that contracts should be used between farmers and final purchasers, thus eliminating the role of middlemen (Young & Vinning, 2007). The administration and monitoring of the contract can be expensive and increase the transaction costs but Government agencies such as Ministry of Agriculture regulate the contracts to ensure mango producers are able to meet the transaction costs. Use of contracts also eliminates transaction costs of searching for trading partners, and market information. This will provide farmers with price certainty and secure market for mango.

Another solution to this problem can be horizontal coordination. Horizontal coordination can be in form of cooperatives and farmer associations. To understand how horizontal coordination affects transaction costs, the causes of transaction costs in the Fiji mango market needs to be understood. Since mango production is scattered (Department of Agriculture, 2009), horizontal coordination can be a means of assisting mango producers to reach economies of scale, better access to assets, improved bargaining power (Pingali et al., 2005) and market information. There is a risk of failure in horizontal coordination due to seeking alternative contractual arrangements where commercialisation demands higher output quality (Pingali et al., 2005). Despite this, the returns from farmer coordination are more lucrative and the risk is shared. The increase in scale through horizontal coordination reduces the transaction cost and supermarkets tend to target those supply chains whose transaction costs are low (Pingali et al., 2005). This solves the issue of scale, consistency, costs of contractual agreement, costs accessing information and costs bargaining for price in the supply since these issues increase the transaction costs.

It is also noted that the middleman play a significant role in the mango industry. Therefore further research can be conducted on their influence in this industry.

CONCLUSION

The wider literature reviewed in this paper indicates that transaction costs has significant impact on mango supply chains based on different markets in Fiji. These markets are categorised into three distinct supply chains characterised by its transactions, relationship amongst the actors and the end markets. The traditional supply chain has the lowest transaction costs for mango producers due to transactions conducted in spot markets. Modern and export market supply chains are faced with a new type of transaction costs which has come from the demand of quality produce. It is recommended that vertical and horizontal coordination can be some of the solutions to overcome the transaction costs in the mango market.

REFERENCE

Anon. (1985). Mango profile: a programme for the development of the commercial mango industry: Ministry of Agriculture, Fiji.

Aphane, M. M. (2011). Small-scale mango farmers, transaction costs and changing agro-food

markets: evidence from Vhembe and Mopani districts, Limpopo Province.
Assuncao, P. E. V., & Wander, A. E. (2015). Transaction costs in beans market in Brazil. *Ciência Rural,* 45(5), 933-938.
Bacolod, E. D. (2014). Fiji 2020 agriculture sector policy agenda: Ministry of Agriculture Retrieved from http://www.globalgreentechcorp.com/yahoo_site_admin/assets/docs/Ag_Policy_Booklet_for_Web.212110312.pdf
Brown, M. F. (2008). Value chain study of tropical dried fruits in Fiji : Promoting healthy snacks Secretariat of the Pacific Community Retrieved from http://lrd.spc.int/pubs/doc_download/55--valuechain-study-report-on-tropical-dried-fruits-of-fiji
Coase, R. H. (1937). The nature of the firm. economica, 4(16), 386-405.
Department of Agriculture. (2009). Fiji national agricultural census - 2009. Retrieved from http://www.fao.org/fileadmin/templates/ess/ess_test_folder/World_Census_Agriculture/Country_info_2010/Reports/Reports_3/FJI_ENG_REP_2009.pdf
Fischer, E., & Qaim, M. (2012). Linking smallholders to markets: determinants and impacts of farmer collective action in Kenya. World Development, 40(6), 1255-1268.
Hobbs, J. E. (1996). A transaction cost approach to supply chain management. *Supply Chain Management: An International Journal*, 1(2), 15-27.
Hobbs, J. E., & Young, L. M. (2000). Closer vertical co-ordination in agri-food supply chains: a conceptual framework and some preliminary evidence. *Supply Chain Management: An International Journal*, 5(3), 131-143.
Kumar, K., &. (2017). Mango export.
Kumar, S., & Palanivel, H. (2016). Fiji report: Analysis of mango markets, trade and strategic research issues in the Asia-Pacific(unpublished): *Australian Centre for International Agricultural Research*.
McGregor, A., & Gonemaituba, W., &. (2002). Fiji Agricultural Marketing: A Policy Framework: Suva, Fiji.
McGregor, A., Gonemaituba, W., & Stice, K. (2009). Natures Way Cooperative (Fiji) Ltd: A Case Study of Agriculture for Growth in the Pacific.
McGregor, A., & Macartney, J. (1985). Fiji Agricultural Sector Study: publisher not identified. Retrieved from https://www.adb.org/publications/fiji-agriculture-sector-review-strategy-growth-and-diversification
McGregor, A., & Stice, K. (2014). Agricultural Value Chain Guide for the Pacific Islands: Making value chain analysis a useful tool in the hands of farmers, traders and policy makers.
Mushobozi, W. L., & Santacoloma, P. (2010). Good Agricultural Practices (GAP) on horticultural production for extension staff in Tanzania. FAO GAP Working Papers Series (FAO).
Pingali, P., Khwaja, Y., & Meijer, M. (2005). Commercializing small farms: Reducing transaction costs. The future of small farms, 61.
South Pacific Trade Commission. (2000). Exporting Fruit and Vegetables to New Zealand, A guide for Pacific Island Producers. Auckland, New Zealand.
Swinnen, J. F. (2007). Global supply chains, standards and the poor: how the globalization of food systems and standards affects rural development and poverty: Cabi.
Van Melle, C., & Buschmann, S. (2013). Comparative analysis of mango value chain models in Benin, Burkina Faso and Ghana. *Rebuilding West Africa's Food Potential*. FAO/IFAD.
Vayssieres, J.-F., Korie, S., Coulibaly, O., Temple, L., & Boueyi, S. P. (2008). The mango tree in central and northern Benin: cultivar inventory, yield assessment, infested stages and loss due to fruit flies (*Diptera tephritidae*). Fruits, 63(6), 335-348.
Veit, R. (2009). Assessing the viability of collection centres for fruit and vegetables in Fiji: a value chain approach. FAO All Acp Agric. Comm. Program. Ser. paper, 7.
Williamson, O. E. (1998). Transaction cost economics: how it works; where it is headed. *De economist*, 146(1), 23-58.
Young, J., & Vinning, G. (2007). Fiji: Commodity Chain Study: Outcomes from the Investigations Implemented to Assess Import Substitution Potentials of Selected Horticultural Products: Food and Agriculture Organization of the United Nations.
Young, L. M., & Hobbs, J. E. (2002). Vertical linkages in agri-food supply chains: changing

roles for producers, commodity groups, and government policy. *Review of Agricultural Economics*, 428-441.

PAPER 4:
THE ROLE OF FARMER ORGANISATIONS IN TROPICAL FRUIT RESEARCH AND DEVELOPMENT: CASE STUDY OF NATURE'S WAY COOPERATIVE IN FIJI

Kyle Stice[1], Kaitu Erasito[2], and Timote Waqainabete[2]
[1]Pacific Island Farmers Organisation Network, Nadi, Fiji
[2]Nature's Way Cooperative, Nadi, Fiji

ABSTRACT

Farmer Organisations (FOs), once a rarity in the Pacific, are emerging as key players in the agriculture sector, making valuable contributions to the livelihoods of smallholder farmers through such areas as agricultural extension, input supply, access to markets and agricultural research. FOs involved in agricultural research utilise a decentralised research model which has proven to be more efficient and effective at meeting their specific needs than the traditional centralised research station model found across the Pacific. Following a number of low output years, Nature's Way Cooperative (NWC) realised that there was a need to assist their farmer/ exporter members in addressing a number of the bottlenecks affecting the supply of produce for export. NWC concluded that if they did not help address these issues the quarantine treatment business would be at serious risk. In 2009 the NWC Research and Extension Service became involved in implementation of the Australian Centre for International Agricultural Research (ACIAR) – funded Fiji Papaya Project and later the ACIAR funded Pacific Breadfruit Project. Through a partnership approach, NWC has fostered research relationships with the Ministry of Agriculture, the Biosecurity Authority of Fiji and the Pacific Community.

NWC works directly with its member farmers and exporters for all applied research work and has achieved a number of major successes using this model including: (1) Papaya: (a) Establishment of a certified seed producer's scheme for Fiji Red Papaya based on research findings. (b) Investment in a commercial hot water dipping treatment available to Fiji papaya exporters through NWC. (c) Encouraged commercial investment at the farm and exporter level in organic papaya production based on research findings and economic analysis. (d) Development of technologies supporting sea freight of papaya from Fiji to New Zealand. Research findings indicate a 50% saving in freight costs with no reduction in fruit quality; (2) Breadfruit (a) A package of best practices for mass propagation of breadfruit using various methods including: root suckers, marcotting and tissue culture. (b) Longterm trials established evaluating performance of trees derived from different propagation types. (c) Investment at the farm level in commercial orchards. (d) Developing intercropping systems with breadfruit.

Keywords: farmer organisation, de-centralised research, papaya, breadfruit

SESSION WRAP UP AND Q&A

Farmers should be central in any planning efforts to be undertaken by research and development agencies and policies. Interest from the floor was observed on the unique work modality of NWC and its effectiveness and success in comparison to other industry peers, to which it was highlighted that the success was largely due to the involvement of its stakeholders as part of its collaborative approach, a focus on developing active farmers and training of farmers on the ground.

THE WAY FORWARD

WRAP-UP SESSION: SYMPOSIUM HIGHLIGHTS AND THE WAY FORWARD

Moderator: Mr. Pascal Liu, Team Leader, International Investment and Tropical Fruits, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy.

Mr. Pascal Liu invited all the session chairs to propose recommendations based on the thematic discussions that progressed throughout the two-day symposium. These were then discussed and further refined for finalisation.

Session 1: Climate Change Impacts, Adaptation, and Mitigation
Moderator: Dr. Desa Hassim, TFNet Chief Executive Officer

Target Stakeholders	Recommendations
Government, farmer organizations, implementation agencies, farmers	Put the farmers first — this must be the first priority when planning. Without farmers, we can't have any supply. Farmers should also be adaptive and proactive in solutions and not just expect help from government agencies.
Government, farmer organizations, implementation agencies, farmers	Propose critical solutions that can be applied to different continents/ regions – extreme weather and change in temperature
Governments, policy makers	Compile the solutions proposed in the Symposium and develop an action plan to adapt/mitigate the effects of climate change

Session 2: Crop Protection, and Pest and Disease Management
Moderator: Mr. Yacob Ahmad, TFNet Board Member

Target Stakeholders	Recommendations
Researchers, breeders, development agencies, farmer organizations	Promote the use of certified disease tolerant/resistant varieties
Government agencies, private sector, growers	Capacity building and implementation of biosecurity and quarantine

Session 3: Crop Diversification, Varietal Improvement, and Biotechnology
Moderator: Dr. Apaitia Macanawai, Ministry of Agriculture, Fiji

Target Stakeholders	Recommendations
Ministry of agriculture and agricultural universities	Diversifying our diets by utilizing underutilized crops — develop and promote
Ministry of agriculture	Strengthen germplasm collection and maintenance, sharing of germplasm
Different stakeholders, research agencies, partners	Close collaboration in terms of research

Session 4: Postharvest, Product Development, and Utilization
Moderator: Dr. Prakash Patil, Indian Council of Agricultural Research, India

Target Stakeholders	Recommendations
Government agencies, farmer organizations, companies	Raise awareness of good postharvest practices
Universities	Provide better institutional capacity in postharvest extension and research
Private agencies with researchers	Provide better access to postharvest information

Session 5: Farmer Support, Extension, and Policy Interventions
Moderator: Mr. Robert Williams, TFNet Board Member

Target Stakeholders	Recommendations
Government, growers, donors	Promote adoption of appropriate production, postharvest, and food processing technologies across the supply chain through cooperatives/similar models
ACIAR, broader donors	Managing sudden impacts of extreme weather/disasters/shocks
Farmer clusters and cooperatives, government	Invest in infrastructure for production, postharvest, food processing, storages, good roads, good refrigeration, transport, and marketing
All stakeholders	Implementation of biosecurity protocols

Additional recommendations

Target Stakeholders	Recommendations
Governments, private sector	Need to incorporate induced natural disasters into business plans, strategies, and policies
Extension workers, farmer organizations	Support efforts by farmers to develop production techniques/ systems that are resilient to climate change — strengthen the capacity of farmer organizations
All stakeholders	*Kotahitanga* ("coming together as one") of all initiatives at local, national, regional, and international levels
All stakeholders	Risk management
Symposium organizers	Maximise the local benefits from all the international forums/ meetings
International organizations, research institutes, academies	Database on underutilized fruit crops
Governments, private sector, farmer groups	Increase collaboration in marketing of tropical fruits

ANNEXES

ANNEX 1: LIST OF PRESENTERS AND PARTICIPANTS

List of presenters

#	Title	Name	Designation/Affiliation	Country	Email	Paper page
1	Dr.	Affandi	Senior Researcher, Indonesian Tropical Fruits Research Institute	Indonesia	Affandi1970@yahoo.com	49
2	Dr.	Arry Supriyanto	Indonesian Citrus and Subtropical Fruit Research Institute	Indonesia	arry_supriyanto@yahoo.com	73
3	Mr.	Atish Chand	Department of Crop Production, College of Agriculture, Fisheries and Forestry, Fiji National University	Fiji	atish.chand@fnu.ac.fj	131
4	Dr.	Chunyu Li	Guangdong Academy of Agricultural Sciences (GDAAS)	China	lichunyu881@163.com	55
5	Dr.	Ganjun Yi	Vice President, Guangdong Academy of Agricultural Sciences (GDAAS)	China	yiganjun@vip.163.com	48
6	Mr.	Danilo Dannug	Supervising Agriculturist, Department of Agriculture Bureau of Plant Industry, Manila	Philippines	naranja112@yahoo.com	118
7	Dr.	Ellina Mansyah	Head, Indonesian Tropical Fruits Research Institute	Indonesia	ellina_mansyah@yahoo.co.id	60
8	Mr.	Felix Miller	Chief Corporate Services, Crops for the Future Research Centre (CFFRC)	Malaysia	felixm@cffresearch.org	59
9	Ms.	Kalolaini Colaitiniyara	Horticulture Section of the Research Division, Ministry of Agriculture	Fiji	kalolainikoto@yahoo.com	70
10	Mr.	Kyle Stice	Research and extension manager, Nature's Way Cooperative (NWC)	Fiji	kylestice@hotmail.com	30
11	Dr.	Lorina A. Galvez	Visayas State University	Philippines	lorina.galvez@vsu.edu.ph	43
13	Mr.	Manoa Iranacolaivalu	Research Officer, Horticulture Section of the Research Division, Ministry of Agriculture	Fiji	iranacola.m@gmail.com	44
14	Dr.	Nick Roskruge	Institute of Agriculture & Environment, Massey University	New Zealand	N.Roskruge@massey.ac.nz	124
15	Dr.	Nguyen Quoc Hung	Director-General, Fruit and Vegetable Research Institute	Vietnam	hungnqrifav@gmail.com	38
16	Mr.	Pascal Liu	Senior Economist, Food and Agriculture Organization of the United Nations	Italy	Pascal.Liu@fao.org	24
17	Dr.	Prakash Patil	Project Coordinator (Fruits), Indian Institute of Horticultural Research (ICAR)	India	pcfruits@gmail.com	43
18	Dr.	Roberta Lauzon	Visayas State University	Philippines	robertalauzon@yahoo.com	103
19	Prof.	Steven J. R. Underhill	University of the Sunshine Coast	Australia	s.underhill@uq.edu.au	81
20	Mr.	Timote Waqainabete	Research and Extension Officer, Nature's Way Cooperative (NWC)	Fiji	timote.w@gmail.com	138
21	Dr.	Wen'e Qi	Researcher, South China Agricultural University	China	qiwene@scau.edu.cn	31

List of participants

#	Title	Name	Designation/Affiliation	Country
1	Mr.	Adre Yagomate	Ministry of Agriculture	Fiji
2	Dr.	Affandi	Indonesian Tropical Fruit Research Institute	Indonesia
3	Mr.	Ajnendra Pranil	Ministry of Agriculture	Fiji
4	Ms.	Amelia Karavanua	Ministry of Agriculture	Fiji
5	Mr.	Ami Chand Sharma	Ministry of Agriculture	Fiji
6	Mr.	Amitesh nand	Ministry of Agriculture	Fiji
7	Dr.	Apaitia Macanawai	Ministry of Agriculture	Fiji
8	Ms.	Aradhna Devi	Ministry of Agriculture	Fiji
9	Mr.	Are Sauliga Matakai	Ministry of Agriculture	Fiji
10	Mr.	Arifurrahman Rusman	International Tropical Fruits Network	Malaysia
11	Dr.	Arry Supriyanto	Indonesian Citrus and Subtropical Research Institute	Indonesia
12	Mr.	Ashok Goundar	Farmer	Fiji
13	Dr.	Ashwini Tiwari	Fiji National University	Fiji
14	Ms.	Ateleni	Ministry of Agriculture	Fiji
15	Dr.	Atish Chand	Fiji National University	Fiji
16	Mr.	Avinesh Dayal	Ministry of Agriculture	Fiji
17	Ms.	Bronwyn Wiseman	PHAMA	Fiji
18	Mr.	Christian Anthony T. Cangao	International Tropical Fruits Network	Malaysia
19	Dr.	Chunyu Li	Guangdong Academy on Agricultural Sciences	China
20	Ms.	Daiana Nabou	Ministry of Agriculture	Fiji
21	Mr.	Danilo Dannug	Bureau of Plant Industry	Philippines
22	Ms.	Dorothy Chandrabalan	International Tropical Fruits Network	Malaysia
23	Dr.	Ellina Mansyah	Indonesian Tropical Fruit Research Institute	Indonesia
24	Mr.	Eremodo T. Kalivetau	Ministry of Agriculture	Fiji
25	Mr.	Felix Miller	Crops for the Future Research Centre	Malaysia
26	Mr.	Filimoni Raiyawa	Ministry of Agriculture	Fiji
27	Dr.	George Y. Culaste	Bureau of Plant Industry	Philippines
28	Dr.	Guiming Deng	Guangdong Academy on Agricultural Sciences	China
29	Mr.	Iowani Kaloulia	Farmer	Fiji
30	Mr.	Isaac Lal	Ministry of Information	Fiji
31	Dr.	Jiwu Zeng	Guangdong Academy on Agricultural Sciences	China
32	Mr.	John David Caldeira	Ra Fruit & Honey	Fiji
33	Mr.	Jope Waqabaca	Ministry of Agriculture	Fiji
34	Mr.	Joseph Chung	Farmer	Fiji
35	Mr.	Josese Tagivetaua	Ministry of Agriculture	Fiji
36	Ms.	Jyotika Deo	Ministry of Agriculture	Fiji
37	Ms.	Kalolaini Colaitiniyara	Ministry of Agriculture	Fiji
38	Mr.	Kyle Stice	Manager, Pacific Island Farmer Org Network (PIFON)	Fiji
39	Mr.	Lasaro Sorovakarua	Farmer	Fiji
40	Dr.	Lorina A. Galvez	Visayas State University	Philippines
41	Ms.	Lusiana Turagakacivi	Ministry of Agriculture	Fiji

List of participants (continued)

#	Title	Name	Designation/Affiliation	Country
42	Ms.	Makereta Pasukamaimaleya	Ministry of Agriculture	Fiji
43	Mr.	Manoa Iranacola	Ministry of Agriculture	Fiji
44	Min.	Inia Seruiratu	Ministry of Agriculture	Fiji
45	Dr.	Mohd. Desa Hj Hassim	International Tropical Fruits Network	Malaysia
46	Mr.	Nareshwar Prasad	Ministry of Agriculture	Fiji
47	Dr.	Nguyen Quoc Hung	Fruit and Vegetable Research Institute	Vietnam
48	Dr.	Nick Roskruge	Massey University	New Zealand
49	Ms.	Olimaipa Tavo	Ministry of Agriculture	Fiji
50	Mr.	Pascal Liu	Food and Agriculture Organization	Italy
51	Mr.	Ponijese Korovulavula	Ministry of Agriculture	Fiji
52	Dr.	Prakash Patil	Indian Institute of Horticultural Research	India
53	Mr.	Pranesh Sagar	Pacific Island Rainforest Foundation	Fiji
54	Ms.	Pritika Sami	Ministry of Agriculture	Fiji
55	Mr.	Rakesh Kumar	Ministry of Agriculture	Fiji
56	Mr.	Robert C. Williams	International Tropical Fruits Network	Australia
57	Dr.	Roberta D. Lauzon	Visayas State University	Philippines
58	Mr.	Saawan Kumar	Ministry of Agriculture	Fiji
59	Dr.	Salesh Kumar	Fiji National University	Fiji
60	Mr.	Sant Kumar	Bula Agro Nursery	Fiji
61	Mr.	Shalendra Prasad	Ministry of Agriculture	Fiji
62	Mr.	Shalendra Reddy	Ministry of Agriculture	Fiji
63	Ms.	Silika Vurebe	Ministry of Agriculture	Fiji
64	Mr.	Simione Lalawailevu	Ministry of Agriculture	Fiji
65	Prof.	Steven JR Underhill	University of Sunshine Coast	Australia
66	Ms.	Sufuawana Hussein	Ministry of Agriculture	Fiji
67	Ms.	Suliana Sala	Ministry of Agriculture	Fiji
68	Dr.	Tekini Nakidakida	Ministry of Agriculture	Fiji
69	Mr.	Timoci Ratuloaloa	Ministry of Agriculture	Fiji
70	Mr.	Timote Waqainabete	Research &Extension Officer- Nature's Way Co-operative	Fiji
71	Mr.	Toloi Vasuidreketi	Ministry of Agriculture	Fiji
72	Mr.	Uraia Waibuta	Ministry of Agriculture	Fiji
73	Dr.	Wen'e Qi	South China Agriculture University	China
74	Mr.	Yacob Ahmad	International Tropical Fruits Network	Malaysia
75	Mr.	Yang	Taiwan Technical Mission	Fiji
76	Dr.	Yi Ganjun	Guangdong Academy on Agricultural Sciences	China

ANNEX 2: POWERPOINT PRESENTATIONS AND PHOTOS

Powerpoint presentations and photos are available at the ISTF2017 website.

Powerpoint presentations: http://www.itfnet.org/istf2017/ppt.php

Photos: http://www.itfnet.org/istf2017/photos.php

INTERNATIONAL TROPICAL FRUITS NETWORK
P.O. Box 334, UPM Post Office
(Block C8, MARDI Headquarters)
43400 Serdang, Selangor
Malaysia

Tel. No.: 603-8941-6589
Fax No.: 603-8941-6591
Email: info@itfnet.org
Website: www.itfnet.org
Facebook: @TFNetOfficial

9 789832 532057