Australian Government

Australian Centre for International Agricultural Research

Final report

project

Tropical tree fruit research and development in the Philippines and northern Australia to increase productivity, resilience and profitability

project number	HORT/2012/095
date published	March 2019
prepared by	Yan Diczbalis
co-authors/ contributors/ collaborators	Lucia M Borines, Roberta D. Lauzon, Lorina A. Galvez, Francisco T. Dayap, Dario T. Lina, Elsie E. Salamat, Alicia Bulawan, Brenda Almeroda, Eric Kent Mapili, Virgilio Loquias, Colin Leung, Mark Hoult and Natalie Dillon
approved by	
final report number	FR2019-111
ISBN	978-1-925747-98-0
published by	ACIAR GPO Box 1571 Canberra ACT 2601 Australia

Contents

1 Acknowledgments

The project team wish to thank jackfruit and fruit growers in the Philippines and Australia who generously contributed their time, support and knowledge to the project.

We also acknowledge the support of our respective institutions and ACIAR for project support and funding.

2 Executive summary

The Philippines contains an extensive collection of tropical fruits, both indigenous and introduced (Coronel 2011) that contribute towards the livelihood of small holder farmers and village food security. The Philippine Government considers that jackfruit, durian and pomelo are emerging industries relative to their established export industry counterparts, such as banana and mango (PCAARRD, 2012) and thus they are being targeted for further research and development to assist their development and export potential.

Recent statistics report that the approximate production areas occupied by jackfruit, pomelo and durian are 14,400, 5,300 and 18,800 ha with associated production volumes of 48,400, 33,400 and 77,500 metric tonnes respectively. The minor crops production data are small in comparison to major export tropical fruits such as banana (450,000 ha producing 9,100,000 tonnes) and mango (190,000 ha producing 825,000 tonnes) (Anit, 2012). Development of jackfruit, durian and pomelo beyond the current domestic supply is limited by low yields associated with disease, poor crop and postharvest management and the lack of processed product to build reliable production and export supply chains.

The Australian tropical fruit industry (lychee, rambutan, pomelo, jackfruit, durian and others), whilst small in comparison, has an excellent collection of genera, species and associated varieties. The industry has developed substantially in the last 20 years and incorporated many advanced technologies. Significant inroads into production, postharvest and supply chain management have been made.

In this project, jackfruit primarily was used as the model crop for investigations on the benefits of nursery hygiene, production technology and processing for industry development.

The primary objectives of the project were multifaceted and included investigation into integrated disease management solutions, investigation of crop management options to improve yield and fruit quality and improved processing options.

In the Philippines, the disease *Phytophthora palmivora* is a major hindrance to production in the nursery and orchard production stages. The project showed that nursery hygiene practices do have an impact on disease introduction and spread in the nursery, which is potentially transferred to the field. The pathogen *Phytophthora* was commonly found in potting media, irrigation water and surfaces in nurseries. The introduction of soilless and sterilised potting media, clean water, rock beds and raised benches, quarantine entry points are all ways of improving nursery hygiene and tree health.

In orchards, disease management was investigated via the use of the plant defence regulator potassium phosphonate. Although the chemical is well proven to assist in the management of Phytophthora in a range of tropical fruits (avocado, papaya, pepper, pineapples, jackfruit and durian), the challenges in complying with registration in the Philippines currently inhibits uptake of the technology. Fertiliser trial results suggested that higher rates of fertiliser in conjunction with organic amendments can increase tree productivity. Investigation of interspecies rootstock scion combinations to improve tree disease resistance and productivity was a core component of the project. Disease susceptibility does vary with jackfruit variety. Several Artocarpus species do display resistance to Phytophthora based on inoculation testing of either detached leaf, stem or intact seedlings. A series of trials demonstrated that interspecies rootstocks is difficult but possible. Data generated suggests that marang (A. odoratissimus), is the most resistant species to Phytophthora. Trial data suggests that it may also impart a dwarfing effect on jackfruit development. Further field testing is required to authenticate the results and test the economics of interspecies grafting as a disease and tree management technique.

Philippine indigenous and introduced Artocarpus species, along with samples from Australia and international sources, were genotyped using DArTseq SNP markers in an effort to better understand the relationships between species with particular reference to

jackfruit and graft success. Further work to examine the relationship between genetic markers and plant traits, such as disease resistance, fruit colour and texture, is now open for further investigation.

The Australian components of the project examined the potential to improve the cyclone resilience of tree crops by trellising. A range of tropical fruit trees, including jackfruit, can be successfully trellised. Terminal flowering crops are difficult to manage on the trellis. During the project, the absence of cyclone effects in the trial area precluded direct testing of cyclone resilience. Trial results demonstrated that trellising is a potential high density production technique that improves fruit quality, ease of harvesting and potentially can improve cyclone resilience by providing a support scaffold to trees that limits tree height. Trials on improved fruit set in lychee and high density rambutan production were also completed under the project. This work supports improved productivity and high density orcharding of tropical exotic species.

The project demonstrated that a range of novel processed products for jackfruit with market potential can be produced. The current range of products developed by the processing team at Visayas State University include dehydrated and vacuum fried product. Fruit maturity is an important factor in producing a good quality processed product. Further work is also required to more reliably identify mature fruit for fresh fruit and processed markets. Extensive work conducted by the Queensland processing team demonstrated that a “fresh cut” product is possible and consumer acceptable with a two week shelf life. The Queensland team also developed sensory profiles to describe jackfruit for market expansion outside of the traditional ethnic markets in Australia.

The project built close links between researchers from three organisations in the Philippines which will lead to improved cooperation in the future. In conjunction with Crawford funding, the project supported capacity building for Filipino researchers, one with specialisation in food processing and sensory evaluation and two horticulture agronomists.

3 Background

Jackfruit (*Atrocarpus heterophyllus* Lam) is a tropical fruit tree grown in most tropical, lowland regions around the world (Saxena et al. 2011). The jackfruit is a multi-purpose species providing food, timber, fuel, fodder and medicinal and industrial products. The primary economic product of jackfruit is the fruit, which is used both when mature and immature (APAARI 2012). It is a promising cash crop in Southeast Asia where it is considered a major fruit (Bareja, 2010). It is a multipurpose species and provides potential sources of income for people in the tropics and subtropics (Hossain and Haq, 2006). The fruit, either ripe or unripe, is the primary economic product (Haq, 2006) with various value added products processed from the fruit.

Jackfruit is one of the most widely grown fruit trees in the Philippines (Acedo, 1992; Lina, 2012). It has a variety of uses and almost all parts of the tree are usable. It is mainly used as food (either fresh ripe fruit or preserved), as a vegetable when green, feed for animals like goats or wood for timber and lumber (such as for guitar making). Some parts are also used as medicine and have many other uses (Haq, 2006).

In 2012 the approximate production area occupied by jackfruit in the Philippines was 14,000 ha, with a production volume of 48,400 metric tons (Anit, 2012). Total production had declined from 51,714 metric tons in 2008 to 46,080 tonnes in 2013 (PSA, 2018). For the area planted, there was minimal increase in hectarage from 14,419 ha in 2008 to 14,526 ha in 2013, with an average annual growth rate of 0.15% (Espino and Espino, Accessed July 2018). The average yield was slightly declining from 3.59 tons/ha in 2008 to 3.17 tons/ha in 2013 at an average annual rate of 2.45%.

A number of jackfruit selections are available in the Philippines with varieties often being selected specifically for a growing region rather than distributed nationally. Jackfruit is a banner commodity in the Eastern Visayas because of the excellent NSIC (National Seed Industry Council) registered jackfruit variety AES-1, or more popularly called ‘EVIARC Sweet’ (EVIARC stands for “Eastern Visayas Integrated Agricultural Research Center”). EVIARC Sweet, which fruits in three years from planting, is claimed to be the world’s sweetest jackfruit, based on a rating of 25.15 degrees Brix (AGRIMAG, 2018).

EVIARC Sweet is a major variety cultivated in over 200 hectares of jackfruit plantations in the cities of Calbayog and Ormoc and different municipalities in Region 8. The variety has been mass propagated by the Department of Agriculture and distributed to farmers through a ‘plant now, pay later’ (PNPL) program which commenced in early 2000 (DA-RFO8, 2012).

Jackfruit is being targeted for further research and development to assist its development and export potential (PCAARRD, 2012). Processed jackfruit food products, like vacuum-fried and dehydrated, were developed by food technologists at the Visayas State University and are starting to appear in the local market. Because of its export potential, the tree has become a component of subsistence and small farmers’ farming.

A major constraint to the production of grafted EVIARC Sweet is its susceptibility to jackfruit decline caused by *Phytophthora palmivora* (Borines et al, 2014). The disease has resulted in significant loss and deterioration of trees on some farms. The disease affects all stages of jackfruit, including nursery seedlings causing dieback. In mature trees, initial symptoms include yellowing of leaves, wilting and defoliation, resulting in death if not managed. The disease was monitored in almost all of the jackfruit plantations that were recipients of the PNPL.

Daniel et al. (2014) and Borines et al. (2013) evaluated a set of disease management recommendations for jackfruit decline and seedling dieback through participatory action research (PAR). These include improved cultural practices such as sanitation, tree mounding, mulching, drainage canals, raised beds for seedlings or use of a resistance booster such as potassium phosphonates. Unfortunately many of the improved cultural

practices recommended, particularly in the nursery environment, were not practised, resulting in the continuation of the status quo (Diczbalis, Fanning, Hoult and Ekman, 2013).

The Australian tropical exotic fruit industry is much smaller than that of the Philippines. It is located north of the “Tropic of Capricorn” with specific production areas in far north Queensland (Cooktown to Tully), Darwin rural communities in the Northern Territory and Carnarvon, Broom and Kununurra in northern Western Australia. The potential value of the industry, prior to cyclone Yasi in February 2011, was assessed as being $16M (Diczbalis, 2012). Over 60 species are produced with 18 having a commercial presence. The top 10 species, by tree number in descending order, are Dragon fruit, Rambutan, Mangosteen, Jackfruit, Pomelo, Durian, Guava, Carambola, Soursop and Duku-Langsat. There are estimated to be approximately 9,200 jackfruit and 5,000 durian trees in production.

There are numerous research and industry development priorities given the extensive range of fruits produced. From an overarching perspective, further R&D priorities include improving cyclone resilience of exotic tropical fruit trees via trellising/canopy management, emergency defoliants to reduce wind resistance and improved propagation methods to improve tree anchorage. This work has just commenced under RIRDC funding. There are opportunities to expand this work with ACIAR funds in conjunction with potential Philippine partners.

There are a number areas of research which would benefit both Filipino and Australian tropical fruit producers. These include; applied nursery hygiene, identification of disease resistant jackfruit clones and or other Artocarpus species, which could be utilised as rootstock,. canopy and nutrition management, non-destructive fruit maturity testing, postharvest storage and improved processing technology of current dehydrated and vacuum fried products as well as the potential for a fresh cut product.

The project aimed to improve the livelihood of smallholder tropical fruit farmers in the southern Philippines and enhance new industry development in tropical Australia by developing a range of production management technologies and processing options which will enhance production and marketing options.

4 Objectives

The project aimed to improve the livelihoods of smallholder tropical fruit farmers in the southern Philippines and enhance new industry development in tropical Australia by developing a range of production management and processing technologies which can be incorporated into fruit production.

The specific objectives include:

Objective 1: To develop and implement integrated disease management solutions to diseases affecting jackfruit

Activities

a. Provide research support for registration and availability constraints for potassium phosphonate (PC).

b. Develop demonstration nurseries at two centres and introduce nursery hygiene regimes to Philippine fruit tree nurseries using information transfer from Australia and demonstration nurseries (PC).

c. Conduct workshops to promote nursery hygiene regimes to Philippine fruit tree nurseries using information transfer from Australia and Philippine demonstration nurseries (PC).

d. Confirm benefits of nursery hygiene protocols by measuring comparative disease loads in the new and conventional system (PC).

e. Initiate work to measure the effect of scion – rootstock combinations for disease resistance (PC).

Objective 2: To develop and implement crop management options which improve productivity and fruit quality in jackfruit

Activities

a. Investigate scion – rootstock combinations and evaluate effects on canopy growth and productivity (PC and A).

b. Evaluate tools to manipulate flowering patterns to spread crop production (PC).

c. Improve crop production by developing crop load and nutrient management techniques (PC).

d. Assess the feasibility of trellising jackfruit, durian and rambutan for cyclone (typhoon) resilience and improved crop production (A).

Objective 3: To develop improved processing options for jackfruit

Activities

a. Refine the current vacuum fried and alternative products produced in the Philippines and evaluate processed products through consumer testing (PC).

b. Investigate ‘fresh cut” processing option and evaluate processed products through consumer testing (A and potentially PC).

5 Methodology

Objective 1: To develop and implement integrated disease management solutions to diseases affecting jackfruit (all Philippines)

Activity a. Provide research support for registration and availability constraints for potassium phosphonate

The project leaders prepared a background briefing note and initiated discussions with PCAARRD and the Fertilizer and Pesticide Authority (FPA) in the Philippines to discuss actions required for the registration of potassium phosphonate (Agriphos 600 or similar) as a plant defence stimulator for the suppression of tree dieback caused by *Phytophthora palmivora*.

In May 2013 the project leader and ACIAR in-country officer met with Dr Norlito R. Gicana (Director FPA). The team was briefed that the essential requirements of registration are;

- Bioefficacy testing by a FPA accredited researcher. Note; funds from the tropical fruit SRA HORT/2012/104 which preceded this project have been utilised for training Dr Lucia Borines and Prof. Elsie Salamat (VSU) to undertake bioefficacy trials.
- A need to garner support from a chemical importer/retailer which leads to an application to import.
- Data generated in previous jackfruit trials, current trials and overseas trials to be used as supporting evidence.

The FPA has a set protocol for registration of plant growth amendments such as potassium phosphonate. Dr Lucia Borines and Prof. Elsie Salamat (VSU) completed training as FPA accredited researchers in Davao City.

Three trials were conducted in Leyte, incorporating nutritional management and phosphonate application. See Objective 2, activity c for trial details.

Activity b. Develop model nurseries at two centres and introduce nursery hygiene regimes to Philippine fruit tree nurseries using information transfer from Australia and demonstration nurseries

Nursery sites at BPI, VSU and DA were sampled for the presence of Phytophthora. Samples were taken from the water source, potting mix ingredients and mixing sites, and growing areas. The results were used to identify the source of Phytophthora in the nursery environment.

Project partners; BPI, VSU and DA in the Philippines, built or modified nurseries using guidelines from the Australian Nursery Industry Accreditation Scheme Australia (NIASA) as benchmarks.

Guidelines to the system include;

- Foot-ware sanitation points at entry points to the nursery to minimise the introduction of off-site pathogens.
- Gravel floor beds or raised benches to avoid contamination with soil splash.
- Introduction of soilless and or sterilised media. Appropriate sterilisation techniques such as solarisation or steam sterilisation were also incorporated, where appropriate.
- Use of accredited clean planting/propagation material.
- Use of new pots or pot washing and sterilisation where appropriate.

- Water treatment (chlorination where the irrigation water is contaminated with Phytophthora).

Establish nurseries and workshop inputs to ensure that best practice recommendations are financially feasible and meet technical requirements for disease management.

Activity c. Conduct workshops to promote nursery hygiene regimes to Philippine fruit tree nurseries using information transfer from Australia and Philippine demonstration nurseries

Yearly workshops on nursery hygiene and appropriate production technology were conducted in conjunction with VSU and DA in Leyte and BPI in Davao for growers. Emphasis on “learning by doing” was utilised to engage tropical fruit growers to help with technology transfer and uptake.

Activity d. Confirm benefits of nursery hygiene protocols by measuring comparative disease loads in the new and conventional system

- Identification of possible sources of Phytophthora in conventional nurseries
  - Samples of potting mixes, soil from germination beds, infected stem and leaves and roots of jackfruit seedlings and irrigation water were collected from different jackfruit nurseries and farms in the Eastern Visayas, Region 8, namely, DA-RIARC Nurseries in San Jorge, Samar and in Abuyog Leyte, Mike Pedroso’s farm in Calbayog, Samar; Job Abuyabor’s farm in Mahaplag, Leyte and VSU (Visayas State University) Nursery in Visca, Baybay City, Leyte, Philippines.
  - Potting ingredient samples from a composite of potting mixes and water samples were taken from water sources/containers, soil flooring in the nurseries and grafting areas. Root samples were also collected from diseased and wilted seedlings. Samples were transferred to the laboratory for Phytophthora detection. Periwinkle flowers (*Catharanthus roseus*) freshly washed and disinfected (with 1% sodium chloride) were used as baits for *Phytophthora*. One gram of soil, potting mix or root sample, or 1 ml of irrigation water was added into the water with the Petal baits and the flower was observed daily for water soaking symptoms, which was an indication of *Phytophthora* infection. The infected petals were examined microscopically for the presence of vegetative and reproductive propagules of the fungus. Phytophthora-specific detection kits (Pocket Diagnostics) were further used to confirm the presence of *P. palmivora* on the different samples.
- Effect of media sanitation, air filled porosity and phosphonate application on plant health.
  - Five trials, two at VSU and three at DA Abuyog, were undertaken to examine the effect of local potting ingredients (soil, partially decomposed rice hulls, carbonised rice hulls, coconut coir and chicken dung), air filled porosity of mixes, media sanitation (solarisation or steaming) and the addition of phosphonate (Phosphro) on jackfruit seedling health and growth.
  - Air-filled porosity ranged from 3.4% for commonly utilised mix (93% alluvial soil + 7% chicken dung) to 34.4% (30% alluvial soil + 35% partially decomposed rice hull + 28% carbonized rice hull +7% chicken dung).
  - In all but the first experiments conducted at VSU and DA, plants were watered twice daily and received weekly applications of foliar nutrients).
  - Where Phosphonate was utilised as part of the treatment regime, the local PhosPhro (4-40-2) was applied as a foliar spray to runoff at 3 mL per L of water.

- Soil sanitation, where added as a treatment, was carried out using a soil steaming technique (Modified 200 L steel drum boiler with the lower portion holding water as the steam source and the upper portion filled with the potting mix with a central flue to allow steam to be evenly distributed through the mix). Soil temperatures were monitored to 65°C (Plate 1a and 1b). The system was introduced from ACIAR trials in Fiji.
- Data collected included; plant height, stem diameter and plant health ratings.

Plate 1a. Water compartment at base of 200 L drum with wooden spacers for the plywood base.

Plate 1b. Plywood base and vented flue to distribute steam

Activity e. Initiate work to measure the effect of scion – rootstock combinations for disease resistance

A range of Artocarpus species are endemic or introduced in the Philippines. Most species, except jackfruit that is produced commercially, appear to be resistant to Phytophthora. The use of the Artocarpus species, other than A. heterophyllus as rootstocks, may offer the potential for resistance to *Phytophthora palmivora*. Scion – rootstock combinations in Artocarpus species are rare and not well documented in the literature. Jackfruit (*Artocarpus heterophyllus*) has been successfully grafted onto other species (A. integer, A. odorotissimus) in preliminary studies conducted in northern Australia. The work related to this activity included;

- Collect and evaluate Phytophthora resistance of Artocarpus species using either detached leaf, stem or seedling inoculation techniques.
- Conduct compatibility scion-stock trials using jackfruit as the scion.
- Conduct, grafting trials to measure compatibility success and field growth.
- Initiate field trials of scion-stock combinations. Commence growth and disease susceptibility measurements.

The specific collection sites of the different *Artocarpus* spp. were: Abuyog, Baybay, Inopacan, Hindang, Mahaplag, Capoocan, Leyte-Leyte, Matag-ob, Barugo, and Jaro in Leyte; Silago, Anahawan, San Juan, St. Bernard, Libagon, Bontoc, Macrohon, Padre Burgos, Tomas Oppus and Maasin in Southern Leyte, Caibiran, in Bilran Province and San Jorge and Calbayog in Samar. *A camansi* seeds were also procured from the National Plant Genetic Resources Laboratory (NPGRL) at the Institute of Plant Breeding in UPLB.

The collected seeds were grown and maintained in the screen house for resistance screening against *P. palmivora.* For all species identified and collected, leaf and shoot tip samples were collected and submitted to the Australian component leader for genotyping.

Artocarpus species collected include: *A. altilis, A. blancoi, A. camansi, A. elasticus, A. integer, A. lakoocha, A. lancaefolius, A. nitudus, A. odoratissimus, A. rigidus, A. sericicarpus, A. vrieseanus*. Seedlings of the above species and a jackfruit control were soil, stem and leaf inoculated with *P. palmivora* and disease symptoms, severity and resistance rated.

Resistant species were tested for graft compatibility as rootstock for Jackfruit by colleagues at DA Abuyog and BPI, Davao and DPIR NT. Due to the difficulty of interspecies grafting, limited field plantings of interspecies grafts occurred at BPI in Davao, Mindinao and DA at Babatngon, Leyte. The effect of these interspecies graft combinations on disease resistance of jackfruit in the field is still being monitored.

Objective 2: To develop crop management options which improve productivity and fruit quality in jackfruit

Activity a. Investigate scion-rootstock combinations and evaluate effects on canopy growth and productivity (PC and A)

Scion – root stock combinations created in the disease resistance component of the work were also examined for their effects on canopy development. Evidence from some early trials conducted in the Northern Territory indicate that the use of alternative Artocarpus species as rootstock can have a marked dwarfing effect on jackfruit (Hoult, *pers. com* 2012).

A range of Artocarpus species were trialled as rootstock by nursery staff at DA Abuyog and BPI Davao. Success rate recorded and field planted for observation of tree development where viable grafted plants where available.

The following rootstock-scion combinations were tested;

- Marang- Jackfruit (*A. odoratissimus- A. heterophyllus*)
- Tugop- Jackfruit (*A. elasticus- A. heterophyllus*)
- Tipolo- Jackfruit (*A. blancoi- A. heterophyllus*)
- Camansi- Jackfruit (*A. camansi- A. heterophyllus*)
- Chempedak-Jackfruit (*A. integer- A. heterophyllus*)

Data gathered included; grafting success at 6 months, and plant height, stem girth below and above graft, branch number, canopy area, fruit set of field planted trees.

Interspecies grafting trials were also conducted at BPI, Davao from 2014 to 2018. The experiment consists of four (4) species, namely: A. odoratissima (Marang); A. blancoi (Tipo); A. camansi (Kamansi/Breadnut) and A. heterophyllus (Jackfruit). Rootstock were selected from seedlings that had developed true leaves with attached cotyledons. The seedlings were grafted to Jackfruit scions after two months. The rootstocks were unwatered for two days, a technique to reduce the latex flow prior to grafting.

Sion material was pre-prepared by tipping new shoots and removing leaves from the shoot up to a fortnight prior to removal from the mother stock tree. The preferred scion wood was well exposed to sunlight with swollen buds in the leaf axils. Wedge grafting was carried out by creating a wedge on the scion wood prior to insertion into a vertical cut in the stock plant stem, which were bound together by grafting tape. The grafted seedlings were covered with plastic tubes to prevent water entry into the grafting union. The plastic tube was removed after two to four weeks, or when the terminal bud of the scion had unfolded its leaf, to allow the scion to continue to grow.

The grafted plants were maintained in the nursery for six months before they were transplanted to the field. Staking was done with 4 x 4 meter spacing, and holes (50 cm wide and 50 cm depth) were prepared. Trees were planted in a RCB design replicated three (3) times.

Genotyping

In an attempt to understand interspecies grafting success or failure from the perspective of genetic relationships, leaf samples of 336 individuals from 22 Artocarpus species were collected from research stations and farmer fields in seven countries between the years 2014 – 2018. Samples were primarily collected within the countries aligned to the project (Philippines and Australia), but where other project or private travel allowed, samples were also collected in Sulawesi, Indonesia; Hawaii, USA; Fiji and Samoa.

Healthy, young, flushing leaf buds were collected from individual trees. Where leaf buds were not available, the next youngest leaf material available at the time was collected. Leaf samples were placed into sealed plastic bags containing silica gel packs for transport back to the Department of Agriculture and Fisheries (DAF) laboratory in Mareeba, Queensland, Australia, where DNA extraction was performed. Each tree sampled had morphological and agronomic traits recorded where possible.

Nucleic acid extraction was performed on 60 – 80 mg fresh leaf tissue or 15 - 20 mg samples of silica-gel dried leaf tissue using the DNeasy® Plant Mini kit (Qiagen® Pty Ltd, Chadstone Centre, Victoria, Australia) and TissueLyser II (Qiagen® Pty Ltd) for disruption of the plant cells. Extractions were carried out according to manufacturer's instructions. DNA was quantified using a NanoDrop 2000 UV-Vis Spectrophotometer (Thermo Scientific, Wilmington, DE, USA) and using a Qubit™ 3.0 Fluorometer (Thermo Scientific). Genomic DNA integrity was assessed by 1% (w/v) horizontal gel electrophoresis. Extracted genomic DNA was stored at 4°C and diluted to a final concentration of 50 - 100 ng.μL^{-1} prior to DArT genotyping analysis.

PCR amplification

PCR amplification was undertaken to ensure the genomic DNA was suitable for DArT analysis. PCR primers for the amplification of the chloroplast ribulose 1,5-bisphosphate carboxylase large subunit (rbcL) gene were used to amplify a region approximately 600 bp in length.

Table 1. SSR marker sequences used for genotyping *Artocarpus* samples

Primers	Sequence 5' - 3'	Reference
rbcLa-F	ATGTCACCACAAACAGAGACTAAAGC	Levin et al, 2003
rbcLa-R	GTAAAATCAAGTCCACCRCG	Kress et al, 2009

rbcL primer sequences used for quality check of genomic DNA

Total PCR volumes were 20 µl and contained 1 x *Taq* DNA polymerase reaction buffer +$(NH_4)_2SO_4$, 3.125 mM $MgCl_2$, 62.5 µM of each dNTP, 0.625 µM of each forward and reverse primer, 1 U of *Taq* DNA polymerase (Thermo Fisher Scientific, Scoresby, Victoria, Australia) and 1 µl of template DNA. Reactions were performed in a MyCycler™ thermal cycler (BioRad, Hercules, CA, USA) with an initial denaturation at 94°C for 5 min followed by 35 cycles consisting of denaturation at 94°C for 30 s, annealing at 55°C for 30 s and extension at 72°C for 1 min, with a final extension at 72°C for 5 min.

Eight microliters of each PCR product was subjected to electrophoresis in a 2% (w/v) agarose gel with EZ-Vision® Three DNA Dye (Amresco®, Solon, OH, USA) in 0.5 x TBE buffer and observed under UV illumination. Five microliters of the DNA molecular weight marker HyperLadder™ 50 bp (Bioline Pty Ltd, Alexandria, NSW, Australia) was run on each agarose gel to determine the molecular weight of amplification products.

Genomic DNA quality was also checked by incubating 1 µl gDNA in 1x restriction enzyme buffer NEBuffer 4 (20 mM Tris-acetate, 10 mM magnesium acetate, 50 mM potassium acetate, 1 mM dithioltheitol, pH 7.9 at 25°C; New England Biolabs, Inc., Ipswich, MA, USA) at 37°C for 2 h. The DNA was then resolved on a 0.8% (w/v) agarose gel with EZ-Vision® Three DNA Dye (Amresco®) in 0.5 x TBE buffer and observed under UV

illumination. This mock digest is to detect the presence of buffer-activated nucleases. Good quality DNA will show a high molecular weight band on the gel image.

Simple sequence repeat (SSR) marker analysis

A selection of 12 SSR markers (Table 1) Witherup et al. (2013) were selected for genetic diversity analysis of 186 *Artocarpus* genomic DNA samples. Genotyping services were provided by the Australian Genome Research Facility (AGRF). The addition of a pigtail sequence (a seven base pair sequence (GTTTCTT) to the 5' end of the reverse primer reduces slippage during PCR. The pigtail also assists in stopping the A+ing of peaks and reduces the variation in the stutter peaks, especially in di-nucleotide repeats. Reduction of the A+ing assists in genotyping the samples.

Table 1. SSR marker sequences used for genotyping *Artocarpus* samples

Marker	Forward Sequence 5'-3'	Reverse Sequence 5'-3'	Repeat motif	Size range
MAA140	6FAM-CCATCCCCCATCTTTCCT	GTTTCTTTCCTCGTTTGCCACAGTG	$(CT)_{25}$	129-170
MAA219	6FAM-ATTTGCATCATGTAGGACA	GTTTCTTGGACACAACGACATTGAC	$(CAT)_8$	247-277
MAA9	NED-AACAGGGTTAAAATCCCTTCAC	GTTTCTTGTTCCCGTTTTGTTCAAAGAG	$(CA)_{15}$	153-173
MAA26	NED-CATGAATGAAACAACATCAGAC	GTTTCTTATAGTCATAAAGCCCTGCG	$(GT)_9$	273-297
MAA182	PET-TACTGGGTCTGAAAAGATGTCT	GTTTCTTCGTTTGCGTTTGGATAAAT	$(CT)_{19}$	182-216
MAA122	VIC-CTGGCCTTCAGTTTTGTCAAC	GTTTCTTCACCAGGCTTCAAGATGAAA	$(GT)_{11}(GA)_4/(GA)_{11}$	241-312
MAA71	6FAM-TTCCTATTTCTTGCAGATTCTC	GTTTCTTAGTGGTGGTAAGATTCAAAGTG	$(CT)_{11}(CA)_{19}$	152-184
MAA105	6FAM-GTTGGGACACTGTGAACTATTC	GTTTCTTAAAAGCTAGTGGATTAGATGCA	$(GT)_{11}$	265-293
MAA40	PET-AGCATTTCAGGTTGGTGAC	GTTTCTTGTTGTTCTGTTTGCCTCATC	$(TG)_{16}$	170-192
MAA96	NED-GGACCTCAAGGATGTGATCTC	GTTTCTTACACGGTCTTCTTTGGATAGC	$(CA)_{14}(TA)_7(TG)_3$	176-220
MAA287	VIC-CTTCCCACTAAATGTAAACG	GTTTCTTTCTCAAACAATGGAGTGATC	$(TCTA)_5$	179-223
MAA156	VIC-CTGGTGCTTCAGCCTAATG	GTTTCTTTCAGCGTCAAAGATAACTCG	$(GA)_3/(GA)_5/(GA)_8/(GA)_{13}$	257-307

DArTSeq platform development

A total of 322 accessions of *Artocarpus* were used for DArT marker development in this study. The DArTseq technology was optimized for *Artocarpus* by selecting the most appropriate complexity reduction method (both the size of the representation and the fraction of a genome selected for assays). Two methods of complexity reduction were tested in *Artocarpus* (PstI-HpaII and PstI-MseI; data not presented) with the PstI-MseI method being selected. DNA samples were processed in digestion/ligation reactions predominantly as per (Kilian et al. 2012) but replacing a single PstI-compatible adaptor with two different adaptors corresponding to two different Restriction Enzyme (RE)

overhangs. The PstI-compatible adapter was designed to include Illumina flowcell attachment sequence, sequencing primer sequence and “staggered”, varying length barcode region, similar to the sequence reported previously (Elshire et al. 2011). Reverse adapter contained flowcell attachment region and MseI-compatible overhang sequence. Only “mixed fragments” (PstI-MseI) are effectively amplified in 30 rounds of PCR. The reaction conditions were 94°C for 1 min, followed by 30 cycles of 94°C for 20 sec, 58°C for 30 sec and 72°C for 45 sec, and then followed by a final extension step of 7 min at 72°C. After PCR, equimolar amounts of amplification products from each sample were bulked and sequenced on HiSeq2500.

The sequencing (single read) was run for 77 bases per cycle. Sequences generated were processed using proprietary DArT analytical pipelines. In the primary pipeline the fastq files are first processed to filter away poor quality sequences, applying more stringent selection criteria to the barcode region compared to the rest of the sequence. In that way the assignments of the sequences to specific samples carried in the “barcode split” step are very reliable. Approximately 1.3 million sequences per barcode/sample were used in marker calling. Finally, identical sequences are collapsed into FASTQCOL. The propriety software package DArTsoft14 is used for marker discovery and scoring from FASTQCOL files. The FASTQCOL files from the *Artocarpus* samples were analysed using DArTsoft14 to output candidate SNP and silicoDArT markers which are polymorphic within the set of samples (Silico- DArT markers are sequences with presence/absence variation in the DArTseq genomic representation). All unique sequences from the set of FASTQCOL files are identified, and clustered by sequence similarity at a distance threshold of 3 base variations. The sequence clusters are then parsed into SNP and silicoDArT markers utilizing a range of metadata parameters derived from the quantity and distribution of each sequence across all samples in the analysis.

A high level of technical replication is included in the DArTseq genotyping process, which enables reproducibility scores to be calculated for each candidate marker. The candidate markers output by DArTsoft14 are further filtered on the basis of the reproducibility values, average count for each sequence or row sum (sequencing depth), the balance of average counts for each SNP allele, and the call rate (proportion of samples for which the marker is scored).

Activity b. Evaluate tools to manipulate flowering patterns in jackfruit to spread crop production (PC)

The mechanisms behind flower induction and flower manipulation in jackfruit are not well understood. Jackfruit flowers are produced at the end of short shoots (footstalks), which emerge from axils on the trunk and branches. Female flowers are predominately produced from footstalks, which emerge from the main trunk and branches, while male flowers form predominately in the upper portion of the tree. The number of fruits set per tree is dependent on the number of female inflorescences produced and the male to female ratio (Lina, 2012).

In Leyte there are two distinct periods of fruit production, the main season (June to October) and the low season (December to February). The timing of these events varies from year to year depending on location and seasonal conditions. Prices achieved during the high season are low. A more even availability of fruit would benefit growers and consumers.

Trials were conducted to investigate the effect of rate and timing of several flower induction techniques on flowering and subsequent fruit set.

Trial implementation scheduled to commence in 2014 was delayed until early 2016 due to Typhoon Yolanda (November 2013) laying waste to many of the regions jackfruit orchards. The trial, was established at Fran’s Farm in Marhen, Ormoc, Leyte and designed to evaluate the effect of different treatment applications on jackfruit flowering. The following treatments were laid in randomized block design with 4 replications:

1. Control
2. Removal of old fruit stalks which have not set immediately after cropping
3. Strategic pruning (top and lower branches of canopy) + fruit stalk removal
4. Nitrogen Injection Urea (1 kg/L) at 80 ml per tree - using chem-jets injectors.
5. Combination of pruning and nitrogen injection (1 kg/L) at 80 ml per tree
6. Nitrogen applied as a granular fertilizer at 1.25 kg per tree to promote new growth
7. Combination of pruning and granular nitrogen application
8. Pruning of top and lower branches of canopy + Drenching of Paclobutrazol (36 ml/L/tree) + Injection of $CaNO_3$ (2.5 kg/L) at 80 ml per tree
9. Strategic pruning of both Upper and lower canopy + Drenching of Paclobutrazol + Drenching of $CaNO_3$ (2.5 kg/L) at 1 L per tree

Application of treatments was completed in July 2016, prior to the off-season. A number of female flowers that emerged a month after application were recorded up until November and female flowers were tagged for recording. Follow up management included the application of two sacks of organic fertilizer per tree. Under-tree brush cutting and ring weeding was completed twice a year.

Activity c. Improve crop production by developing crop load and nutrient management techniques (PC)

There is a large diversity of fruit size among jackfruit selections. Jackfruit have been recorded up to 60 kg in weight. Most commercial lines of Jackfruit produce 30 plus fruit at 8 to 12 kg in weight (300 kg/tree).

The general effect noted by farmers in Australia and the Philippines is smaller fruit size, particularly for late setting fruit and the start of tree decline in areas without a fertiliser program. Some growers practice crop load management to ensure the production of quality fruit and to delay the onset of tree decline. Dayap, et al (2012), in a PCAARRD supported study, reported that the addition of DA recommended rates of fertiliser improves yield through improved fruit size. Regulation of fruit numbers to 15 in the on-season and 8 fruits in minor-season is considered optimal for producing fruit of maximum weight, an important commercial consideration. The authors suggested that an additional three years of data is required to give conclusive results and validate the data.

As part of this study three trials were conducted. The first, in conjunction with a private grower, and the second on the DA research station at Abuyog, utilised nutrition management that was combined in a split plot arrangement with fruit load regulation (unregulated and 15 fruit maximum) and the application of potassium phosphonate (no phosphonate + phosphonate).

Trail details

Trial One – Mahaplag, Leyte, Jackfruit farm Mr. Job Abuyabor

Fertiliser – main plot

- A0 - Grower practice – 1 - 2 bags of chicken bedding (rice hull with chicken manure)
- A1 - 250 g complete fertilizer (16-16-16), 200 g muriate of potash (0-0-60), 15 kg OM
- A2 - 500 g complete fertilizer (16-16-16), 400 g muriate of potash (0-0-60), 30 kg OM
- A3 - 750 g complete fertilizer (16-16-16), 600 g muriate of potash (0-0-60), 45 kg OM
- A4 - Commercial organic fertilizer from Ormoc (N-1.66%, P-5466 mg/kg, K-6410 mg/kg)

Phosphonate – subplot

- B1 - Phosphonate was applied via soil drenching and foliar spraying using a motorized sprayer. The application was based on recommended rate of 1 L of PhosPro to 200 L water with follow-up application after 15 days for spraying and 1 L of PhosPro in 40 L of water. Two litres of phosphonate solution was applied to each tree as soil drenching. This was applied at two week intervals for four consecutive times
- B2 - Without Phosphonate

Fruit load regulation – sub-subplot

- C1 - Unregulated
- C2 - Regulated (15 fruit max)

Trial 2 – VSU Pomology field trial, BayBay, Leyte

Fertilizer – main plot

- F0 - Control no inputs
- F1 - Complete fertilizer (CF), two applications/year: Y1- 100 g and 150 g/tree; Y2- 250 g and 500 g/tree (16-16-16)
- F2 - Organic fertilizer (OF), two applications/year: Y1- 5 kg and 10 kg/tree; Y2-15 kg and 30 kg/tree; (carbonized rice hull with sludge: N=0.4243%, P=1.1403%, K=0.6015%)
- F3 - OF + 50% CF, Two applications/year: Y1- 5 kg OF + 50 g CF and 10 kg OF + 65 g CF; Y2 -15 kg OF + 125 g CF and 30 kg OF + 250 g CF

Phosphonate – subplot

- P0 - Without phosphonate
- P1 - Applied once year at the rate of 2 L Phosphonate/40 L water as drench and 1 L phosphonate/200 L water as spray, applied 4 consecutive times at two weeks interval.

Trial 3 – DA Abuyog Experimental Station, Leyte RCBD Trial with three replications

Phosphonate – main plot

- A - with phosphonate treatment (Application of phosphonate was done by two methods, drenching and spraying, 2 meters away from the base of the tree. Drenching was carried out by mixing 1.5 litres of phosphonate (PhosPro 4-40-2) per 30 litres of water and 2 litres of solution per sample tree. This was done over four consecutive weeks. Spraying was by mixing 500 ml phosphonate (PhosPro 4-40-2) into 100 litres of water and 16 litres per sample tree. This was done twice in 15 days interval)
- B - without phosphonate treatment

Fertiliser – subplot

- T0 - Control (no application of fertilizers)
- T1 - Rec. Rate (RR) (30 kg OF + 800 g T-14 + 800 g MOP/tree)
- T2 - 50% below RR (15 kg OF + 400 g T-14 + 400 g MOP/tree)
- T3 - 50% above RR 45 kg OF + 1200 g T-14 + 1200 g MOP/tree)
- T4 - Organic Fertilizer alone (30 kg/tree)

Activity d. Assess the feasibility of trellising tropical fruit trees for cyclone (typhoon) resilience and improved crop production. Evaluate early performance of clonal marcotted rambutan hedge systems (A)

In Australia, trellis trials to examine the suitability of a range of tropical tree species for trellising were conducted. Trellising is viewed as a way to minimise tree loss during cyclonic events, which the region producing the bulk of tropical fruit commonly experiences e.g. Cyclone Larry in 2006 and Cyclone Yasi in 2011. The trellising of trees necessitates consideration of tree growth and flowering habits. Jackfruit is monoecious with both male and female flowers on the same tree. Flowers (male or female) are borne separately on short axillary leafy twigs “footstalks” which develop from the main trunk or mature branches. The tree structure and flowering habits potentially lends itself to trellising.

Durian flowers are perfect with both carpels and stamens present. Flowers are borne on the main branches (ramiflorous) and occasionally on the main trunk (cauliflorous). The tree structure and flowering habit lends itself to trellising.

Rambutan flowers are borne on terminal inflorescences, with flowers of commercial varieties being hermaphrodite, effectively female in nature. Of the tree species the terminal flowering rambutan is the least likely to be adaptable to trellis culture.

Trial 1

Sixty four Durian trees (varieties P88, Gumpun, Ganyaw, Kradom Tong, Red Prawn) were grown on an open V Trellis (open Tatura) trial block established on a cooperative grower’s property on the Tropical North Queensland coast near Tully in 2013. The V Trellis trellis had 5 wires, the first at 70 cm, then at 40 cm spacing’s with a total height of 2.4 m (Plate 2). The base of the V trellis was 0.5 m apart and the poles angled at 17.5° from vertical. Trees were irrigated with micro sprinklers, mulched, weeded and fertilised regularly to encourage vigorous growth.

Plate 2. Durian on Tatura (V) trellis.

Plate 3. Cocoa on espalier with horizontal branches.

Trees were stagger planted 2.85 m apart on each side of the trellis giving a planting density of 1559 trees/Ha at a 4.5 m row width. Trees of all varieties were trained with a single central leader with horizontal lateral branches on each of the wires. The central leader was weaved between the trellis wires as it grew to provide additional support during cyclonic winds rather than just relying on the wire fasteners used in training for support.

To train the trees onto the trellis wires, both adjustable rubber and hard plastic fasteners were used. The adjustable ties were good for variable sized branches, as they stretched so they did not cause ring barking or break easily and could be reused, however they

were expensive. The plastic fasteners were cheaper and they didn't move on the wires so they were good for holding branches in position but were brittle and can cause ring barking.

Observations of growth habit, tree vigour, branching patterns, flowering, fruit quality and cropping levels were collected over a four year period as the trees established and matured on the trellis. The aim of the trials was to determine the suitability of Durian for trellis production and to provide some guidelines for growing Durian on trellis.

Trial 2

A trellis trial block was established on the South Johnstone research station near Innisfail in North Queensland in May 2013. Guava (variety Thai White), longan (variety Kohala) and cocoa (seedlings) were chosen for the trial because of their different growth and flowering characteristics. Trees were planted on two different trellis designs (open Tatura "V" and fence) and as free standing conventionally planted trees. All plants were planted at a 3 m spacing in each of the three planting systems. For the calculation of yields/ha it was assumed that the rows of each planting system in a commercial orchard situation would be planted as close as possible with consideration of shading and machinery access. A row spacing of 4.5 m was used for the Tatura trellis, giving a tree density of 1480 trees/ha, a 3 m row spacing was used for the fence trellis giving a tree density of 1110 trees/ha and a 5 m row spacing was used for the conventionally planted trees giving a tree density of 667 trees/ha. For both trellis designs 5 wires 40 cm apart were used, giving a 2 m trellis height.

For each of the three species, the trees growing on the trellises were trained onto the wires with a single central leader using either the palmette (fanned branches at 45°) or espalier (horizontal branches at 180°) training method. For cocoa, an additional training method called upright fruiting offshoot (UFO) was also tested. In this training method the seedlings were laid over at 45° to encourage side shoot development and these shoots were trained using the fanned method. The central leader was weaved between the trellis wires and the lateral branches wrapped around the wires as they grew to provide additional support during cyclonic winds rather than just relying on the wire fasteners used in training for support. The conventionally planted free standing trees were pruned according to normal industry standards. Trees were irrigated with drippers, mulched, weeded and fertilised regularly to encourage vigorous growth.

Observations of growth habit, tree vigour, branching patterns, flowering, fruit quality and cropping levels were collected over a four year period as the trees established and matured on the trellises. The aim of the trials was to determine the suitability and production levels of the three different tropical fruit trees grown on different trellis types using different training methods and comparing this with the performance of conventionally planted trees.

Guava

Guava trees are extremely vigorous and have good natural branching so were quickly and easily established on the fence and Tatura trellises. Branches are flexible and easy to bend and tie to the trellis wires. Vigorous growth and good branching allowed vertical (central leader) and horizontal or fan growth (laterals) to be developed together. Good branching allowed sub laterals to be established at regular intervals (15 cm) along the main lateral. The sub laterals were pruned about 30 cm from the lateral so that they did not cross the wires above or below or cause too much shading. The conventional free standing trees were pruned with branches radiating out from a central leader as they are in commercial orchards. The good lateral and sub lateral development combined with the axillary flowering habit of guava produced plenty of sites for flowering and cropping.

Longan

Longans (cv. Kohala) have vigorous vegetative growth and can be established reasonably easily and quickly onto a fence or Tatura trellis. The poor natural branching on occasions made it difficult to develop all of the main and sub laterals in the correct positions. In hindsight it may have been better to develop vertical and lateral growth separately rather than together as was done in this trial.

During establishment the main stem (central leader) was allowed to grow continuously to the top wire and then tipped. Branching from this central leader was used to form the main horizontal or fanned laterals and all the other shoots on the main stem were removed. The sub laterals on the main branches were developed in the same way, by selecting branches at 10-20 cm intervals along the lateral to form sub laterals, and all the other shoots were removed. The sub laterals were pruned back to 3-4 nodes while the main lateral was allowed to continue growing along the wire. Growth from the sub laterals became the primary site for flowering and cropping in the mature trees. The conventional free standing trees were pruned to a single trunk to 50 cm height with a rounded vase shaped canopy.

Longan trees handled the frequent pruning without any damage or sunburn on the stems or fruit.

Cocoa

Cocoa trees have an unusual growth and fruiting habit compared to many other tropical tree crops. This presents both advantages and possible disadvantages to trellising. The flowers and fruit are borne on the main trunk and branches, therefore yields increase quite slowly in early establishment because it takes some time for the stems and branches to develop to sufficient size to start cropping. This limits the very early yield advantages of trellising seen in other crops. Cropping from the main stems is an advantage once the main branches and stems have been established because the fruit is easily accessed for harvesting. Also because Cocoa can flower and fruit off the same wood year after year, the cropping laterals developed can be left in place permanently and fruit harvested from roughly the same position. This presents the possibility of being able to mechanically or robotically harvest the fruit in the future.

The unusual vegetative growth habit of seedling cocoa also presents some challenges for trellising. The trees have two distinct types of branches, orthotropic which grows vertically and plagiotropic which grows horizontally. Growth of the main stem and any side shoots from the main stem initially only grow vertically, which is the case for newly planted trees (a genetic instinct to reach for the light from a rainforest floor). These upright shoots are called chupons or suckers. Once these vertical shoots reach around a meter or more in height they stop growing vertically and produce a whorl of 3-5 branches called a jorquette. These are horizontally orientated. The tree grows taller when the process is repeated and a chupon shoot is produced from the main stem below the jorquette and grows up through the horizontal branches until it forms another jorquette of horizontal branches above the previous one. This growth habit presents a challenge for trellising trees but is quite useful for establishing conventionally planted free standing trees because they tend to form a single trunk at least a meter tall and a canopy of horizontal branches above this, which makes access for harvesting and harvesting itself quite easy. The problem arises in accessing fruit higher in the canopy beyond the first jorquette of branches. If the natural growth habit of cocoa can be modified using trellising, it might be possible to develop rows of trees with a narrow two dimensional scaffold of evenly spaced permanent fruiting branches starting from close to the ground up to a fixed height (Plate 3). This could increase yields and would allow for easy access to the trees for harvesting and other management operations.

The exception to the growth patterns described above occurs if trees are propagated from plagiotropic wood either by cutting or grafting, as this will produce trees with only plagiotropic branches.

Rambutan- evaluation of clonal hedge production systems established by marcotts.

A key industry constraint to further rambutan development in northern Australia is the lack of cost effective planting stock of elite commercial cultivars. This reflects a high level of propagation skill required, a long propagation time frame (up to 2 years) and small volume requirements of propagules, which makes it unattractive for wholesale nurseries to produce. Earlier research identified marcotting (air-layering) of rambutan as potentially an economical and efficient method of clonal propagation in northern Australia. It has also proven to be a method for establishing new plantings that orchardists have recently adopted. However long term field evaluation of the commercial viability of own-rooted marcotts, comparative to budded propagules, has not been undertaken. The trial work evaluated the early performance of a clonal hedged, orchard system established from marcotts for the leading four commercial rambutan cultivars in the NT.

Continued evaluation of these under this ACIAR project, will quantify marcott influences in rambutan and assess the commercial applicability of clonal high density hedge systems for north Australian rambutan producers.

Objective 3: To develop improved processing options for jackfruit

Activity a. Refine the current vacuum fried and alternative products produced in the Philippines (PC)

Measure the effect of fruit maturity on the quality of fresh and processed product (PC)

The first study completed in Objective 3, was the evaluation of fruit maturity and its effects on the quality and acceptability of vacuum fried sweet jackfruit '*Artocarpus heterophylus Lam'* chips produced at Eastern Visayas Integrated Agricultural Research Center (EVIARC). Four maturity periods; 85, 88, 91 and 94 days after bagging of fruits were studied. Furthermore, the effect of fruit location on tree, flesh location in fruit, size and thickness of flesh were the conditions evaluated. Analysis of physico-chemical properties include; pH, total titratable acidity (TTA), total soluble solids (TSS), thickness and pectin of fresh mature flesh. Additionally sensory attributes includes; colour, aroma, texture, oiliness and general acceptability of vacuum-fried jackfruit flesh were evaluated by semi-trained panellists. Consumer acceptability was determined by subjecting the product to consumer evaluation and results show that fruit maturity significantly influenced product acceptability.

A second set of trials were conducted to examine fruit maturity that was based on the number of days after anthesis (DAA) until the fruit was harvested for processing. Three stages of maturity that were used include 110, 120 and 130 DAA. Anthesis is the term given to the opening of either female or male inflorescence of jackfruit. An inflorescence is said to have opened already when the stipule unfolds to at least a 30 to 40° angle from its apex to the base. Tagging was done at the farm during anthesis and only the female inflorescences were tagged. Constant monitoring was performed until the desired maturity was attained and the fruits were harvested. The harvested fruits were stored at the pilot plant for five days prior to processing.

The quality of the fruit after harvest and after storage were evaluated and compared. The parameters that were evaluated for the external indices included the peel colour, spine density (number of spines per unit area), average volume, average weight and density of the fruit. Physical and chemical properties of the fruit pulp (deseeded fruit bulb) including the colour, firmness, thickness, total soluble solids, pH and titratable acidity were also evaluated. All of these analyses were performed, both for the fruits after harvest and after five days of storage to compare the effect of maturity and storage on the identified maturity indices.

Comparison of methods used for identifying fruit maturity (NIR, acoustic and heat-sums) (A)

Non-invasive measurement methods can be a useful way of determining fruit maturity by predicting a combination of chemical characteristics. Developing an appropriate calibration model requires reference or 'training sets' that cover not only the entire spectrum of quantities of interest (i.e., dry matter %, etc), but also compositional space, instrument space and measurement condition space (e.g., sample handling and presentation). This avoids the need to extrapolate beyond the boundaries of the calibration set and makes the calibration robust and extensive. Temporal and spatial effects have major impacts on the robustness of the NIRS calibration models and must be incorporated into the development of the calibration model.

The spectral characteristics of the jackfruit were measured on a bench top Matrix-F, FT-NIR spectrophotometer (Bruker Optics, Ettlingen, Germany; operating software: OPUS™ version 5.1 - 6.5) in the 830 – 2500 nm range. Spectra were obtained in diffuse reflectance mode, using a standard 4 x 20 watt tungsten light source fibre-coupled emission head fitted to the spectrometer.

The external emission head was placed directly above the jackfruit (0° configuration). A light reducing box with a 60 mm diameter cut out window was used to hold the jackfruit, so that the area of interest was directly exposed to the focal point of the emission head. A path-length of approximately 170 mm from the external emission head light source to the surface of the jackfruit provided a spectral scan diameter on the area of interest of approximately 50 mm.

Initiate trials to improve overall quality of vacuum fried jackfruit chips (PC)

Packaging and processing optimisation trials were completed at Visayas State University (VSU) to improve the overall quality of the vacuum fried jackfruit chips. Optimisation by packaging include nitrogen gas flushing, oxygen observer evaluations, which evaluated the influence on physico-chemical properties, microbial properties, shelf life quality, sensory quality and consumer acceptability. This study focused on the storage study of the vacuum fried jackfruit pulp. Approximately 30 grams of the vacuum fried jackfruit pulp processed from the 120 DAA fruit maturity was packed using a 0.10 mm thick metallized laminate bag and different thickness of plastic packaging materials.

Three methods of packing were used as the treatments including the control, nitrogen flushing and the use of an oxygen absorber. Samples prior to packaging were subjected to analyses to obtain the initial data. Vacuum fried jackfruit pulps were packed following the identified treatments. For nitrogen flushing, the samples were packed using an electric pumping (filling) gas automatic vacuum machine with 10 MPa nitrogen gas. For treatment 3, the oxygen absorber was oven dried for 24 hours prior to packing. All samples were stored at 25°C, 35°C and 45°C. Accelerated shelf life studies were conducted on these samples following the procedure of Shema (2015) with slight modifications. As a measure of shelf life, the vacuum fried jackfruit were analysed for water activity, moisture content, free fatty acids, peroxide value, and textural quality (hardness, crunchiness/crispiness, tooth packing, and fracturability). The withdrawal of the samples was done weekly for analyses and was performed until the eighth week of storage. Texture and rancidity of the vacuum fried jackfruit were monitored since they are important qualities that determine the storage life of the vacuum fried products.

The chemical characterisation of frying oil and sensory quality evaluation of vacuum fried jackfruit as influenced by the frying cycle was also evaluated. This was completed by analysis of free fatty acid (FFA), acid value (AV) and peroxide value (PV) of the oil extracted from the product (1st, 5th, 10th, 15th and 20th frying cycle vacuum fried jackfruit pulp).

Consumer testing of processed product in the Philippines (PC)

The optimal packaging and product process parameters from previous trials were selected and subjected to consumer acceptability and a Preference Test to determine the position of the product in the market.

The jackfruit product variants, including dehydrated and vacuum fried chips were subjected to sensory evaluation to determine if product processes had desirable sensory attributes. Consumer testing employed 100 panellists (student, faculty and staff and guests of the university) to compare between the VSU developed products and the existing commercial products. Vacuum fried jackfruit chips were evaluated together with commercial vacuum fried jackfruit chips (Vietnam). In addition, dehydrated jackfruit were sourced from a commercial counterpart (Cebu City) for the evaluation.

Activity b. Investigate 'fresh cut' processing option

Conduct trials on "fresh cut" jackfruit (PC)

The second component of Objective 3, was to investigate fresh cut options of the sweet jackfruit '*Artocarpus heterophylus Lam'* produced at EVIARC.

The physico-chemical and microbial properties on minimal processed jackfruit flesh were evaluated as a function of different levels of the identified pre-treatment solutions, including; firming agents (calcium chloride), acidification (ascorbic acid), sodium hypochlorite, The effect of deseeding, storage temperatures and conditions on the quality of jackfruit flesh were evaluated utilising optimum pre-treatment solutions identified in the previous study. Quality descriptive scores and acceptability ratings of different treatments were examined by a sensory panel.

Unripe jackfruit of the same variety were also trialled to evaluate preservatives (sodium metabisulphite, sodium benzoate), blanching, fruit maturity and acidification (ascorbic acid). Data was collected to evaluate shelf life performance and determine the effects of the variables on different parameters studied.

Conduct trials on "fresh cut" jackfruit (A)

A literature review (2013) was conducted on minimally processed jackfruits as the primary objective of the first component in this project. The literature review examined recent studies in the development of value added products using acid dipping treatments, packaging technologies and edible coating to achieve extended shelf life.

The Innova database is an online food and beverage platform tool which was utilised to complete an international product review (2017). The review aimed to provide a preliminary report on annual jackfruit product launches worldwide from January 2011 to December 2016. This allowed the study to identify development trends, category launches, growth opportunities and potential price points per kg.

Novel fresh cut jackfruit processing technologies were developed by the Innovative Food Technologies (IFT) group at DAF in Australia, in collaboration with the Partner Country. Incorporating previous studies completed at Visayas State University (VSU), this knowledge was used to test several options in the preliminary trials for the next stage. This processing trial was completed through commercial partnership with Stewart Brother Farms at North Queensland, who kindly provided all required jackfruit samples. Preliminary trials were completed by examining the locally grown jackfruit varieties 'Amber' and 'Rajang' for physico-chemistry including °brix, pH, moisture content, weight, density and flesh recovery.

Undertake processing trials in pilot plant using protocol(s) developed in year 1 to make products for shelf life and sensory/consumer testing (A)

A packaging study, based on the information collected from literature reviews and preliminary studies from previous components was completed in the IFT pilot plant facility (2017).

This trial utilised both phyto-sanitation and dipping solution treatments in combination with three different packaging options (polypropylene [pp] container, vacuum pack and barrier film) to evaluate product shelf life quality over 17 days. Ascorbic acid, citric acids and calcium chloride levels were evaluated from both literature reviews and research trials completed in the Philippines (PC) at VSU. The purpose of this research was to complete chemical, microbiological and sensory assessments to study fruit deterioration during product shelf life.

Consumer sensory testing was also completed to qualitatively evaluate the sensory properties of fresh-cut jackfruit and Identify similarities and differences in the sensory properties as influenced by packaging type and treatment.

Conduct consumer testing of processed product in Australia (A)

Sensory profiles of the 'Rajang' and 'Amber jackfruit varieties were completed as part of the trials to quantitatively evaluate the sensory attributes with the aim of compiling a profile that can be used to market the fruit. A panel of trained sensory assessors (n=10) with previous experience in the evaluation of fresh produce were recruited for the study.

Training sessions were conducted over a two week period whereby sensory assessors conducted the following exercises:

- Individual attribute generation; assessors were provided with one aril of each varietal placed in individual blind coded pots and asked to assess each sample for the following attributes – appearance, aroma, flavour, texture and aftertaste. Assessors noted the sensory descriptors they associated with each attribute, writing them into a table.
- Consensus; the panel discussed their individual descriptors as a group (led by the panel leader). The outcome of which was a table of sensory descriptors that the panel agree encompass all attributes of the two varietals.
- Definition; the panel and panel leader define each sensory descriptor and determine the correct sensory standard to be used.
- Practice; the sensory assessors conducted several practice sessions, using the clearly defined list of descriptors and line scales in order to quantitatively assess each varietal. The panel leader followed the progress of the panel ensuring that each assessor was using the attributes in accordance with the rest of the panel and that agreed upon during training.

Formal evaluation sessions were conducted over one week following successful completion of the training phase.

- Formal evaluations took place under controlled conditions in the isolated sensory booths at the Health and Food Sciences Precinct, Coopers Plains (HFSP).
- Samples were assessed in quadruplicate in a balanced and rotated order, to prevent order bias.
- Sensory assessors were provided with a full list of sensory descriptors, their definitions and standards and asked to familiarise themselves with these prior to sample evaluations.

Acceptability of VSU developed dehydrated and vacuum-Fried jackfruit pulps were also tested in Australia through DAF collaboration work. Mean sensory scores were collected by using a consumer panel recruited at the Coopers Plains facility to evaluate appearance, aroma, flavour, texture and overall liking to the Australian palate.

6 Achievements against activities and outputs/milestones

Objective 1: To develop and implement integrated disease management solutions to diseases affecting jackfruit

no.	activity	outputs/ milestones	completion date	comments
1.1	Pursue registration and availability constraints for potassium phosphonate (PC)	Contact relevant registration authorities and obtain clarification of data required for registration Clarify pathway to obtain registration of potassium phosphonate and initiate process Carry out necessary experiments and report Product registration for the management of Phtytophthora palmivora in jackfruit and potentially underutilised tropical fruit trees	Philippines Fertiliser and Pesticide authority contacted (May 2013) October 2013 April 2014, 2015 and 2016 May 2017 or earlier if possible	Discussions held with PFPA re. the issue Dr's Lucy Borines and Elise Salamat undertake training for researchers conducting pesticide trials to submit for analysis Difficulty accessing potassium phosphonate Meeting held with Sagrix, wholesalers of phosphonate products. Main product marketed is not dipotassium phosphonate. Product is imported from the US exclusively for Dole and used in Pineapples. Sagrix and Dole do not want the product registered as a fungicide, preferring its current fertiliser status. Product (PhosPro 4:40:2) made available to Dr Borines for incorporation in the field trial at Mahaplag. Fungicide registration is not going to be pursued unless supported by commercial wholesaler/retailers and government authorities. Facts reported to ACIAR and PCAARRD project review meeting in July 2015/2016 and 2017.

no.	activity	outputs/ milestones	completion date	comments
1.2	*Develop nursery hygiene protocols suited to the Philippines.* *Support the construction of model nurseries at BPI-Davao (Mindanao) and DA- Abuyog (Leyte) and potentially at DA-San Jorge (Samar). (PC)*	Construction of model nurseries at BPI-Davao and DA-Abuyog and potentially DA-San Jorge Development of nursery hygiene production guidelines	February 2014 May 2016	**Model nursery construction** Discussion re concept with BPI, DA and VSU BPI the first to initiate major change with gravel beds in nursery area. Hygiene incorporated as part of nursery accreditation workshops Demonstration nursery constructed at DA Abuyog in June 2017. **Identification of disease in the nursery environment.** Testing of DA nursery water supply, soil, potting mix ingredients and surfaces for Phytophthora contamination Trials initiated to determine the effect of, media pasteurisation, air filled porosity (AFP) and phosphonate on plant growth and disease development. Key observations/learnings to date; • High AFP media require additional watering and fertiliser management • High AFP media can benefit plant growth • Plants were taller, had larger stem diameters and carried more leaves with the addition of potassium phosphonate • Pasteurised and phosphonate reduces disease rating

no.	activity	outputs/ milestones	completion date	comments
1.3	Conduct workshops to promote nursery hygiene regimes to southern Philippines fruit tree nurseries using information transfer from Australia and Philippine demonstration nurseries. (PC)	Develop and present workshops Develop workshops with distribution of extension materials. Present workshops to tropical fruit industry members in Australia. Nursery hygiene training with potential visits by Philippine collaborators to accredited fruit tree nurseries in Australia Extend nursery technology to durian and pomelo industry via BPI - Davao	August 2014, 2015, 2016 March 2015, 2017 March 2015 Apr 14, 15,16 and 2017	The BPI-Davao Nursery has upgraded the nursery floor with gravel beds since the initiation of the project. Nursery accreditation workshops are regularly run at BPI, Davao by project partner Virgilio Loquias. Virgilio estimates that up to 500 participants have benefited from additional inputs on nursery hygiene as a result of the project. At DA-Abuyog a demonstration nursery was completed in September 2017. The demonstration nursery was used as the site for nursery training for Leyte farmers and nurserymen. Dr Francisco Dayap (DA) and Dr Dario Lina (VSU) both participated in a Crawford/project funded visit to Australia in April 2016. Nursery visits in Darwin and the Atherton Tableland were a core component of the training. Dr's Dayap and Lina visit disease free accredited nurseries in Australia Discussions re design; cement or rock floor, benches; foot bath at entry/exit points and potential to chlorinate water. A nursery hygiene workshop was conducted by DA and VSU in March 2017 at the Abuyog research facility. Sixty five growers and nursery personnel received training. BPI, Davao have incorporated nursery hygiene in their farmer training courses, in which over 500 farmers were trained during the course of the project. Nursery hygiene workshops have been presented to north Queensland and NT growers as part of tropical fruit workshop/field days.
1.4	Confirm benefits of nursery hygiene protocols by measuring comparative disease loads in the new and conventional system. (PC)	Monitor disease status of plants produced under conventional and improved hygiene systems Measure nursery seedling survival Monitor field survival at six monthly intervals over three years.	This activity has not been undertaken and awaits completion of activity 1.2	Nursery work conducted at DA Abuyog Multiple nursery trials have been undertaken by DA and VSU. High air filled porosity media has been difficult to manage in the Philippines. Slow release fertiliser and automated irrigation systems are not readily available or affordable and early trials were compromised due to a lack of fertiliser and watering management.

no.	activity	outputs/ milestones	completion date	comments
1.5	Initiate work to measure the effect of scion – rootstock combinations for disease resistance in jackfruit (PC)	Evaluate Phytophthora resistance of other Artocarpus species Commence scion-stock trials jackfruit with RIARC - Abuyog. Grafting trials to examine the influence of stock seedling age and scion preparation on graft take. Initiate field trials of scion-stock combinations. Commence growth and disease susceptibility measurements.	June 14 Jan-Feb 14 Apr-Jun 14, end Dec 14 July 14, end March 17 Review May each year	Artocarpus species tolerance/resistance ratings have been conducted on six species (*blancoi, camansi, elasticus, integer, heterophyllus and ordoratissimus*) using three inoculation techniques (detached leaf, detached stem and seedling). A total of 77 specimens have been inoculated. Ratings differ slightly depending on techniques for most species. Over-all techniques, A. *odoratissimus* (marang) is the most tolerant with A. *integer* (champadek) being the least tolerant. The pathology team at VSU plan to rescreen all species with emphasis on jackfruit accessions using detached stem inoculation. A small trial conducted in Australia of both north Qld and NT accessions, using detached stem inoculation resulted in marang being susceptible.
1.6	Rapid selection of improved clones from seedling based orchards (NT) and genotyping of jackfruit genepool?	Rapid screening of NT seedling based jackfruit orchards for improved clone selection Genotype selected clones.	Dec 14 July 15	OP seedling selection blocks • 13 diverse seedling blocks established • 2 years 4 seedling blocks flowering (10-17% of seedlings within a seed lot flowering) • 3 years 10 seedling blocks flowering (5-70% seedlings within a seed lot flowering) • Jackfruit seedlings quick to transition from juvenile to reproductive phase=potential for rapid improvement • Leaf samples of the initial 13 samples have been collected for genomic analysis. • Evaluation of fruit for first stage clonal selection undertaken. Genotyping • 262 Artocarpus species collected from 20 species • 83 samples of A. heterophyllus • countries with 116 and 87 samples collected from the Philippines and Australia respectively. • DNA extraction carried out by DAF • Initial use of markers developed for breadfruit resulted in poor separation of species DART sequencing technology used for diversity analysis has resulted in a clear separation of species and samples within species.

PC = partner country, A = Australia

Objective 2: To develop and implement crop management options which improve productivity and fruit quality in jackfruit

no.	activity	outputs/ milestones	completion date	comments
2.1	Investigate scion – rootstock combinations and evaluate effects on canopy development. (PC&A)	Initiate field trials of scion-stock combinations. Commence growth measurements.	On-going March 17 Review May each year	Due to the difficulty in mastering the interspecies grafting this component of the project experienced difficulties. The team at BPI – Davao have had the most success with interspecies grafting and have progressed to small field plots. A number of graft combinations (Stock/scion) have been trialled and include; Marang/Jackfruit, Tipo/Jackfruit, jackfruit/jackfruit, Tipo/breadfruit, Kamansi/breadfruit, Marang/breadfruit, Jackfruit/breadfruit, Tipo/chempedak, Kamansi/Tipo and Kamansi/Marang Observations to date: Jackfruit appears to be compatible with Marang, Tipo and itself. Both the marang and tipo stock resulted in some level of jackfruit scion overgrowth. The marang stock results in shorter internodes and a smaller tree. At this stage the field planting remains a demonstration plot.
	Grafting Trials of Different Artocarpus species (DA Component)		On-going	The DA team at Abuyog have experienced compatibility problems for all species except for A. integer as a stock. A small field trial has been planted at Babatngon Experimental Station (DA) and includes a comparison of chempedak/jackfruit and jackfruit/jackfruit grafts. At July 2017 only the jackfruit/jackfruit and chempedek/jackfruit combinations have survived in the field. In the NT, similar problems have been experienced. Interspecies graft success has varied with time of graft, species used and jackfruit accession. A further 13 species were trialled.

no.	activity	outputs/ milestones	completion date	comments
2.2	*Develop tools to manipulate flowering patterns in jackfruit to spread crop production and income generation (PC)*	Plan and initiate field trials Record time of flowering and fruit set. Assess treatments and refine as required. Record results and consider issues related to registration of products.	July 13 – Dec 13 Mar 17 May 14, 15, 16 Apr-May 17	The start of this trial was delayed due to a lack of suitable field sites following typhoon Haiyan. An orchard was selected, north west of Ormoc early last year and treatments imposed in June/July 2016 with the consent of the grower/owner. Treatments include; 1. Untreated (control) 2. Removal of old fruit stalks which have not set immediately after cropping 3. Strategic pruning (top and lower branches of canopy) + fruit stalks 4. Nitrogen injection 2% Urea with potassium phosphonate 5. Combination of pruning and nitrogen injection 6. Nitrogen applied as a granular fertiliser to promote new growth 7. Combination of pruning and granular nitrogen application 8. Pruning of top and lower branches of canopy + Drenching of Paclobutrazol (36 ml/L/tree) + Injection of $CaNO_3$ (2.5 kg/L) at 80 ml per tree 9. Strategic pruning of both Upper and lower canopy + Drenching of Paclobutrazol + Drenching of $CaNO_3$ (2.5 kg/L) at 1 L per tree Initial fertilization (organic amendment) of the treatment trees was done.

2.3	*Improve crop production in jackfruit by developing crop load and nutrient management techniques.* *(PC)*	Plan and initiate trials to examine the effect of crop load. Determine the nutrient content of whole fruit, record commercial fertiliser input practices. Develop a jackfruit nutrient budget.	On-going	Three field trials are in progress in the Philippines, Trial 1: Mahaplag – Hob's farm, Experimental design, RCB – Split Plot with 4 blocks. MAIN FACTOR 1. 50% DA recommendation 2. 100 % DA recommendation (30 kg OF + 500 g C + 400 g MP) 3. 150% DA recommendation 4. commercial organic fertilizer Jobs current practice (rice hull with chicken manure) SUBPLOT • With PhosPro • Without PhosPro SUB-SUBPLOT • Regulated Fruit • Unregulated Conclusions as of July 2017 Application of 100-150% DA RR and Commercial organic fertilizer generally improved tree canopy. Furthermore, application of phosphonate and fruit load regulation have reduced canker and disease severity. Application of 150% DA RR and commercial organic fertilizer have increase flowering in unregulated trees. Application of 150% DA RR and commercial organic fertilizer have increase mean total fruit weight harvested in unregulated trees. Application of commercial organic fertilizer have increase mean total fruit number harvest in unregulated trees. The co-operators current practice have significantly produced more kilos of Jackfruit per peso of fertilizer inputs in regulated trees and is comparable to 50% DA RR, 150% DA RR and commercial organic fertilizer in unregulated trees. Trial 2: Abuyog – Department of Agriculture. Initiated late 2014. Main Plot 1. Control 2. Potassium phosphonate Sub Plot • Control (no fertiliser) • DA Recommended fertiliser rate (30 kg organic + 800 g T14 + 400 g MOP) • 50% DA Recommended fertiliser rate (15 kg organic + 400 g T14 + 200 g MOP) • 150% DA Recommended fertiliser rate (45 kg organic + 1200 g T14 + 600 g MOP) • Organic fertiliser (38 kg/tree/year)

no.	activity	outputs/ milestones	completion date	comments
				Conclusions as of July 2017. • Application of phosphonate influenced the performance of the trees in which 70 to 84% of the shoots and leaves were green and vigorous, and reduction of number of lesion were also observed. • Trees applied with organic fertilizer alone minimizes the formation of lesions and improved health conditions. • Phosphonate and organic fertilizer application can reduce phytophthora infection and improve plant performance. • Cost and availability on the phosphonate application should be considered **Plan of Activities** • Continue data collection • Cost and return analysis Trial 3: BayBay – VSU Pomology block. Initiated early 2015. Main Plot • Control – no fertiliser • Inorganic inputs • Organic • Organic + 50% of inorganic Sub Plot • Nil potassium phosphonate • Potassium phosphonate applied twice/year Summary of results as of July 2017. Preliminary tree growth measurements canopy (height, width and trunk diameter above and below the graft) have been recorded. Trees have only commenced flowering as of March 2017. Thus there are no results to report at this stage. Leaf and soil sampling has occurred in the Philippines and Australia (NT and north Queensland). Fruit samples have been collected but are yet to be analysed Following another round of tree nutrition sampling nutrient budgeting calculations will commence.

2.4	Examine growth and productivity of trellised jackfruit, durian and rambutan for cyclone (typhoon) resilience and improved crop production. Evaluate clonal hedge orchard systems and rootstocks in rambutan production(A)	Plan and initiate trellising trials in Australia Develop trellis systems Monitor tree growth and productivity. Record tree survival In the event of a cyclone. Report on the economics of trellising Quantify early performance of several rambutan stock/scion combinations and clonal hedge systems NT Evaluate the effect of anti-gibberellins on panicle length and fruit set in lychee. Trial implemented to evaluate the effect of uniconazol and paclobutrazol on flower/panicle	Ongoin	DAF, South Johnstone. Four Trellising systems • V- Trellis • Espalier • T- trellis • Control (standalone) Three species with differing plant architecture and flowering. • Guava (plagiotropic and axial flowering) • Longan (orthotropic and terminal flowering) • Seedling Cocoa (orthotropic/plagiotropic and cauliflorous) Maximum yields achieved in the last year (16/17) are on the V-trellis trials planted at a population of 1333 t/ha. They are 59.7 t/ha for guava (horizontal branch), 38.4 t pods/ha for cocoa (45° branched), and 35.9 t/ha for longan (180° 15/16 season) Jackfruit trellis plantings are being monitored on two commercial sites. Site 1. • Jackfruit: multi trunk, T-trellis shaped • Variety: Rajang • Tree age: 8.5 years • Fruit/tree: 40 fruit/tree at 10 kg/fruit • Tree Spacing: 9 x 6 m spacing • Estimated Yield: 74 T/ha Site 2. • Jackfruit: single trunk, T-trellis shaped • Variety: Rajang • Tree Age: 3 years • Fruit/tree: 6 fruit/tree at 12 kg/fruit • Tree Spacing: 7 x 5 m spacing Estimated Yield: 20.5 T/ha NT DPI&R are trialling clonal, high density (6.7 x 2 m) orchard systems. • Marcotting (air-layering) rambutans most reliable method of clonal propagation with quick industry adoption of method. • Field establishment very good with 95-100% survival across 4 commercial cultivars. • Non-bearing growth rates very uniform with only “Binjai” cultivar marginally slower. • Cropping has commenced in the third year after planting with an average of 9.0 kg per tree (6,700 kg/ha) for the variety R167

no.	activity	outputs/ milestones	completion date	comments
	Flowering and fruit-set management of FZS lychee (A)		2015g	Lychee floral development trials carried out during 2015/16 season. Results are inconclusive due to low temperature conditions at anthesis. Lychee Treatments included; two anti-gibberellins (uniconazol and paclobutrazol) plus and minus micro nutrients; micronutrients alone and control (water) were applied at early panicle development in July 2015. The change in panicle length and fruit set per plot were measured in November 2015 prior to harvest. Panicle length change and fruit number per plot were not significantly different among treatments. Poor fruit set was encountered in all treatments and throughout the remainder of the orchard due to sub-optimal temperatures during the crucial fruit set phase.

PC = partner country, A = Australia

Objective 3: To develop improved processing options for jackfruit

no.	Activity	outputs/ milestones	completion date	comments
3a	Measure the effect maturity on the quality of fresh and processed product. (PC)	Data available on effect of fruit maturity on product quality	2016	Data collected on fruit maturity (on four different maturity periods) and the effect on vacuum fried product. Quality parameters include physico-chemistry and consumer acceptability to determine an ideal maturity index. Evaluation of the effects of fruit maturity on nutritional quality and shelf life of vacuum fried product through processing parameters. Packaging optimisations and effects include nitrogen flushing and oxygen absorbers.
	Compare methods of identifying fruit maturity (NIR, acoustic and heat sums) (A)	Data available to enable selection of maturity tool	2016	Completion of a preliminary trial involving NIR to identify fruit maturity by analysis of physico-chemistry characteristics. Collection of datasets that developed a ground calibration curve, this can be used as a baseline model to develop a maturity tool in the future.
	Initiate trials to improve current vacuum fried jackfruit chips (PC)	Identification of improved processing options	2017	Established optimal nitrogen gas levels to improve packaging processes for producing fried jackfruit chips. Established optimal oil quality parameters to improve drying processes for producing fried jackfruit chips.
	Conduct consumer testing of processed product in the Philippines (PC/A)	Obtain data on consumer preference	2017	Both Vacuum fried and dried jackfruit products under previous activities were subject to consumer testing at partner country to obtain data on preference and product quality. Equivalent products were also tested in collaboration with DAF in an Australian environment. This includes the facilitation of developing a consumer preference data collection template and gathering feedback from Australian consumers.
3b	Conduct trials on “fresh cut” jackfruit (PC/A)	Identify processes for fresh cut product	2014	Literature review on examining studies in the development of value added products to achieve extended shelf life. International product review on jackfruit products using an online food and beverage platform (Innova database). Examined Australian grown jackfruit varieties to determine physico-chemistry characteristics. Developed an appropriate treatment dipping and packaging solution for pilot plant study to produce a minimally processed ‘fresh cut’ product.
	Undertake processing trials in pilot plant using protocol(s) developed in year 1 to make products for shelf life and sensory/consumer testing. (A)	Develop process to produce a commercial product	2017	Implementation of appropriate fruit sanitation and treatment processes to evaluate shelf life performance. Development of different packaging types (vacuum and barrier) to evaluate shelf life performance.

no.	Activity	outputs/ milestones	completion date	comments
	Conduct consumer testing of processed product in Australia. (A)	Obtain data on consumer preference	2017	Completion of sensory profiling work for Australian grown jackfruit varieties that developed sensory descriptors and attributes. Data collection during a consumer trial to gauge responses for preferences.

7 Key results and discussion

Objective 1: To develop and implement integrated disease management solutions to diseases affecting jackfruit (all Philippines)

Activity a. Provide research support for registration and availability constraints for potassium phosphonate

The registration process for potassium phosphonate in the Philippines was not pursued because it became apparent, following considerable discussions with registration authorities and commercial retailers, that a commercial wholesaler/retailer is required to initiate the registration process. Concurrently a similar product (PhosPro – Phosphorous acid) became available via Sagrex Corporation. This was utilised in the trials conducted.

Activity b. Develop model nurseries at two centres and introduce nursery hygiene regimes to Philippine fruit tree nurseries using information transfer from Australia and demonstration nurseries

By the project conclusion, two research nurseries used as training facilities had been developed and upgraded. The nursery at DA Abuyog was renovated to include protective structures, gravel beds and elevated benches with appropriate sanitation control.

At the BPI research facility, Davao, the nursery floor had been extensively upgraded to gravel flooring.

Guidelines to the nurseries developed include;

- Foot-ware sanitation points at entry points to the nursery to minimise the introduction of off-site pathogens
- Gravel floor beds or raised benches to avoid contamination with soil splash
- Introduction of soilless and or sterilised media. Appropriate sterilisation techniques such as solarisation or steam sterilisation were incorporated where appropriate.
- Use of accredited clean planting/propagation material
- Use of new pots or pot washing and sterilisation where appropriate.
- Water treatment (chlorination where the irrigation water is known to be contaminated with Phytophthora).

See Appendix Objective 1b for photographs of model nursery constructed at DA Abuyog.

Activity c. Conduct workshops to promote nursery hygiene regimes to Philippine fruit tree nurseries using information transfer from Australia and Philippine demonstration nurseries

The following plant nursery training and management workshops were conducted during the course of the project.

DA-Abuyog, Leyte

1. Farmers and Extension Workers conducted on May 23-25, 2016 with 25 participants.
2. Nursery operators, nursery in-charges and propagators, conducted on June 10-11, 2016 with 45 participants.
3. Farmers and Agricultural Extension Workers conducted on December 20-21, 2016 with 45 participants.
4. Nursery Operators in the region, plant propagators, DA Technicians conducted on February 27-28, 2017 with 35 participants. This include lectures and practicum regarding nursery management practices

5. A nursery hygiene workshop was conducted by DA and VSU in March 2017 at the Abuyog research facility. Sixty five growers and nursery personnel received training.

BPI-Davao

The nursery accreditation workshops were regularly conducted by project partner Virgilio Loquias who estimates that up to 500 participants have benefited from additional inputs on nursery hygiene as a result of the project.

Australia

Nursery hygiene components were presented as part of jackfruit, rambutan and cyclone resilience workshops presented in the Northern Territory (NT) and the Wet Tropics of far north Queensland.

Dr Francisco Dayap (DA) and Dr Dario Lina (VSU) both participated in a Crawford/project funded visit to Australia in April 2016. Nursery visits in Darwin (Darwin Plant Wholesalers – Darryl South) and the Atherton Tablelands (Turkinje Nursery – Peter Lavers) were a core component of the training.

Activity d. Confirm benefits of nursery hygiene protocols by measuring comparative disease loads in the new and conventional system

Identification of possible sources of phytophthora in the nursery

Phytophthora palmivora was detected in most potting mixes and soil samples taken from different jackfruit nurseries and farms in Samar and Leyte, Philippines. The organism was also detected in the potting mix and germination beds at DA-RIARC, Abuyog Leyte, the principal site of jackfruit clone production for release to farmers. This confirmed that without any alteration of nursery practices, jackfruit seedlings are sources of *P. palmivora* inoculum that can carry the pathogen to the orchard.

Irrigation water, especially if from a surface/open well, can be a potential source of inoculum. Infected seedlings are also sources of primary inoculum in the field.

Five trials were conducted during the course of the project, two at VSU and three at DA, Abuyog to examine the effect of nursery potting practices on jackfruit plant vigour and health. The trails incorporated variables such as;

- potting mix ingredients (soil, partially composted rice hulls, carbonised rice hulls, coconut coir)
- differing ingredient ratios to produce mixes with air filled porosity ranging from 3.4 to 34%,
- sanitation – soil pasteurisation via solarisation or steaming
- use of potassium phosphonate for disease management as a drench or foliar application

The principal findings of the research trials are;

- Plant vigour is principally determined by nutrient and water management during the nursery stage. The use of high air filled capacity mixes, known to be beneficial to the production of healthy plants needs to be supported by regular nutrient and irrigation inputs.
- Higher air filled porosity mixes can support the production of healthy plants if adequate nutrition and irrigation inputs are applied.
- Potting mix pasteurisation may exacerbate disease ratings where plants are inoculated with pathogen post planting.

Recommendations:

- Jackfruit seedlings can be raised in unsterilized or sterilized potting media with air-filled porosity from 3.9% to 21% without affecting the growth and health of the seedlings, provided that seedlings are placed in raised benches under a protected structure.
- Adequate, cultural management practices such as watering, fertilizer and weed control, insect pest and disease control are required.

Results of the trials are shown in Appendix Objective 1d.

Activity e. Initiate work to measure the effect of scion – rootstock combinations for disease resistance

Ninety two accessions of Artocarpus species and 40 jackfruit clones were collected and tested for tolerance to Phytophthora palmivora using either seedling, detached leaf or stem inoculation techniques. Detached leaf and stem methods were easier to instigate and repeat compared to seedling techniques, which require longer term planning and management. In general results using detached leaf and stem were replicated in seedling inoculation. This suggests that the three methods are reliable indicators of disease susceptibility. There was a range in responses between the same species collected from different regions, suggesting that tolerance is less to do with genetics but a reflection of the reality of the disease triangle (pathogen, host and environment) on tolerance responses.

Of the 91 *Artocarpus* spp. collected from Eastern Visayas. The highest number was of Tipo, *Artocarpus blancoi* (37), followed by Camansi, *A. camansi* (18), Kulo, *A. altilis* (16), Tugop, *A. elasticus* (12), Marang or *A. odoratissimus* (7) and the lone chempedak, *A. integer* which was evaluated using stem V-cut and detached leaf inoculation. Only 71 of these accessions were evaluated against *P. palmivora* using the chosen detached shoot tip method of inoculation (Table 2). Photographs of leaves, fruits and seeds of some of these diverse *Artocarpus* collections are shown in Appendix Objective1e reflecting the high diversity of *Artocarpus* spp. in the Eastern Visayas.

Table 2. Suggested species tolerance to *Phytophthora palmivora* by region and species.

Tolerance rating	Species/Region
Highly resistant	Tipolo (Bitanhuan, Baybay) Tipolo (Poblacion, Hindang), Tipolo (Libagon) Tipolo (St. Bernard) Tipolo (Anahawan) Tipolo (Dapdap, Alangalang) Tipolo (Hibucawan, Jaro) Tipolo (Tangnan, Carigara) Kulo (Sto. Nino, Capoocan) Marang (Capoocan) Tipolo (Tibak, Sta. Fe) Tipolo (Balire, Tunga)
Resistant	Marang (Malapoc Sur, Maasin) Kulo (Talahud, Almeria) Antipolo (Maasin) Kulo (Anahawan) Tipolo (Caibiran)

Tolerance rating	Species/Region
Moderately resistant	Marang (Malapoc Norte, Maasin) Kulo (Tubod, Silago) Marang (Mayuga, Lebagon) Tipolo (Palo) Camansi (Capoocan) Camansi (Macopa, Jaro) Camansi (Lunay Zone 3, Kananga) Camansi (Balire, Tunga) Tugop (Dapdap, Alangalang) Marang (Kawayan)
Moderately susceptible	Kulo (Bontoc, Hindang) Camansi (Caulanguhan, Caibiran) Tipolo (Merida) Antipolo (Baybay) Marang (Bontoc) Marang (Pangi, Lebagon) Tugop (Palo) Tugop (Sta. Fe) Tipolo (Macopa, Jaro)
Susceptible	Camansi (Tahud, Inopacan) Camansi (Rizal, Maasin) Kulo (Hantag, Maasin) Kulo (Caulanguhan, Caibiran) Tipolo (Barubod, Kawayan) Kulo (Maasin) Tipolo (Lemon, Capoocan) Camansi (Tagak, Carigara)
Highly Susceptible	Kulo (Plaridel, Baybay) Tugop (Poblacion, Hindang) Tipolo (Canaan, Caibiran) Tipolo (Caibiran-i) Camansi (Caibiran) Tipolo (Baganito, Kawayan) Tipolo (Caibiran-d) Kulo (Bilwang, Isabel) Camansi (Bilwang, Isabel) Camansi (Palompon) Camansi (Ormoc) Kulo (Merida) Camansi (Merida) Tugop (Mahaplag) Kulo (Padre Burgos) Camansi (Malitbog) Tugop (Pangi, Lebagon) Tugop (Tabigi, Abuyog) Tugop (San Juaquin, Capoocan) Tugop (Balire, Tunga) Tipolo (Caibiran) Tipolo (Caibiran) Tugop (Caibiran) Jackfruit EVIARC sweet Tugop (Caibiran) Tugop (Lemon) Tugop (Caibiran) Jackfruit (EVIARC Sweet)

Of the 40 jackfruit clones tested, only five were rated highly resistant, five resistant and a further four moderately resistant. Based on the statistical analysis of the lesion length data there are only two groups, susceptible and at best moderately resistant.

Objective 2: To develop crop management options which improve productivity and fruit quality in jackfruit

Activity a. Investigate scion-rootstock combinations and evaluate effects on canopy growth and productivity (PC and A)

Jackfruit propagation is still in its infancy, with most production based on seedling trees. In the Philippines, Malaysia, Thailand and Vietnam significant improvements have been made by the selection of clones and propagation via grafting. Common grafting techniques are approach, bud, chip, epicotyl and wedge grafting. In most cases grafting occurs on its own rootstock, thereby minimising compatibility issues.

In this study we have examined the potential to use other species as rootstock, with two aims in mind. Firstly, the potential for disease resistance, with particular reference to *Phytophthora palmivora* and secondly the potential to decrease canopy vigour and improve fruit set. Work was conducted by project colleagues, at DA – Abuyog and BPI Davao, Philippines and by the Department of Primary Industry and Resources, Northern Territory, Australia.

Australia

Propagation

Given the “early” development phase of the Australian jackfruit industry, very little standardising of jackfruit propagation methods has occurred. Watson (1985) over three decades ago highlighted this issue for the Australian tropical fruits sector and this still remains the case despite strong industry demand for quality planting stock. A small number of “pioneering” orchardists and plant propagators have gained considerable knowledge on techniques developed in their own regional environment and for their specific germplasm, however this knowledge is often not publicly available.

Fruit quality and seed recovery

Jackfruit has a “recalcitrant” (RC) seed and this phenomena is known for many tropical tree crops such as rambutan, mango, cocoa and rubber. One of the fundamental characteristics of recalcitrant seeds is they are physiologically active throughout the whole seed development phase and are sensitive to seed moisture loss. With moisture loss, germination is diminished or severely affected as a result of disrupted metabolic functions. Also potential fungal and bacterial infection is heightened as microflora colonise seed from decaying fruits.

Interest in jackfruit rootstocks is primarily to ensure maximum recovery of uniform propagules thus ensuring uniform field planting stock for orchard establishment. Current seed extraction protocols for jackfruit and other *Artocarpus* species is:

- Seed collection from firm but mature fruit harvested direct from the tree; seed extracted before any appreciable fruit decay commences.
- Seed lots rinsed in running tap water for a minimum of 10 minutes to remove sugars and perianth flesh remnants, surface air dried and immediately sown.
- If short term storage is required (maximum 7 days @ >15°C), seed lots post extraction are wrapped loosely in dry newspaper and placed in sealable plastic bags.

Seed treatments for improved germination

A screening trial was undertaken on the effect of testa and seed coat removal on improving germination in *Artocarpus* species (*A. heterophyllus, sarawakensis, odoratissimus* and *rigidus*). Removal of hard testa and the seed coat or a simple "nicking" of the testa and seed coat at the micropylar scar advanced germination by 7-10 days and improved germination percentage. Whilst of some interest, the time taken to treat individual seeds may preclude its use for commercial quantities of seeds. These treatments may have some merit when the recovery of a maximum number of propagules is important, such as new germplasm seed lot introductions.

Seed orientation at sowing influences the recovery of quality seedlings. Seeds that are positioned with the micropylar scar placed basally into the media consistently generate a greater number of seedlings with good, straight tap roots. Seeds that are sown haphazardly with various orientations within a batch will generate more constricted and bent taproots due to the geotropism of jackfruit roots.

Rootstock seedling uniformity and better roots

Some seed lot accessions are more uniform with less "culls" or off-type seedlings then others. Seedling growth studies were undertaken with several *Artocarpus* species known from previous work to be compatible with some Jackfruit scions. Data was subjected to multiple regression analysis to test predictive values of each parameter.

For jackfruit seedlings (*A. heterophyllus*), a basal stem diameter was a stronger indicator of better seedling root system than seedling height. For all other species there was a similar trend, however the relationship was not as strong as for jackfruit seedling batches (Table 3). Also stem basal diameters gave a better prediction of whole seedling root biomass. For jackfruit propagation, it is suggested that poorer seedlings within a batch are culled visually by seedling stem basal diameter, that is girth, rather than seedling height prior to grafting.

Table 3. Predictive value of *Artocarpus* seedling growth parameters (n=50; p<0.001 or n.s. = not significant)

Species	Predictor	Response			
		Whole plant dry weight (g)		Root dry weight (g)	
		R^2	Estimate[a]	R^2	Estimate
A. heterophyllus (n=59)	Stem height (mm)	0.30	0.02	0.05 n.s.	0.01
	Stem diameter (mm)	0.78	4.50	0.69	1.48
A. odoratissimus (n=39)	Stem height (mm)	0.52	0.03	0.38	0.01
	Stem diameter (mm)	0.63	3.05	0.52	1.05
A. rigidus (n=43)	Stem height (mm)	0.38	0.02	0.29	0.01
	Stem diameter (mm)	0.49	3.37	0.56	1.30
A. sarawakensis (n=33)	Stem height (mm)	0.38	0.02	0.52	0.02
	Stem diameter (mm)	0.49	3.37	0.79	1.50

[a] *estimate is the mean "response" increment for the "predictor" value*

A second study was undertaken to quantify seedling uniformity within and between jackfruit seed lots with interest in root biomass for different accession seed lots. Potentially greater root biomass may enhance nutrient and water uptake and also whole tree stability within the orchard, irrespective of which scion cultivar is grafted to a given rootstock seedling.

Across all seed lots stem diameter significantly predicted root system biomass. Seedling root system biomass was nearly 3 times greater for the best seed lot CP190 compared to the lowest root biomass seed lot CP149 (Figure 1). Also, within seed lot variability was dependant on seed lot accession with coefficients of uniformity for root biomass varying from 30 to over 60% within a seedling batch (n=40). The practical implications of these

studies are: 1. within a seed lot, a visual culling of seedlings by size of basal stem girth will remove poorer seedlings and reduce variability of propagules for orchard establishment; 2. seed source accessions for jackfruit rootstock use could be selected for more uniformity and greater root biomass.

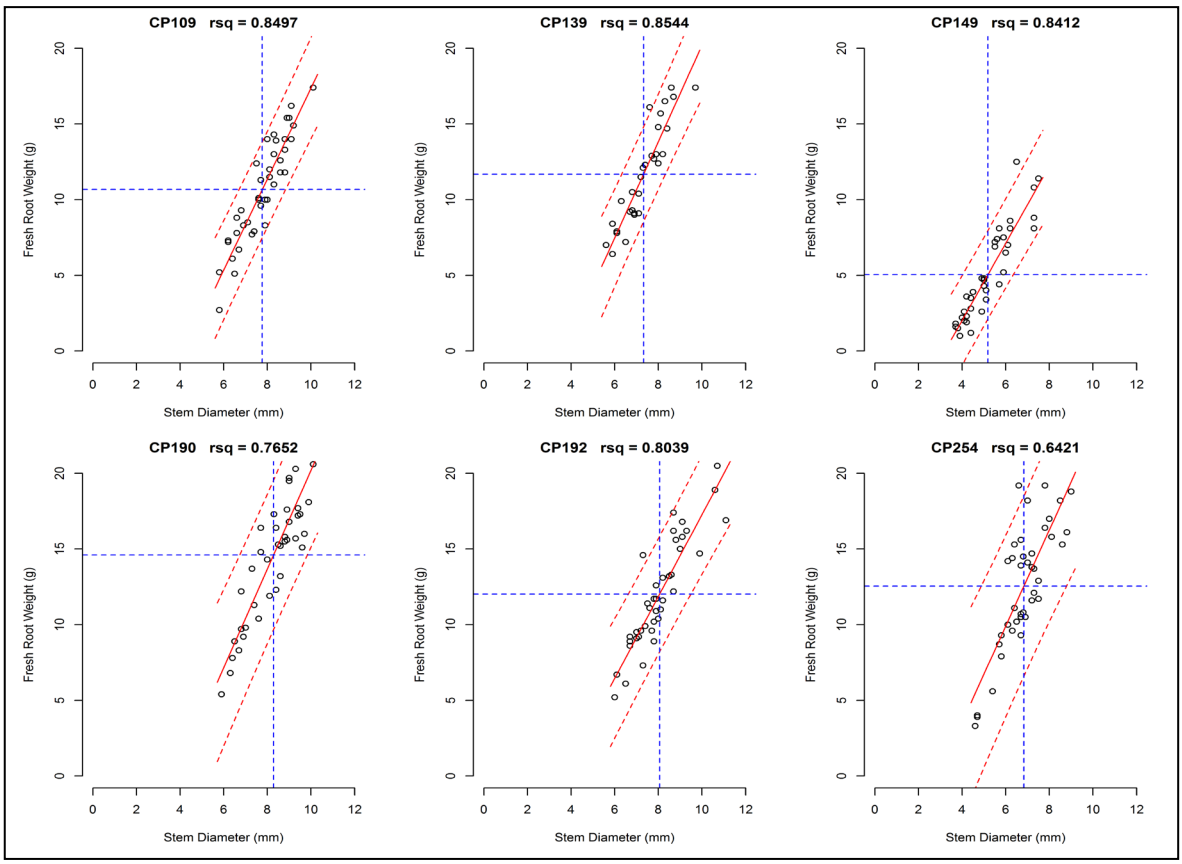


Figure 1. Regression analysis of jackfruit seedling growth parameters (n=40; p<0.001)

Jackfruit grafting

Propagation studies on the graft compatibility of the *Artocarpus* genus with several species from the Berrimah Farm gene pool were studied for initial graft compatibility with Jackfruit scion wood (Table 4). Some novel combinations have been obtained and field verification of the impact of rootstock on selected jackfruit scion performance and long term graft compatibility is warranted. Successful “graft take” for jackfruit also appears to be scion cultivar/selection specific with some jackfruit clones grafting very easily (vis.>75% graft take) and others proving to be very difficult (vis. 0 to <10% graft take).

Table 4. Summary of graft studies with jackfruit and *Artocarpus* species

NT accession	Rootstock species	Preliminary *A. heterophyllus* scion graft observations, Berrimah Research Farm (2015-16)
216	*Artocarpus odoratissimus*	80% graft take; 2 lots; single scion; n=25
217	*Artocarpus hypargyreus*	70% graft take; 1 lot; n=6; excessive scion overgrowth; delayed incompatibility; field trees died @ 18 mths.
221	*Artocarpus sarawakensis*	100% graft take; 2 lots; n=12; excessive scion overgrowth
223	*Artocarpus kemando*	0% graft take; 1 lot; n= 10
226	*Artocarpus integer*	10% graft take; 1 lot; n=8
241	*Artocarpus rigidus*	82% graft take; 2 lots; n=20
228	*Artocarpus heterophyllus*	0-100% graft take i.e. scion dependant; several lots; n>200
NT accession	**Rootstock species**	**Preliminary *A. glaucus* (NT 219) scion graft observations, Berrimah Research Farm (2015-16)**
213	*Artocarpus heterophyllus*	80% graft take; reciprocal i.e. species grafted on Jackfruit; n=8; NT endemic species; poor graft union; “benching” of stock to scion?

Vegetative cuttings

In a preliminary study, eight jackfruit accessions were prepared as either terminal or back cuts approximately 4 nodes per cutting with 2 x terminal half leaves/cutting retained. All cuttings received a 10 second basal dip in 4000 ppm KIBA and then were placed in a mist house. Leaf loss data was collected at 6 weeks and root number/cut at 8 weeks. Final rooted cutting numbers were determined at potting up 12 weeks from setting. Accessions as well as cutting type varied in adventitious root formation and also their ability to retain leaf prior to root initiation (Table 5). Further development of jackfruit cutting methods is warranted given the positive response from this initial investigation.

Table 5. Cutting observations for 8 jackfruit accessions (n=18; * p<0.001)

Observation	Accession							
	236	234	242	245	246	229	213	215
leaf loss/terminal cut*	0.9	1.1	0.3	0.3	0.3	0.0	0.1	0.0
leaf loss/back cut*	1.7	2.0	1.6	2.0	1.2	1.6	1.9	0.8
root no./terminal cut*	0.8	0.0	0.0	1	0.1	0.0	0.4	0.9
root no./back cut*	1.2	0.0	0.9	2	0.4	0.7	1.6	1.9
% rooted terminal cuts	50	0	0	50	6	0	28	61
% rooted back cuts	33	0	28	6	11	6	22	67

In June 2017, 60 jackfruit cuttings, 15-20 cm long sourced from mature terminal shoots of the clone Rajang. Ten cuttings per treatment were treated with a range of rooting hormone options prior to placement in a Proforma plug (preformed peat and coir plugs) and struck in a heated sand bed misting chamber (temperature 28°C and misting for 60 seconds every 15 minutes from 6 am to 6 pm. The successful strike rate varied from 25 to 83% dependent on rooting hormone used (Table 6).

Table 6. Jackfruit cutting (cv. Rajang) strike rate as related to rooting hormone.

Rooting hormone utilised	Root development %
Control (no hormone utilised)	33%
Auxinone 0.075 g/L IAA and NAA	25%
Purple Clonex gel 3 g/L IBA	58%
Red Clonex gel 8 g/L IBA	75%
Rootex-P powder 3 g/L IBA	83%
Rootex-P powder 8 g/L IBA	75%

Root development was first noticed at 29 days after placement and up to 122 days, with the bulk of cuttings rooted by 90 days. The success rate of cuttings is promising and the method deserves further examination. The question of long-term field survival of cuttings needs to be examined. The NT results suggest that the accession chosen may have a significant effect on final cutting success.

Philippines

DA-Abuyog

At the DA research station five interspecies Arocarpus stock (A. integer (chempedak); A. camansi (camansi); A. odoratissimus (marang); A. elasticus (Tugop) and A. blancoi (Tipolo or Topo) were utilised in grafting experiments with jackfruit. Six experiments were conducted over the duration of the project. The graft survival rates at 6 months were 55.5% for A. integer, 0% for A. camansi, 13.3% for A. odoratissimus, 9.7% for A. elasticus and 3.2 % for A. blancoi

See Appendix Objective 2a for trail data.

BPI Davao

The rootstock species markedly influenced the growth and performance of the jackfruit scion. The Kamansi (A. camansi) stock was incompatible and did not survive in the nursery and hence was not able to be included in the field planting. At one year after planting, jackfruit on its own scion was 154 cm high, followed by jackfruit on tipolo (A. blancoi) at 101 cm and jackfruit on marang (A. odoratissimus) at 74 cm. The stock scion girth ratio was 0.8, 1.3 and 1.0 respectively.

There was a strong incompatibility between jackfruit and Tipolo (A. blancoi), less so with jackfruit on marang and excellent compatibility with Jackfruit on jackfruit.

At four years after grafting the growth performance, yield and susceptibility to Phytophthora was influenced by the treatments. The jackfruit marang combination was shorter and had a smaller trunk size, with smaller canopy size with better production compared to jackfruit on its own stock.

At four years after planting, only two of the graft combinations were growing productively. Jackfruit on jackfruit was 13.2 m high relative to jackfruit on marang at 7.7 m high. The scion-stock girth ratio was 0.85 and 0.52 respectively. Fruit production, although variable appears to be higher in the jackfruit-marang combination.

The marang rootstock trees obtained zero infection after 4 years from field planting as compared with jackfruit rootstock (2 out of 4) which is already infected with canker on the collar, at the base of the tree near the soil line.

The combination may be healthy and productive for a period of time and then decline due to longer term compatibility issues. The scion-stock combination must be long-lived, both physiologically and morphologically. Such combination may display dwarfing or vigorism, and either may not be a factor in the longevity of the combination, but the tree size factor does exist.

In this study, the marang (*Artocarpus odoratissimus*) rootstock for jackfruit may possess resistance to soil borne disease like Phytophthora and be more productive at an early stage. Despite the limited replications (3), the combination produces shorter stature and smaller canopy trees. Ideally, this work should be expanded to larger scale multi-location trials. Nevertheless the challenge remains at the nursery stage to ensure a higher strike rate at grafting.

See Appendix Objective 2a for tabulated results.

Artocarpus genotyping

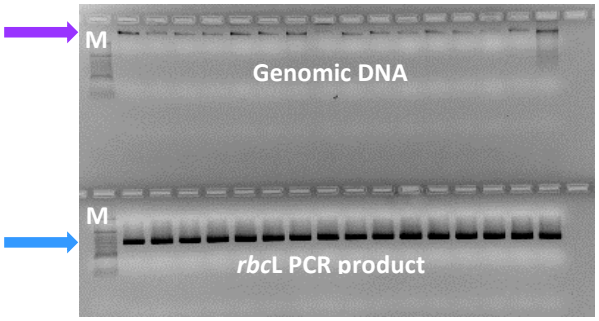
Results

Plant material and nucleic acid extraction

High molecular weight genomic DNA was extracted from 322 of the 336 *Artocarpus* and outgroup species tissue samples. Fourteen samples failed genomic DNA extraction after numerous attempts and were excluded from the molecular analysis.

PCR amplification

All DNA samples extracted amplified the approx. 600 bp fragment as seen in Plate 4.



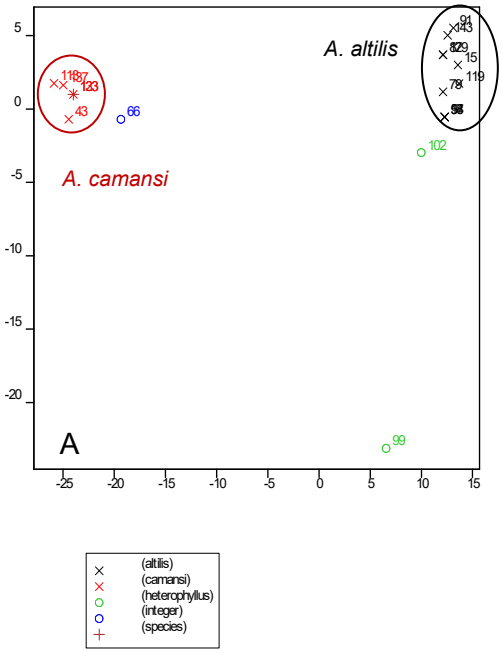
M = molecular weight marker

Figure 6. Agarose gel to visualise genomic DNA quality and amplification of *rbcL* PCR products.

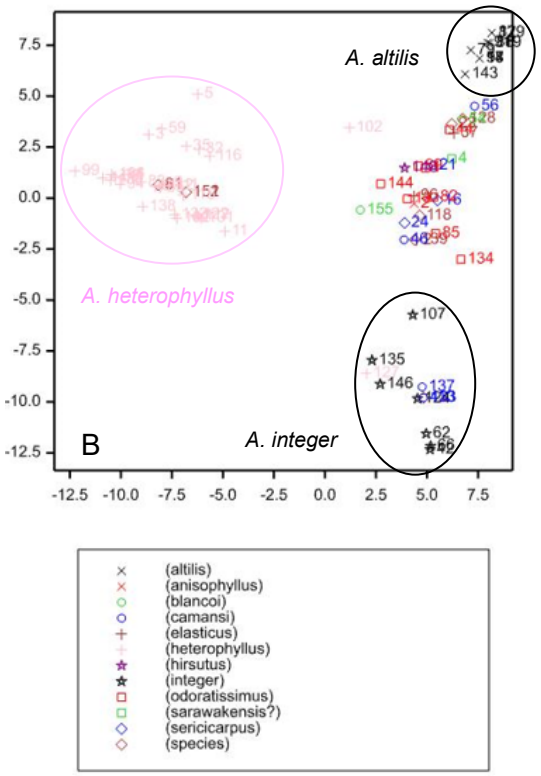
Simple sequence repeat (SSR) marker analysis

Of the 12 selected SSR markers used, MAA26 was dropped due to amplification failure across all *Artocarpus* species. A further six markers (MAA9, MAA40, MAA71, MAA96, MAA219 and MAA287) did not amplify in *A. heterophyllus.* Table 7 shows the success of marker amplification in each of the *Artocarpus* species analysed. Only marker MAA40 was successfully amplified in the outgroup species *Morus*, while marker MAA105 was the only marker to successfully amplify in the outgroup *Ficus pseudopalma.*

Numbers on all graphs represent the sample number 1-155 (data not included). Only 18 of the *Artocarpus* samples amplified all 11 SSR markers. The PCoA separated *A. camansi* and *A. altilis,* with *A. integer* sitting close to *A. camansi.* Only two samples of *A. heterophyllus* amplified all 11 SSR markers and with one sample sitting close to *A. altilis* and one sitting by itself. It is likely that these two samples are not the same species with one sample being misnamed. Figure 2 shows that 83 samples amplified six SSR markers. The PCoA plot separated *A. altilis, A. heterophyllus* and *A. integer*. The remaining species did not clearly separate into groups but remained clustered together. This indicates that there are not enough informative markers to separate all the *Artocarpus* species.



Includes only lines with markers 1- 11 present
N=18 (out of 155)



Includes only lines with markers 1- 5 and 8 present
N=83 (out of 155)

Figure 2. PCoA plots of *Artocarpus* data with A) 18 samples with 11 SSR marker data and B) 83 samples with six SSR marker data.

Table 7. Successful SSR marker amplification in each of the *Artocarpus* and outgroup species analysed.

Marker # for PCoA	3	6	10	5	2	9	1	8	11	7	4
Species	**MAA140**	**MAA219**	**MAA9**	**MAA182**	**MAA122**	**MAA71**	**MAA105**	**MAA40**	**MAA96**	**MAA287**	**MAA156**
A. altilis	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A. anisophyllus	✓	✓	×	✓	✓	×	✓	✓	✓	✓	✓
A. blancoi	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓
A. camansi	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
A. elasticus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
A. glaucus	✓	×	×	×	×	×	✓	×	×	×	✓
A. heterophyllus	✓	×	×	✓	✓	×	✓	×	×	×	✓
A. hirsutus	✓	×	×	✓	✓	×	✓	✓	×	✓	✓
A. hypagyreus	✓	×	×	✓	✓	✓	✓	✓	×	✓	✓
A. integer	✓	✓	×	✓	✓	×	✓	✓	×	✓	✓
A. kemando	✓	×	×	✓	✓	×	✓	✓	×	✓	×
A. lakoocha	✓	×	×	×	×	×	✓	×	×	×	✓
A. odoratissimus	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓
A. rigidus	✓	×	×	✓	✓	✓	✓	✓	×	✓	✓
A. sarawakensis	✓	×	×	✓	✓	✓	✓	✓	✓	✓	✓
A. sericicarpus	✓	✓	×	✓	✓	✓	✓	✓	×	✓	✓
F. pseudopalma	×	×	×	×	×	×	✓	×	×	×	×
Morus	×	×	×	×	×	×	×	✓	×	×	×

DArTSeq SNP analysis

A total of 137,634 DArTseq SNP markers were generated for the 322 samples representing different ecological and geographical areas of Australia, the Philippines, Hawaii, Fiji and Samoa.

The quality of DArTseq markers was assessed by different quality parameters, including reproducibility values, average count for each sequence or row sum (sequencing depth), the balance of average counts for each SNP allele, and the call rate (proportion of samples for which the marker is scored). Quality control parameters included >95% call rate, >95% reproducibility, and >0.05 one ratio (Table 8). Monomorphic alleles were also filtered out of the data set. Following marker filtering a total of 1899 DarTseq SNP markers showed polymorphism and were used for further analysis (Figure 3).

Table 8. Number of SNPs within *Artocarpus* populations detected by DArT and remaining SNPs after filtration

	SNP 2 row format file (Original)	Filter loci call rate 95%	Filter individual call rate 95%	Filter reproducibility 95%
Total genotypes	322	322	278	322
#SNP	137634	1900	1167	1899
Missing data	18170837	18936		18920
% missing data	41%	3%		3.09%

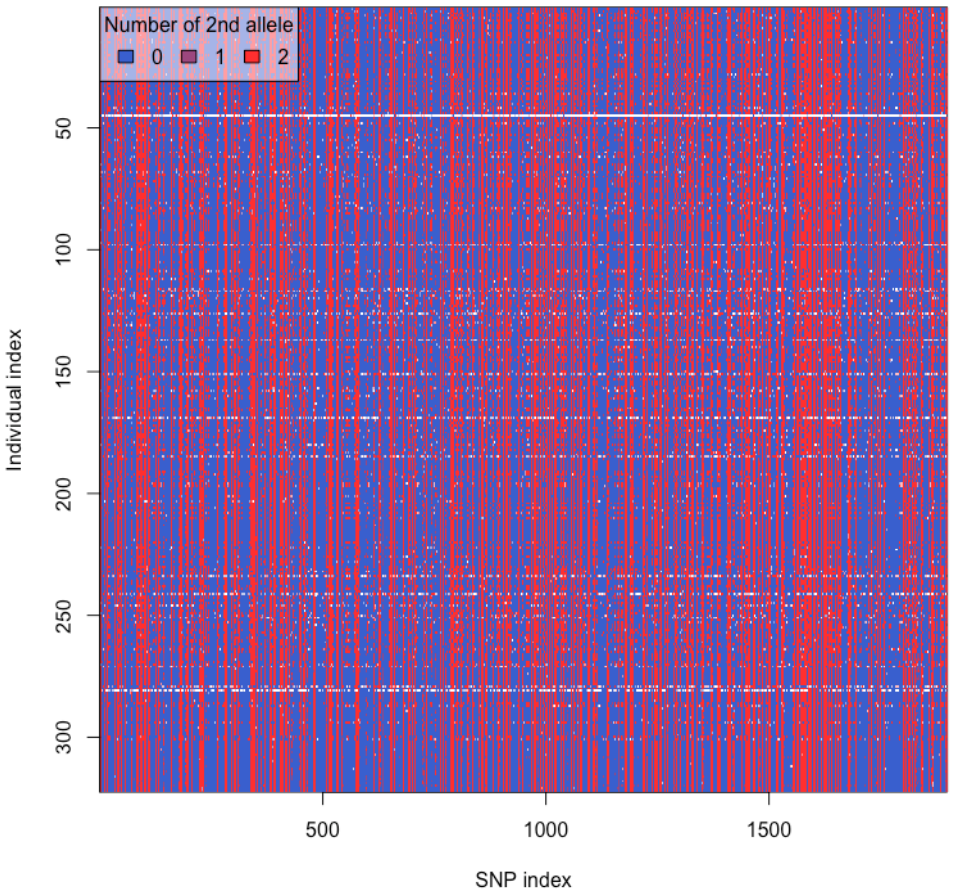


Figure 3. Quality control - overview of missing data (white tile) in individual sample raw data.

The DArTseq marker data set was used to calculate the Euclidean genetic distance among the 322 *Artocarpus* samples and a PCoA was performed with 100 bootstrap replicates (Figure 4). The SNP markers were able to separate *A. heterophyllus* (orange circle), *A. altilis* (olive circle) and *A. integer* (turquoise circle). The remaining samples were not as clearly separated to identify their groupings and relationships to each other. PCoA Axis 1 explained 54.6 % of the total variance while PCoA Axis 1 and 2 combined explained 70.2 % of the total variance. PCoA Axis 1-3 combined explained 74.9 % of the total variance.

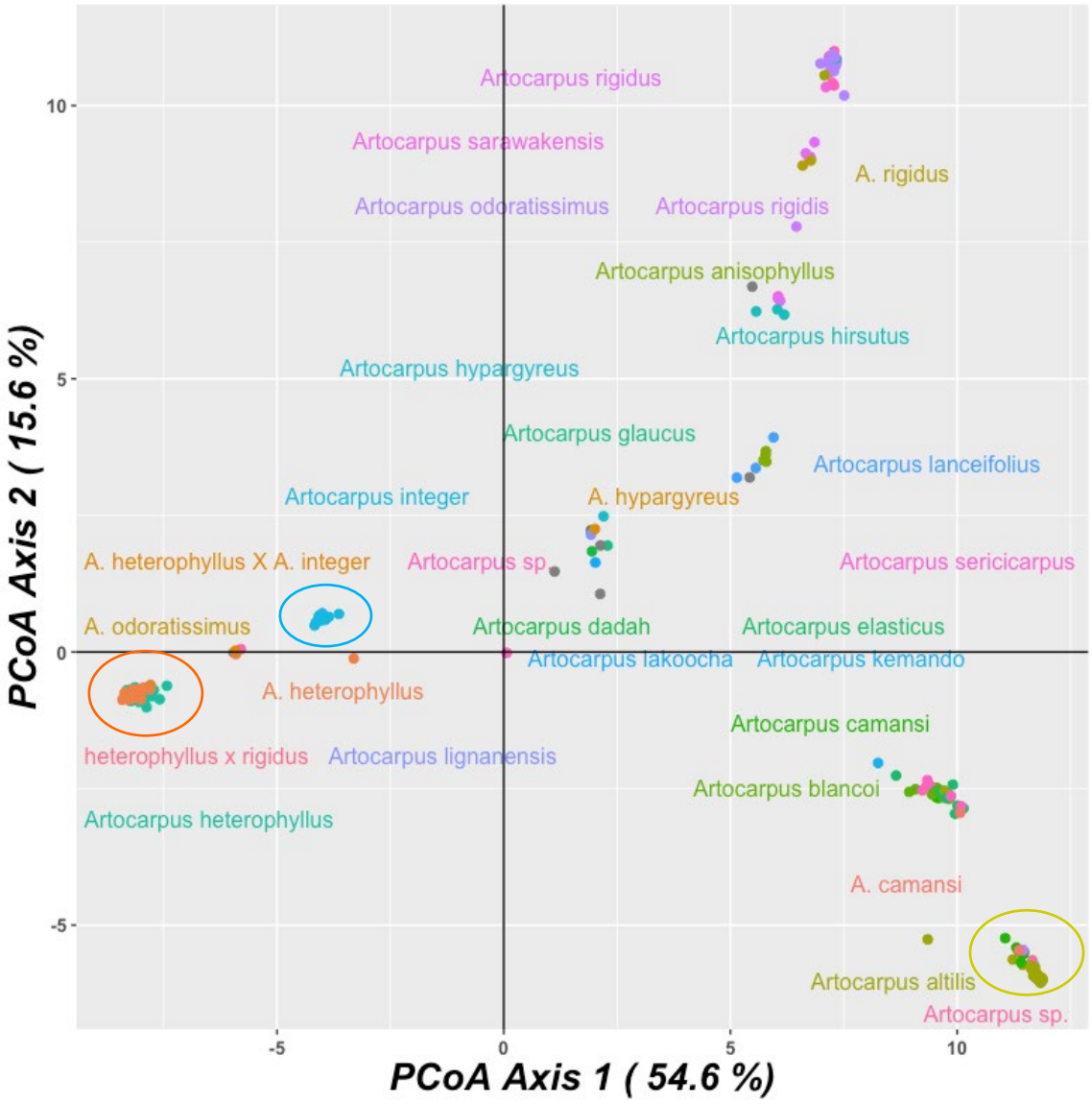


Figure 4. Cluster dendrogram by species identification

A dendrogram was constructed for all the samples based on the Euclidean genetic distance (Figures 5 and 6). DArTseq based UPGMA analysis grouped.

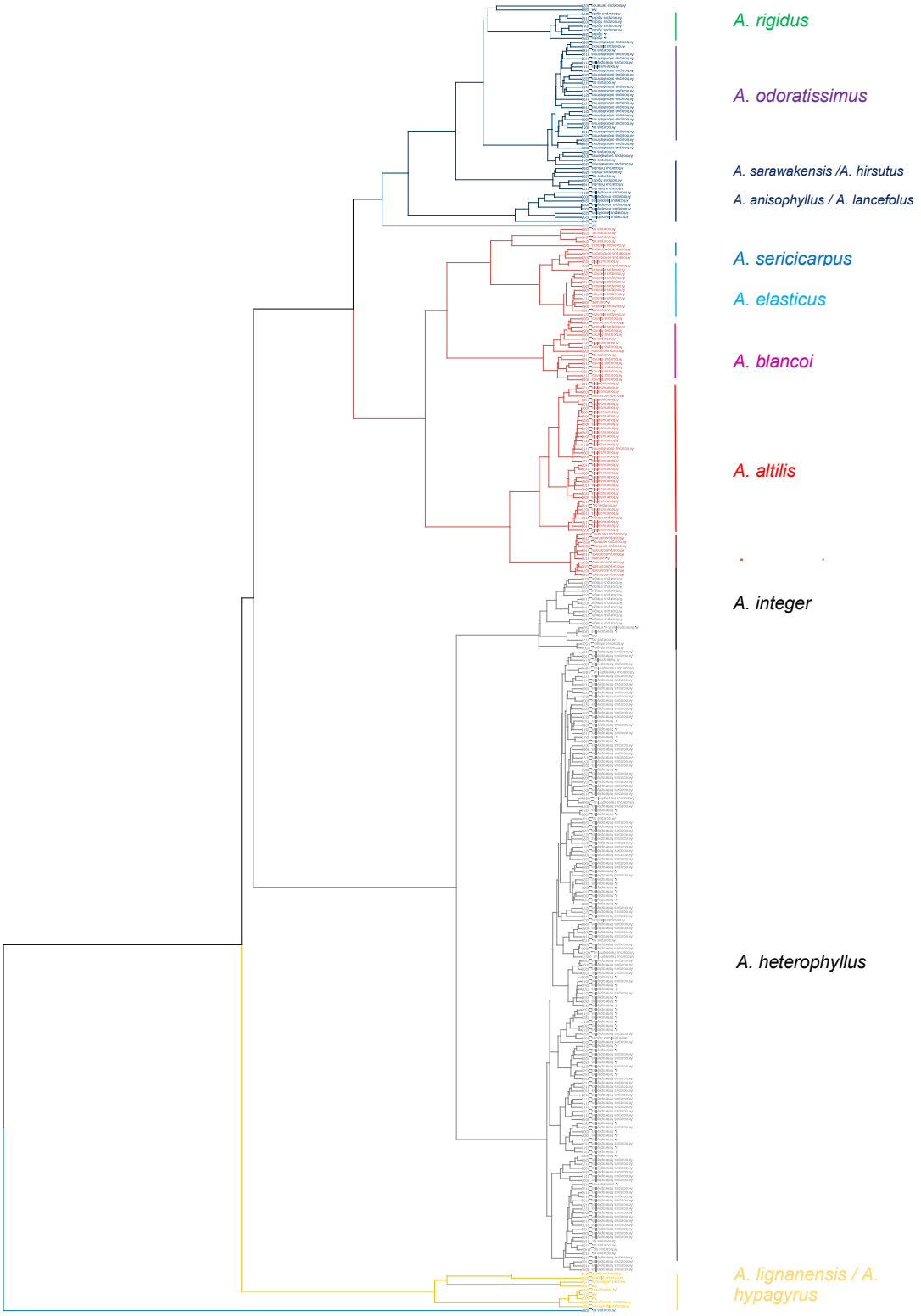


Figure 4. Cluster dendrogram by species identification

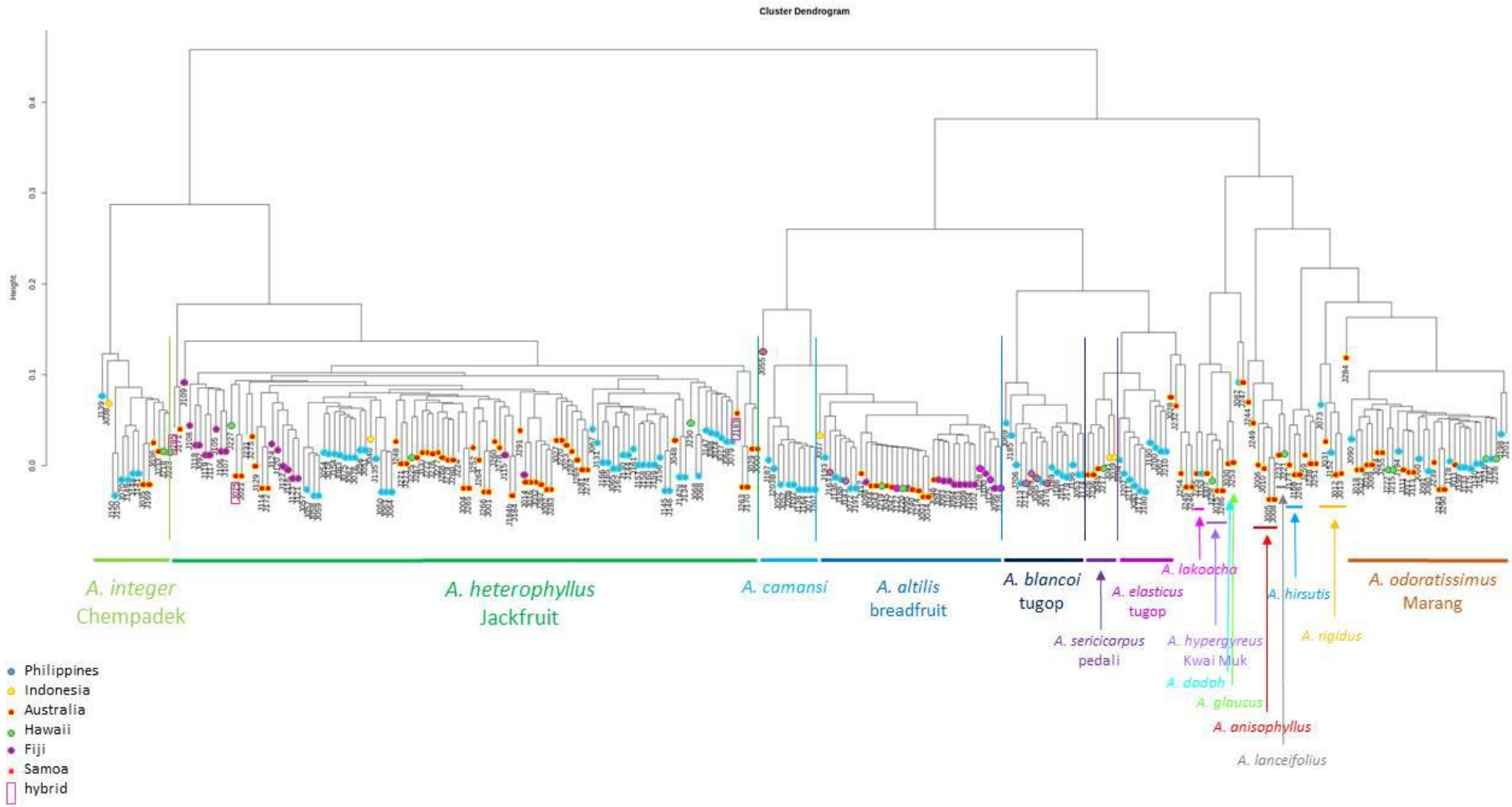


Figure 6. Cluster diagram by species identification and country of origin.

Silico DArTSeq analysis

A subset of 273 of the total 322 individual *Artocarpus* and related species genomic DNA samples were analysed to assess genetic diversity among and within populations using the DARwin software. A subset of 215 of the total 129,582 silicoDArT markers were used for the PCoA (Figure 7). This plot shows a close relationship of A. altilis with A. camansi, while A. heterophyllus is closely related to A. integer.

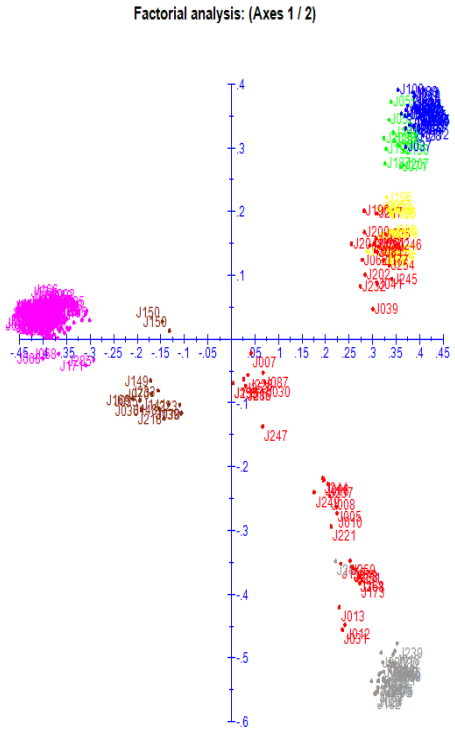


Figure 7 **PCoA of 273 *Artocarpus* species and 215 silicoDArT markers. *A. altilis* - blue, *A. blancoi* -yellow, *A. camansi* - green, *A. heterophyllus* - pink, *A. integer* - brown, *A. odoratissimus* - grey, unknown – red.**

A phylogenetic tree (unrooted) using unweighted neighbour joining method based on genetic dissimilarity was produced (Figure 8). The results of the phylogenetic tree are the same as that produced by the PCoA plot.

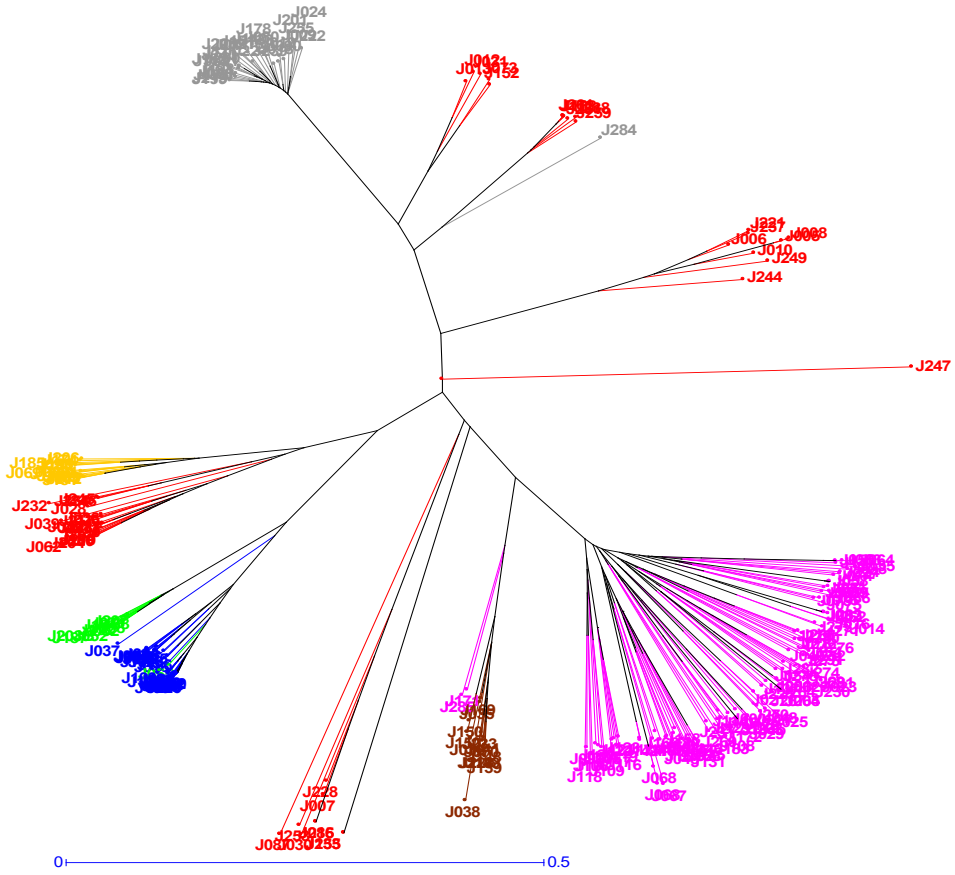


Figure 8. Phylogenetic tree of 273 *Artocarpus* species and 215 silicoDArT markers. *A. altilis* - blue, *A. blancoi* -yellow, *A. camansi* - green, *A. heterophyllus* - pink, *A. integer* - brown, *A. odoratissimus* - grey, unknown – red.

Conclusion

Simple sequence repeat (SSR) marker analysis

Witherup et al. reported markers MAA26, MAA105, and MAA196 did not amplify in *A. altilis*, *A. camansi*, *A. mariannensis*, or the hybrids *A. altilis* x *A. mariannensis*. However, MAA26 was reported to amplify PCR products in *A. heterophyllus*. After repeated failure to amplify PCR products in any of our samples marker MAA26 was dropped from this study. In agreement with the results of Witherup et al, the markers MAA40, MAA71, MAA96, MAA219 and MAA287 did not amplify PCR products in *A. heterophyllus* in our study.

Both the SNP and silico DArT markers have shown the relationships of the *Artocarpus* species. *A. altilis* is closely related to *A. camansi*. *A. heterophyllus* is closely related to *A. integer*. *A. odoratissimus* and *A. rigidus* are closely related and more related to *A. altilis* than *A. heterophyllus*.

Activity b. Evaluate tools to manipulate flowering patterns in jackfruit to spread crop production (PC)

The limited duration of the trial, due to the late start makes it difficult to interpret result. The results of the flower induction trial conducted at Marhen, Ormoc City showed that after treatment application in 2016, treatment 8, i.e., pruning the top and lower branches of jackfruit, drenching Paclobutrazol and injection of $CaNO_3$ produced more shoots which is important for the production of fruit stalk (Figure. A5-1). Later in the season (August to November 2016)

treatment 9, pruning top and lower branches, drenching Paclobutrazol and drenching of $CaNO_3$ induced more female flower compared to other treatments (Figure A5-2). By Aug-Oct 2017, however, treatment 2, i.e., the removal of old fruit stalks, which have not set immediately after cropping, produced more female flowers compared to other treatments (Figure A5-3).

Experience combined with the limited trail data suggests that internal pruning of old fruit stalks and water shoots, regular nutrition management and top pruning are all management techniques worth considering for the promotion of off season flowering.

See Appendix 5 – Objective 2b for data associated with the trial.

Activity c. Improve crop production by developing crop load and nutrient management techniques (PC)

Results of the four year trail conducted by VSU at Job Abuyabor's farm Mahaplag highlighted the complexity associated with measuring the effects of treatments on farm trials. Over the four years there was no significant difference in fruit count and yield despite treatment overlays of fertiliser, fruit regulation and use of PhosPro (the local source of potassium phosphonate).

Four year average accumulated yields for the following fertiliser treatments Commercial Organic, 150% DA recommendation, 100% DA recommendation, 50% DA recommendation and farmer practice (chicken bedding manure) were 254, 238, 195, 165 and 133 kg per tree.

Interestingly, the accumulated yield of regulated (max 15 fruit/tree) trees was 209 kg/tree compared with 186 kg/tree for unregulated trees.

Based on the mean yield data the use of PhosPro for the amelioration of Phytophthora appeared to have a negative effect.

In a similar trial conducted at DA – Abuyog where five levels of fertiliser input (Control, DA recommended rate, 50 % DA rate, 150% DA rate and organic fertiliser where applied with or without PhosPro. Accumulated yield over 18 months responded to fertiliser treatments as expected with the highest accumulated yield of 164 kg/tree for the 150% DA rate significantly higher than 117 kg, 115 kg, 103 kg and 90 kg achieved for the DA recommended rate, organic fertiliser, 50% DA rate and control respectively. The accumulated yields for phosphonate treatments were not significantly different at 121 kg/tree and 114 kg/tree for plus phosphonate and minus phosphonate respectively.

An cost and returns analysis of the results for 30 jackfruit trees suggest that net income for the 150% DA rate treatment was P22,180 P10,000 or less for the remaining fertiliser treatments.

See Appendix 6-Objective 2c for data tables.

Activity d. Assess the feasibility of trellising tropical fruit trees for cyclone (typhoon) resilience and improved crop production. Concurrently evaluate early performance of clonal rambutan hedge systems and stock influence on scion performance (A)

Centre for Wet Tropics Agriculture, South Johnstone

Trellising systems trial

The trellis was constructed using end posts of 150 mm CCA treated pine posts. Inter row posts, 125 mm, were placed every 12 m along the rows. All posts were 3 m in length with 1 m buried into the ground. The 2 m of posts above the ground had 2.65 mm high tensile wire strung from post to post, 40 cm apart, forming a five wire trellis system.

A row of control (free standing trees) were included in conjunction with three trellis configurations which included V-Trellis (or open Tatura); Espalier; and T-trellis.

Tree spacing was 3 m between trees within the row and 5 m between rows. The espalier and T Trellis rows had a planting density of 667 trees/ha and the V trellis rows were planted at double the population (1334 trees/ha).

Three species with differing plant architecture and flowering positions were tested.

- Guava – Thai white; (plagiotropic growth and axial flowering)
- Longan – vr. Kohala; (orthotropic growth and terminal flowering)
- Seedling Cocoa - (orthotropic/plagiotropic growth and cauliflorous flowering)

Within each trellis type and for each tree species several tree training configurations were imposed. Guava and longan trees were either trained at (180°) – central vertical leader with the main lateral branches attached to the horizontal wires and production promoted on secondary laterals), (45°) – central vertical leader with the main lateral branches angled at approximately 45° from the vertical with production promoted on secondary laterals. For cocoa, an additional pruning configuration was imposed (Upright Fruiting offshoots -UFO) – where the main orthotropic shoot was pulled over at a 45° angle and the cropping was promoted on the additional cupons (water shoots) and resultant jorquette branches which developed.

Performance summary

Guava

Guava trees grow vigorously, are precocious and can flower and fruit for most of the year in a tropical environment. The trees have a plagiotropic growth habit with extensive branching if left unpruned. Flowers appear from leaf axils on new growth and quite often bear fruit from leaf axils directly opposite each other. When fruiting, the trees can produce multiple fruit per node and fruit weights were generally in the 200 to 400 gm range with occasional fruit up to 1 kg in weight.

Production of fruit commenced in the May 2014, approximately 1 year after planting. Production increased up to the 2016-2017 season where maximum yields were achieved. Over a four year period of fruit production, the V Trellis structure produced an average 37 t/ha in the 180° training system and 28 t/ha in the 45° fanned branch configuration. In the same season, yields on the espalier and T-trellis trellis systems were ranged from 17 to 22 t/ha, whereas the free standing trees achieved a yield of 19 t/ha.

The mean yields over all producing years for all trellis and training configurations ranged from 14.6 for the T trellis 45° to 36.9 t/ha in the V trellis 180° treatment The yield of free standing trees was equivalent to 20.1 t/ha. The higher yields achieved in the V trellis system are directly related to tree population which was double that of the other treatments. Hence, trees in each trellis system configured at the correct row spacing could be equally high yielding. The 180° pruning (horizontal lateral) configuration was the preferred system for guava which allowed for ease of pruning and picking. Once fully formed on the trellis the trees maintain their configuration with minimal follow up pruning. For high intensity production utilising mechanical pruning, the espalier trellis system is preferable.

Longan

The longan tree is a vigorous terminally flowering crop that bears large panicles of fruit at the ends of the branches. It has an orthotropic growth habit and can have numerous vegetative flushes during the warmer months of the year. The trees were trained onto the different trellis systems as either fanned and horizontal branches. The terminal flowering nature of longan means that yields are directly related to the number of terminals. During the training of the longan trees it was observed that pulling the branches onto the wires produced more secondary laterals branches than the fanned training. The fanned training system was quick to fill the trellis top wire but lacked sufficient secondary laterals. Notching or scoring the wood had little success in producing secondary shoot development on the lower portion of

the trellis and on 45° fanned branches. New vegetative growth could only be achieved reliably by pruning the tops out of branches, reducing the effect of strong apical dominance.

The wet tropical coast of far north Queensland is considered sub-optimal for the production of longan due to the lack of cold induction during the cooler months. In August 2015, the trees had a root drench application of potassium chlorate (35 g/L and 1 L per tree) to assist with floral initiation. Two months later flowering occurred throughout the trial. The trees were netted in January 2016 and fruit was harvested in March. As per guava, the highest yield achieved was in the V trellis system due to the higher population density, 35.9 t/ha and 32.7 t/ha for the 180 and 45 treatments respectively. The free standing trees produced an average yield of 19.7 t/ha and the fence (espalier) trellis 18.8 and 15 t/ha for the 180 and 45 pruning configurations respectively. Only minimal (negligible) cropping was achieved in the next two seasons, despite the use of potassium chlorate. With terminal crops such as longans, the number of terminals per tree is directly related to yield. The trees that were free standing produced as much fruit per hectare as the trellis systems of the same planting density of 667 trees per hectare. Appropriate row spacing configurations would allow single row trellis or modified freestanding trees with a cable support for cyclone resilience to yield as high as the V trellis.

Terminal bearing crops that require heavy pruning after harvesting may be better suited to less elaborate trellis systems. As the fanned trees produced over 70% of their fruit on the top wires, a lower trellis system with a similar number of terminal branches may produce the same yields on a lower 1 to 3 wire trellis and have better wind resistance to cyclonic events.

Cocoa

Cocoa is a cauliferous tropical tree crop that flowers and fruits directly off the main trunk and branches. The trees produce a mass of small flowers and only a small percentage (<5%) develop into pods. The seedling tree first grows as a single orthotropic trunk with leaves developing in a spiral pattern. The single stem (trunk) will naturally branch (jorquette) when 1 to 1.5 m high into 4-5 branches, which are plagiotropic where leaves develop on a single plain alternating opposite each other. The plagiotropic (fan) branches are easily shaped through regular pruning. If the main trunk is left unmanaged new water shoots (chupons) orthotropic in nature will develop into and above the original canopy before jorquetting. This pattern is repeated in trees in the wild state thus producing a multi-story canopy.

Seedling trees used for the trial were planted in May 2013, approximately five months after germination. At planting each tree was initially protected in a shade-cloth tube held up by stakes as young seedling cocoa trees are susceptible to wind and sun damage. The shade-cloth was removed 2-3 months later depending on individual plant vigour.

The training of the cocoa trees included horizontal, fanned and upright fruiting offshoots (UFO). The horizontal and fanned methods included training both chupon and jorquette branches directly onto the wires (180) or fanned (45). The UFO method requires leaning the main stem over on a 45° angle and then fanning the new developed chupons up and onto the trellis opposite the growth of the main stem. During the training of orthotropic chupon branches onto the wire for the horizontal method, the branch would continue to turn and grow upwards. The branches frequently snapped, lost leaves and cracked due to sun damage.

Once a tree produced the jorquette, the training of wood either fanned or horizontal was more successful as the wood is plagiotropic. Some trees grew a jorquette higher on the main stem which resulted in less suitable wood. New chupon wood from the base of the tree could also be used for training, but the chupon wood on an established tree tends to be too vigorous. If the chupon wood was bent over onto the bottom wire of the trellis in a full shaded position, it could be used to produce more branches further out from the main trunk resulting in more trellis area filled with canopy. Once bent over more vegetative buds grew, resulting in improved canopy coverage.

In June 2015, the harvesting and of cocoa pods commenced. Pods were harvested from both jorquette and chupon wood throughout the trees. Extrapolation from the small plot size, 4 or 8 trees per treatment resulted in average annual tree pod yields over three season of 29.8 t/ha, 24.1, 20.1, 16.8. 14.5 and 11.3 t/ha in the V trellis 45°, Fence 45, V trellis 180, Fence UPO, Fence 180 and free standing trees respectively. The performance on T-trellis was somewhere in between. The average tonnes per hectare of cocoa pods harvested was generally higher in the V trellis system compared to other trellis and pruning arrangements. However, at 1334 trees per hectare, the average yields are only 20% higher than some of the other trellising systems that have 667 trees per hectare. Hence at appropriate row spacing single row trellis systems could result in similar high yields with the added advantage of being more amenable to mechanical pruning.

The averaged data across the training systems suggested that training primary branches of cocoa at a fanned angle to the main stem, produces higher yields than the horizontal method. This occurred consistently in the three trellis systems. Training orthrotropic branches onto wires is not ideal unless carefully managed, and the risk of damaging the wood is higher. Many cocoa pods that did develop on horizontal branches appeared sun damaged and prematurely ripened.

See Appendix 7-Objective 2d for production data

Durian

Trellising trial, DAF, Far north Queensland

The demonstration trial block at East Feluga proved that durian can be trellised onto V Trellis (Open Tatura) structure which provides lateral branch support and a structured canopy The trees were productive, producing 9.1 t/ha four years after planting. The trellis structure may assist durian tree to be more resilient to cyclones. This work, has raised many issues. Most of the issues relate directly to farmers having a sound understanding of how crops grow, flower, fruit and whether pruning and training methods can build a tree onto a trellis that does not significantly impact growth, health and yield.

See Appendix 7-Objective 2d for data and a brief report.

Jackfruit

Jackfruit trellis plantings were monitored on two commercial sites.

Site 1.

- Multi trunk, T-trellis support for upper canopy
- Variety: Rajang
- Tree age: 8.5 years
- Fruit/tree: 40 fruit/tree at 10 kg/fruit
- Tree Spacing: 9 x 6 m spacing, 185 trees/ha
- Estimated Yield: 74 t/ha

Site 2.

- Single trunk, T-trellis support for upper canopy
- Variety - Rajang
- Tree Age: 3 years
- Fruit/tree: 6 fruit/tree at 12 kg/fruit
- Tree Spacing: 7 x 5 m spacing, 285 trees/ha
- Estimated Yield: 20.5 t/ha

Rambutan

NT DPI&R Rambutan clonal, high density (6.7 x 2 m) orchard systems

- Marcotting (air-layering) rambutans most reliable method of clonal propagation with quick industry adoption of method.
- Field establishment was excellent with 95-100% survival across 4 commercial cultivars.
- Non-bearing growth rates were uniform with only the cultivar “Binjai” marginally slower.
- Cropping commenced in the third year after planting with an average of 9.0 kg per tree (6,700 kg/ha) for the variety R167.

Lychee

Queensland DAF – Lychee floral development and fruit set

Lychee Treatments included; two anti-gibberellins (uniconazol and paclobutrazol) plus and minus micro nutrients; micronutrients alone and control (water) were applied at early panicle development in July 2015. The change in panicle length and fruit set per plot were measured in November 2015 prior to harvest.

Panicle length change and fruit number per plot were not significantly different among treatments. Poor fruit set was encountered in all treatments and throughout the remainder of the orchard due to sub-optimal temperatures during the crucial fruit set phase.

Objective 3: To develop improved processing options for jackfruit.

Activity a. Refine the current vacuum fried and alternative products produced in the Philippines (PC)

a.1 Measure the effect of fruit maturity on the quality of fresh and processed product (PC)

Results of the first phase of the study showed that some fruit characteristics can be used as good maturity indices. The colour of the fruit peel changes from green to yellowish green or brownish yellow as the fruit matures. Overripe fruit tend to have brownish tinge on the yellowish colour of the fruit peel. The colour of the fruit pulp can also be a good indicator of fruit maturity. Less mature or unripe fruit have whitish to very light yellow colour. The yellow colour intensified as the fruit maturity progressed. Advanced mature fruit are already ripe and have a bright to dark yellow fruit pulp. Spine density per unit area of the fruit peel is also a good maturity index. Less mature fruit has higher spine density. The spines widened as the fruit matures and ripens. Hence, the ripe fruits have lesser spine density than their

younger counterpart. During storage, shrinkage and weight loss occurred and the spine density of the fruit increased irrespective of the fruit maturity. Still, more mature fruit has lesser spine density than the younger fruit.

The physico-chemical properties of the fruit pulp also provided a good maturity index. The TSS of the freshly harvested fruits is very low and increases after storage when the fruit matures or ripens. Mature fruit has higher TSS values, as attributed by the conversion of starch materials in the unripe fruit into sugar as the fruit ripens. The acidity of the fruit pulp, as indicated by the pH and titratable acidity, also increased as the fruit ripens. However, when the fruit is overripe, the acidity decreased as attributed to the utilization of some organic acids by the respiration process during ripening. On the contrary, the fruit weight, volume and density of jackfruit cannot be used as reliable indices for maturity.

For the second part of the study, results revealed that at 120 Days after anthesis (DAA) fruit maturity is best suited for the processing of vacuum fried jackfruit. The maturity is just right and the fruit pulp had the highest retention of vitamin C after vacuum frying. It also has the highest total phenolic content after vacuum frying. The mean acceptability scores of all sensory attributes of the fruit pulp for this maturity falls within the “like slightly to like extremely” category of the 9-point Hedonic rating scale indicating that the vacuum fried pulp produced from 120 DAA is highly acceptable by the sensory panel members. Conversely, the 110 DAA fruit had inferior quality as compared with the two ripe fruits, the 120 and 130 DAA. It received a general acceptability score which is within the category of “dislike slightly to dislike moderately” of the 9-point Hedonic rating scale.

a.2 Comparison of methods used for identifying fruit maturity (NIR, acoustic and heat-sums) (A)

A preliminary study aimed to assess the potential of Near Infrared Spectroscopy (NIRS) in diffuse reflectance mode as a rapid and non-invasive technique to assess jackfruit for °brix %, citric acid %, dry matter % and “days to ripe” was completed by the Innovative Food Technologies (IFT) group from Department of Agriculture and Fisheries (DAF).

Due to the limited number of available jackfruit (8 fruit), spectra were collected at 6 locations around the jackfruit and in obtaining each sample spectrum, 16 scans at a resolution of 8 cm-1 were collected and averaged. Initial NIR methods were developed to assess fruit maturity, however require further research and refining for both methodology and spectra collection platform, plus assessment of sufficient jackfruit numbers to enable construction of robust calibration models to predict jackfruit samples.

a.3 Initiate trials to improve overall quality of vacuum fried jackfruit chips (PC)

For this part of the study, it was found that the moisture content and water activity of the vacuum fried jackfruit pulp significantly increased during storage. This increase in the moisture content resulted to the negative changes on the textural quality of the product as the storage period increased. Likewise, the free fatty acid content (% oleic acid) and the peroxide value of the products increased significantly with the progression of the storage period. All results favoured with the use of oxygen absorber as an improvement of the packaging method for the vacuum fried jackfruit.

The use of oxygen absorber, significantly maintained the low moisture content and water activity of the packed samples for a longer storage period. Likewise, it resulted to the least FFA and peroxide value of the product for a longer storage period. This means that rancidity was significantly reduced by the used of oxygen absorber. Estimation of the shelf life of the vacuum fried jackfruit pulp revealed that without using the nitrogen flushing and oxygen absorber, the product will have an estimated shelf life equivalent to 7.96 weeks. The vacuum fried jackfruit pulp in a nitrogen flushed packaged will have about 10.53 weeks and the product with oxygen absorber will have the longest estimated shelf life of 10.71 weeks. The use of nitrogen flushing showed a promising result for the extension of the storage quality of

the vacuum fried jackfruit. However, the packaging material was not thick enough to resist punctures during the packaging due to the sharp edges of the vacuum fried jackfruit pulp. Results provided evidences that the current packaging of the vacuum fried jackfruit can be improved with the use of oxygen absorber. Nitrogen flushing is also a good option but it required a thicker packaging material.

In the frying cycle optimisation evaluations, it was found that free fatty acids, acid values and peroxide values all increase in values with additional cycles. This can be observed in Table 9. Overall, the general acceptability of the product from 1st to 15th frying cycle is decreasingly comparable to the acceptability of the product from 20th frying cycle even though its acceptability rating is still satisfactory. This is primarily because of the chemical quality (rancidity) changes in oil that has been used for several times. The general acceptability of the product was dictated by the significance of aroma and taste. Hence, the general acceptability of the product decreases with increasing number of reusing the oil in vacuum frying.

Table 9. Chemical analysis of oil extracted from vacuum fried jackfruit

TREATMENT	% FFA^{ns}	AV^{ns}	PV (meq oxygen/kg)*
Cycle 1	0.1068 ± 0.2085	0.2125 ± 0.4149	4.0247 ± 0.3175^{a}
Cycle 5	0.1127 ± 0.1669	0.2243 ± 0.3321	8.1876 ± 0.3367^{b}
Cycle 10	0.1154 ± 0.3219	0.2297 ± 0.6407	9.6214 ± 0.3587^{c}
Cycle 15	0.1166 ± 0.1100	0.2320 ± 0.2190	16.5347 ± 0.4587^{d}
Cycle 20	0.1203 ± 0.0704	0.2395 ± 0.1400	17.7113 ± 0.9709^{d}

Mean ± standard deviation of replicate analysis (n=3)
Values with the same superscripts within the column are not significantly different ($p < 0.05$)
* - significant at $p < 0.05$, ns – not significant at $p \leq 0.05$

a.4 Consumer testing of processed product in the Philippines (PC)

Results in consumer evaluation showed that in dehydrated jackfruit pulp, 88% of the consumer liked the VSU developed product but 91% liked its commercial counterpart. In terms of product appearance, 49% preferred the VSU developed product and 51% preferred the commercial counterpart. Sweetness and soft texture were the identified attributes in the commercial product that consumer preferred most.

For vacuum fried jackfruit results showed that VSU developed vacuum fried jackfruit is acceptable among 95% of the consumers while 83% like the commercial counterpart (imported sample). In terms of product preference, 77% preferred the VSU developed product and 23% preferred the commercial sample. Presence of jackfruit aroma and right sweetness are the most identified attributes in VSU developed vacuum fried jackfruit.

Activity b. Investigate 'fresh cut' processing option

Conduct trials on "fresh cut" jackfruit (PC)

In initial sub-activity trials that utilised sodium hypochlorite, calcium chloride and ascorbic acid pre-treatments to produce a minimally processed jackfruit, results show that treatments treated with 20 ppm sodium hypochlorite has relatively lower colony forming units per mL (cfu/mL) for bacteria, moulds and yeast compared with those treatments treated with 10 ppm sodium hypochlorite (Table 10). This result has been observed to be relatively consistent from day 0 until day 5. Treatments with the highest levels of sodium hypochlorite and ascorbic acid concentration has very low microbial load from days 0 to 5, which, could infer a possible synergistic anti-microbial effect of both agents onto the product.

Further acid treatment optimisation work (up to 9 days shelf life) revealed that treatment 14 with 0.004 sodium hypochlorite, 0.75 $CaCl_2$ and 1.0 ascorbic acid (% w/v) achieved the highest mean acceptability rating in all sensory attributes evaluated except aroma. The mean sensory ratings of the sensory attributes ranged from 8.17 and 8.57 equivalent to like very much of the 9-point hedonic scale. Upon superimposing the contour plots of ratings of all the sensory attributes evaluated, the general acceptability an optimum combination of NaOCl, $CaCl_2$, ascorbic acid (% w/v) was established.

Table 10. Summary of Mean acceptability scores for the organoleptic properties of Minimally Processed Jackfruit (EVIARC Sweet) as affected by the different levels of NaOCl, $CaCl_2$ and Ascorbic Acid

Trt	A	B	C	Color	Aroma	Sweetness	Sourness	Texture	Off-taste	Off-odor	General
1	0.0025	0.5	1	7.86	7.07	7.07	7.43	7.36	6.93	7.36	6.86
2	0.0055	0.5	1	7.5	7.43	7.43	7.79	7.43	7.29	7.43	7.71
3	0.0025	1	1	7.57	7.43	7.64	7.71	7.5	7.29	7.79	7.71
4	0.0055	1	1	7.86	7.86	7.57	7.93	7.79	7.57	7.64	8.00
5	0.0025	0.75	0.5	7.5.0	7.79	7.79	7.93	7.79	7.71	8.00	7.71
6	0.0055	0.75	0.5	8.14	8.21	7.5	8.00	7.93	7.86	7.57	7.79
7	0.0025	0.75	1.5	7.57	8.00	7.64	7.5	7.64	7.07	7.93	8.07
8	0.0055	0.75	1.5	7.79	7.64	6.93	7.21	7.79	7.43	7.57	7.43
9	0.004	0.5	0.5	8.07	7.93	7.36	7.93	7.64	7.86	7.93	7.71
10	0.004	1	0.5	7.57	7.57	7	7.86	7.57	7.86	7.71	7.57
11	0.004	0.5	1.5	8.00	7.71	7.36	7.5	7.71	7.5	7.57	7.79
12	0.004	1	1.5	7.79	8.14	7.5	7.71	7.57	7.93	8.07	7.79
13	0.004	0.75	1	7.86	7.36	7.29	7.86	8.14	7.50	8.00	7.71
14	0.004	0.75	1	8.5	7.93	8.21	8.14	8.36	8.36	8.57	8.07
15	0.004	0.75	1	8.14	7.64	7.57	7.93	7.71	8.00	7.57	7.71

N = 14; values in red means lowest; values in green means highest; A-NaOCl; B-$CaCl_2$; C-AA

When analysing differences between deseeding and storage temperatures, observations show that these conditions are critical in affecting product physico-chemical quality (TSS, TA, pH, colour, firmness, microbial) and sensory shelf life. In particular, it was 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. Treatments which are deseeded had a 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.

Lastly, results observed on unripe jackfruit processed using preservative variables (sodium metabisulphite, sodium benzoate) and processing parameters) show that on day 1, ascorbic acid level, presence of underwater cutting and fruit maturity showed consistent significant effects on all days of storage for microbial analysis. At the succeeding days the same

variables were found to have significant effect but with the addition of the levels of sodium benzoate of which was found to be statistically significant on day 3 to day 7 (Table 11). Further physico-chemical interactions and analysis results can be found in the partner country report.

Table 11. Effect of fresh-cut jackfruit preservative treatments on microbial analysis.

VARIABLES	STORAGE PERIOD			
	DAY 1	DAY 3	DAY 5	DAY 7
Mean/Intercept	4.6676*	3.8230*	4.6543*	5.2927*
Ascorbic Acid	-0.9295*	-0.7345*	-0.8024*	-0.8854*
Sodium Metabisulfite	-0.0374	-0.0134	0.1830	0.0202
Sodium Benzoate	-0.1627	-1.3931*	-0.9604*	-0.3343*
Cutting Underwater	1.2104**	-0.4798**	0.2593**	0.2364
Presence of Blanching	-0.2166	0.2757	0.0428	0.0594
Packaging Type	-0.6553	0.4683	0.0747	-0.0667
Maturity	-0.7354*	-0.9419*	-0.3775**	-0.2658*

Significance of p≤ 0.05

Conduct trials on “fresh cut” jackfruit (A)

A literature review (2013) conducted on minimally processed jackfruits has identified suitable acid dipping treatments including ascorbic acid, citric acid and calcium chloride which was shown to be effective in shelf life extension. Packaging technologies include utilisation of pouches or trays which utilises modified atmosphere packaging. This involves in reducing oxygen levels and increasing carbon dioxide/nitrogen to delay polyphenol oxidase reactions and maintaining fruit quality.

Preliminary fresh cut evaluations utilising literature protocols determined that a seed-in whole aril product was most suitable for assessment as it reduced fruit damage, processing time while increasing product recovery. Acidification treatments and packaging were also shown to be effectiveness on the extending product shelf life.

Lastly in the international product review, product category; freeze dried, vacuum fried and deep fried chips are all highly produced in the snack market. It is also common for small amounts of sliced jackfruit and puree to be utilised in processed refrigerated packaged goods including puddings, yoghurt, ice creams and coconut jelly. New product innovations in immature jackfruits are now also utilised as meat alternative for whole meal packages in combination with rice, sandwiches or wraps and advertised as a vegan, cholesterol free, low fat and low carbohydrate foods. The overall global tracked launch activity in jackfruit products fluctuated from 2011 to 2014 and showed 80% positive growth from 2015 (31 jackfruit products) to 2016 (56 jackfruit products).

Undertake processing trials in pilot plant using protocol(s) developed in year 1 to make products for shelf life and sensory/consumer testing (A)

Overall, sensory was the primary focus in the packaging study (2017) that determines fruit quality over the shelf life period. Out of the three packaging variations trialled, vacuum pack had the poorest performance due to very poor fruit quality on day 8 including bruising, off flavour and darker colour measurements, which was significantly different in comparison with the other two types of packaging. Furthermore, fruit deterioration accelerated quickly after day 8 with increase in moisture loss and decline in aroma and flavour.

Both barrier packaging and polypropylene (PP) packaging had similar performance with product lasting a minimum 8 days and being inedible by the panel by day 14. It was concluded that samples with pre-treatment had performed better than no treatment overall, showing a slower decline in appearance and eating quality for barrier packaging.

An additional packaging study (2017) was completed with improved fruit maturity selection (higher °brix, shorter storage times) and microbiological tests were significantly improved with little or no TPC, yeast or mould growth observed in all samples through from day 1 to day 26. These results also are consistent with sensory comments with no mould or yeast growth observed by participants. No changes in texture or off aromas were also noted up to day 15. Overall, shelf life trials which have shown that minimal processing dips and packaging can potentially lead to shelf life extension of a fresh cut product in physical, chemical, microbiological and sensory parameters. It is recommended further work to be completed to optimise fruit treatments/maturity to improve fruit quality and safety.

Conduct consumer testing of processed product in Australia (A)

Fresh cut and flavour profiling (A work)

Extensive sensory profiling work has been completed on both Australian grown jackfruit 'Rajang' and 'Amber' varieties. This was evaluated by a panel of trained sensory assessors to generate individual attributes, definitions, and quantitatively measure intensity. The below extract is the summary description for both varieties.

'Rajang'

Elicits a mid-strength aroma intensity with distinct notes of jammy and overripe banana, 'Rajang' has a sweet aroma with hints of orange lolly. A strong flavour is characterised by an overripe banana attribute and milder notes of artificial sweetness and orange lolly. 'Rajang' has medium firmness with a slight rubbery and fibrous texture, however, it is also juicy. The artificial sweet flavour lingers into the aftertaste which also has slight notes of green banana.

'Amber'

Overall a milder fruit, 'Amber' has a mid-strength aroma intensity with slight hints of jammy and musty, overripe banana is the dominant aroma characteristic detected at low-medium intensity. Flavour intensity is medium to high, however, only low levels of the attributes orange lolly and artificial sweet were detected. 'Amber' is a very firm fruit, fibrous and rubbery, but like 'Rajang' it is still juicy. Despite the mild flavour, the aftertaste of 'Amber' is of medium intensity with a distinct green banana attribute.

As most Australians are not familiar with jackfruit flavour profiles, having specific sensory descriptors are very valuable to attract new consumers through recognisable fruits and flavours such as jam or overripe banana. An additional consumer trial was also completed to comment and gauge responses for the overall liking, appearance, aroma, flavour and texture of both jackfruit varietals. Initial quantitative results in this trial determined that 'Rajang' was the preferred variety amongst Australian consumers. Moreover, this sensory methodology can also be further applied in commercial research for both local and overseas markets.

Vacuum fried and dehydrated (A & PC work)

The acceptability of the vacuum fried jackfruit ranged from 6.76 to 7.05 which means like slightly to like moderately using the 9-point hedonic scale. While for the dehydrated jackfruit ranged from 5.32 to 7.01 which imply neither like nor dislike to like moderately (Table 12). Statistical analyses show no significant difference between the dehydrated and vacuum-fried jackfruit pulps in all of the parameters evaluated except aroma.

Texture acceptability of Vacuum fried jackfruit was not significantly different with dehydrated as noted by the panel which indicates that the panel liked the texture of the two products. This data will just mean that the Australian panellists were not yet very familiar with the food products evaluated considering that they were not familiar with them.

The overall liking of the two products are 7.05 (like moderately) and 6.32 (like slightly) for vacuum fried jackfruit and dehydrated jackfruit, respectively. Results imply that the vacuum fried jackfruit was more acceptable to them than the dehydrated jackfruit. Statistical analysis

shows that the two food products are not significantly different with respect to overall liking as evaluated by Australian palate. This implies that the two products are comparable with respect to over-all liking.

Table 12. Mean sensory scores of the two jackfruit food products from the Philippines

	Appearance^{ns}	Aroma**	Flavour^{ns}	Texture^{ns}	Overall-liking^{ns}
Vacuum fried Jackfruit	6.98	6.76	7.20	6.96	7.05
Dehydrated Jackfruit	7.01	5.32	6.32	6.00	6.32

**highly significant at 1%, n=32

8 Impacts

8.1 Scientific impacts – now and in 5 years

The project is multifaceted with components that include adoption of existing practices and applied research. Jackfruit production occurs throughout the tropical world with a production focus from the Indian sub-continent through to SE Asia and more recently in tropical regions of Central and South America. Making new information available on tree production, establishment, crop management and processing will benefit tropical agrarian economies.

- Activities with new scientific impact include;
  - The development of scion–rootstock combinations with potential for disease resistance.
  - The development of scion – rootstock combinations which alter canopy development and potentially enhance tree productivity. Observations at two sites suggest that A. *odoratissimus has a dwarfing effect on jackfruit growth.*
- Activities building on existing scientific knowledge
  - Development and evaluation of novel value added products for jackfruit through consumer testing.
  - Enhanced disease resistance due to the introduction of improved nursery hygiene.
  - Improved tree productivity resulting from cropping manipulation and nutrient management
  - Efficacy of potassium phosphonate for Phytophthora disease management

8.2 Capacity impacts – now and in 5 years

In the Philippines, project objectives promoted capacity building in nursery management, tree propagation and orchard management with an emphasis on the production and management of disease free trees. The processing of fruit and subsequent sensory profiling of products was also supported through research.

Nursery operators, plant propagators and nursery managers were trained on improved and hygienic nursery practices.

Capacity building was further encouraged with horticulturists and processing partners from VSU and DA undertaking training in Australia with the assistance of Crawford Funding. The experiences and skills learned from this exchange will be passed on to new students.

Three of the project staff (Dr. Lorina Galvez, Dr. Dario Lina and Dr. Franacisco Dayap) travelled to Australia and underwent the following training:

1. Dr. Galvez – Training on shelf-life testing of vacuum-fried jackfruit and development of frozen jackfruit from April 16-May 6 at QDAF 39, Kessels Rd. Copper Plains, Brisbane, Queensland, Australia.

2. Dr. Dayap and Dr. Lina from April 16-May 1, 2016:

   a.Exposure to Jackfruit Processing at QDAF, Brisbane, Queensland, Australia

   b. Scion-Rootstock Trials at the Center for Wet Tropical Agriculture at South Johnstone, Cairns, North Queensland, Australia and

c. Nursery hygiene at Dept. of Primary Industry and Fisheries, Berrimah Research Station, Darwin, Northern Territory, Australia

Propagation skills developed in the Philippines and experience gained in interspecies grafting will be incorporated into the emerging jackfruit industry in Australia.

8.3 Community impacts – now and in 5 years

The recipients of nursery workshop training have understood the relationship between potting mix components, nursery layout, water and potting mix sterilisation and the introduction of disease. The ability to measure the community impact of the workshops was not able to be captured by the project.

Based on limited field planted tree numbers at BPI Davao and NT DPI&R from the grafting trials, marang/jackfruit stock/scion combinations do supress vigour. This work requires testing in a fully replicated field trial. However, it is likely that the positive results from preliminary results are extended to industry that it will be trialled by producers. An unexpected example is the successful graft between breadnut (*A. camansi*) and breadfruit (*A. altilis*) which was a by-product of the proposal and carried out by BPI-Davao. This union appears to be successful and has already been shown to reduce breadfruit vigour and lead to earlier flowering and fruit set than conventional root suckers. As a result, the institution is providing grafts to growers on a commercial basis.

In the Philippines, improved and diverse jackfruit processing options has led to the development and sustainability of village and farm processing groups such as the Baybay Women's processing cooperative and jackfruit drying initiative at Job Abuyabor's farm.

Processing business' in Lyte, Cebu and Davao have expressed interest in technologies developed by the VSU processing group.

8.3.1 Economic impacts

The cost and returns calculated for the jackfruit phosphonate and fertiliser trial at DA, Abuyog (Table A6-15) indicate that the application of phosphonate resulted in a net income increase of PhP 3,371 per block of 30 trees relative to non-phosphonate treated trees. A 4.5% increase in net income. Similarly, inorganic fertiliser inputs at the DA recommended rate and 50% higher than the DA recommendations resulted in a gain of PhP 1,826 and PhP 12,551 respectively compared to the organic fertiliser alone treatment.

The project objectives were all aimed at increasing productivity throughout the production chain (nursery, field, postharvest and processing). Many of the successful project outcomes have the potential to lead to improved economic outcomes for jackfruit if supported by Government policy.

In the Philippines, production of minor tropical fruit is carried out on a relatively large scale. The gross value of minor crops is not readily accessed but an estimate can be made from production volume data and the respective retail prices. For jackfruit, the retail value is PhP1,210M or $A30.3M. A 5% improvement in productivity would lead to an additional PhP60.6M or $A1.52M.

Improved processing options and quality of product will ultimately lead to improved commercial returns.

8.3.2 Social impacts

The major social impacts are via improved economic outcomes. Industry diversification, particularly a high value crop such as jackfruit, benefits smallholder farmers and regional

economies. Improved returns to farmers and their families' means they are better able to clothe feed and educate their children.

Trellising work in Australia and potentially transferred to the Philippines, if successful, will improve tree survival following cyclonic events and hence improved commercial outcomes for tropical fruit growers.

8.3.3 Environmental impacts

Project objectives which lead to improved productivity create improved environmental outcomes. Components of the project leading to improve environmental outcomes include;

Nursery hygiene - the project will assist in the creation of a system where disease free plants enter the orchard, where appropriate agronomic and disease management programs are in place, thus reducing pesticide inputs. Productive farms require less area and reduce the risk of deforestation.

Nutrition and crop load management - better understanding of nutritional requirements and crop load will lead to efficient use of nutrients and hence less runoff and pollution of tropical streams, environs and ocean systems.

8.4 Communication and dissemination activities

Most of the activities in this research are long term so only few dissemination activities had been conducted so far. These are the following:

1. Paper presented during the Plenary Session of the ACIAR-PCAARRD Philippines Horticulture Program Annual Review Meeting, August 13-14, 2015 at Waterfront Insular Hotel, Hotel Davao City.
2. Paper presented during the Plenary Session of the ACIAR-PCAARRD Philippines Horticulture Program Annual Review Meeting, August 13-14, 2015 at Waterfront Insular Hotel, Hotel Davao City.
3. Paper presented during the Plenary Session of the ACIAR-PCAARRD Philippines Horticulture Program Annual Review Meeting, August 13-14, 2015 at Waterfront Insular Hotel, Hotel Davao City.
4. Paper presented during the Regional RD&E Symposium held at Sabin, Resort Hotel, Ormoc City, December 3-4, 2015
5. Poster paper presented "Collection and Evaluation of Different *Artocarpus* Species Against *Phytophthora palmivora,* Butler Causing Jackfruit Decline" during the Philippine Society for the Study of Nature Annual Scientific Conference to at Siliman University, Dumaguete City on May 25-27, 2016.
6. Poster paper presented, titled "Collection and Evaluation of Different *Artocarpus Species* Against *Phytophthora palmivora,* Butler Causing Jackfruit Decline" during Annual Meeting of the Crop Science Society of the Philippines June 13-18, 2016.
7. Paper and poster presented during the Plenary Session of the ACIAR-PCAARRD Philippines Horticulture Program Annual Review Meeting last July 17-18, 2017 at Quest Hotel, Cebu City.
8. Dr Lucia Borines, Prof. Elsie Salamat of VSU and Dr Carlos S. de la Cruz of the Department of Agriculture Regional Field Office 8 presented oral papers during the 4th AFSA International Conference on Food Safety and Food Security at Siem Reap, Ankor Wat, Cambodia from August 10-12, 2018. The three papers are output of this project. The titles of papers presented are the following:

- Dr Lucia Borines – Reaction of Jackfruit Accessions and *Artocarpus* Relatives to Jackfruit Decline Pathogen, *Phytophthora palmivora Butler*
- Prof. Elsie Salamat- Detection of *Phytophthora palmivora* and Evaluation of the Effect of Sanitation, Porosity of Potting Media and Phosphonate on the Health of Jackfruit Seedlings
- Dr Carlos S. de la Cruz - Scion-Rootstock Compatibility of Jackfruit with *Artocarpus* Related Species and Field Trial for Resistance to *Phytophthora* Disease

9 Conclusions and recommendations

9.1 Conclusions

The impact of Phytophthora in disease susceptible crops such as jackfruit in the Philippines does impact negatively on tree health and productivity. Interestingly, the disease is not a limiting factor for jackfruit production in northern Australia where, although the pathogen is present, it yet to be recorded in jackfruit.

The project has demonstrated that a range of inputs at the nursery stage can lower disease pressure thus reducing the spread of the disease into new areas. A range of field measures are also available, which include, mounding, improved drainage, mulching, application of potassium phosphonate and nutrient management to ensure trees are free of stress and can maintain productivity. Potassium phosphonate – a plant defence regulator, is a readily available disease management tool that has not generally been accepted in the Philippines, possibly due to the government's active encouragement of organic agriculture.

The project has developed an improved understanding of genetic relationships in the genus Artocarpus. This is pertinent in terms of potential disease resistance of species and their potential to be used as interspecies stock for grafted jackfruit. The project has demonstrated that interspecies grafting is difficult and success rates are stock, scion and grafting technique dependent.

Production of tropical fruit trees in cyclonic zones is a high risk activity with the potential for major tree loss as demonstrated by Typhoon Yolanda in the Philippines and Cyclones Larry and Yasi in far north Queensland. Project activities demonstrated that trellising of tropical tree crops is feasible. The added structural support provided by the trellis may improve cyclone resilience.

Current methods of processing jackfruit products such as vacuum-fried jackfruit, are improved. New value-added products are also developed from jackfruit such as Garlic-Chili Flavored, Vacuum Green Fried Jackfruit, Jackfruit Sweet Sauce, Jackfruit Gravy and "Langkamote". These are generally acceptable to the consumers. Work on a fresh cut jackfruit product in Australia has the potential to lead to a new product which will be readily acceptable to the bulk of Australian consumers.

9.2 Recommendations

The expertise developed during the conduct of the project will assist the future development of the jackfruit industry in the Philippines.

Our partners should;

- continue to promote the introduction of nursery production protocols incorporating non soil media and sterilisation of potting mixes, clean water source and raised benches and/or gravel beds. This will lead to the production of healthy disease free plants for future orchard establishment.
- continue the identification of disease resistant rootstock and improve grafting techniques for disease resistance
- research the potential of interspecies grafting for the production of jackfruit and other economically important Artocarpus species such as breadfruit
- develop demonstration orchards which incorporate the learnings of HORT/2007/067 and this project.
- Incorporate findings from the ACIAR jackfruit projects into the production of other Phytophthora susceptible crops.

- Promote the production and use of jackfruit processed products and develop products for specific market niches

In Australia, jackfruit should be viewed as a potential new fruit crop for tropical Australia. Increased research input is suggested in the following areas;

- identification of high bearing, high fruit quality selections incorporating both yellow and orange crunchy fruit types
- investigate the productivity of free standing versus high density trellised trees
- objective fruit maturity measurement methods
- improve post-harvest fruit rot management for whole fruit
- promote the potential of “fresh cut” fruit to expand the market for fresh fruit.

10 References

10.1 References cited in report

Acedo A. 1992. Acedo Jr., A.L. 1992. Jackfruit Biology, Production, Use and Philippine Research. Monograph Number 1. Forestry/ Fuelwood Research and Development (F/FRED) Project, Arlington, Virginia.

AGRIMAG. 2018. The world's greatest sweetest jackfruit just got sweeter. http://agriculture.com.ph/2018/01/02/worlds-greatest-sweetest-jack-fruit-just-got-sweeter/.

Akbar MA and Samad MA. 1995. Effect of replacement of green grass by jackfruit leaf (Artocarpus heterophyllus). Nutrition of Herbivores. Elsevier. France. 203 pp.

Anit, E. 2012. Overview of minor tropical fruit production in the Philippines- Issues and Challenges. In a web report on "Value Chain Enhancements to Improve Market Access for Minor Tropical Fruits in the Philippines" The Bureau of Plant Industry (BPI) in cooperation with International Tropical Fruits Network (TFNet). http://www.bpi.da.gov.ph/news_20121005_bpiandtfnetworkshop.php.

APAARI. 2012. Jackfruit Improvement in the Asia-Pacific Region – A Status Report. Asia-Pacific Association of Agricultural Research Institutions, Bangkok, Thailand. 182 p.

BAREJA BG. 2010. Jackfruit, a promising cash crop. https://www.cropsreview.com/jackfruit.html

Borines LM, Guadalquiver GA, Palermo VG, De La Cruz CS, Abuyabor J, Pedroso MA, Marcelino RM Munoz J, Daniel R AND Guest DI. 2013. Participatory action research on Phytophthora management delivers positive outcomes for smallholder jackfruit farmers. Pp 31-44 in: Smallholder Hopes: horticulture, people and soil. Oakeshott J. and Hall D. (eds) 2013. ACIAR Proceedings 139.

Borines LM, Palermo VG, Guadalquiver GA, Dwyer C, Drenth A, Daniel R and Guest D. 2014. Jackfruit decline caused by *Phytophthora palmivora* (Butler). Australasian Plant Pathology. 43(2): 123-129. DOI 10.1007/s13313-013-0241-z.

DA-RFO8. 2012. EVIARC Sweet. http://da08.da.gov.ph/index.php/media-resources/da-news/315-jackfruit.

Daniel R, Borines LM, Soguilon C, Montiel C, Palermo VG, Guadalquiver M, Pedroso M. ET AL. 2014. Development of disease management recommendations for the durian and jackfruit industries in the Philippines using farmer participatory research. Food Security: The Science, Sociology and Economics of Food Production and Access to Food. ISSN 1876-4517. Food Sec. DOI.1007/S12571-014-0352-6.

Drenth A and Guest DI. 2004. Diversity and management of Phytophthora in southeast Asia. ACIAR Monograph series no. 114. Australian Centre for International Agricultural Research, Canberra. http://aciar.gov.au/publication/MN114.

Elevitch CR and Manner HI. 2006. Artocarpus heterophyllus (jackfruit) Moraceae (mulberry family). Species Profiles for Pacific Island Agroforestry (www.traditionaltree.org). https://retirenicaragua.files.wordpress.com/2012/05/a-heterophyllus-jackfruit1.pdf

Elshire RJ, Glaubitz JC, Sun Q, Poland JA, Kawamoto K, Buckler ES, et al. A Robust, Simple Genotyping-by-Sequencing (GBS) Approach for High Diversity Species. Orban L, editor. PLoS ONE. 2011; 6:e19379. DOI: 10.1371/journal.pone.0019379.g006 PMID: 21573248

Espino RRC and Espino MRC. (Accessed July 2018). The status of fruit industry in the Philippines. Food and Fertilizer Technology Center. http://www.fftc.agnet.org/library.php?func=view&id=20150810090507

Gruber B, Unmack P, Berry O, and Georges A (2017) dartR: an R package to facilitate analysis of SNP data generated from reduced representation genome sequencing. Molecular Ecology Resources 18(3). DOI: 10.1111/1755-0998.12745.

Haq N. 2006. Jackfruit, Artocarpus heterophyllus, Southampton Center for Underutilised Crops, University of Southampton, Southampton, UK. 192 p.

Kilian A, Wenzl P, Huttner E, Carling J, Xia L, Blois H, et al. Diversity arrays technology: a generic genome profiling technology on open platforms. Methods Mol. Biol. 2012; 888: 67–89. DOI: 10.1007/978-1-61779-870-2_5 PMID: 22665276

Kress WJ, Erickson DL, Jones FA, Swenson NG, Perez R, et al. (2009) Plant DNA barcodes and a community phylogeny of a tropical forest dynamics plot in Panama. Proceedings of the National Academy of Sciences 106: 18621–18626.

Levin RA, Wagner WL, Hoch PC, et al. (2003) Family-Level Relationships of Onagraceae Based on Chloroplast rbcL and ndhF Data. American Journal of Botany, vol 90:107-115 (modified from Soltis P et al. (1992) Proceedings of National Academy of Sciences USA, 89: 449-451.

Lina. 2012. Phenology, Reproductive Biology and Improvement of Jackfruit Productions Using Growth Regulators and Assisted Pollination. PhD Dissertation, University of the Philippines, Los Banos, Laguna. 135 pp.

PCAARRD. 2012. A bounty of tropical Fruits in 2020. PCAARRD ISP – Industry Strategic S&T Plan. http://www.pcaarrd.dost.gov.ph/home/isp/index.php/tropical-fruits. Accessed December 2012.

PSA (Philippine Statistics Authority. Accessed July 2018. Database Complete List. http://countrystat.psa.gov.ph/

Saxena A, Bawa AS and Raju PS. 2011. Jackfruit (Artocarpus heterophyllus Lam.) in Postharvest Biology and Technology of Tropical and Subtropical Fruits. Elsevier. https://s100.copyright.com/AppDispatchServlet?publisherName=ELS&contentID=B9781845697358500127&orderBeanReset=true

Smith, R.W., and Z. Dunsiger eds. Southampton Center for Underutilized Crop. University of Southampton, West Sussex, U.K.

STATISTA. (Accessed, 2018). Production of jackfruit in the Philippines from 2008 to 2013 (in metric tons). https://www.statista.com/statistics/590131/production-of-jackfruit-philippines/

Tripepi RR. 2018. What Is Your Substrate Trying to Tell You. http://www.extension.uidaho.edu/nursery/Landscape%20problems/Substrate/pH%20and%20EC%20of%20soilless%20media.PDF

Witherup, C., Ragone, D., Wiesner-Hanks, T., Irish, B., Scheffler, B., Simpson, S., Zee, F., Zuberi, M.I., and Zerega, N.J.C. (2013). Development of Microsatellite Loci in *Artocarpus altilis* (Moraceae) and Cross-Amplification in Congeneric Species. Applications in Plant Sciences 1, 1200423.

10.2 List of publications produced by project

A number of drafts are currently in various stages of preparation.

11 Appendixes

Appendix 1. Objective 1b

Figure A1-1. The improved fruit nursery and nursery training course conducted at the Abuyog Experimental Station, Balinsasayao, Abuyog, Leyte, Philippines.

Appendix 2. Objective 1d

Table A2-1. ***Phytophthora palmivora*** **detection from potting media, soil, jackfruit seedling roots and irrigation water from DA-RIARC Abuyog, nursery, Abuyabor's Farm in Mahaplag Leyte, DA-RIARC San Jorge Samar and Pedroso Farm nursery in Calbayog City.**

Type of Sample	Source	Phytophthora Detection	
		Microscopic Examination of Baits (Periwinkle Flower)*	Pocket Diagnostic Kit**
Negative Control	(Sterile water and disinfected Periwinkle)	(-)	-
Positive Control	*P. palmivora* (VSU007)	(+) few zoospores, mycelia, sporangia	+++
Seedling Potting Mix	VSU fruit nursery	(+) plenty of zoospores, mycelia, chlamydospores, zoospores, sporangia	+++
Irrigation Water	VSU fruit nursery	(-)	-
Seedling Potting Mix	Calbayog (Pedroso nursery)	(+) plenty of zoospores, mycelia, sporangia	+++
Soil from Germinating Bed	Calbayog (Pedroso nursery)	(+) plenty of zoospores, mycelia, sporangia	+++
Irrigation water 1	Calbayog (deep well near seedlings Pedroso nursery)	(+) few zoospores, mycelia	++
Irrigation water 2	Calbayog (Mike's deep well near far end of plantation)	(+) few zoospores	+
Seedling Potting Mix	DA-RIARC, Abuyog, Area 1 (near the entrance)	(+) zoospores, mycelia	++
Seedling Potting Mix	DA-RIARC, Abuyog, Area 2 (front of tissue culture lab)	(+) zoospores, mycelia, sporangia	++
Soil	DA-RIARC, Abuyog, germinating bed near entrance)	(+) few zoospores	+
Irrigation Water 1	DA-RIARC, Abuyog, (Faucet near Entrance)	(+) few zoospores	+
Irrigation Water 2	DA-RIARC, Abuyog, Faucet inside screenhouse	(-)	-
Irrigation Water 3	DA-RIARC, Abuyog, Faucet near growing area	(-)	-
Root of seedling	San Jorge nursery	(-)	-
Irrigation Water 1	San Jorge (from Blue Container 1)	(-)	-
Irrigation Water 2	San Jorge (from Blue Container 2)	(-)	-
Roots of jackfruit seedling	Mahaplag (Job's seedling)	(+) zoospores, mycelia, sporangia	+++
Water	(PDDL faucet outside of building)	(-)	-

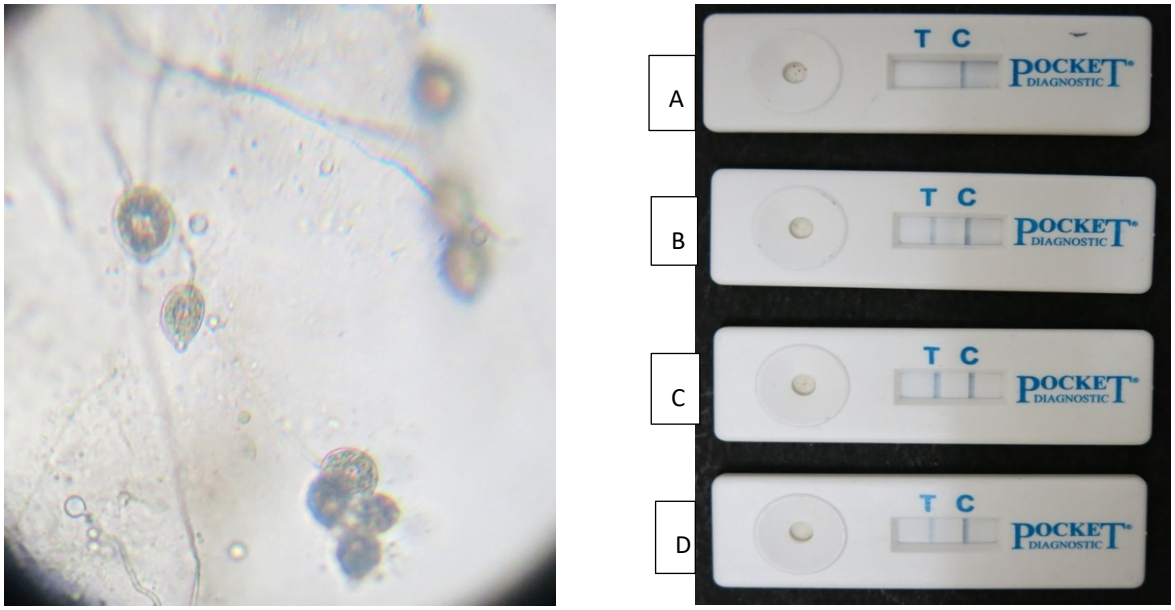


Figure A2-1. **Photomicrograph of *P. Palmivora* sporangia, hyphae and encysted zoospores from the periwinkle bait as seen under 400x electric microscope (left) and *Phytophthora* confirmation using Pocket diagnostic kit (A- negative control (Periwinkle flower only in sterile water), B- Positive Control (Phytophthora VSU007 isolate), C-Potting mix at VSU Nursery, D-Potting Mix at DA-RIARC, Abuyog, Leyte. Philippines).**

Table A2-2. **Composition and percentages of potting mix from DA-RIARC Abuyog composed of varying levels of alluvial soil, rice hull, carbonized rice hull and chicken dung and their air-filled porosities measured separately at VSU and Abuyog Leyte (First VSU AFP Trial).**

Treatment	Alluvial Soil (%)	Partially Decompose Rice Hull (%)	Carbonized Rice Hull (%)	Dried Chicken Dung (%)	Air-Filled Porosity Measurement (%) VSU
DA1	72	14	7	7	16.39
DA2	60	20	13	7	22.13
DA3	50	25	18	7	27.49
DA4	40	30	23	7	29.46
DA5	30	35	28	7	34.40
DA6	93	-	-	7	3.42
VSU Nursery potting media	25% soil	25% rice hull matting in poultry.	25% fly ash	25% mudpress	16.47

Table A2-3. Mean plant height (cm) every two weeks and mean height increment as affected by different air-filled porosities (First VSU AFP Trial).

Treatment	AFP (%)**	Plant Height (cm)						
		7 Days (1 wk)	21 Days (3 wks)	35 Days (5 wks)	49 Days (7 wks)	63 Days (9 wks)	77 Days (11 wks)	91 Days (13 wks)
DA1	16.39	31.6	43.8	53.0	62.4 ab	68.9 ab	72.7 ab	76.7 ab
DA2	22.13	26.7	39.2	50.3	66.0 a	83.9 a	87.9 a	91.7 a
DA3	27.49	27.5	39.5	49.7	65.8 a	77.5 ab	80.3 ab	83.5 ab
DA4	29.46	24.6	34.9	41.7	42.9 bc	42.5 c	38.1 c	37.8 c
DA5	34.40	26.7	37.8	45.5	56.6 ab	55.2 bc	57.1 bc	58.6 bc
DA6	3.42	30.8	42.9	50.9	66.9 a	83.3 a	94.1 a	101.1 a
VSU Potting mix	16.47	23.60	28.1	34.8	35.6 c	36.3 c	35.6 c	35.6 c
CV		13.3	15.9	15.4	18.8	18.9	20.6	20.72

**Means within a column followed by the same letter are not significantly different at 5% Tukey's HSD.*
***AFP-Air filled porosity (%).*

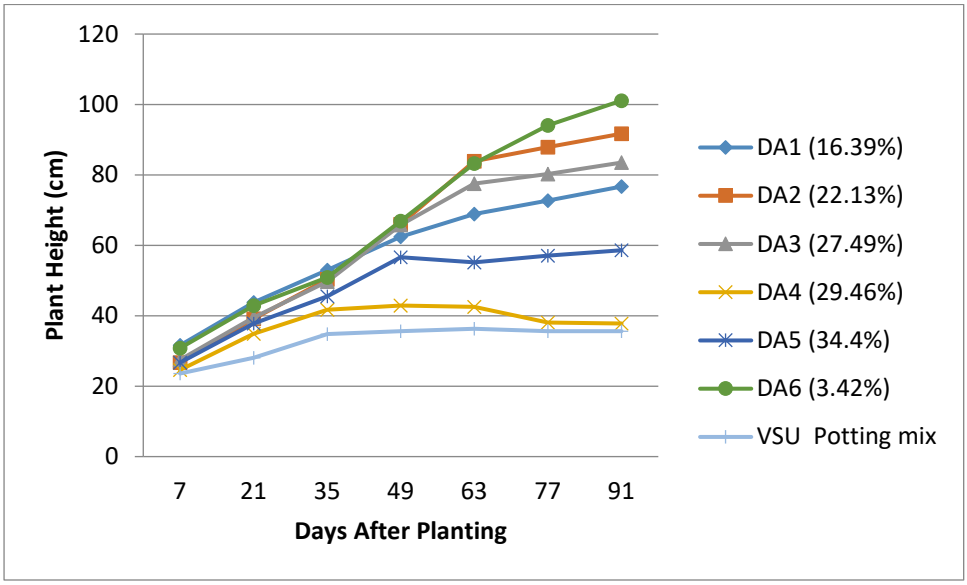


Figure A2-2. Progression in plant height as affected by different air-filled porosities of potting mixes (First VSU AFP Trial).

Table A2-4. Disease severity rating of jackfruit seedlings as affected by different air filled porosities of potting media (First VSU AFP Trial).

Treatment	AFP (%)	Disease Severity Rating**					
		1 week	3 weeks	5 weeks	7 weeks	9 weeks	11 weeks
DA1	16.39	0	1.17	3.00	3.50 ab	3.50 a	3.50 a
DA2	22.13	0	0	1.83	2.33 ab	2.83 ab	2.83 ab
DA3	27.49	0	0.33	2.00	2.83 ab	2.83 ab	2.83 ab
DA4	29.46	0	1.33	3.50	4.00 a	4.50 a	4.67 a
DA5	39.40	0	1.00	2.67	3.00 ab	3.33 ab	3.50 a
DA6	3.42	0.17	1.00	1.50	1.50 b	1.50 b	1.50 b
VSU Potting mix	16.47	0	0.33	3.17	4.33 a	4.67 a	4.67 a
CV		11.10	26.40	21.66	18.07	15.83	15.79

Means within a column having the same letter are not significantly different at 5% level Tukey's HSD. Rating Scale: 0 = no disease, 1 = mild loose of turgidity and mild yellowing, 2 = moderate yellowing, 3 = severe yellowing, 4 = defoliated leaves and 5 = dead.

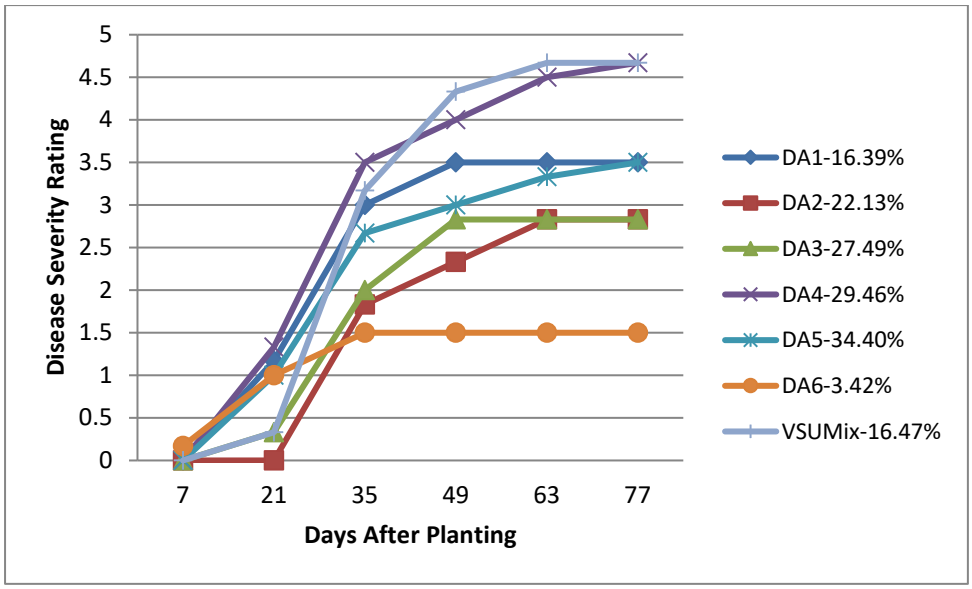


Figure A2-3. Disease severity rate progression of jackfruit seedlings as affected by different AFPs (First VSU AFP Trial).

Table A2-5. Chemical measurement of pH, electrical conductivity and water holding capacity of the potting mixes (Second VSU AFP Trial).

Treatments	Composition	Ave. Porosity (%)	pH	EC (mS/m)	Water holding Capacity (%)
Potting Mix 1	90% garden soil + 10% chicken dung	4.0	6.1	1.26	70.85
Potting Mix 2	30% garden soil + 30% CRH + 30% sand + 10% chicken dung	11.1	6.8	0.69	66.21
Potting Mix 3	20% garden soil + 20% CRH + 20% RH +20% coir dust + 10% sand + 10% chicken dung	21.0	6.0	1.01	99.98

Table A2-6. Mean Plant height (cm) of Jackfruit seedling as affected by different treatments (Second VSU AFP Trial)

Treatments		Months					
		1	2	3	4	5	6
MP	S1 Unsterilized	28.9[b]	29.6[b]	31.5[b]	32.2[b]	34.9	39.7
	S2 Sterilized	34.0[a]	34.3[a]	35.1[a]	35.7[a]	35.3	37.5
SP	I1 Uninoculated	32.1	32.2	33.5	34.1	34.8	38.2
	I2 Inoculated	30.9	31.7	33.1	34.8	35.5	39.1
SSP	P1 Nil Phosphonate	31.8	32.1	33.5	34.8	35.5	39.4
	P2 Phosphonate applied	31.2	31.8	33.1	34.2	34.7	37.8
SSSP	PM1 4% air-filled porosity	20.0[c]	28.1[c]	28.9[c]	29.9[c]	30.4[c]	33.8[c]
	PM2 11% air-filled porosity	32.0[b]	32.2[b]	33.8[b]	34.6[b]	35.1[b]	38.0[b]
	PM3 21% air-filled porosity	34.4[a]	35.6[a]	37.3[a]	38.9[a]	39.8[a]	44.0[a]
MP:SP		ns	ns	ns	ns	ns	ns
MP:SSP		ns	ns	ns	ns	ns	ns
MP:SSSP		ns	ns	ns	ns	ns	ns
SP:SSSP		ns	ns	ns	ns	ns	ns
SSP:SSSP		ns	ns	ns	ns	ns	ns
MP:SP:SSP		ns	ns	ns	ns	ns	*
MP:SP:SSSP		*	*	*	*	*	ns
MP:SSP:SSSP		ns	ns	ns	ns	ns	ns
SP:SSP:SSSP		ns	ns	ns	ns	ns	ns
MP:SP:SSP:SSSP		ns	ns	ns	ns	ns	ns
CV %		15.1	14.7	14.7	14.8	18.5	22.5

[a] Means with the same letter are not significantly different at 5% level of significance using Tukey's HSD.

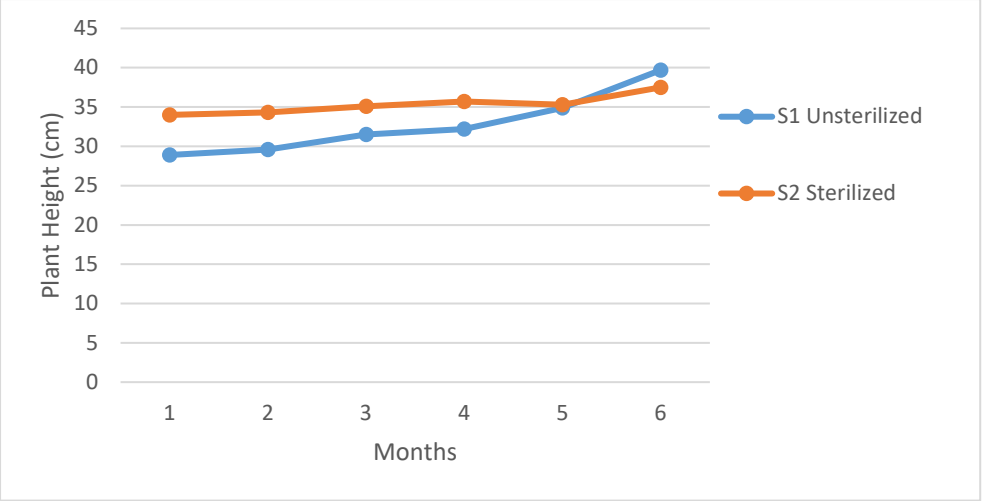


Figure A2-4. Mean plant height (cm) of jackfruit seedlings as affected by sterilization from 1 to 6 months after planting.

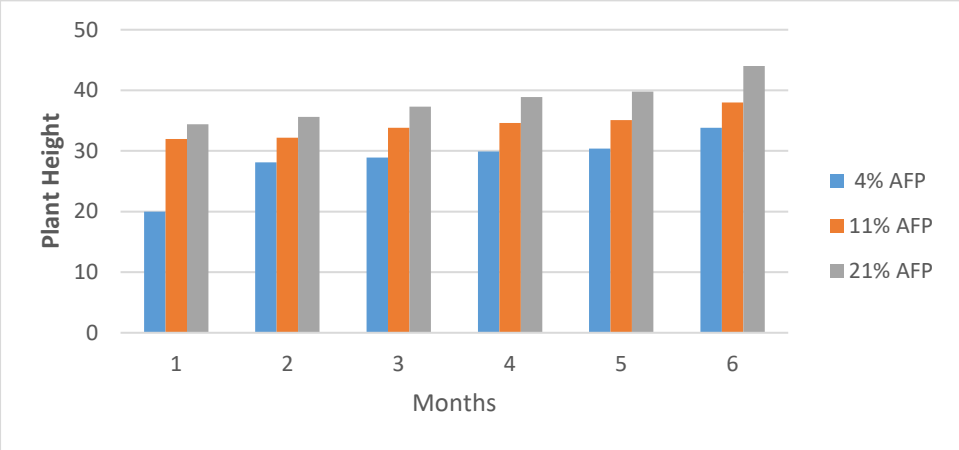


Figure A2-5. Plant height of jackfruit seedlings as affected by air filled porosity of the potting medium from 1 to 6 months after planting.

Table A2-7. Mean stem diameter (mm) as affected by different treatments. (Second VSU AFP Trial)

Treatments		Months					
		1	2	3	4	5	6
MP	S1 Unsterilized	3.1	3.4[b]	4.3	4.9	5.3[a]	5.7[a]
	S2 Sterilized	3.2	3.7[a]	4.3	4.9	4.7[b]	4.6[b]
SP	I1 Uninoculated	3.1	3.5	4.3	4.9	4.9	5.0
	I2 Inoculated	3.1	3.5	4.3	4.9	5.1	5.3
SSP	P1 Nil Phosphonate	3.2	3.5	4.4	5.0	5.1	5.1
	P2 Phosphonate applied fortnightly	3.1	3.6	4.2	4.9	4.9	5.1
SSSP	PM1 4% air-filled porosity	3.1	3.5	4.0[b]	4.4[b]	4.5[b]	4.3[b]
	PM2 11% air-filled porosity	3.2	3.6	4.4[a]	5.0[a]	4.9[ab]	5.0[b]
	PM3 21% air-filled porosity	3.2	3.6	4.6[a]	5.4[a]	5.6[a]	6.0[a]
MP:SP		ns	ns	ns	ns	ns	ns
MP:SSP		ns	ns	ns	ns	ns	ns
MP:SSSP		ns	ns	ns	ns	ns	*
SP:SSSP		ns	ns	ns	ns	ns	ns
SSP:SSSP		ns	*	ns	ns	ns	ns
MP:SP:SSP		ns	ns	ns	ns	ns	ns
MP:SP:SSSP		ns	ns	ns	ns	ns	ns
MP:SSP:SSSP		ns	ns	ns	ns	ns	ns
SP:SSP:SSSP		*	ns	ns	ns	ns	ns
MP:SP:SSP:SSSP		ns	ns	ns	ns	ns	ns
CV %		22.2	19.5	20.6	14.9	16.9	22.5

[a] *Means with the same letter are not significantly different at 5% level of significant*

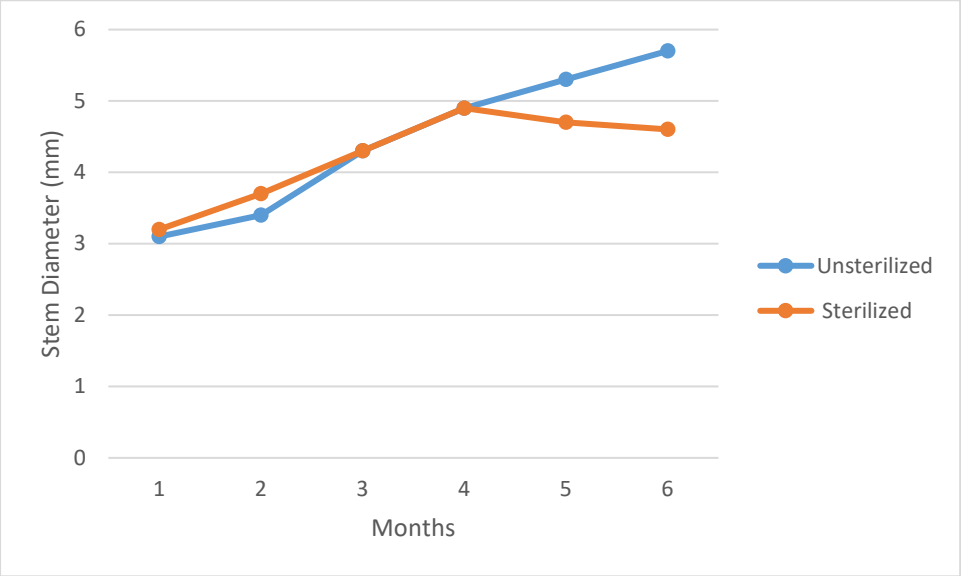


Figure A2-6. Stem diameter of jackfruit seedlings as affected sterilization of the potting medium from 1 to 6 months after planting.

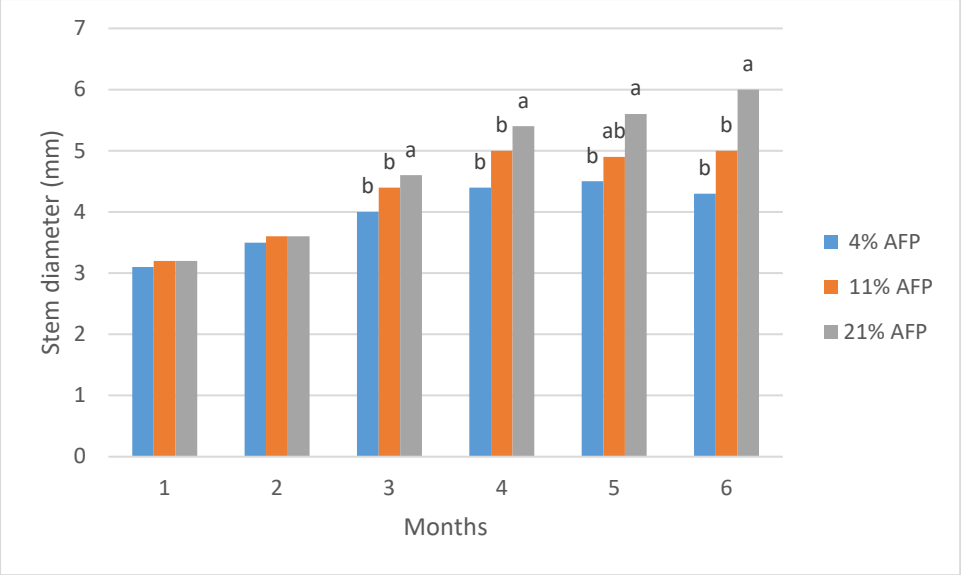


Figure A2-7. Stem diameter of jackfruit seedlings as affected by AFP of the potting medium from 1 to 6 months after planting.

Table A2-8. Mean stem diameter (mm) in the 6th month as affected by interaction between media sterilization and air-filled porosity. (Second VSU AFP Trial)

Treatments	Unsterilized	Sterilized
4% air-filled porosity	4.75 [b]	3.86
11% air-filled porosity	5.21 [b]	5.08
21% air-filled porosity	7.38 [a] [A]	4.71 [B]

[a] means with the same small letter in a column are not significantly different at 5% level of significant
[A] means with the same capital letter in a row are not significantly different at 5% level of significant

Table A2-9. Mean Plant health rating of jackfruit seedling as affected by different treatments. (Second VSU AFP Trial)

Treatments		Months					
		1	2	3	4	5	6
MP	S1 Unsterilized	1.2	1.5	1.5	2.0	2.1	2.0 [b]
	S2 Sterilized	1.6	2.0	2.0	2.8	1.7	2.8 [a]
SP	I1 Uninoculated	1.4	1.8	1.7	2.4	2.1	2.2
	I2 Inoculated	1.5	1.7	1.8	2.4	2.5	2.7
SSP	P1 Nil Phosphonate	1.3	1.7	1.7	2.4	2.4	2.6
	P2 Phosphonate applied fortnightly	1.6	1.8	1.9	2.4	2.2	2.3
SSSP	PM1 4% air-filled porosity	1.6	2.1	2.1	2.7	2.6	2.4
	PM2 11% air-filled porosity	1.3	1.5	1.6	2.5	2.4	2.7
	PM3 21% air-filled porosity	1.5	1.6	1.5	1.9	1.9	2.2
MP:SP		*	ns	ns	ns	*	ns
MP:SSP		ns	ns	ns	ns	ns	ns
MP:SSSP		ns	ns	ns	*	ns	ns
SP:SSSP		ns	*	*	ns	ns	ns
SSP:SSSP		ns	ns	ns	ns	ns	ns
MP:SP:SSP		ns	ns	ns	ns	ns	ns
MP:SP:SSSP		ns	*	ns	ns	ns	ns
MP:SSP:SSSP		ns	ns	ns	ns	ns	ns
SP:SSP:SSSP		ns	ns	ns	ns	ns	ns
MP:SP:SSP:SSSP		ns	ns	ns	ns	ns	ns
CV %		15.6	23.2	25.3	25.7	26.6	26.8

[a] Means with the same letter are not significantly different at 5% level of significant
Rating scale: 1-No disease, 2 – pin-sized water-soaked lesion appearance, 3-Leaf discoloration and dropping of leaves, drying of leaves to leaf defoliation, 5- wilting/dead plants.

Table A2-10. Mean Plant health rating of jackfruit seedling in the 5th month as affected by interaction between media sterilization and Inoculation. (Second VSU AFP Trial)

Treatments	Unsterilized	Sterilized
Uninoculated	2.25	2.03 [b]
Inoculated	1.89 [B]	3.08 [a] [A]

[a] means with the same letter in a column are not significantly different at 5% level of significant
[A] means with the same letter in a row are not significantly different at 5% level of significant
Rating scale: 1-No disease, 2 – pin-sized water-soaked lesion appearance, 3-Leaf discoloration and dropping of leaves, drying of leaves to leaf defoliation, 5- wilting/dead plants.

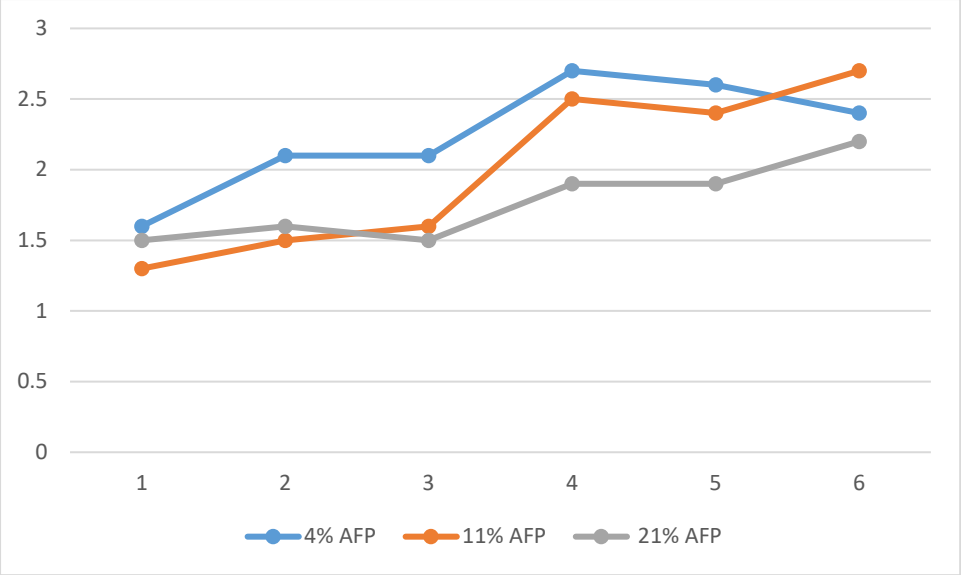


Figure A2-8. Plant health of seedlings as affected by AFP of the potting medium from 1 to 6 months after planting.

Table A2-11. Mean Dry weight (g) of Jackfruit seedling as affected by different treatments. (Second VSU AFP Trial)

Treatments		STEM	ROOT	TOTAL
MP	S1- Unsterilized	12.4[a]	3.6[a]	16.0[a]
	S2- Sterilized	4.6[b]	1.5[b]	6.0[b]
SP	I1- Uninoculated	8.2	2.5	10.7
	I2- Inoculated	8.4	2.6	11.4
SSP	P1- Nil Phosphonate	8.7	2.7	11.3
	P2-Phosphonate applied	8.3	2.5	10.8
SSSP	PM1- 4% air-filled porosity	6.6[b]	2.0[b]	8.6[b]
	PM2-11% air-filled porosity	7.1[b]	2.3[b]	9.4[b]
	PM3- 21% air-filled porosity	11.8[a]	3.4[a]	15.2[a]
	MP:SP	ns	ns	ns
	MP:SSP	ns	ns	ns
	MP:SSSP	*	ns	ns
	SP:SSSP	ns	ns	ns
	SSP:SSSP	ns	ns	ns
	MP:SP:SSP	ns	ns	ns
	MP:SP:SSSP	ns	ns	ns
	MP:SSP:SSSP	ns	ns	ns
	SP:SSP:SSSP	ns	ns	ns
	MP:SP:SSP:SSSP	ns	ns	ns
	CV %	51.4	44.1	52.1

[a] *Means with the same letter are not significantly different at 5% level of significance*

Table A2-12. Mean Dry weight (g) of Jackfruit seedling as affected by interaction between by air-filled porosity and media sterilization. (Second VSU AFP Trial)

Treatments	Unsterilized	Sterilized
4% air-filled porosity	9.82 [b A]	3.44 [B]
11% air-filled porosity	9.28 [b]	4.94
21% air-filled porosity	18.05 [a A]	5.51 [B]

[a] means within a column followed by the same letter in a column are not significantly different at 5% level of significant
[A] means with the same letter in a row are not significantly different at 5% level of significant

Table A2-13. Average plant height, stem diameter, number of leaves and percent survival of jackfruit seedlings grown in the different potting mix with varying air-filled porosity

Treatments		Air-filled Porosity (%)	Plant Height (cm)	Stem diameter (mm)	No. of leaves	Percent survival
T1	(72% alluvial soil + 7% partially decomposed rice hull + 7% carbonized rice hull + 7% chicken dung)	16.39	34.53 a	4.58	8 a	90.67
T2	(60% alluvial soil + 20% partially decomposed rice hull + 13% carbonized rice hull + 7% chicken dung)	22.39	32.13 ab	4.18	8 a	90.67
T3	(50% alluvial soil + 25% partially decomposed rice hull + 18% carbonized rice hull + 7% chicken dung)	27.49	33.48 a	4.22	8 a	92.00
T4	(40% alluvial soil + 30% partially decomposed rice hull + 23% carbonized rice hull + 7% chicken dung)	29.46	33.16 a	4.28	9 a	93.33
T5	(30% alluvial soil + 35% partially decomposed rice hull + 28% carbonized rice hull + 7% chicken dung)	34.40	30.72 ab	4.56	8 a	84.00
T6	(93% alluvial soil + 7% chicken dung)	3.42	39.21 a	4.47	9 a	74.67
T7	(25% soil + 25% fly ash + 25% mud press + 25% chicken dung)	16.47	22.83 b	3.36	6 b	68.00
CV (%)			10.12	6.61	11.16	11.12

Mean with the same letter are not significantly different at 5% level of significant (HSD test)

Table A2-14. Average plant height, stem diameter of scion & rootstock and number of leaves of grafted jackfruit seedlings grown in the different potting mix with varying air-filled porosity.

Treatments		Air-filled Porosity (%)	Plant Height (cm)	Stem diameter (mm)		No. of leaves
				scion	rootstock	
T1	(72% alluvial soil + 7% partially decomposed rice hull + 7% carbonized rice hull + 7% chicken dung)	16.39	61.47 bc	5.29 ab	4.86 ab	16 ab
T2	(60% alluvial soil + 20% partially decomposed rice hull + 13% carbonized rice hull + 7% chicken dung)	22.39	62.71 b	5.22 ab	4.84 ab	15 ab
T3	(50% alluvial soil + 25% partially decomposed rice hull + 18% carbonized rice hull + 7% chicken dung)	27.49	65.33 ab	5.36 ab	5.16 ab	18 ab
T4	(40% alluvial soil + 30% partially decomposed rice hull + 23% carbonized rice hull + 7% chicken dung)	29.46	67.40 ab	5.6 a	4.93 ab	16 ab
T5	(30% alluvial soil + 35% partially decomposed rice hull + 28% carbonized rice hull + 7% chicken dung)	34.4	53.82 c	4.72 b	4.36 b	13 b
T6	(93% alluvial soil + 7% chicken dung)	3.42	72.58 a	5.59 a	5.51 a	21 a
CV (%)			4.75*	12.89*	5.75*	7.29*

Mean with the same letter are not significantly different at 5% level of significant (HSD test)

Table A2-15. Chemical measurement of pH and electrical conductivity of potting mixes

Treatments	Composition	Ave. Porosity (%)	pH	EC (mS/m)	Water Holding Capacity (%)
Potting Mix 1	90% garden soil + 10% chicken dung	3.97	6.1	1.26	70.85
Potting Mix 2	30% garden soil + 30% CRH + 30% sand + 10% chicken dung	11.1	6.8	0.69	66.21
Potting Mix 3	20% garden soil + 20% CRH + 20% RH +20% coir dust + 10% sand + 10% chicken dung	21	6.0	1.01	99.98

Mean with the same letter are not significantly different at 5% level of significant (HSD test)

Table A2-16. Average plant height and stem diameter of jackfruit seedlings in un-sanitized and sanitized media applied with/ without phosphonate grown in the different potting mix as influence by Air Filled Porosity.

Treatments	Plant Height (cm)	Stem diameter (mm)
Sanitation (Main plot)		
Un-sanitized media	67.6b	8.98b
Sanitized media	98.2a	11.82a
CV (%)	**10.21***	**7.37***
Phosphonate (Sub plot)		
Without phosphonate	82.8	10.40
With phosphonate	83.0	10.40
CV (%)	**8.42**	**7.10**
Potting Media w/ varying AFP		
PM1 (90% garden soil + 10% chicken dung. AFP- 3.9%)	85.9a	10.56a
PM2 (30% garden soil + 30% carbonized rice hull + 30% sand + 10% chicken dung. AFP- 11.1%)	79.3b	10.17b
PM3 (20% garden soil + 20% carbonized rice hull + 20% rice hull + 20% coco coir dust + 10% sand + 10% chicken dung. AFP- 21%)	83.3a	10.46a
CV (%)	**8.99***	**8.00***

Mean with the same letter are not significantly different at 5% level of significant (HSD test)

Table A2-17. Average plant health and seedling survival of jackfruit seedlings in un-sanitized and sanitized media applied with/ without phosphonate grown in the different potting mix as influence by Air Filled Porosity.

Treatments	Plant Health	Seedling survival
Sanitation (Main plot)		
Un-sanitized media	1	100%
Sanitized media	1	100%
Phosphonate (Sub plot)		
Without phosphonate	1	100%
With phosphonate	1	100%
Potting Media w/ varying AFP		
PM1 (90% garden soil + 10% chicken dung. AFP- 3.9%)	1	100%
PM2 (30% garden soil + 30% carbonized rice hull + 30% sand + 10% chicken dung. AFP- 11.1%)	1	100%
PM3 (20% garden soil + 20% carbonized rice hull + 20% rice hull + 20% coco coir dust + 10% sand + 10% chicken dung. AFP- 21%)	1	100%

Mean with the same letter are not significantly different at 5% level of significant (HSD test)

Appendix 3. Objective 1e

Table A3-1. Mean Phytophthora leaf lesion diameter of jackfruit (EVIARC Sweet), champedak, camansi, marang, antipolo and tugop.

Species And Source	Leaf Lesion Diameter (cm)
Control	0.00 [c]
Chempedak (Abuyog)	5.62 [a]
Jackfruit (Abuyog)	3.07 [b]
Camansi (Foodtech, VSU)	1.53 [bc]
Marang (Abuyog)	0.00 [c]
Antipolo (Brgy. Gabas)	0.93 [bc]
Tugop (San Jorge, Samar)	2.50 [b]
CV	18.38

Means followed by the same letter are not significantly different at 5% Tukey's HSD.

Table A3-2. Mean leaf lesion diameter of different jackfruit accessions from Abuyog Experiment Station germplasm collection.

Jackfruit Accessions	Lesion Diameter (cm)
EVIARC Sweet (agar only)	0.00 [b]
EVIARC Sweet (Inoculated)	0.60 [b]
Abuyog 01	0.26 [b]
AES 2- Malasian	0.83 [b]
Baybay 26	1.03 [b]
Biliran 05	0.00 [b]
Hilongos 09	2.50 [b]
Inopacan 04	0.43 [b]
Kambuok 04	12.17 [a]
Lagranha	1.10 [b]
Latexless-Grafted	1.23 [b]
Malitbog 01	2.47 [b]
Mayorga 01	0.43 [b]
Perez	0.83 [b]
Sinampilo	0.20 [b]
Sta Fe 06	2.67 [b]
Tolosa 0	0.47 [b]
CV (a) CV (b)	28.07 31.36

Means followed by the same letter are not significantly different at 5% Tukey's HSD.

Table A3-3. *Artocarpus* spp. collections from different municipalities and cities in Leyte, Southern Leyte, Eastern Samar and Biliran provinces.

Batch	Local Name	Date Collected	Place Collected	Coordinates
1	Tipo	6/26/2015	Haena, Baybay	N 11' 09.260 ;E 124' 56.558 ;El 34 m
1	Tipo	6/26/2015	Haena, Baybay	N 11' 09.260 ;E 124' 56.558 ;El 34 m
1	Tipo	6/26/2015	Bitanhuan, Baybay	N 10' 35.378; E 124' 45.979; 8 m
1	Kulo	6/26/2015	Plaridel	N 10' 33.829; E 124' 45.908; 21 m
1	Camansi	6/26/2015	Tahud, Inopacan, Leyte	N 10' 32.371;E 124' 46.065; El 17 m
1	Kulo	6/26/2015	Bontoc-Hindang, Leyte	N 10' 28.348; E 124' 43.737; El 12 m
1	Tipo	6/26/2015	Pob 1, Hindang	N 10' 25.762 ;E 124' 43.689 ;El 16 m
1	Tugop	6/26/2015	Pob 1, Hindang	N 10' 25.721 ;E 124' 43.667; El 21 m
1	Tipo	6/26/2015	Pob 1, Hindang	N 10' 25.721 ;E 124' 43.667; El 21 m
1	Kulo	6/26/2015	Ibarra-Maasin	N 10' 07.543; E 124' 52.934; 34 m
1	Camansi	6/26/2015	Rizal, Maasin	N 10' 07.544 ; E 124' 52.936 ; 152 m
1	Kulo	6/26/2015	Hantag, Maasin	N 10' 10.555 ;E 124' 50.495 ;El 275 m
1	Tipo	6/26/2015	Hantag, Maasin	N 10' 10.555 ;E 124' 50.495 ;El 275 m
1	Marang	6/26/2015	Malapoc Sur	N 10' 11.724; E 124' 49.753; 229 m
1	Marang	6/26/2015	Malapoc Norte, Maasin	N 10' 12.092; E 124' 50.146; 298 m
1	Tipo	6/26/2015	Tam-Is, Maasin	N 10' 09.538 ;E 124' 46.874 ;El 41 m
2	Marang	7/9-10/2015	Villa Sol	N 10' 37.790; E 124' 55.129; 351 m
2	Tugop	7/9-10/2015	Tabigi, Abuyog	N 10' 43.783; E 124' 59.152; 67 m
2	Tugop	7/9-10/2015	Tabigi, Abuyog	N 10' 43.783; E 124' 59.152; 67 m
2	Kulo	7/9-10/2015	Tubod, Silago	N 10' 31.985; E 125' 09.320; 81 m
2	Tipo	7/9-10/2015	Silago	N 10' 31.309; E 125' 09.633; 40 m
2	Kulo	7/9-10/2015	Anahawan	N 10' 15.973; E 125' 15.406; 5 m
2	Camansi	7/9-10/2015	Anahawan	N 10' 31.135; E 125' 09.865; 5 m
2	Tipo	7/9-10/2015	Anahawan	N 10' 15.406; E 125' 14.929; 33 m
2	Tipo	7/9-10/2015	Anahawan	N 10' 14.429; E 125' 14.914; 38 m
2	Marang	7/9-10/2015	Basak, San Juan	N 10' 15.537; E 125' 10.874; 24 m
2	Tipo	7/9-10/2015	St. Bernard	N 10' 13.805; E 125' 07.646; 37 m
2	Tipo	7/9-10/2015	Lebagon	N 10' 15.102; E 125' 04.310; 32 m
2	Marang	7/9-10/2015	Mayuga, Lebagon	N 10' 15.513; E 125' 04.106; 34 m
2	Tugop	7/9-10/2015	Pangi, Lebagon	N 10' 20.609; E 125' 02.191; 30 m
2	Marang	7/9-10/2015	Pangi, Lebagon	N 10' 20.609; E 125' 02.191; 30 m
2	Marang	7/9-10/2015	Bontoc, So.Leyte	N 10' 19.753; E 124' 54.584; 112 m
3	Tipo	7/14/2015	Amparo, Macrohon	N 10' 44.827; E 124'
3	Tipo	7/14/2015	Amparo, Macrohon	N 10' 44.827; E 124'
3	Kulo	7/14/2015	San Juaquin, Macrohon	NO GPS
3	Tipo	7/14/2015	Asuncion, Macrohon	No GPS data
3	Kulo	7/14/2015	Cantutang, Padre Burgos	N 10' 02.330; E 125' 01.391; 54 m
3	Tipo	7/14/2015	Cantamuac, Malitbog	N 10' 06.555; E 125' 00.579; 25 m
3	Camansi	7/14/2015	San Jose, Malitbog	N 10' 08.887; E 124' 59.892; 24 m
3	Tipo	7/14/2015	Huwagon, Malitbog	N 10' 13.479; E 124' 58.724; 31 m
3	Tipo	7/14/2015	San Antonio, Tomas Oppus	N 10' 19.470; E 124' 58.829; 32 m

Batch	Local Name	Date Collected	Place Collected	Coordinates
3	Tipo	7/14/2015	San Antonio, Tomas Oppus	N 10' 17.541; E 124' 58.836; 29 m
3	Tipo	7/14/2015	Tomas Oppus	N 10' 19.410; E 124' 58.376; 34
3	Tipo	7/14/2015	Tomas Oppus	N 10' 19.410; E 124' 58.376; 34
3	Tugop	7/14/2015	Uguis, Mahaplag	N 10' 34.176; E 124' 57.477; 91
3	Tugop	7/14/2015	San Isidro, Mahaplag	N 10' 34.246; E 124' 57.529; 83
3	Tipo	7/14/2015	San Isidro, Mahaplag	N 10' 34.345; E 124' 57.591; 92
4	Camansi	7/16-17/2015	Sto. Nino, Capoocan	N 10' 34.344; E 124' 57.592; 216
4	Tugop	7/16-17/2015	Lemon, Capoocan	N 11' 17.457; E 124' 33.864; 85
4	Marang	7/16-17/2015	Kawaya, Leyte-Leyte	N 11' 25.892; E 124' 28.129; 52
4	Tipo	7/16-17/2015	Caibiran	N 11' 31.517; E 124' 36.597; 134
4	Tipo	7/16-17/2015	Caibiran	N 11' 31.503; E 124' 36.598; 136
4	Camansi	7/16-17/2015	Bariis, Caibiran	N 11' 31.501; E 124' 36. 600; 45
4	Camansi	7/16-17/2015	Manlabang, Caibiran	N 11' 31.501; E 124' 36.600; 28
4	Camansi	7/16-17/2015	Manlabang, Caibiran	N 11' 31.501; E 124' 36.600; 28
4	Tugop	7/16-17/2015	Caibiran	N 11' 33.888; E 124' 34.430; 63
4	Tugop	7/16-17/2015	Caibiran	N 11' 33.878; E 124' 34.160; 62
4	Tugop	7/16-17/2015	Caibiran	N 11' 33.784; E 124' 33.922; 76
4	Tugop	7/16-17/2015	Caibiran	N 11' 33.764; E 124' 33.882; 86
4	Kulo	7/16-17/2015	Caibiran	N 11' 34.757; E 124' 27.522; 190
4	Tipo	7/16-17/2016	Caibiran	N 11' 34.757; E 124' 27.522; 190
5	Camansi	11/25/2015	Brgy. Balagtas, Matag-Ob	N 11' 08.598; E 125' 22.583; 69 m
5	Tipo	11/25/2015	Capoocan	N 11' 18.511; E 124' 34.722; 88 m
5	Kulo	11/25/2015	Brgy. Kolasian, Capoocan	N 11' 18.207; E 124' 37.195; 42 m
5	Camansi	11/25/2015	Bgry. Abango, Barugo	N 11' 16.106; E 124' 44.285; 54 m
5	Camansi	11/25/2015	Jaro	N 11' 13.670; E 124' 45.971; 73 m
5	Camansi	11/25/2015	Ulutan, Jaro	N 11' 12.007; E 124' 47.766; 80 m
6	Tipo	4/22/2016	Katipunan, Sta Fe	N 11' 01.510; E 124' 32.971; 49 m
6	Tipo	4/22/2016	Calsadahay, Buraen	N 10' 56.829; E 124' 55.122;
7	Kulo	7/1/2016	Uson Caibiran	N 11' 32.351; E 124' 36.621; 68 m
7	Tipo	7/1/2016	Baganito Kawayan	N 11' 42.052; E 124' 26.187; 15 m
7	Kulo	7/1/2016	Talahud Almeria	N 11' 38.403; E 124' 21.691; 37 m
7	Tipo	7/1/2016	Caibiran	N 11' 34.712; E 124' 33.360; 39 m
7	Kulo	7/1/2016	Caulanguhan Caibiran	N 11' 35.599; E 124' 33.486; 28 m
7	Tipo	7/1/2016	Canaan Caibiran	N 10' 12.093; E 124' 50.148; 108 m
7	Camansi	7/1/2016	Caulanguhan Caibiran	N 11' 35.599; E 124' 33.456; 28 m
7	Tipo	7/1/2016	Barubod Kawayan	N 11' 41.707; E 124' 23.545; 63 m
7	Tipo	7/1/2016	Caibiran	N 11' 36.548; E 124' 33.771; 43 m
7	Camansi	7/1/2016	Caibiran	N 11' 34.839; E 124' 32.956; 54 m
8	Camansi	9/28/2016	Ormoc	N 11' 38.403; E 124' 21.691; 39 m
8	Tipo	9/28/2016	Merida	N 10' 58.289; E 124' 32.190; 29 m
8	Camansi	9/28/2016	Merida	N 10' 56.516; E 124' 32.670; 29 m
8	Kulo	9/28/2016	Merida	N 10' 54.661; E 124' 31.958
8	Kulo	9/28/2016	Bilwang, Isabel	N 10' 52.913; E 124' 28.093; 33 m

Batch	Local Name	Date Collected	Place Collected	Coordinates
8	Camansi	9/28/2016	Bilwang, Isabel	N 10' 52.913; E 124' 28.093; 33 m
8	Camansi	9/28/2016	Palompon	N 11' 06.130; E 124' 23.653; 43 m
9	Kulo	11/7/2016	Lawaan Eastern Samar	N 11' 11.717; E 124' 47.008; 43 m
9	Tipo	11/8/2016	Lawaan Eastern Samar	N 11' 07.239; E 125' 15.070; 24 m
9	Tipo	11/9/2016	Lawaan Eastern Samar	N 11' 08.401; E 125' 16.723; 21 m
9	Tugop	11/10/2016	Quinapondan E. Samar	N 11' 10.816; E 125' 32.244; 35 m
9	Kulo	11/11/2016	Gen. Macarthur E. Samar	N 11' 16.883; E 125' 33.083; 12 m
9	Tipo	11/12/2016	Lorente Eastern Samar	N 11' 26.582; E 125' 30.476; 41 m

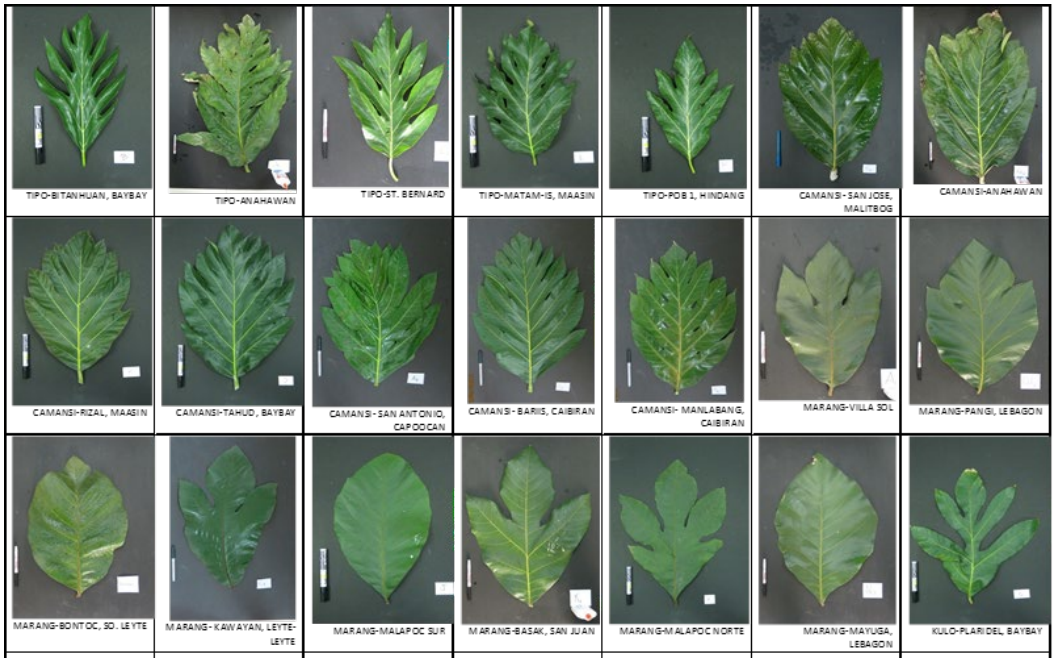


Figure A3-1. Leaves of different *Artocarpus* spp. collected from Eastern Visayas.

Figure A3-2. Fruits of different *Artocarpus* spp. collected from Eastern Visaya

Figure A3-3. Seeds of different *Artocarpus* spp. collected from Eastern Visayas.

Table A3-4. Means of lesion length (cm) of shoot tips of *Artocarpus sp*. collected from Baybay, Inopacan and Hindang in Leyte province and Maasin. So. Leyte.

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Tipolo (Bitanhuan, Baybay)	0.0 [c]	10	HR
Tipolo (Poblacion, Hindang)	0.9 [c]	10	HR
Marang (Malapoc Sur, Maasin)	1.4 [bc]	9	R
Marang (Malapoc Norte, Maasin)	3.1 [bc]	7	MR
Kulo (Bontoc, Hindang)	5.7 [ab]	5	MS
Camansi (Tahud, Inopacan)	7.8 [a]	3	S
Camansi (Rizal, Maasin)	8.5 [a]	2	S
Kulo (Hantag, Maasin)	8.7 [a]	2	S
Kulo (Plaridel, Baybay)	9.1 [a]	1	HS
Tugop (Poblacion, Hindang)	9.1 [a]	1	HS
CV% 21			

[a] Means with the same letter are not significantly different at 5% level of significant

Table A3-5. Means of lesion length (cm) of shoot tips of *Artocapus sp*. collected from Biliran Province.

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Kulo (Talahud, Almeria)	1.2 [e]	9	R
Camansi (Caulanguhan, Caibiran)	5.7 [d]	5	MS
Kulo (Caulanguhan, Caibiran)	7.5 [cd]	3	S
Tipolo (Barubod, Kawayan)	7.7 [cd]	3	S
Tipolo (Canaan, Caibiran)	9.0 [bcd]	1	HS
Tipolo (Caibiran-i)	9.2 [bcd]	1	HS
Camansi (Caibiran)	9.7 [abc]	1	HS
Tipolo (Baganito, Kawayan)	11.8 [ab]	1	HS
Tipolo (Caibiran-d)	13.2 [a]	1	HS
CV% 12.4			

[a] Means with the same letter are not significantly different at 5% level of significant

Table A3-6. Means of lesion length (cm) of shoot tips of *Artocapus sp*. collected from Ormoc, Merida, Isabel and Palompon on September 28, 2016.

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Tipolo (Merida)	4.5 [b]	6	MS
Kulo (Bilwang, Isabel)	14.0 [a]	1	HS
Camansi (Bilwang, Isabel)	9.5 [ab]	1	HS
Camansi (Palompon)	10.0 [ab]	1	HS
Camansi (Ormoc)	11.2 [ab]	1	HS
Kulo (Merida)	12.0 [a]	1	HS
Camansi (Merida)	12.5 [a]	1	HS
CV% 21			

[a] Means with the same letter are not significantly different at 5% level of significant

Table A3-7. Means of lesion length (cm) of shoot tips of *Artocapus sp.* collected from Malitbog, Padre Burgos, Maasin, Mahaplag and Baybay on September 4, 2017

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Control (uninoculated)	0.0 [d]	10	HR
Antipolo (Maasin)	1.5 [d]	9	R
Antipolo (Baybay)	4.8 [c]	6	MS
Kulo (Maasin)	8.9 [b]	2	S
Tugop (Mahaplag)	9.4 [b]	1	HS
Kulo (Padre Burgos)	20.0 [a]	1	HS
Camansi (Malitbog)	11.5 [b]	1	HS
CV% 16.8			

[a] Means with the same letter are not significantly different at 5% level of significant

Table A3-8. Means of lesion length (cm) of shoot tips of *Artocapus sp.* collected from Lebagon, Bontoc, Anahawan, St. Bernard, Silago and Abuyog on October 11, 2017

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Tipolo (Libagon)	0.04 [c]	10	HR
Tipolo (St. Bernard)	0.50 [c]	10	HR
Tipolo (Anahawan)	0.78 [c]	10	HR
Kulo (Anahawan)	1.66 [c]	9	R
Kulo (Tubod, Silago)	2.30 [c]	8	MR
Marang (Mayuga, Lebagon)	4.00 [bc]	7	MR
Marang (Bontoc)	5.48 [bc]	5	MS
Marang (Pangi, Lebagon)	5.68 [bc]	5	MS
Tugop (Pangi, Lebagon)	9.26 [b]	1	HS
Tugop (Tabigi, Abuyog)	16.40 [a]	1	HS
Jackfruit (EVIARC Sweet)	20.00 [a]	1	HS
CV% 31.9			

[a] Means with the same letter are not significantly different at 5% level of significant

Table A3-9. Means of lesion length (cm) of shoot tips of *Artocapus sp.* collected from Kananga, Capoocan, Jaro, Alangalang, Tunga, Sta Fe, and Palo March 6, 2018

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Tipolo (Dapdap, Alangalang)	0.0 [c]	10	HR
Tipolo (Hibucawan, Jaro)	0.0 [c]	10	HR
Tipolo (Tangnan, Carigara)	0.0 [c]	10	HR
Kulo (Sto. Nino, Capoocan)	0.0 [c]	10	HR
Marang (Capoocan)	0.5 [c]	10	HR
Tipolo (Tibak, Sta. Fe)	0.6 [c]	10	HR
Tipolo (Balire, Tunga)	0.7 [c]	10	HR
Tipolo (Palo)	2.8 [c]	8	MR
Camansi (Capoocan)	2.8 [c]	8	MR
Camansi (Macopa, Jaro)	3.3 [c]	7	MR
Camansi (Lunay Zone 3, Kananga)	3.5 [c]	7	MR
Camansi (Balire, Tunga)	3.6 [bc]	7	MR
Tugop (Dapdap, Alangalang)	4.0 [bc]	7	MR
Tugop (Palo)	4.5 [bc]	6	MS
Tugop (Sta. Fe)	4.6 [bc]	6	MS
Tipolo (Macopa, Jaro)	4.9 [bc]	6	MS
Tipolo (Lemon, Capoocan)	6.7 [bc]	4	S
Camansi (Tagak, Carigara)	7.2 [bc]	3	S
Tugop (San Juaquin, Capoocan)	9.3 [ab]	1	HS
Tugop (Balire, Tunga)	13.6 [a]	1	HS
CV% 35.8			

[a] Means with the same letter are not significantly different at 5% level of significant

Table A3-10. Means of lesion length (cm) of shoot tips of *Artocapus sp.* collected Lemon, Kawayan and Caibiran March 16, 2018

Species/Place	Lesion length (cm)	Tolerance Rating	Reaction
Tipolo (Caibiran) L.1	1.7 [cd]	9	R
Marang (Kawayan, Leyte)	3.7 [cd]	7	MR
Tipolo (Caibiran) L	9.1 [bc]	1	HS
Tipolo (Caibiran)	13.5 [ab]	1	HS
Tugop (Caibiran) (I)	16.9 [ab]	1	HS
Jackfruit EVIARC sweet	17.0 [ab]	1	HS
Tugop (Caibiran) (J)	17.1 [ab]	1	HS
Tugop (Lemon)	18.1 [a]	1	HS
Tugop (Caibiran) (h)	20.0 [a]	1	HS
CV% 33.4			

[a] Means with the same letter are not significantly different at 5% level of significant

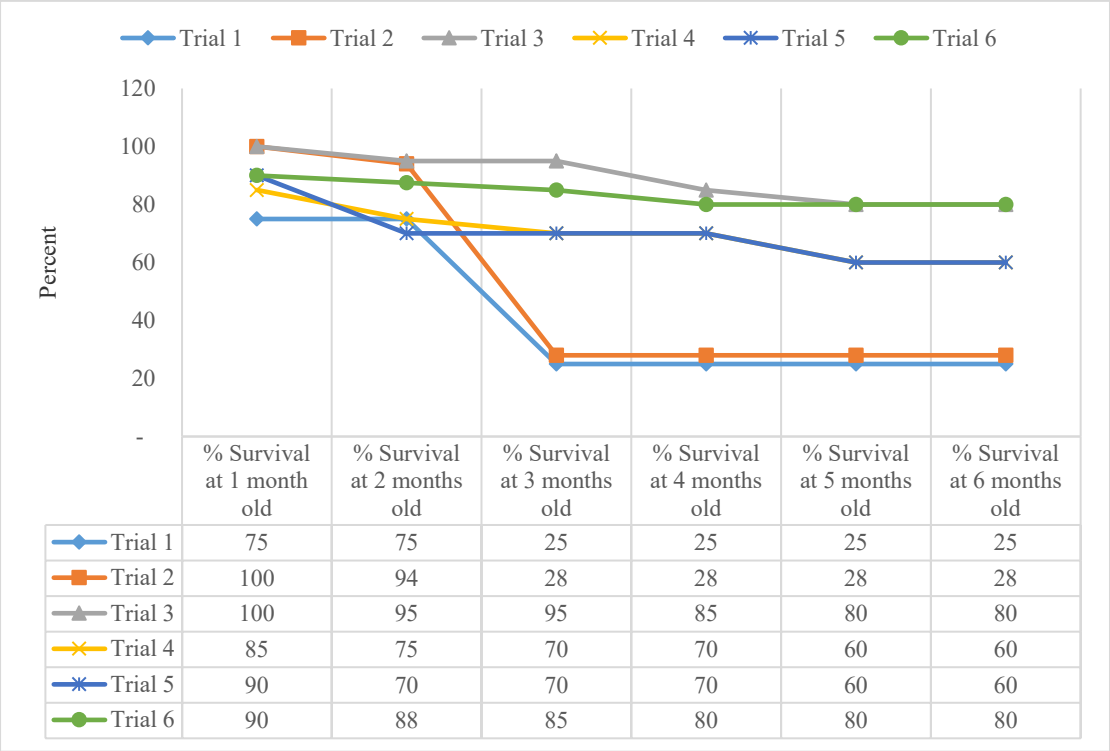
Table A3-11. Mean Lesion length (cm) of different Jackfruit Accessions shoot tips one week after inoculation of *P. palmivora*

Accessions	Lesion length (cm)		Tolerance Rating	Reaction
Control (Uninoculated)	0.0	j	10	HR
Mancol 09	0.7	ij	10	HR
Sta Fe 05	0.9	ij	10	HR
Latexless	1.0	ij	10	HR
Torres	1.0	ij	10	HR
Biliran 04	1.1	ij	9	R
Dulag 01	1.3	hij	9	R
Mandaue	1.6	ghij	9	R
Bato 01	1.7	ghij	9	R
Mahaplag 08	1.8	ghij	9	R
Leyte 02	2.9	fghij	8	MR
Cambook 07	2.9	fghij	8	MR
Sinampilo	3.2	fghij	7	MR
Ormoc 12	3.5	fghij	7	MR
STIARC	4.2	fghij	6	MS
Candadam 19	4.3	fghij	6	MS
Palo 05	5.0	efjhij	6	MS
La Granja 10	5.2	defghij	5	MS
CL 01	6.0	cdefghij	5	MS
Hindang 01	6.8	bcdefghij	4	S
Hilongos 04	7.6	bcdefghij	3	S
BJUNEV 06	7.9	abcdefghij	3	S
Perez	8.4	abcdefghij	2	S
Ormoc 15	8.9	abcdefghij	2	S
Padre Burgos	9.1	abcdefghij	1	HS
Tolosa 02	9.3	abcdefghij	1	HS
Cambook 17	9.6	abcdefghij	1	HS
Matalom 09	10.6	abcdefghij	1	HS
Inopacan 02	12.5	abcdefghi	1	HS
Mayorga 02	12.5	abcdefghi	1	HS
Cambook 04	13.5	abcdefgh	1	HS
Maasin 07	13.7	abcdefg	1	HS
Mc Arthur 02	14.4	abcdef	1	HS
Naval 05	14.7	abcdef	1	HS
Almeria 02	15.1	abcdef	1	HS
Malitbog 01	16.7	abcd	1	HS
Oppus 05	17.5	abcd	1	HS
LV 01	18.1	abc	1	HS
EVIARC Sweet	18.2	abc	1	HS
Hibunawan	18.7	ab	1	HS
Sapinit 04	20.0	a	1	HS

[a] *Means with the same letter are not significantly different at 5% level of significant*

Appendix 4. Objective 2a

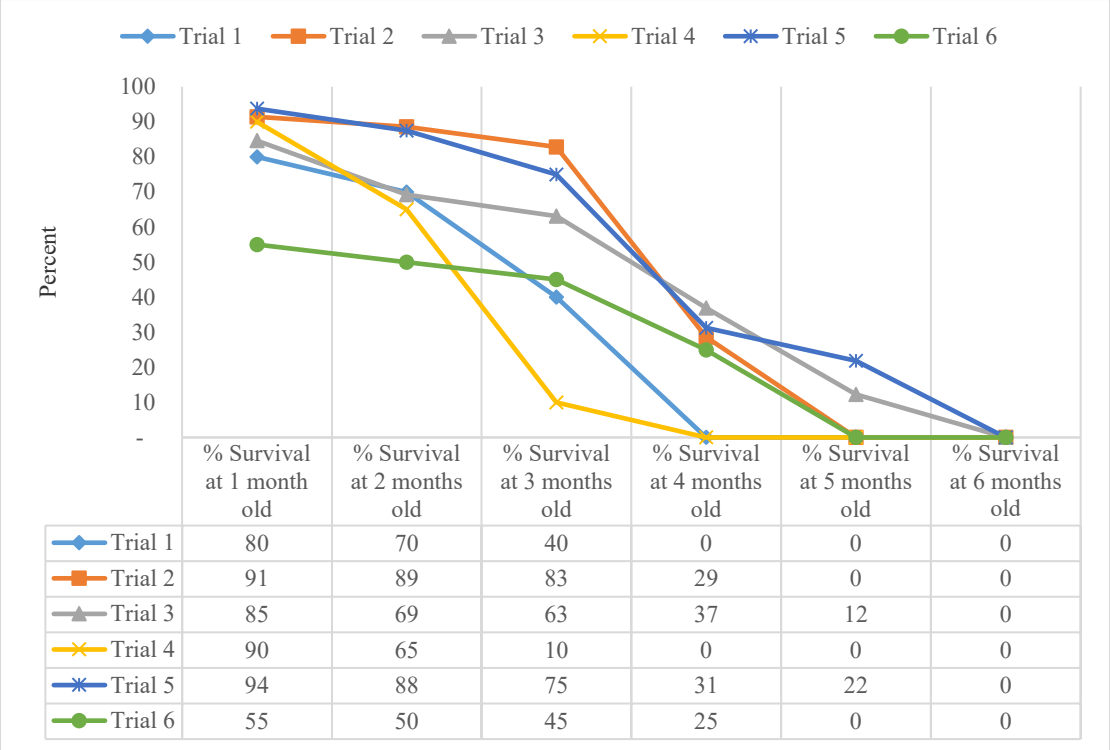
Interspecies grafting trials DA-Abuyog



	% Survival at 1 month old	% Survival at 2 months old	% Survival at 3 months old	% Survival at 4 months old	% Survival at 5 months old	% Survival at 6 months old
Trial 1	75	75	25	25	25	25
Trial 2	100	94	28	28	28	28
Trial 3	100	95	95	85	80	80
Trial 4	85	75	70	70	60	60
Trial 5	90	70	70	70	60	60
Trial 6	90	88	85	80	80	80

Figure A4-1. Percent survived grafts of chempedak-jack combination from 1 to 6 months old

Figure A4-2. Chempedak-jack and jack-jack combination



	% Survival at 1 month old	% Survival at 2 months old	% Survival at 3 months old	% Survival at 4 months old	% Survival at 5 months old	% Survival at 6 months old
Trial 1	80	70	40	0	0	0
Trial 2	91	89	83	29	0	0
Trial 3	85	69	63	37	12	0
Trial 4	90	65	10	0	0	0
Trial 5	94	88	75	31	22	0
Trial 6	55	50	45	25	0	0

Figure A4-3. Percent survived grafts of camansi-jack combination from 1 to 6 months old

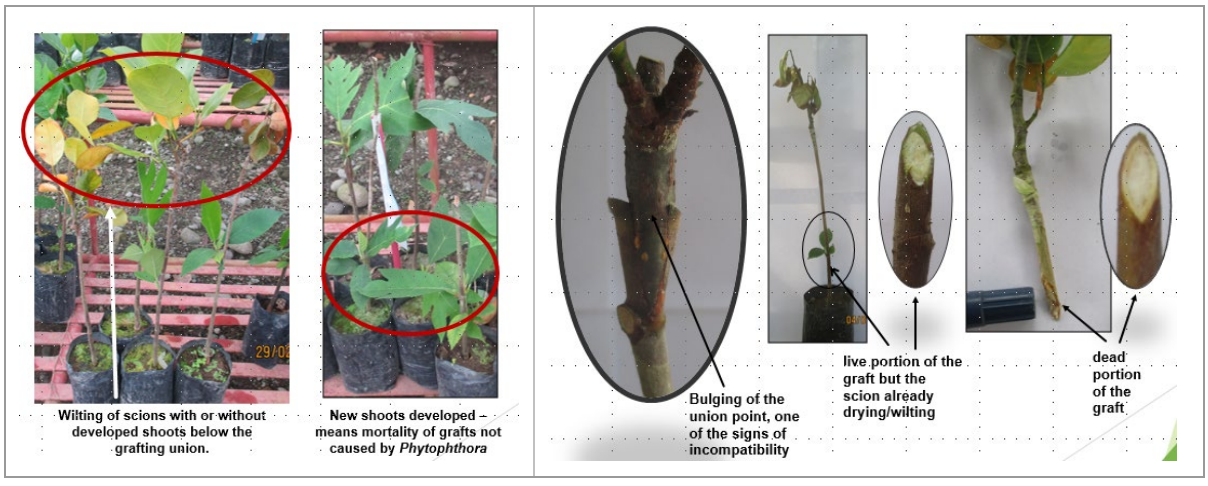
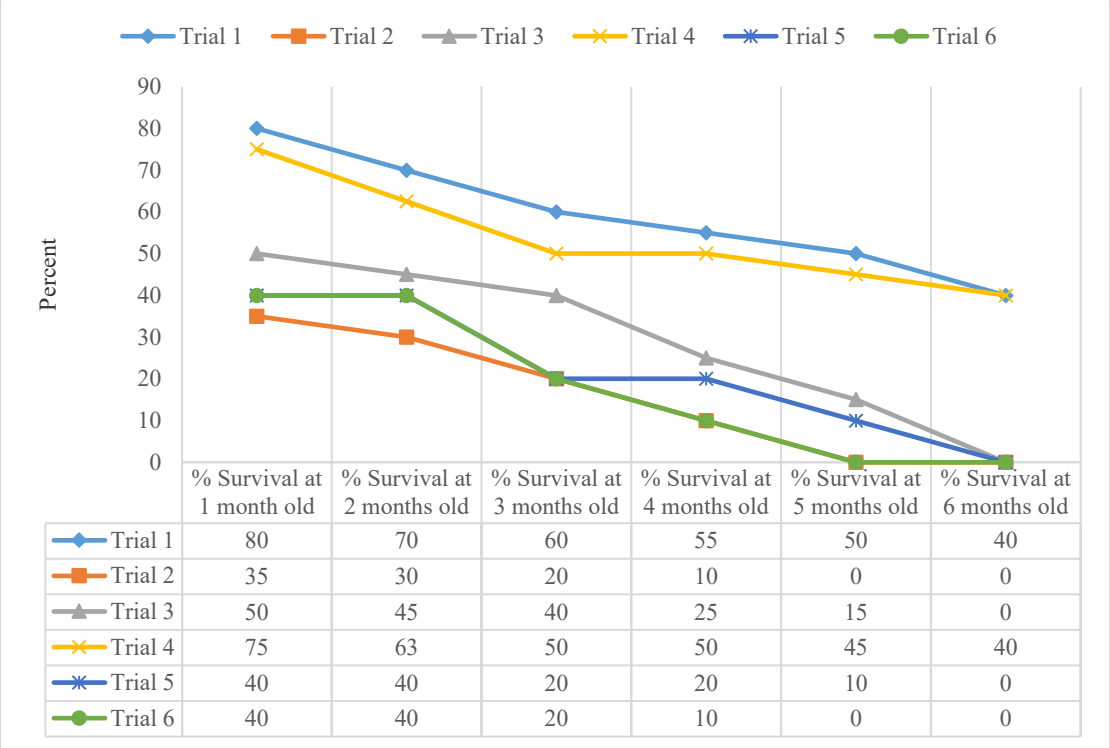
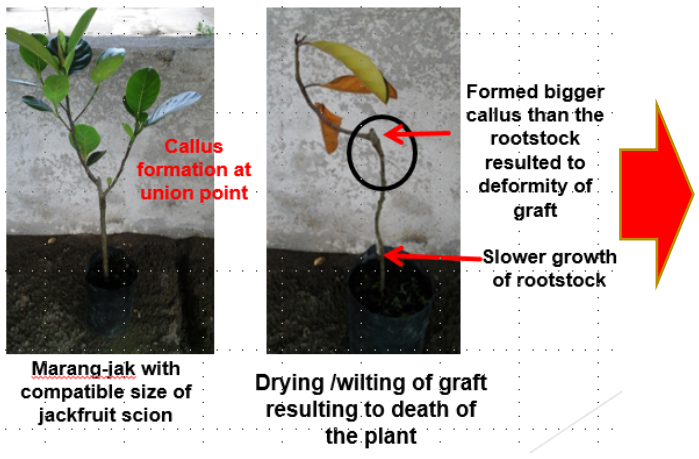


Figure A4-4. Camansi-jack and jack-jack combination



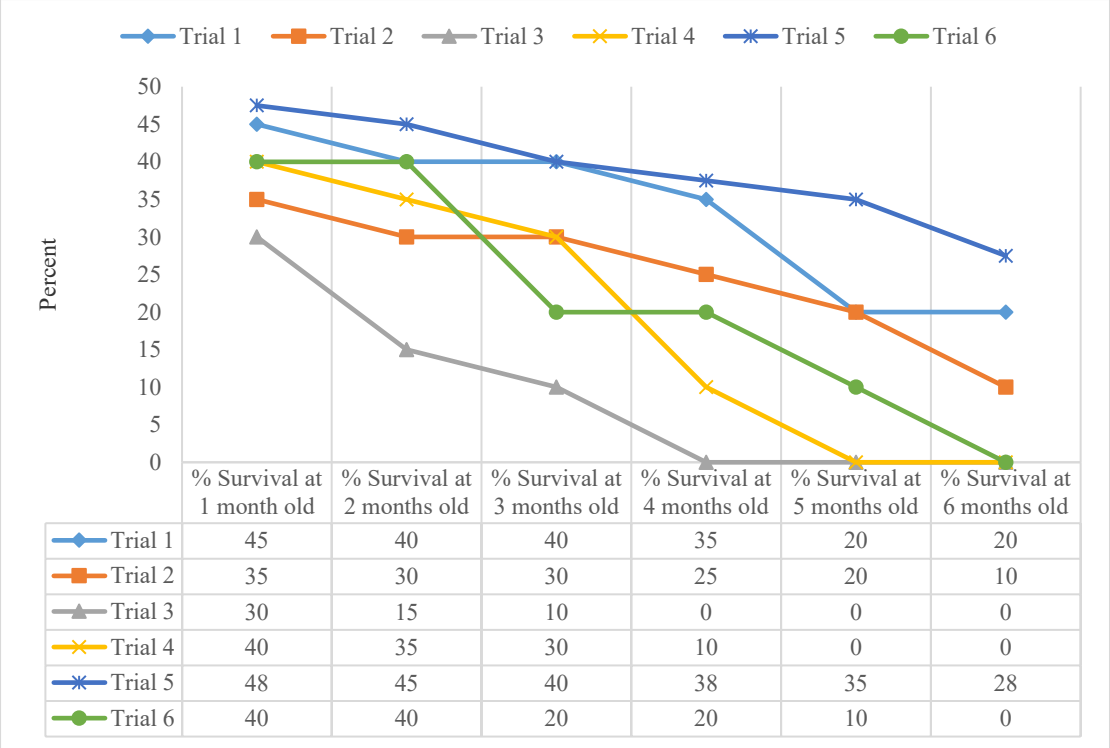
	% Survival at 1 month old	% Survival at 2 months old	% Survival at 3 months old	% Survival at 4 months old	% Survival at 5 months old	% Survival at 6 months old
Trial 1	80	70	60	55	50	40
Trial 2	35	30	20	10	0	0
Trial 3	50	45	40	25	15	0
Trial 4	75	63	50	50	45	40
Trial 5	40	40	20	20	10	0
Trial 6	40	40	20	10	0	0

Figure A4-5. Percent survived grafts of marang-jack combination from 1 to 6 months old



Marang-jack show yellowing of leaves and wilting of seedlings

Figure A4-6. Marang-jack and jack-jack combination



	% Survival at 1 month old	% Survival at 2 months old	% Survival at 3 months old	% Survival at 4 months old	% Survival at 5 months old	% Survival at 6 months old
Trial 1	45	40	40	35	20	20
Trial 2	35	30	30	25	20	10
Trial 3	30	15	10	0	0	0
Trial 4	40	35	30	10	0	0
Trial 5	48	45	40	38	35	28
Trial 6	40	40	20	20	10	0

Figure A4-7. Percent survived grafts of tugop-jack combination from 1 to 6 months old

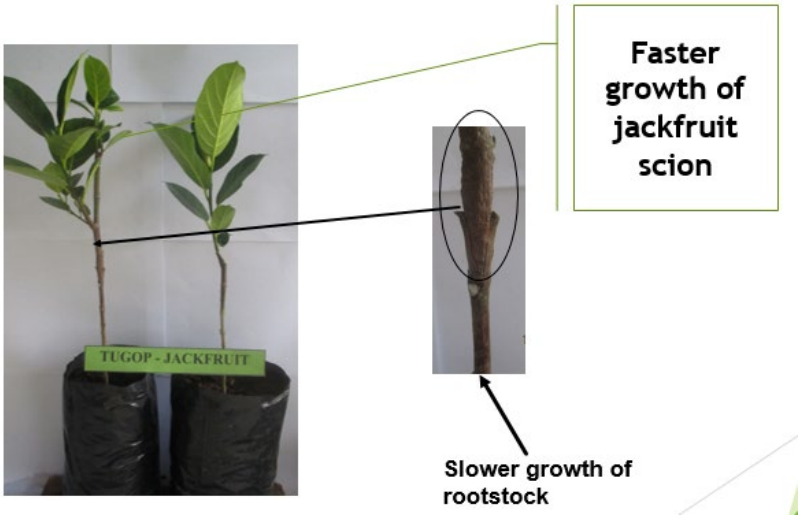
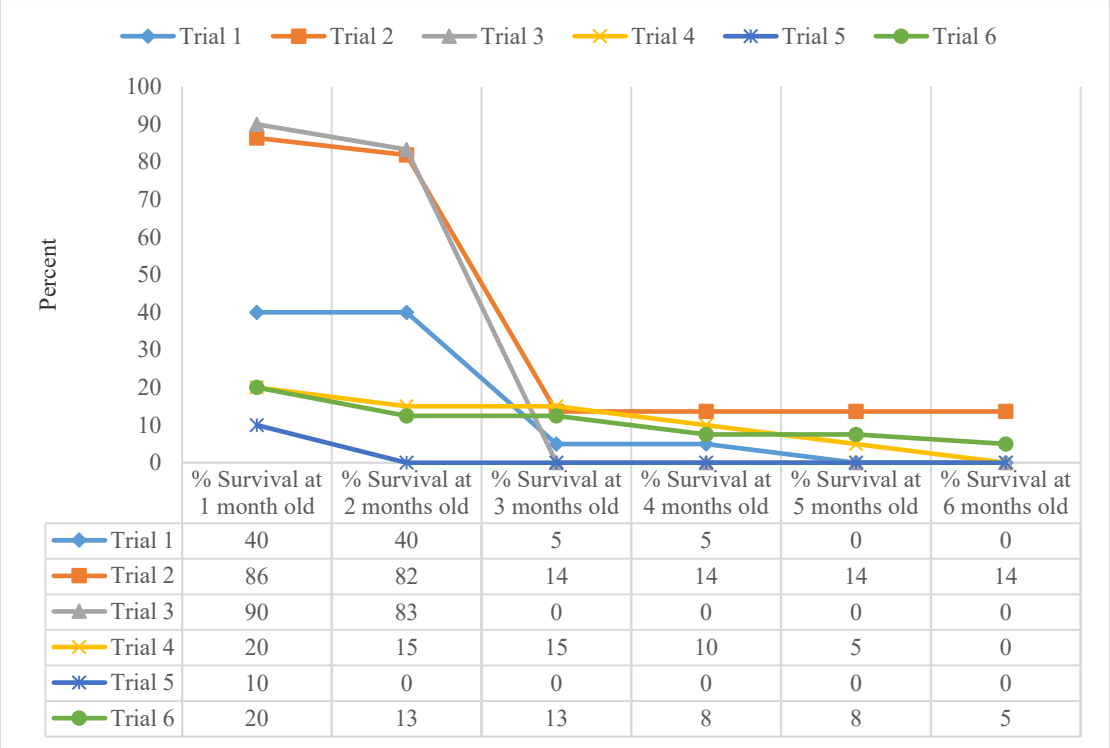


Figure A4-8. Tugop-jack and jack-jack combination



	% Survival at 1 month old	% Survival at 2 months old	% Survival at 3 months old	% Survival at 4 months old	% Survival at 5 months old	% Survival at 6 months old
Trial 1	40	40	5	5	0	0
Trial 2	86	82	14	14	14	14
Trial 3	90	83	0	0	0	0
Trial 4	20	15	15	10	5	0
Trial 5	10	0	0	0	0	0
Trial 6	20	13	13	8	8	5

Figure A4-9. Percent survive grafts of tipolo-jack combination from first month old to 6 months old.

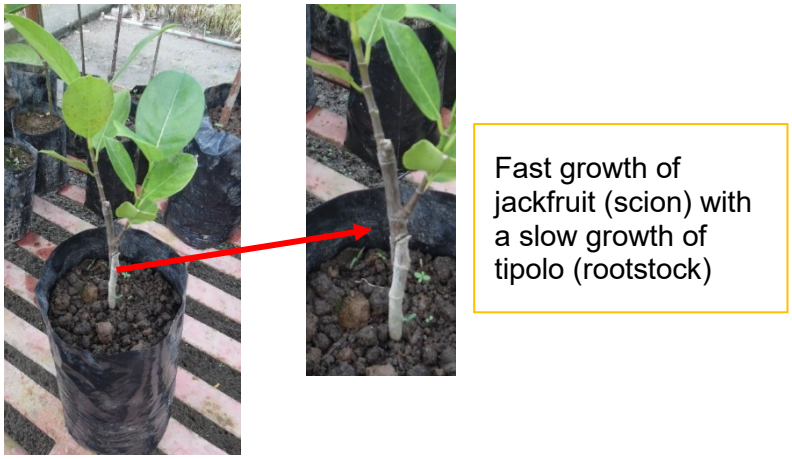
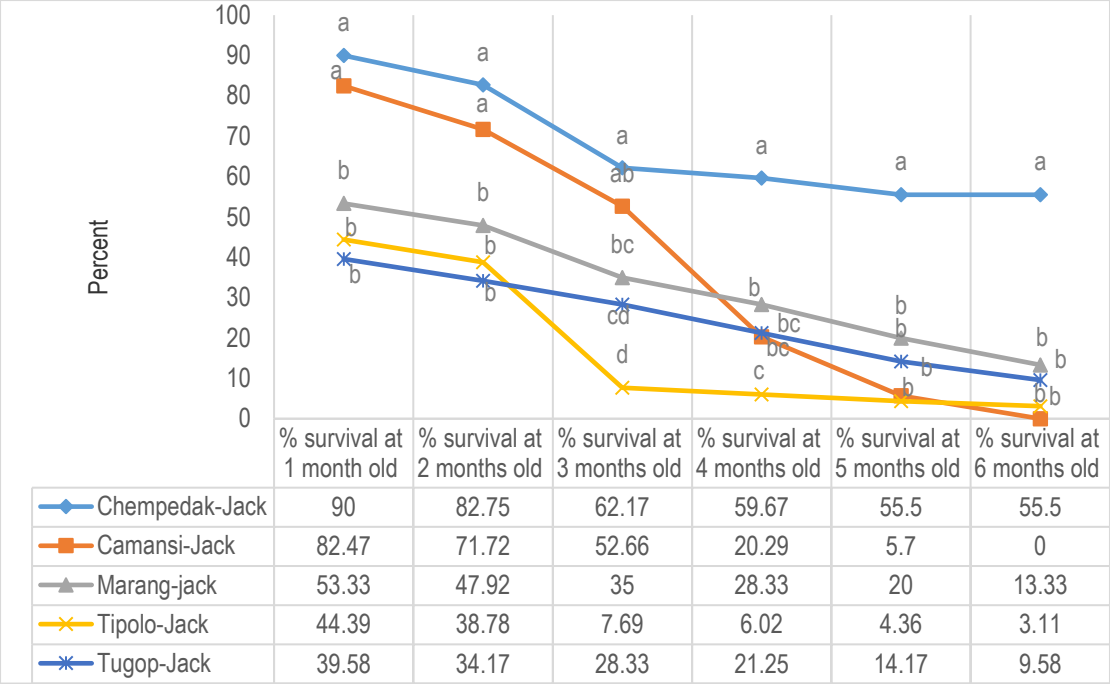


Figure A4-10. Tipolo-jack and jack-jack combination



	% survival at 1 month old	% survival at 2 months old	% survival at 3 months old	% survival at 4 months old	% survival at 5 months old	% survival at 6 months old
Chempedak-Jack	90	82.75	62.17	59.67	55.5	55.5
Camansi-Jack	82.47	71.72	52.66	20.29	5.7	0
Marang-jack	53.33	47.92	35	28.33	20	13.33
Tipolo-Jack	44.39	38.78	7.69	6.02	4.36	3.11
Tugop-Jack	39.58	34.17	28.33	21.25	14.17	9.58

Figure A4-11. Percent survival of the different *Artocarpus* species combinations from 1 to 6 months old of grafting

Table A4-1. Survived grafts of camansi-jack combination after three to five months from grafting using cleft and saddle grafting

Trials	Stock-Scion Combination	Type of grafting	Total Grafts	Age of the Stock (month)	Percent Survival at 3 months after grafting	Percent Survival at 5 months after grafting
First Trial	Camansi-jack	Cleft grafting	10	6	20%	0%
		Saddle grafting	10	6	0%	0%
Second Trial	Camansi-jack	Cleft grafting	10	7	50%	0%
		Saddle grafting	10	7	40%	0%
Control	Jackfruit- Jack	Cleft grafting	10	3	70%	70%
		Saddle grafting	10	3	50%	50%

Figure A4-12. Camansi-jackfruit combination showing decay portion of the union of the graft.

Table A4-2. Survive grafts of marang-jack and jack-jack combination after three to five months from grafting using different grafting operations.

Trials	Stock-Scion Combination	Type of grafting	Total Grafts	Age of the stock (month)	% Survival at 3 months after grafting	% Survival at 5 months after grafting	% Survival at 7 months after grafting
First Trial	Marang-jack	Cleft grafting	10	12	20%	20%	0%
		Saddle grafting	10	12	10%	10%	0%
Second Trial	Marang-jack	Cleft grafting	10	13	40%	40%	20%
		Saddle grafting	10	13	20%	20%	0%
Control	Jackfruit-Jack	Cleft grafting	10	3	70%	70%	60%
		Saddle grafting	10	3	50%	50%	50%

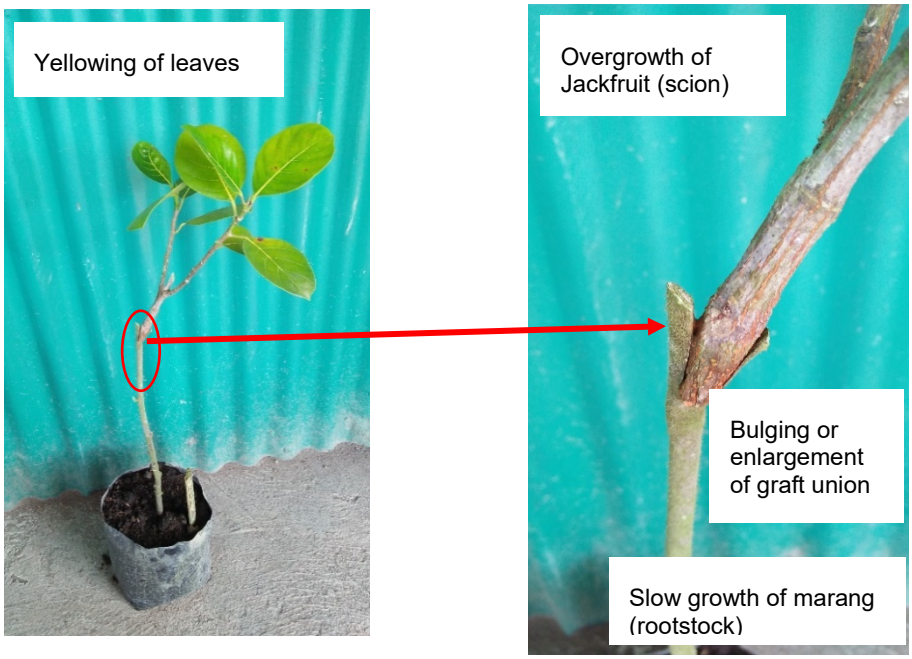


Figure A4-13. Marang-jackfruit combination showing yellowing of leaves, overgrowth of scion, bulging of union grafts and slow growth of rootstock

Table A4-3. Average plant height and stem diameter (below and above union) of chempedak- jackfruit and jackfruit- jackfruit combination after 1 month, 12 months, 18 months and 24 months old of graft from field establishment

Combination	1 month old			12 months old			18 months old			24 months old		
	Plant height (cm)	below union (mm)	above union (mm)	Plant height (cm)	below union (mm)	above union (mm)	Plant height (cm)	below union (mm)	above union (mm)	Plant height (cm)	below union (mm)	above union (mm)
Chempedak-Jackfruit	68.77 a	6.18	6.85	255.9	25.48 a	22.32	324.67	31.67	29.17	417.33	35.67	34.67
Jackfruit-Jackfruit	56.33 b	6.47	6.18	202.93	18.18 b	18.82	258.67	27.33	25	396.67	32.33	30.33
CV (%)	4.08*	26.81	22.85	10.94	6.7*	18.68	7.98	15.96	8.69	13.74	14.61	7.64

Mean with the same letter are not significantly different at 5% level of significant (Least Significance Different test (LSD))

Table A4-4. Average wide of canopy of chempedak-jack and jack-jack combination

Combination	Wide of canopy (cm)
Chempedak-Jackfruit	265.33
Jackfruit-Jackfruit	230.67
CV (%)	12.78

Mean with the same letter are not significantly different at 5% level of significant (Least Significance Different test (LSD))

Figure A4-14. Canopy appearance of a) Jackfruit on Chempedak and b) Jackfruit on its own scion.

Figure A4-15. Chempedak-jackfruit combination produces four (4) fruits compared to jackfruit-jackfruit after 3 years from establishment

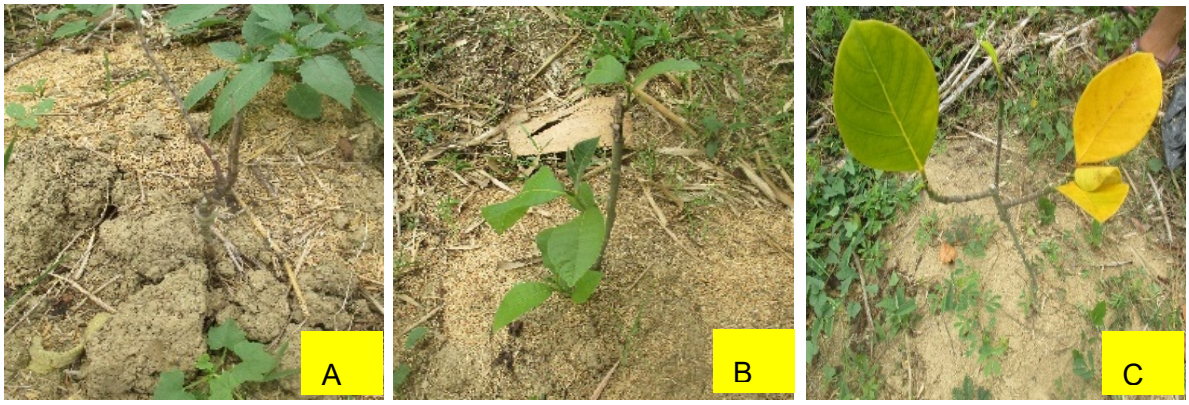


Figure A4-16. Seedling of camansi-jack (A), marang-jack (B) & tugop-jack (C) combination in the field

Interspecies grafting trials BPI Davao

Table A4-5. Growth performance of jackfruit as influenced by its rootstock (2015)

Rootstock	Average Plant Height (cm)	Average Girth (cm)		Number of Branches	Reaction / Remark
		Below (Rootstock)	Above (Scion)		
Jackfruit x Jackfruit	154.33a	2.21a	1.84b	8.67b	
Marang x Jackfruit	74.00b	1.28b	1.32b	5.25c	Slight incompatibility
Tipoo x Jackfruit	100.67b	1.98a	2.55a	12.00a	Showing severe incompatibility
Level of Significance	5%	5%	5%	5%	
CV	17.91	20.86	19.82	22.96	

Table A4-6. Growth performance yield and pest reaction of jackfruit as influenced by its rootstocks (2018)

Rootstock	Average Plant Height (m)	Average Girth (cm)		Canopy m^2	Average Number of Fruits	Reaction to Pests
		Below (Rootstock)	Above (Scion)			
Jackfruit x Jackfruit	13.19	17.48	14.99	20.72	1.67	2 plants with canker lesions at the collar of an infected tree
Marang x Jackfruit	7.66	11.91	6.18	15.05	4.75	0
P values	0.03*	0.13 - ns	0.05*	0.52 – ns	0.30 – ns	
	0.01**	0.06 - 10%	0.02*	0.26 - ns	0.15 - ns	

Figure A4-17. Jackfruit on its own rootstock showing canker lesions at the collar of an infected tree developing at the soil line

Figure A4-18. Jackfruit on Marang showing healthy rootstocks with fruits growing near the soil line

Figure A4-19. Jackfruit on Marang fruiting in 2017

Figure A4-20. Jackfruit on Antipolo displaying severe incompatibility (2015)

Appendix 5. Objective 2b

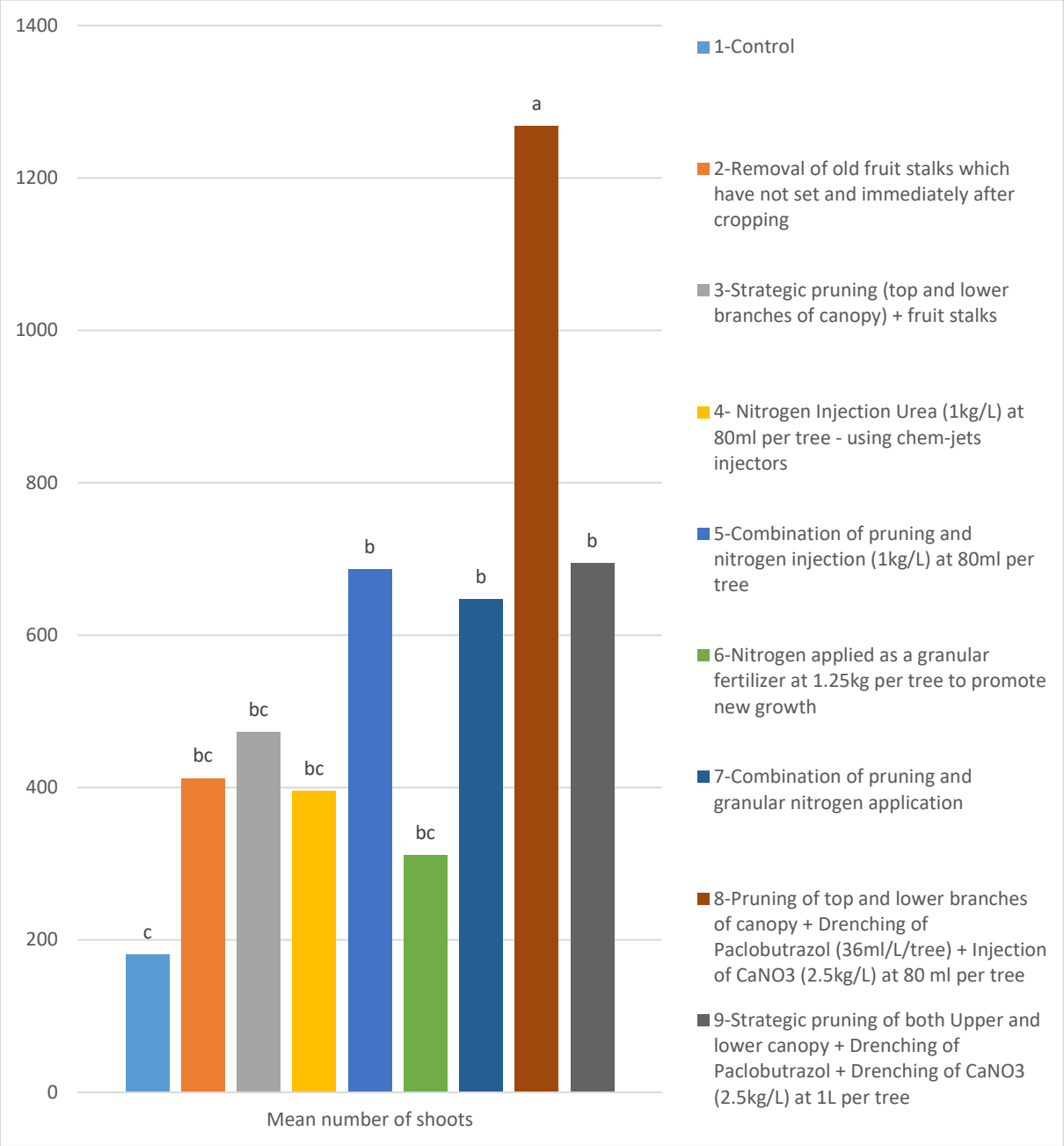


Figure A5-1. Mean number of shoots after application of treatments in 2016

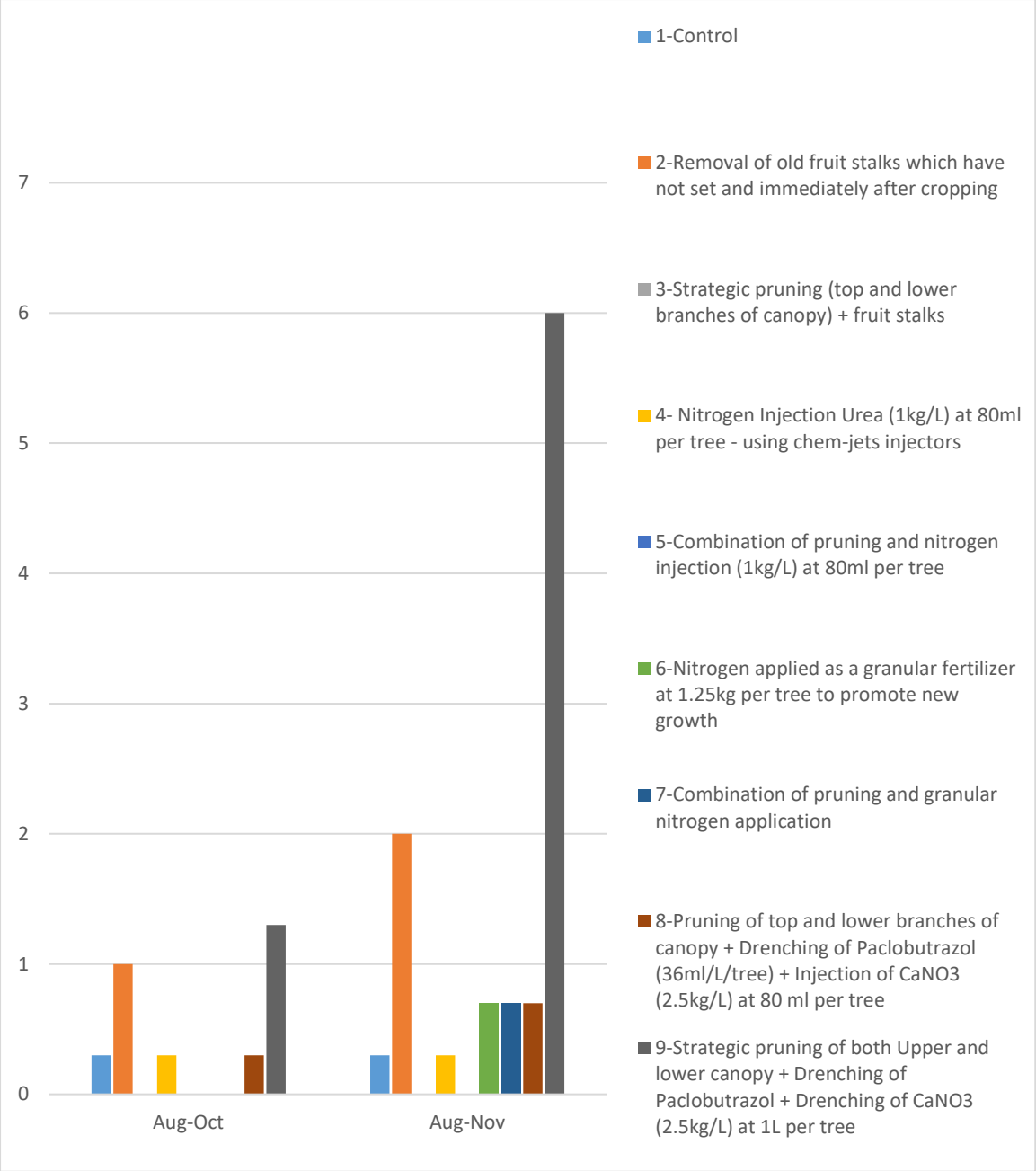


Figure A5-2. Mean number of off-season female flower that emerged from August to November 2016.

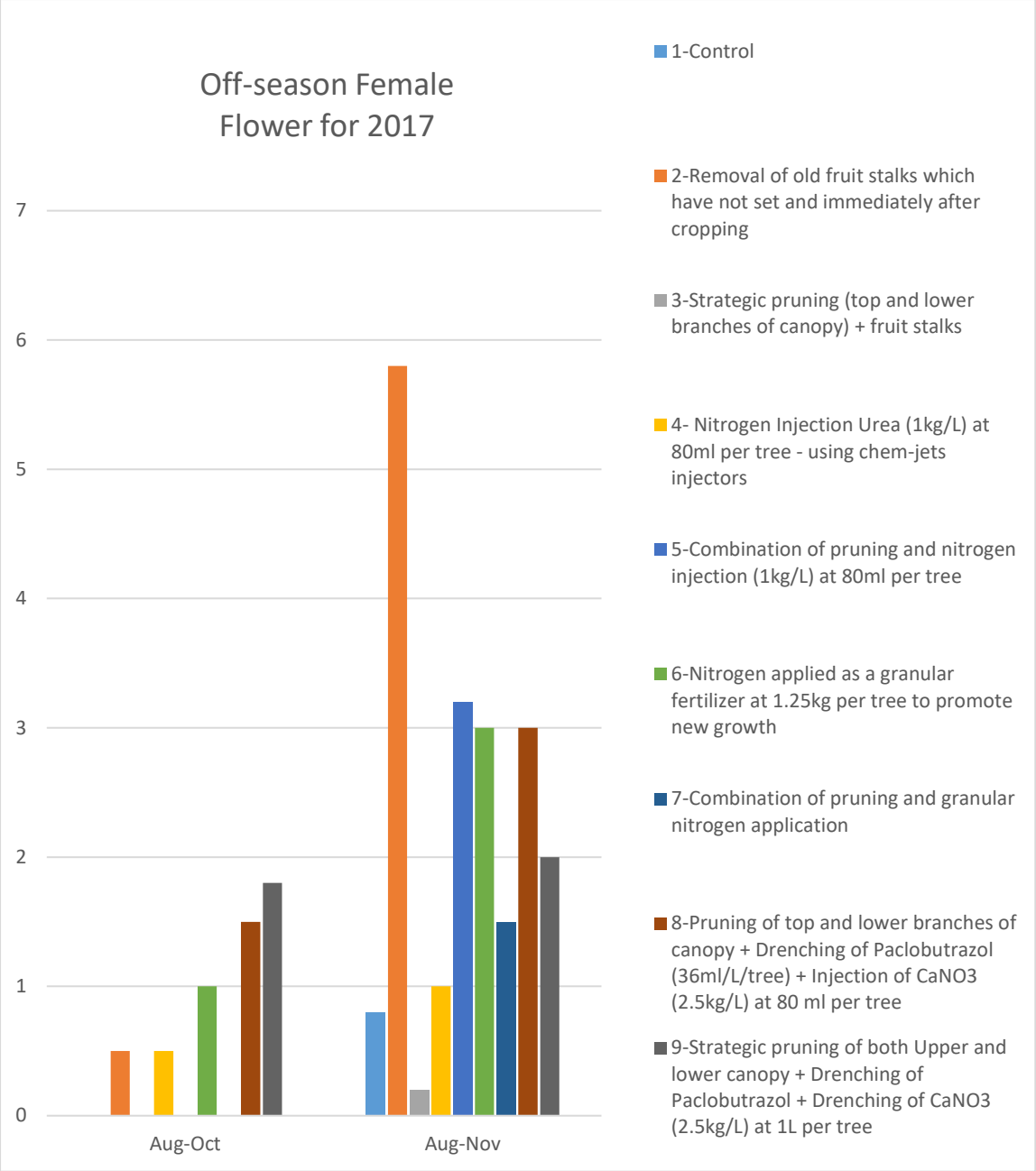


Figure A5-3. Mean number of off- season female flower that emerged from August to November 2017.

Appendix 6. Objective 2c

Table A6-1. Means of Canopy ratings from the 1st to the 9th rating as affected by fertilization, phosphonate and fruit load regulation.

TREATMENT	1	2	3	4	5	6	7	8	9
FERTILIZER (A)									
50% DA Recommendation	2.1	1.9	1.6	1.4[ab]	1.8	1.4[ab]	1.5	1.7	1.4
100% DA Recommendation	2.1	1.9	1.6	1.2[bc]	1.6	1.3[b]	1.2	1.6	1.5
150% DA recommendation	2.3	1.8	1.5	1.0[c]	1.4	1.1[b]	1.1	1.3	1.3
Commercial Organic Fertilizer	2.2	1.8	1.5	1.4[ab]	1.3	1.1[b]	1.2	1.3	1.3
Job's Practice (control)	2.3	2.1	2.0	1.6[a]	1.5	1.7[a]	1.4	1.4	1.5
PHOSPRO (B)									
With	2.2	1.8[b]	1.6	1.4	1.5	1.3	1.2	1.4	1.3
Without	2.2	2.0[a]	1.7	1.3	1.5	1.4	1.3	1.4	1.4
FRUIT REG (C)									
Regulated	2.2	1.6	1.6	1.2	1.4	1.2	1.2	1.4	1.4
Unregulated	2.3	1.9	1.6	1.4	1.6	1.4	1.4	1.5	1.4
Fertilizer:Fruit Regulation	ns	ns	ns	*	ns	ns	ns	ns	ns
Phospro:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer:Phospro:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns
A	8.6	21.5	15.3	17.2	22.6	12.3	11.2	19.5	14.5
CV % B	7.4	18.8	22.0	15.4	13.2	12.5	13.6	12.3	14.4
C	6.4	14.1	9.4	8.2	18.1	17.4	15.7	17.7	16.5

[a] means with the same letter in a column are not significantly different at 5% level of significant

Canopy Rating:

1 Branches, shoots and canopy crown are 85 to 100% green and vigorous

2 Branches, shoots and canopy crown are 70 to 84% green and vigorous

3 Branches, shoots and canopy crown are 55 to 69% green and vigorous

4 Branches, shoots and canopy crown are 40 to 54% green and vigorous

5 Branches, shoots and canopy crown are below 25 to 39% green and vigorous

Table A6-2. Means of Canopy ratings in the 4th rating as affected by interaction between fertilizer application and fruit load regulation

FERTILIZER APPLICATION	REGULATED	UNREGULATED
50% DA Recommendation	1.1 [a B]	1.8 [a A]
100% DA Recommendation	1.3 [a]	1.1 [b]
150% DA recommendation	1.0 [a]	1.0 [b]
Commercial Organic Fertilizer	1.4 [a]	1.4 [ab]
Job's Practice (control)	1.4 [a B]	1.8 [a A]

[a] means with the same letter in a column are not significantly different at 5% level of significant
[A] means with the same letter in a row are not significantly different at 5% level of significant

Table A6-3. Mean of Severity ratings from the 1st to the 9th rating as affected by fertilization, phosphonate and fruit load regulation.

TREATMENT	1	2	3	4	5	6	7	8	9
FERTILIZER (A)									
50% DA Recommendation	2.8	2.4	2.7	2.5	3.1	3.1	3.2	2.8	3.3
100% DA Recommendation	2.8	2.8	2.6	2.5	2.9	3.0	3.1	2.4	3.2
150% DA recommendation	2.8	2.6	2.5	2.2	2.6	2.7	2.8	2.3	3.1
Commercial Organic Fertilizer	2.9	2.7	2.6	2.3	2.6	2.8	2.7	2.3	2.8
Job's Practice (control)	3.2	2.9	2.8	2.6	2.9	3.0	3.1	2.6	3.3
PHOSPRO (B)									
With	2.9	2.7	2.4[b]	2.3	2.8	3.0	3.0	2.6	3.0
Without	2.8	2.6	2.8[a]	2.6	2.9	3.0	2.9	2.4	3.2
FRUIT REG (C)									
Regulated	2.8	2.6	2.5	2.3[b]	2.7[b]	2.8[b]	2.8	2.5	3.1
Unregulated	2.3	2.7	2.7	2.5[a]	3.0[a]	3.1[a]	3.1	2.5	3.1
Fertilizer:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns
Phospro:Fruit Regulation	ns	*	ns	ns	ns	ns	ns	ns	ns
Fertilizer:Phospro:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns
A	10.8	25.7	12.6	12.3	16.7	13.2	11.3	11.4	18.3
CV % B	7.6	19.4	9.0	9.4	9.5	8.7	9.0	9.0	30.8
C	9.0	11.4	6.2	7.4	8.6	8.2	8.5	10.4	21.8

[a] means with the same letter in a column are not significantly different at 5% level of significant

Table A6-4. Means of Severity ratings in the 2nd rating as affected by interaction between fertilizer application and phosphonate

FERTILIZER APPLICATION	With Phospro	Without Phospro
50% DA Recommendation	2.2 [b]	2.6 [a]
100% DA Recommendation	2.6 [ab]	3.0 [a]
150% DA recommendation	2.5 [ab]	2.4 [a]
Commercial Organic Fertilizer	2.6 [ab]	2.7 [a]
Job's Practice (control)	3.3 [a A]	2.6 [a B]

[a] means with the same letter in a column are not significantly different at 5% level of significant
[A] means with the same letter in a row are not significantly different at 5% level of significant

Table A6-5. Means of Canker ratings from the 1st to the 9th rating.

TREATMENT	1	2	3	4	5	6	7	8	9
FERTILIZER (A)									
50% DA Recommendation	2.5	2.8	2.9	2.8	3.2	3.3	3.2	3.0	3.2[a]
100% DA Recommendation	2.8	3.0	2.9	3.1	3.1	3.2	3.2	2.7	3.1[a]
150% DA recommendation	2.5	2.7	2.6	2.5	2.7	2.6	2.7	2.5	2.5[b]
Commercial Organic Fertilizer	2.8	2.7	2.7	2.7	2.8	2.8	2.8	2.5	2.5[b]
Job's Practice (control)	3.1	2.9	3.1	3.1	3.0	3.3	3.2	3.0	3.2[a]
PHOSPRO (B)									
With	2.8	2.8	2.6[b]	2.8	2.9	3.1	3.1	2.7	2.9
Without	2.8	2.8	3.0[a]	2.9	3.0	3.0	3.0	2.7	2.9
FRUIT REG (C)									
Regulated	2.7	2.3[b]	2.7[b]	2.7	2.8[b]	2.9[b]	2.8[b]	2.6	2.9
Unregulated	2.8	3.0[a]	2.9[a]	3.0	3.1[a]	3.2[a]	3.2[a]	2.8	2.9
Fertilizer:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns
Phospro:Fruit Regulation	*	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer:Phospro:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns
A	13.7	16.6	14.5	15.5	16.8	13.1	15.1	17.6	19.8
CV % B	9.0	11.7	10.6	7.6	10.0	10.7	11.1	8.1	17.0
C	7.9	9.3	6.9	8.6	10.1	9.6	8.4	12.1	15.5

[a] means with the same letter in a column are not significantly different at 5% level of significant

Table A6-6. Means of Canker rating in the 1st rating is affected by interaction between fruit regulation and Phospro

FRUIT REGULATION	With Phospro	Without Phospro
Regulated	2.8 [a]	2.5 [b]
Unregulated	2.7 [a]	3.0 [a]

[a] means with the same letter in a column are not significantly different at 5% level of significant

Table A6-7. Mean Female Flower count of Jackfruit Trees as affected by fertilization, PhosPro and fruit load regulation.

TREATMENTS		2015	2016	2017	2018	TOTAL
FERTILIZER (A)						
	50% DA Recommendation	2.6	14.9	18.4	8.4	44.4
	100% DA Recommendation	2.4	17.9	21.5	7.7	49.6
	150% DA recommendation	4.4	18.6	30.3	8.7	62.0
	Commercial Organic Fertilizer	5.1	21.6	29.6	11.6	67.9
	Job's Practice (control)	3.8	13.8	16.8	6.5	40.9
PHOSPRO (B)						
	With	2.5[b]	15.4	18.0[b]	6.2[b]	42.0[b]
	Without	4.9[a]	19.4	28.7[a]	10.9[a]	63.9[a]
FRUIT REGULATION (C)						
	Regulated	3.2	18.4	23.8	8.9	54.3
	Unregulated	4.2	16.3	22.9	8.3	51.6
Fertilizer:Fruit Regulation		*	ns	ns	ns	ns
Phospro:Fruit Regulation		ns	ns	*	ns	ns
Fertilizer:Phospro:Fruit Regulation		ns	ns	ns	ns	ns
	A	42.2	34.4	37.7	40.2	33.0
CV %	B	63.1	29.4	44.3	45.0	32.0
	C	52.7	24.9	29.1	45.5	26.3

[a] means with the same letter in a column are not significantly different at 5% level of significant

Table A6-8. Mean Female Flower count of Jackfruit Trees for 2015 as affected by interaction between fertilizer and fruit regulation.

FERTILIZER APPLICATION	REGULATED	UNREGULATED
50% DA Recommendation	3.3 [a]	2.0 [c]
100% DA Recommendation	2.6 [a]	2.3 [bc]
150% DA recommendation	2.5 [a]	6.4 [ab]
Commercial Organic Fertilizer	2.1 [a B]	8.1 [a A]
Job's Practice (control)	5.6 [a]	2.0 [c]

[a] means with the same letter in a column are not significantly different at 5% level of significant
[A] means with the same letter in a row are not significantly different at 5% level of significant

Table A6-9. Mean Female Flower count of Jackfruit Trees for 2017 as affected by interaction between phosphonate and fruit regulation.

PHOSPRO	REGULATED	UNREGULATED
With	21.2 [a]	14.8 [b]
Without	26.4 [a]	30.9 [a]

[a] means with the same letter in a column are not significantly different at 5% level of significant

Table A6-10. Mean Yield data of Jackfruit trees from February 2015 to March 2018.

TREATMENTS	2015		2016		2017		2018		TOTAL	
	Fruit count	Fruit wt. (kg)	Fruit count	Fruit wt. (kg)	Fruit count	Fruit wt. (kg)	Fruit count	Fruit wt. (kg)	Fruit count	Fruit wt. (kg)
FERTILIZER (A)										
50% DA RR	5.9[a]	45.8[a]	6.8	65.0[b]	4.3	36.3	2.1	18.6	19.1	165.6
100% DA RR	5.2[a]	50.1[a]	6.1	64.9[b]	6.2	60.6	1.9	19.4	19.4	195.1
150% DA RR	5.9[a]	55.5[a]	9.4	92.3[a b]	7.0	65.7	2.4	24.8	24.8	238.3
Commercial Organic Fertilizer	5.4[a]	44.9[a]	10.6	110.1[a]	7.7	73.3	2.4	25.8	26.1	254.1
Job's Practice (control)	0.7[b]	5.7[b]	6.3	60.3[b]	5.6	52.6	1.4	14.6	14.1	133.1
PHOSPRO (B)										
With	4.1	36.4	6.6[b]	67.5	4.8	45.2	2.0	19.2	17.5	168.2
Without	5.2	44.4	9.1[a]	89.6	7.5	70.2	2.1	22.2	23.9	226.3
FRUIT REGULATION (C)										
Regulated	4.7	44.7	8.1	80.3	6.9	64.4	2.1	19.5	21.7	208.9
Unregulated	4.6	36.1	7.6	76.7	5.4	60.0	2.0	21.8	19.7	185.6
Fertilizer:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Phospro:Fruit Regulation	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Fertilizer:Phospro:Fruit Regulation	ns	ns	*	*	ns	ns	ns	ns	ns	ns
CV % A	45.7	50.1	31.3	35.1	42.9	49.9	46.4	67.1	37.6	38.6
CV % B	48.3	53.3	36.4	41.8	48.6	54.1	53.2	80.0	42.4	43.3
CV % C	31.8	44.6	27.1	31.9	31.0	37.0	47.6	74.0	25.4	29.4

[a] *means with the same letter in a column are not significantly different at 5% level of significant*

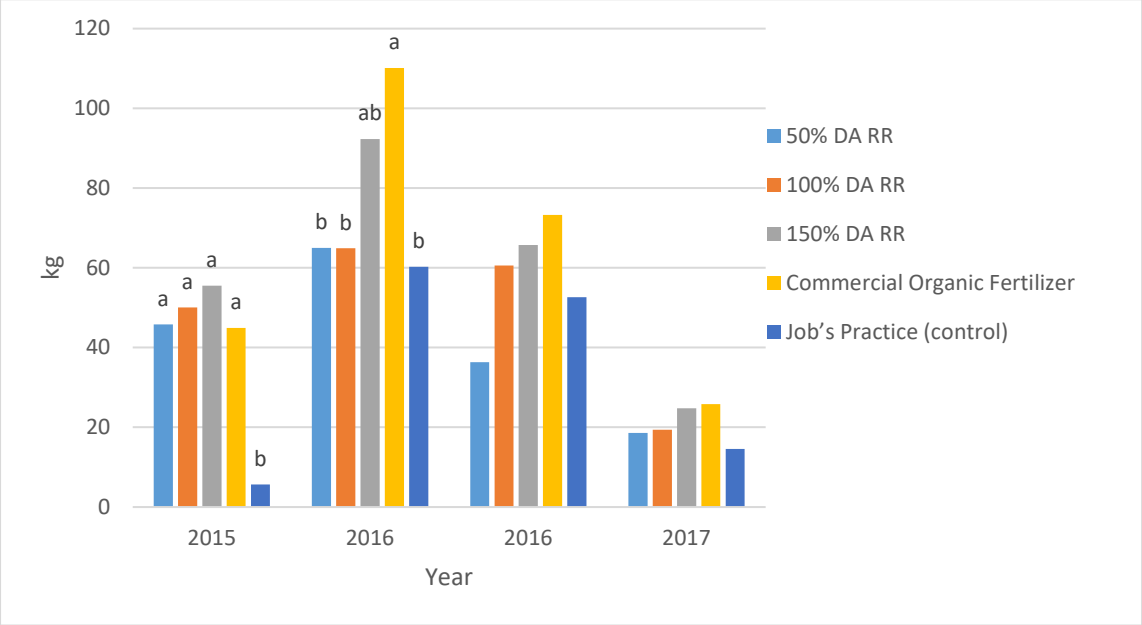


Figure A6-1. Yield of jackfruit (kg) as affected by different fertilizer levels.

Table A6-11. Mean number of fruits in 2016 as affected by interaction between fertilizer, phosphonate and fruit load regulation.

FERTILIZER	W/ PHOSPRO	W/O PHOSPRO
Regulated		
50% DA Recommendation	6.5	9.0
100% DA Recommendation	7.0	6.3
150% DA recommendation	8.5	7.8
Commercial Organic Fertilizer	9.8	10.0 B
Job's Practice (control)	4.8	11.0
Unregulated		
50% DA Recommendation	6.5	5.3 b
100% DA Recommendation	5.0	6.3 b
150% DA recommendation	11.0	10.3 ab
Commercial Organic Fertilizer	4.5 B	18.0 a A A
Job's Practice (control)	2.3	7.3 b

a means with the same letter in a column are not significantly different at 5% level of significant
A means with the same letter in a row are not significantly different at 5% level of significant

Table A6-12. Mean Yield data on 2016 fruit weight as affected by interaction between fertilizer, phosphonate and fruit load regulation.

FERTILIZER	W/ PHOSPRO	W/O PHOSPRO
Regulated		
50% DA Recommendation	59.6	84.4
100% DA Recommendation	80.1	60.4
150% DA recommendation	94.1	77.6
Commercial Organic Fertilizer	94.3	90.5 B
Job's Practice (control)	55.6	106.4
Unregulated		
50% DA Recommendation	62.5	53.5 b
100% DA Recommendation	57.9	61.3 b
150% DA recommendation	101.5	96.0 b
Commercial Organic Fertilizer	49.0 B	206.8 a A A
Job's Practice (control)	20.0	59.0 b

a means with the same letter in a column are not significantly different at 5% level of significant
A means with the same letter in a row are not significantly different at 5% level of significant

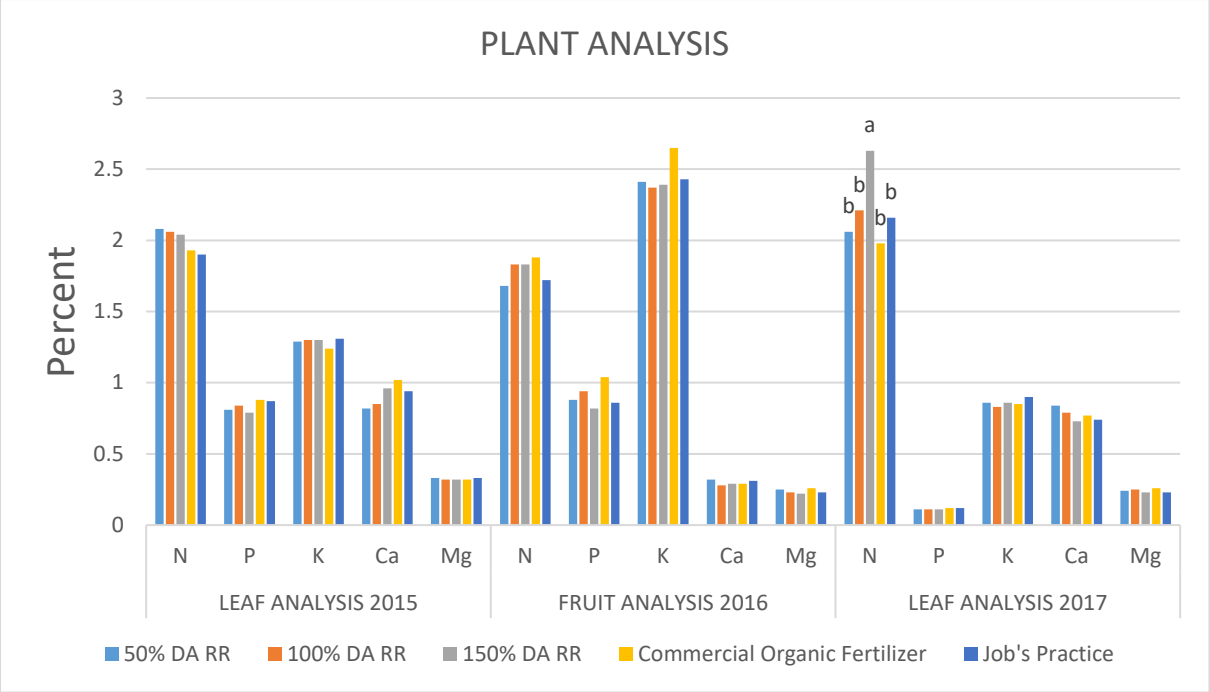


Figure A6-2. Nutrient analysis on Leaf and Fruit of Jackfruit Trees in Mahaplag, Leyte as affected by different fertilizer treatments

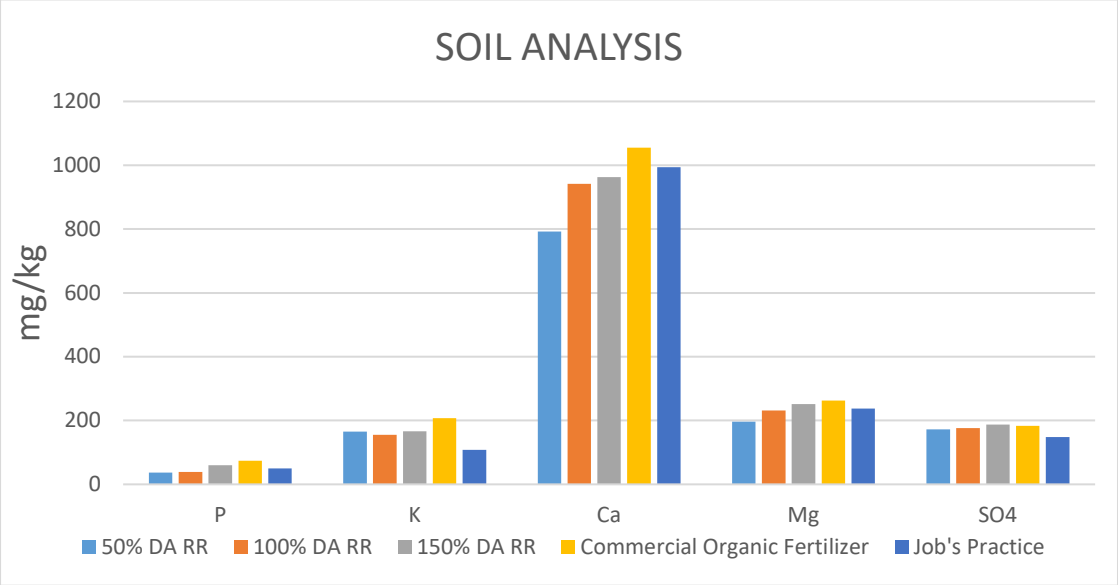


Figure A6-3. Soil analysis of Jackfruit Trees in Mahaplag, Leyte as affected by different fertilizer treatments.

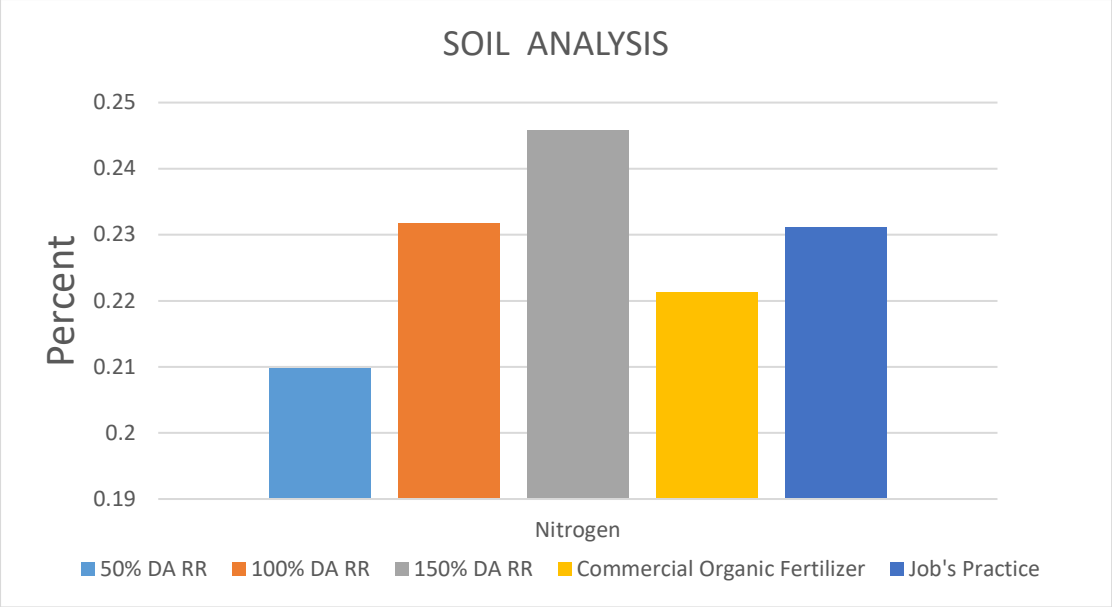


Figure A6-4. Soil analysis of Jackfruit Trees in Mahaplag, Leyte as affected by different fertilizer treatments

Table A6-13. Ratings on canopy appearance, canker lesions, and disease severity per tree as affected by the application of different rates of organic and inorganic fertilizer with and without phosphonate on jackfruit at AES, Abuyog, Leyte (Sept. 2016- March 2018)

Treatment	Canopy appearance rating		Canker lesion rating		Disease severity rating	
Phosphonate Application (A)	Before	After	Before	After	Before	After
With Phosphonate	3.4	2.5 b	3.4	2.5	3.3	2.1
Without Phosphonate	3.9	3.4 a	3.2	2.8	3.3	2.9
Fertilizer Application (B)						
T0-Control	3.7	3.7 a	3.3	3.2 a	3.5	3.0 a
T1-Rec. Rate (RR)	3.7	2.5 bc	3.4	2.7 b	3.5	2.5 b
T2-50% below RR	3.7	3.4 a	3.5	2.9 ab	3.4	2.5 b
T3-50% above RR	3.7	2.8 b	3.2	2.2 c	3.0	2.4 b
T4-Organic Fertilizer (OF) alone	3.7	2.3 c	3.2	2.5 bc	3.2	2.4 b
CV a (%)	21.7	16.5	9.6	6.9	5.5	21.6
CV b (%)	7.0	13.2	12.4	13.7	15.4	13.0

Means with the same letter are not significantly different at 5% level of significance (Least Significant Difference (LSD) Test)

Legend:

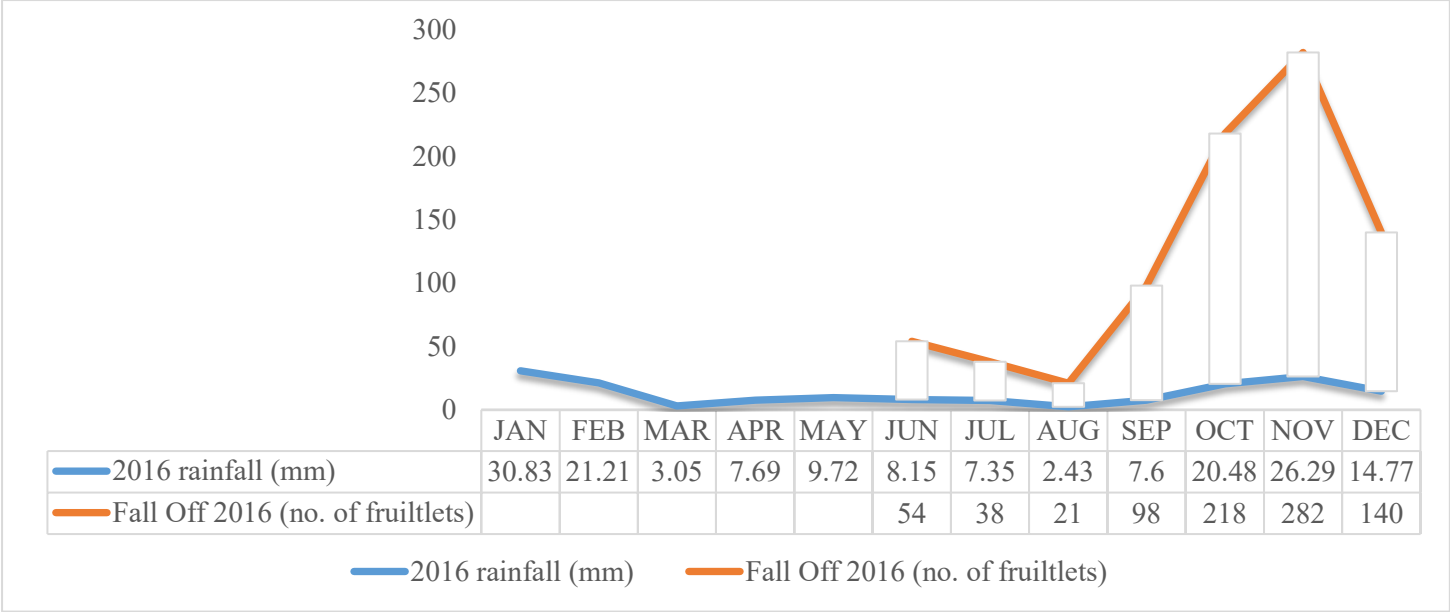
T0-Control (no application of fertilizers)

T1-Rec. Rate (RR) (30 kg OF + 800 g T-14 + 800 g MOP/tree)

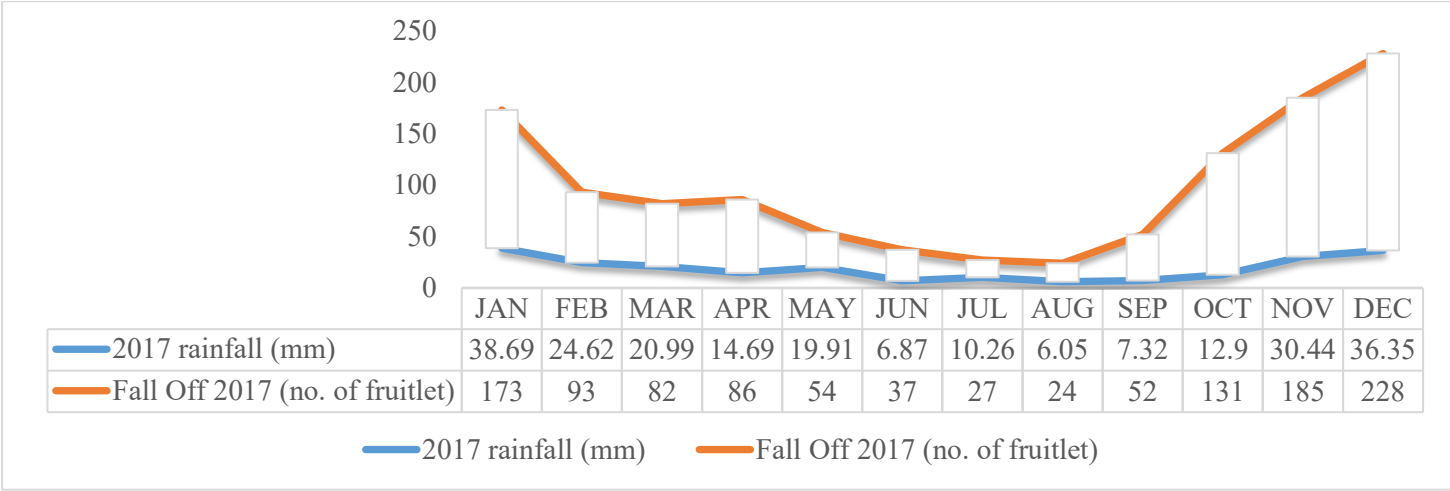
T2-50% below RR (15 kg OF + 400 g T-14 + 400 g MOP/tree)

T3-50% above RR (45 kg OF + 1,200 g T-14 + 1,200 g MOP/tree)

T4-Organic Fertilizer (OF) alone (30 kg/tree)



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2016 rainfall (mm)	30.83	21.21	3.05	7.69	9.72	8.15	7.35	2.43	7.6	20.48	26.29	14.77
Fall Off 2016 (no. of fruiltlets)						54	38	21	98	218	282	140



	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
2017 rainfall (mm)	38.69	24.62	20.99	14.69	19.91	6.87	10.26	6.05	7.32	12.9	30.44	36.35
Fall Off 2017 (no. of fruitlet)	173	93	82	86	54	37	27	24	52	131	185	228

Figure A6-5. Rainfall and fall off (fruitlet) data of Abuyog Experiment Station from Jan. to Dec. 2016-2017.

Table A6-14. Average no. of fruit, average weight of fruit, average total weight of fruit and damaged incidence of fruit per tree as affected by the application of different rates of organic and inorganic fertilizer with and without phosphonate on jackfruit at AES, Abuyog, Leyte (Sept. 2016- March 2018).

Treatment	Average no. of fruit/tree	Average weight of fruit/tree (kg)	Average total weight of fruit/tree (kg)	Damaged Incidence fruit/tree
Phosphonate Application (A)				
With Phosphonate	11.4	10.2	121.2	2.5
Without Phosphonate	10.8	9.9	113.8	3.0
Fertilizer Application (B)				
T0-Control	9.7 b	8.7 b	89.7 c	3.0a
T1-Rec. Rate (RR)	11.2 ab	10.0 ab	116.9 b	2.7b
T2-50% below RR	9.7 b	10.3 a	102.5 bc	3.0a
T3-50% above RR	13.9 a	11.4 a	164.0 a	2.7b
T4-Organic Fertilizer (OF) alone	11.2 ab	10.2 ab	114.5 b	2.5b
CV a (%)	11.8	11.0	5.9	20.0
CV b (%)	21.2	14.0	12.7	9.5

Means with the same letter are not significantly different at 5% level of significance (Least Significant Difference (LSD) Test

Legend:

T0-Control (no application of fertilizers)

T1-Rec. Rate (RR) (30 kg OF + 800 g T-14 + 800 g MOP/tree)

T2-50% below RR (15 kg OF + 400 g T-14 + 400 g MOP/tree)

T3-50% above RR (45 kg OF + 1,200 g T-14 +1,200 g MOP/tree)

T4-Organic Fertilizer (OF) alone (30 kg/tree)

Table A6-15. Cost and Return (Php) of 30 trees jackfruit (Sept. 2016- March 2018)

Parameters	with phosphonate	without phosphonate	T0 (control)	T1 Rec. Rate (RR)	T2 50% below RR	T3 50% above RR	T4 Organic Fertilizer alone
Return:							
Sales of fruits (marketable fruits)	119,120.0	111,375.0	33,515.0	44,205.0	43,395.0	63,615.0	45,765.0
Cost:							
Materials							
Sharkskin	11,912.0	11,137.5	3,351.5	4,420.5	4,339.5	6,361.5	4,576.5
Phosphonate	3,000.00	-	-	-	-	-	-
Complete	-	-	-	230.4	115.0	345.6	-
MOP	-	-	-	192.0	96.0	288.0	-
Organic Fertilizer (wellgrow)	-	-	-	5,760.0	2,880.0	8,640.0	5,760.0
Labour							
Spraying of M.a SPW isolate	7,200.0	7,200.0	7,200.0	7,200.0	7,200.0	7,200.0	7,200.0
Under brushing	1,200.0	1,200.0	1,200.0	1,200.0	1,200.0	1,200.0	1,200.0
Ring weeding	2,400.0	2,400.0	2,400.0	2,400.0	2,400.0	2,400.0	2,400.0
Wrapping, harvesting & hauling	14,400.0	14,400.0	14,400.0	14,400.0	14,400.0	14,400.0	14,400.0
application of fertilizer	-	-		600.0	600.0	600.0	600.0
application of phosphonate	600.0	-	-	-	-	-	-
Total Cost	**40,712.0**	**36,337.5**	**28,551.5**	**36,402.9**	**33,230.5**	**41,435.1**	**36,136.5**
Net Income	**78,408.0**	**75,037.5**	**4,963.5**	**7,802.1**	**10,164.5**	**22,179.9**	**9,628.5**

**Farm Gate Price Php50.00/ kg.*

Legend:

T0-Control (no application of fertilizers)

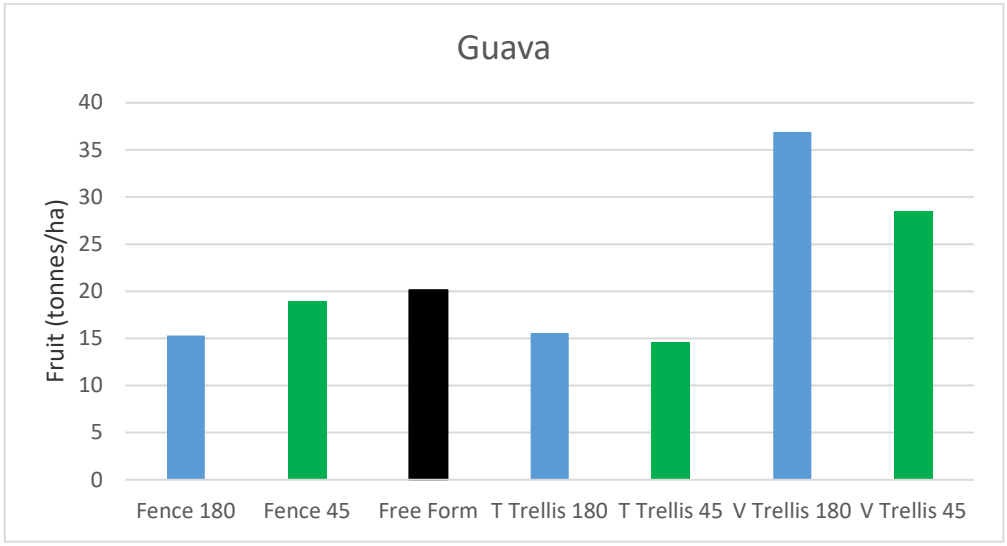
T1-Rec. Rate (RR) (30 kg OF + 800 g T-14+800 g MOP/tree)

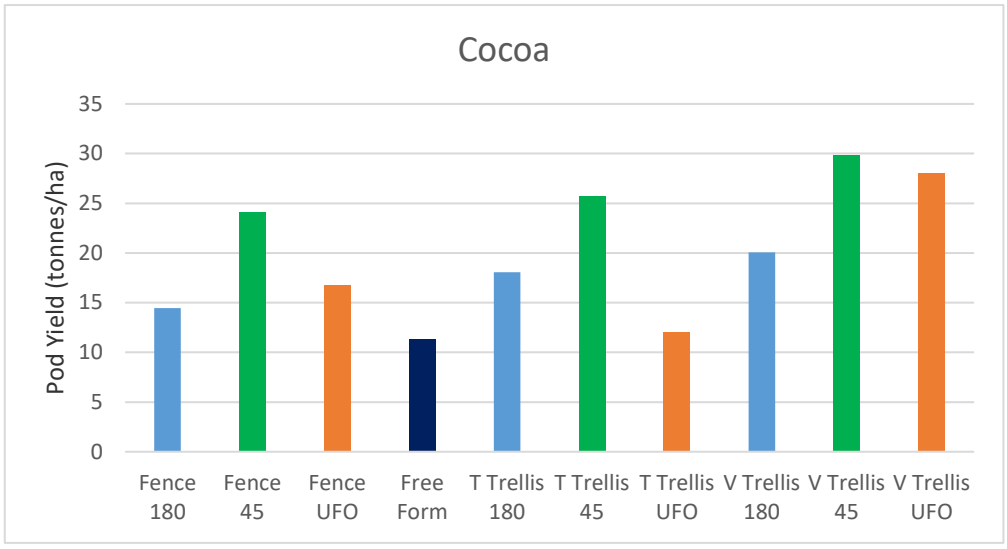
T2-50% below RR (15 kg OF + 400 g T-14+400 g MOP/tree)

T3-50% above RR (45 kg OF + 1,200 g T-14+1,200 g MOP/tree)

T4-Organic Fertilizer (OF) alone (30 kg/tree)

Appendix 7. Objective 2d





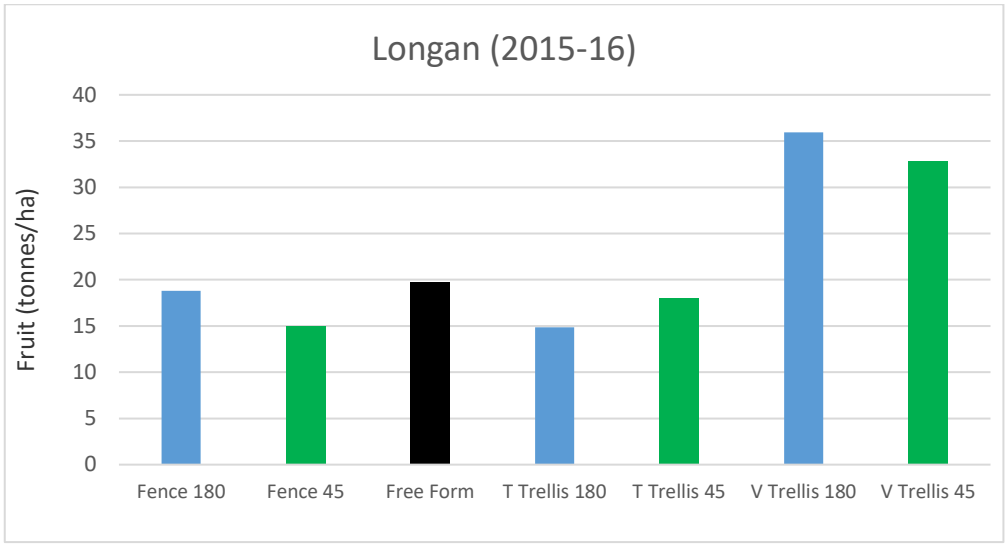


Figure A7-1. Mean yield over three season (2015-2018).

Durian demonstration trial site East Feluga – Neil Wiltshire

Between the months of March and April 2013, grafted durian trees were planted into an Open Tatura trellis row at Peter and Allison Sallera's farm at East Feluga. Trees were planted on each side of the trellis structure and planted 2.85 m apart along the row. As the planting configuration is a double row, trees on one side are staggered planting to the centre gap of trees on the other side of the trellis. Trees consisted of P88, Gumpun, Ganyaw, Kradom Tong, Red Prawn and an unnamed variety. The planting density of the trial was 1559 trees/Ha. All lateral branches on the trees were trained horizontally on the wires. Secondary branches were allowed to grow off the primary lateral branches and pruned approximately 50 cm out from the wire.

Durian secondary branch emergence is quite prolific and >60% of secondary branches were removed at a young age to allow adequate light distribution throughout the tree. To demonstrate the importance of maintaining adequate canopy area while attempting to have trees grow into their allocated area on the trellis, a demonstration pruning technique was applied on some durian trees. As a part of that pruning strategy, secondary branches were pruned at three different percentages to observe the effect of primary branch development. Trees were grouped into Treatment 1 (all 2nd branches removed), Treatment 2 (50% 2nd branches removed) and Treatment 3 (<25% 2nd branches removed). As the primary branch continued to grow, 30-50 cm from the new apical growth was pruned according to allocated treatment. Older wood, more than 30-50 cm from apical growth was allowed to develop secondary branches with every 2 out of 3 branches removed to maintain light distribution.

In 2015 primary branch growth rates were compared to the total lineal meterage of secondary branches.

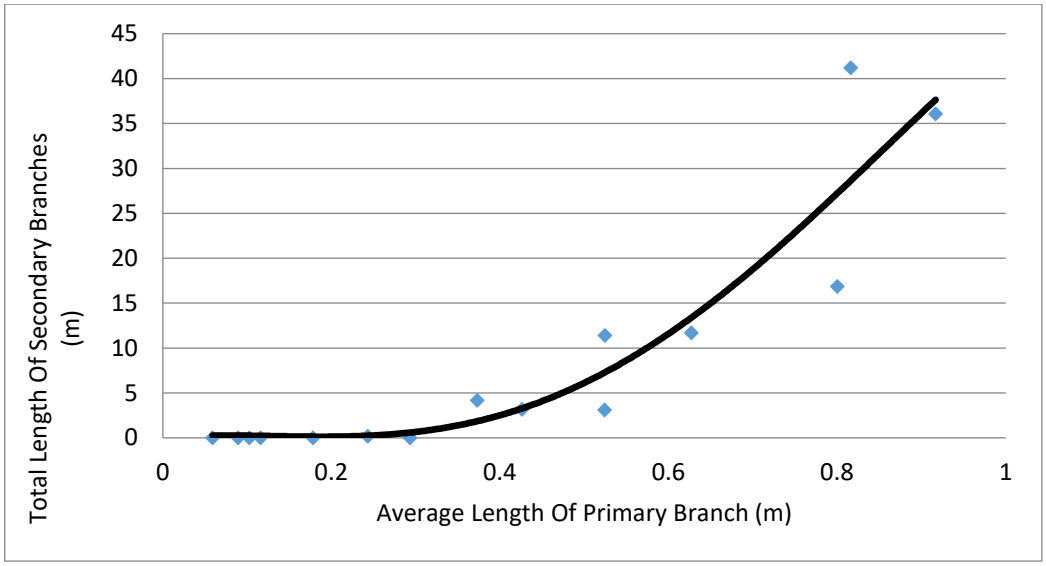


Figure A7-2. Primary Branch Lengths Compared to Secondary Branch Totals

The data suggests that removing too many secondary branches may reduce the growth of the primary branch on the trellis wire. It has also been report by Salakpetch (2005), that productive branches should have a diameter between 4 to 10 cm and in a position that they can receive a photosynthetic photon flux density (PPFD) more than 90 µmol m^{-2} s^{-1}. During the trial period, lower limbs on some trees did suffer from dieback and appeared to coincide with periods of excess canopy surface area on branches higher in the canopy structure. Data also indicates that primary branch diameter was also higher in Treatment 2 & 3 where more secondary branches were left.

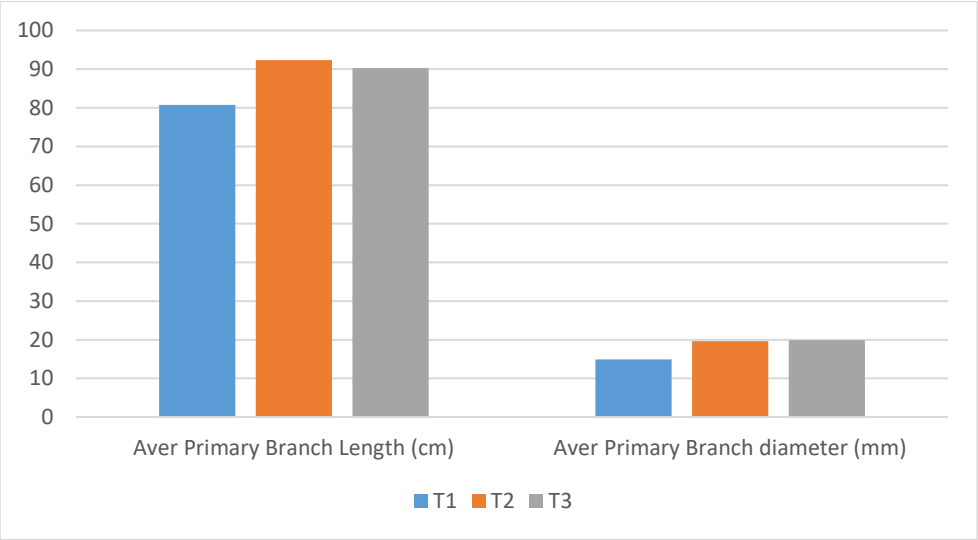


Figure A7-3. Durian agronomic data of trees with different secondary pruning treatments measured in 2015

In August 2017, further agronomic data was measured on the durian trial which continued to suggest that Treatment 2 & 3 were producing more growth in trees.

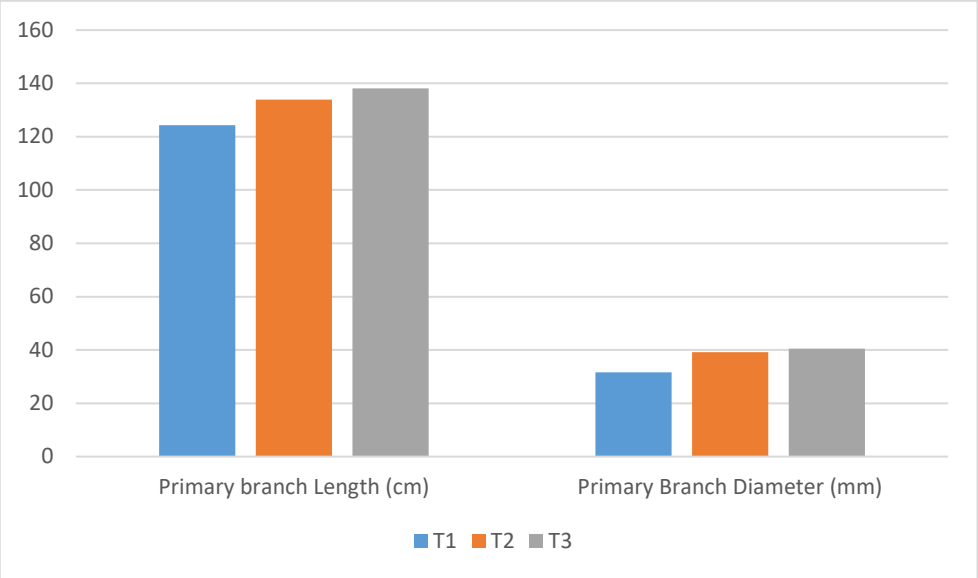


Figure A7-4. Durian agronomic data of trees with different secondary pruning treatments measured in 2017

Early observations of those trees where most secondary branches were removed (T1), the incidence of new bud emergence was quite slow or, in some incidences no new buds emerged and the wood appeared bare or blind of buds.

Overall, this work highlighted the need to understand the importance of knowing how your trellised tree responds to pruning early in life. It would appear that as long as light distribution is not significantly affected, the more leaf area combined with the right canopy structure will results in productive growth of the tree.

Figure A7-5. Trellised Durian Tree

From what was observed from the growth of those durian trees, plagiotropic crops are suitable for trellising due to their ability to grow horizontally along the wires of a trellis system. The growth habit tends to be more outward then upward compared to orthotropic crops.

The training of plagiotropic crops on trellis structures should take into consideration a range of issues that is unique to plagiotropic wood. When selecting lateral branches to train onto the wires it is important that bending or wrapping branches onto wires is avoided. As the leaf arrangement of plagiotropic wood is generally opposite each other, the plane or orientation of the leaf nodes can be shifted such that new leaf growth will be more vertical than horizontal. The result is that new branches on the top side of wood will have more vigour and growth of branches on the downward side is reduced. By keeping branches more horizontally, new growth from those branches will grow more evenly and the structuring of fruiting branches that grow 90 degrees out from the wire will create better light distribution throughout the canopy.

Care should be taken in how you structure secondary branches on a lateral primary branch. To maximise light distribution throughout the tree, consideration should be given to the position of all branches throughout the canopy. Distance between branches will change depending on the size and orientation of leaves. Trees with larger leaves that are more upright, will require wider distances between branches. Trees with smaller leaves that are more downward facing may have closer branches.

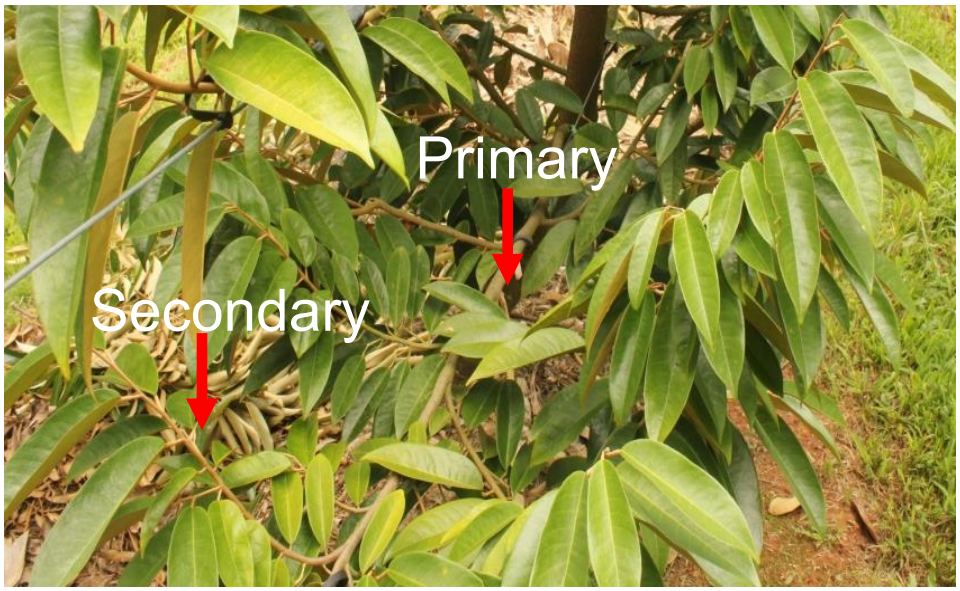


Figure A7-6. Primary and secondary branch structure in durians.

The position of fruit and size of fruit will also determine the structure of branches throughout a trellised tree. Some durian trees have quite larger fruit +3 kg, and produce tight clusters of flowers that emerge directly from the main trunk or woody branches (cauliflorous).To reduce damage to fruit rubbing against each other, branch positioning would be wider. Soursop, produce most flowers from leaf axils on younger branches and fruit is generally smaller. Therefore the spacing of soursop branches could be closer than durian.

Figure A7-7. Durian flowering.

However, due to soursop flowering on current season wood, the pruning of branches each year would vary to durian. The length of secondary branches or fruiting branches of soursop could be pruned back closer to the primary branch. This would also allow better light distribution throughout the tree.

In August 2016, the trees appeared mature enough to bear flowers and we decided to test whether we could induce flowering on trees that had been planted in the ground for 42 months. Salakpetch (2005), reported that a dry period which should occur continuously for 7-14 days would assist with triggering the flowering process. Weather conditions in North Queensland are quite unpredictable and the ability to control the soil drying process is limited. As the durian trees were already supported by the Open Tatura trellis structure it

was decided to modify the structure to include a rain out cover system that could be used to dry out the soil and that could roll back into place to expose trees to natural weather conditions after flowering and fruit set. Solarfilm plastic was used to cover the trees using 1 inch irrigation pipe to support the covers along the row.

Figure A7-8. Construction of rain out covers.

While the rain out covers were in place soil moistures were monitored and trees were assessed for the emergence of flowering buds. In early October, flowering buds appeared and the irrigation was turned back on. The rain out covers were not removed until late November so that rain would not impact pollination. Hand pollination of flowers in anthesis was carried out in the early evenings to maximise the fruit set success rates. In 2017 the use of the rain out covers were used again over the similar 2016 timeframe. Both years, fruit were harvested during the following months of March and April.

Table A7-1. Fruit yield information from durian

	2016/17	2017/18
Fruiting Trees	9	23
Fruit Counts	37	61
Total fruit weights (kg)	52.6	114.3
Average fruit weight (kg)	1.42	1.87
Average t/ha of fruiting trees	9.11	7.75

The durian trees are still quite young and one would expect that 2018/19 yields will continue to increase. The majority of fruit was harvested from P88 and Kradom Tong varieties. The Red Prawn variety may require a longer stressing event than other varieties. Gumpun had produced some fruit in 2017/18 but fruit were still immature. Both Ganyaw trees died and therefore no fruit were assessed.

Overall, the management of the durian trees mainly consisted of three main pruning periods. In the first three years of the trial trees were pruned in January-February, May-June and October-November. Once the trees were covered with the rainout covers, pruning of trees that flowered and produced fruit was scaled back. A heavier prune was carried out after fruiting May-June and a lighter prune in August. A small prune was also done normally after fruit set to increase light interception but this was not done in 2018.

Figure A7-9. Growth of Kradom Tong durian tree on trellis.

The demonstration trial block at East Feluga has shown that durian can be trellised onto an Open Tatura trellis structure which may provide the support and structured canopy to make a durian tree more resilient to cyclones. From this work, it has been determined that there are many issues to trellising a plagiotropic crop on such a trellis structure. Most of the issues relate directly to farmers having a good understanding of how crops grow, flower and fruit, and whether pruning and training methods can build a tree onto a trellis that does not significantly impact growth, health and yield.

1. Plagiotropic trees such as durian and soursop grow well in a horizontal aspect along the wires.
2. Pull branches onto wires starting from the base end and leave tip raised off the wire if possible.
3. Avoid twisting branches around wires or downward on to wires.
4. Leave more secondary branches to grow without causing significant shading below.
5. If you feel pruning is required prune from the central main leader outwards and prune 2 out of 3 branches no further than half way along the branch at a time.
6. As primary branches on the wire reach their allocated area on the wire, tip prune those secondary branches from where you have last pruned at step 5.
7. Know where in the tree your flowers will appear from. Don’t prune off flowering wood before flowering season.
8. All pruning should allow even light throughout the branches and branches should be spaced with flower and fruit size in mind.
9. Avoid fertilising with high nitrogen to limit excessive growth. Use good quality organic mulch.

Positives of trellising plagiotropic crops:

- Trellis wires provide good support while trees are young.
- Wire spacing helps to structure how to build a more even canopy
- Once the tree height has passed the top wire trees less than 3 m heights are less susceptible to stronger wind strength than free standing trees
- Flowering that requires hand pollination is more accessible.

- Wires can support heavier fruit and reduce branch bending that may affect light distribution
- Insecticide/fungicide applications are easier to apply to smaller trees
- Trellis structure a permanent structure that can be used to support insect/bird netting or rain out covers
- Open Tatura trellis structure allows higher planting density systems than other trellis structures.
- Reduced need for ladders or elevated platforms.

Negatives of trellising plagiotropic crops:

- Farmers must have a full understanding of crop they are growing and differences between varieties. Some plagiotropic crops have varieties that have more upright growth habits which requires different management. Must understand the balance between canopy area and light distribution as big canopy with poor light distribution will significantly impact yields for most species.
- Pruning of plagiotropic crops on the inside of the Open Tatura trellis structure requires hand pruning unless expensive mechanical pruning equipment is available.
- Initial expensive outlay to purchase and construct trellis

Appendix 8. Objective 3a

Conducted experiment on Effect of Fruit Location on the Physico-chemical Properties of Jackfruit Pulp. The pH of pulp from fruit located at the middle and lower part of the tree were significantly higher than the pH of the pulp from the fruit located at the top portion of the tree.

Table A8-1. Physico-chemical properties of jackfruit pulps as influenced by fruit location

Fruit Location	pH**	TSS (°B)**	TTA (%)	Thickness (mm)*
Top	4.22b	24.41b	0.68	3.52b
Middle	4.47a	24.03c	0.56	5.30a
Bottom	4.45a	26.98a	0.65	3.56b

The Total Soluble Solids (TSS) of the pulp from the fruit located at the lower portion of the tree is significantly higher than the TSS of the pulp of the fruit located at the top and middle portion of the fruit. Pulp from fruit located at the middle portion of the fruit thicker than those located at top and bottom portion of the fruit.

Effect of Pulp Location in Fruit on the Physico- chemical Properties of Jackfruit Pulp. Pulp located at the bottom portion of the fruit is significantly higher than the pH of the pulp from the top and middle portion of the fruit (Table 53). Pulp located at the top portion of the fruit has a higher TSS value than pulp from the middle and bottom portion of the fruit. Pulp located at the upper part of the tree has the highest TTA.

Table A8-2. Physico-chemical properties of jackfruit pulps as influenced by pulp location

Pulp Location	pH**	TSS (°B)**	TTA (%)	Thickness (mm)*
Top	3.97b	31.00a	0.57a	3.12
Middle	4.11b	26.40b	0.44b	3.02
Bottom	4.80a	27.00b	0.26c	3.40

Influence of Nitrogen Gas Levels on the Quality of Vacuum-Fried Jackfruit. Flushing of nitrogen gas into packed vacuum fried jackfruit does not significantly alter the sensory attributes of the product except taste.

Table A8-3. Mean acceptability ratings of vacuum fried jackfruit as influenced by levels of nitrogen after 12 days of storage at 37°C storage temperature.

Treatment	Sensory Attributes						
N gas levels	Colour	Aroma	Texture	Taste*	Crispiness	Off Odour	Gen. Acc.
Control	7.1	7.4	7.4	7.21b	7.7	7.2	7.5
0 N	7.5	7.5	7.6	7.81a	7.6	7.6	7.7
10 MPa	7.3	7.5	7.7	7.69ab	7.9	7.3	7.7
20 MPa	7.1	7.3	7.4	7.44b	7.6	7.7	7.6

Microbial count of nitrogen flushed vacuum fried jackfruit is lower than the control (Table 55). Microbial count of all treatments evaluated was found below the tolerable levels set by the Philippine National Standards which is 10^6.

Acceptability of VSU developed dehydrated and vacuum fried jackfruit pulps in Australian Palate. Results of consumer evaluation for dehydrated jackfruit pulp showed that 88% of the consumer liked the VSU developed product but 91% liked its commercial counterpart. In terms of product appearance, 49% preferred the VSU developed product and 51% preferred the commercial counterpart (Table 56). Sweetness and soft texture were the identified attributes in the commercial product that consumer preferred most.

Development of Sugarless Dehydrated Jackfruit Pulp. Sugarless dehydrated jackfruit was developed with an overall mean general acceptability rating that ranged from 6.6 to 7.4 with an overall mean rating of 6.97 equivalent to “like moderately” of the Hedonic scale.

Table A8-4. Average total plate count of vacuum fried jackfruit as influenced by level of nitrogen gas after 12 days of storage at accelerated storage conditions.

Treatment	Nitrogen Levels (MPA)	Total Plate Count
1	0	246,154 (ESPC)
2	10	161,538 (SPC)
3	20	171,795 (ESPC)

Table A8-5. Consumer responses towards VSU-developed dehydrated jackfruit and its commercial counterpart.

Sample	Consumers Responses (%)		
	Like	Dislike	Preference
VSU Dehydrated	88	12	49
Commercial	91	9	51

Table A8-6. Mean[1] acceptability scores[2] of the sensory attributes of sugarless dehydrated as influenced by the levels of puree to pulp ratio.

Treatment	Puree Ratio	Soaking Time (hr)	Sensory Attributes				
			Colour	Texture	Aroma	Taste	Gen. Acc.
1	1:1/2	8	7.5	7.1	7.5	6.6	6.9
2	1:1/2	16	7.6	6.5	7.5	7.2	6.9
3	1:1/2	24	8.1	6.9	7.6	7.3	7.3
4	1:1	8	7.4	6.9	6.6	6.6	6.7
5	1:1	16	7.7	6.5	6.9	6.9	6.6
6	1:1	24	7.8	7.4	7.5	7.2	7.4
7	1:1 ½	8	7.3	7.1	6.9	6.8	7
8	1:1 ½	16	7.4	6.2	6.9	6.6	6.6
9	1:1 ½	24	7.4	6.9	7.3	7.3	7.3
All runs			7.58	6.83	7.91	6.94	6.97

Appendix 9. Objective 3b

Optimization of firming agent, anti-microbial agent and acidulant for the production of fresh cut jackfruit

Results revealed that 0.004 NaOCl, 0.75 $CaCl_2$ and 1.0 ascorbic acid (% w/v) got the highest mean acceptability rating in all sensory attributes evaluated except aroma.

Effect of deseeding, storage temperature and storage condition on the quality of minimally processed jackfruit pulps

It was observed that treatments which have intact fruit pulps (with seed) had slight change in TSS during the 3-day storage period compared to treatments which are deseeded that shows abrupt decrease in TSS. Ruptured fruit tissue can also increase the surface area of the pulp which is a good medium for microbial growth that may be a cause of fermentation thus sugars are converted into other organic compounds. Another observation noted is that treatments with intact fruit pulps also exhibit increase in their TSS at the early stage of storage. The low temperature helps decrease the rate of respiration thus allowing senescence to take place slowly and makes the fruit pulp sweeter.

Product development

New products such as Garlic-Chili Flavoured Vacuum Green Fried Jackfruit, Jackfruit Sweet Sauce, Jackfruit Gravy and “Langkamote” Ice cream were developed.

Table A9-1. Mean[1] acceptability scores[2] of the sensory attributes of sugarless dehydrated as influenced by the levels of puree to pulp ratio.

Treatment	Puree Ratio	Soaking Time (hr)	Sensory Attributes				
			Colour	Texture	Aroma	Taste	Gen. Acc.
1	1:1/2	8	7.5	7.1	7.5	6.6	6.9
2	1:1/2	16	7.6	6.5	7.5	7.2	6.9
3	1:1/2	24	8.1	6.9	7.6	7.3	7.3
4	1:1	8	7.4	6.9	6.6	6.6	6.7
5	1:1	16	7.7	6.5	6.9	6.9	6.6
6	1:1	24	7.8	7.4	7.5	7.2	7.4
7	1:1 ½	8	7.3	7.1	6.9	6.8	7
8	1:1 ½	16	7.4	6.2	6.9	6.6	6.6
9	1:1 ½	24	7.4	6.9	7.3	7.3	7.3
All runs			7.58	6.83	7.91	6.94	6.97

Table A9-2. Summary of mean acceptability scores for the organoleptic properties of minimally processed jackfruit (EVIARC Sweet) as affected by the different levels of NaOCl, CaCl2 and ascorbic acid

Treatment	A	B	C	Colour	Aroma	Sweetness	Sourness	Texture	Off-taste	Off-odour	General
1	0.0025	0.5	1	7.86	7.07	7.07	7.43	7.36	6.93	7.36	6.86
2	0.0055	0.5	1	7.5	7.43	7.43	7.79	7.43	7.29	7.43	7.71
3	0.0025	1	1	7.57	7.43	7.64	7.71	7.5	7.29	7.79	7.71
4	0.0055	1	1	7.86	7.86	7.57	7.93	7.79	7.57	7.64	8.00
5	0.0025	0.75	0.5	7.5.0	7.79	7.79	7.93	7.79	7.71	8.00	7.71
6	0.0055	0.75	0.5	8.14	8.21	7.5	8.00	7.93	7.86	7.57	7.79
7	0.0025	0.75	1.5	7.57	8.00	7.64	7.5	7.64	7.07	7.93	8.07
8	0.0055	0.75	1.5	7.79	7.64	6.93	7.21	7.79	7.43	7.57	7.43
9	0.004	0.5	0.5	8.07	7.93	7.36	7.93	7.64	7.86	7.93	7.71
10	0.004	1	0.5	7.57	7.57	7	7.86	7.57	7.86	7.71	7.57
11	0.004	0.5	1.5	8.00	7.71	7.36	7.5	7.71	7.5	7.57	7.79
12	0.004	1	1.5	7.79	8.14	7.5	7.71	7.57	7.93	8.07	7.79
13	0.004	0.75	1	7.86	7.36	7.29	7.86	8.14	7.50	8.00	7.71
14	0.004	0.75	1	8.5	7.93	8.21	8.14	8.36	8.36	8.57	8.07
15	0.004	0.75	1	8.14	7.64	7.57	7.93	7.71	8.00	7.57	7.71

N = 14; values in red means lowest; values in green means highest; A-NaOCl; B-$CaCl_2$; C-AA

a

b

Figure A9-1. Vacuum packed fresh-cut jackfruit at (a) chilled and (b) room temperature storage (3 days)

Appendix 10. Preliminary research

Component one: Literature review (2013)

Compiled and written by Dr Dianna Liu (DAF IFT)

In view of the current trend, consumers are demanding wholesome, nutritional, convenient produces that still retain their natural characteristics as much as possible. Minimally processed fruits and vegetables have been acquiring increasing importance in consumer markets due to their great convenience, high nutritional value, excellent sensorial quality and good sanitary security. Minimally processed also termed fresh-cut or lightly processed can be defined as any fresh fruit that has been physically modified from its original form including washing, peeling, slicing and chemical treatments to obtain 100% edible product that is subsequently packed and kept for cold storage.

Consumers generally evaluate a product based on sensory attributes such as colour, aroma and taste, texture and nutritional value. Another important attribute to be considered in fresh-cut products is its safety. Fresh-cut fruits by nature are highly susceptible to both physiological and microbial spoilage. Minimal processing of fresh-cut fruits removes the natural protection of the epidermis and destroys the internal compartmentalization that separates enzymes from substrates that allows the contact between enzymes and substrates making them more susceptible to physiological deterioration. In addition, the release of nutrients from the cut surfaces of the fruit can be used as a medium for microbial growth.

Deterioration of the sensory, microbial and physico-chemical properties of fresh-cut fruits during minimal processing is a prevailing challenge in most developing countries where fresh-cut technology is not fully exhausted and not well practiced. To address these issues, certain techniques like the use of chemical agents that can preserve product quality have been practiced through the years to ensure consumer satisfaction. However, at present, there is no single chemical agent that can prevent microbial contamination while preserving the physico-chemical and sensory properties of fresh-cut fruits.

The fresh-cut fruit industry is a growing sector in the food business both in developing and developed countries. This is mainly attributed to its potential to replace unhealthy snack foods in the market as a healthy source of diet. With the growing popularity of fresh-cut products, scientific studies are being made to assure safety while keeping the highest nutritional properties and best sensory qualities of fresh-cut fruits. Fresh-cut jackfruit offers some advantages such as the ease in serving portions of an otherwise large and difficult to-peel jackfruit, reduction in packaging and transportation costs and minimising quarantine barriers in some importing countries. The supply of fresh-cut jackfruit is an excellent alternative, as the latex present in the fruit making it more difficult to handle and consume. There is an increase in demand for minimally processed jackfruit in Singapore and European markets (Alumbro, 2014). If a method that can preserve the fresh fruit's characteristics and enhance its shelf stability can be developed, fresh-cut jackfruit will boost the fruit's potential both locally and internationally.

Modern technologies for the development of value added products from jackfruit are evaluated by Saxena et al (2013) in India where the popularity of jackfruit is limited to the growing regions only (southern and north-eastern belts of India). Value addition to jackfruit was carried out including minimally processed bulbs. Evaluation of physicochemical parameters during storage and feasibility of the developed products was also carried out. All of the products showed microbiological safety. In the case of minimally processed jackfruit bulbs, the shelf-life was found to be 21 days at 6°C.

The effect of 240 nm UV radiation exposure on microbial reduction of fresh-cut jackfruit was studied (Bizura Hasida, Nur Aida, Zaipun and Hairiyah, 2013). Different time and way of exposure affected the microbial population throughout storage. Five minutes direct UV

exposure effectively reduced total plate count and total coliforms but not total yeast and moulds.

The influence of pre-treatment and different packaging to enhance the postharvest shelf-life of minimally processed jackfruit bulbs under different storage conditions was investigated by Sally et al (2011). Dip pre-treatment with citric acid along with polypropylene (PP) packaging and storage under deep-freeze temperature were found to be effective in restricting physiological losses in weight and ascorbic acid and minimizing deteriorative changes in sensory attributes, pH, titratable acidity and total soluble solids. Citric acid pre-treatment along with polypropylene (PP) of 300 gauge packages were found to be superior to PP and polystyrene (PS) in limiting microbial counts in the samples. There was significant ($p<0.05$) difference in quality between pre-treated and control samples. Based on the sensory attributes and microbiological contamination, the shelf-life of pre-treated samples was 10 to 12 days under refrigeration storage (3-5°C) and 18 to 20 days under deep-freeze storage (-12°C).

Saxena et al. (2011) evaluated fresh-cut jackfruit bulbs for quality changes as effect of an additive pre-treatment followed by chitosan coating. They found controlled atmosphere (CA) conditions, pre-treatment, as well as chitosan coating in synergy with each other, could significantly minimize the loss in total phenolics and ascorbic acid content of the samples to the levels of around 5% and 17%, respectively, during extended storage up to 50 days. Chitosan coating could also restrict the changes in microbial load. The controlled atmosphere condition of 3 kPa O_2 + 6 kPa CO_2 was found to render higher efficacy in retaining quality attributes of the samples.

Ulloa et al. (2010) studied the effect of different dipping solutions on the physicochemical and microbiological quality of fresh-cut jackfruits packed in polypropylene boxes and stored at 6°C. They found the combined effect of 1.5 g/l potassium sorbate, 10 g/l citric acid and 10 g/l ascorbic acid had significantly lower ($P < 0.05$) microbial counts and produced the best physicochemical result.

Another study done by Saxena et al (2009) using CaCl2, ascorbic acid (AA), and sodium benzoate in combination with mild acidified conditions for storage of fresh-cut jackfruits under modified atmosphere. A loss of 7%. 8%, 43%, and 31% was found for total phenolics (TP), total flavonoids (TF), total carotenoids (TC), and AA contents respectively in the pre-treated samples kept under gas mixture flushed polyethylene bags towards the end of 35 days storage at 6°C

Saxena et al (2012) used Response Surface Methodology to model the effects of minimal processing treatments on jackfruit bulbs quality. A second-order polynomial model was proposed. The recommended processing conditions for maximizing firmness, L value and overall acceptability and minimizing juice leakage, and browning index in the samples at the end of 20 days of low temperature storage were found to be 1% $CaCl_2$, 0.02% AA and 30 min of treatment time.

Adiani et al (2014) used SPME-GCMS in combination with chemometrics as a non-destructive method for rapid assessment of microbial quality of minimally processed fruits stored at 4°C and 10°C. Predictive models of the total viable count (TVC) and yeast and mould count (Y&M) prepared by Partial Least Square Regression (PLS-R) using total ion current (TIC) and total mass spectral data as independent variables. All PLS-R models correlating microbial quality with GC spectral data and total mass spectral data demonstrated high regression coefficient ($R> 0.93$). Models generated using TIC performed better in comparison with models prepared with total mass spectral data against test data. Ethanol, ethyl acetate and 3-methyl-1-butanol were identified as major compounds responsible for the observed correlations.

Godoy et al. (2010) evaluated the impact of storage temperature (3°C and 6°C) on minimally processed jackfruits of firm texture. The minimally processed fruits showed significant differences in relation to the control fruits in terms of pH values, total soluble

solids, total titratable acidity and vitamin C, with no difference in humidity. The fresh-cut products exhibited sensory qualities similar to those of the fresh fruit.

Component one: International product review (2017)

Compiled and written by Colin Leung (DAF IFT)

Background

Innova database is an online food and beverage product platform tool made by Innova Market Insights which collects new product information on brands, ingredients, packaging, patents and promotions. Globally this provides a source for new product tracking, trends and innovation. This knowledge and market analysis reports in leading food and beverage companies benefits include:

- Profit market analysis can be forecasted utilising price per kg information in each product category.
- Monitor worldwide product innovation in consumer packaged goods
- Detailed analysis including product description and nutritional data
- Track and monitor new technology, flavour and formulation trends
- Proprietary analysis software to generate data, graph and charts

This jackfruit international product review is a preliminary report focusing on the annual Jackfruit new product launch analysis from January 2011 to December 2016. It will provide information on product development trends and compiles this data into top product categories. Therefore, enabling the exploration of processing options in both Philippines and Australian markets for future research projects.

Methodology

Jackfruit search criteria (Table A10-1) lists the parameters in the Innova database search. Irrespective of the total amount utilised, jackfruit included in the ingredient declaration in any new products will be included in the results. Global geographic analysis covers six major regions – North America, Europe, Asia, Australia/New Zealand, Latin America and Middle East/North Africa (MENA). MENA covers the following countries – Algeria, Egypt, Morocco, Tunisia, Bahrain, Iran, Israel, Kuwait, Pakistan, Qatar, Saudi Arabia, Turkey and United Arab Emirates.

Table A10-1. Innova Search Criteria Fields

Innova Search Criteria Field	Search option
Free text search	Jackfruit
Market Categories	All Food Categories
Countries	All Countries
Positioning	All positions
Flavours	All Flavours
Ingredients	All Ingredients
Date	Jan 2011-Dec 2016

Global top 15 country analysis

Jackfruit product launches in 2011-2016 were categorised by the top 15 countries in the Innova database. It is important to note that the analysis only records products that were initially launched in that country, not those which are imported.

In total, 227 products were recorded globally and the majority of the products were launched in the Asia Pacific region. No products were recorded in the top 15 country for

Middle East/North Africa area. Countries with the highest market share include; China (46 products), Indonesia (51 products), Philippines (35 products) and Vietnam (24 products), with over 68% of the market. North America had fewer products with United States (20 products) and Canada (3 l products). Lastly other countries such as Australia (2 products) and Europe (11 products) were minorities.

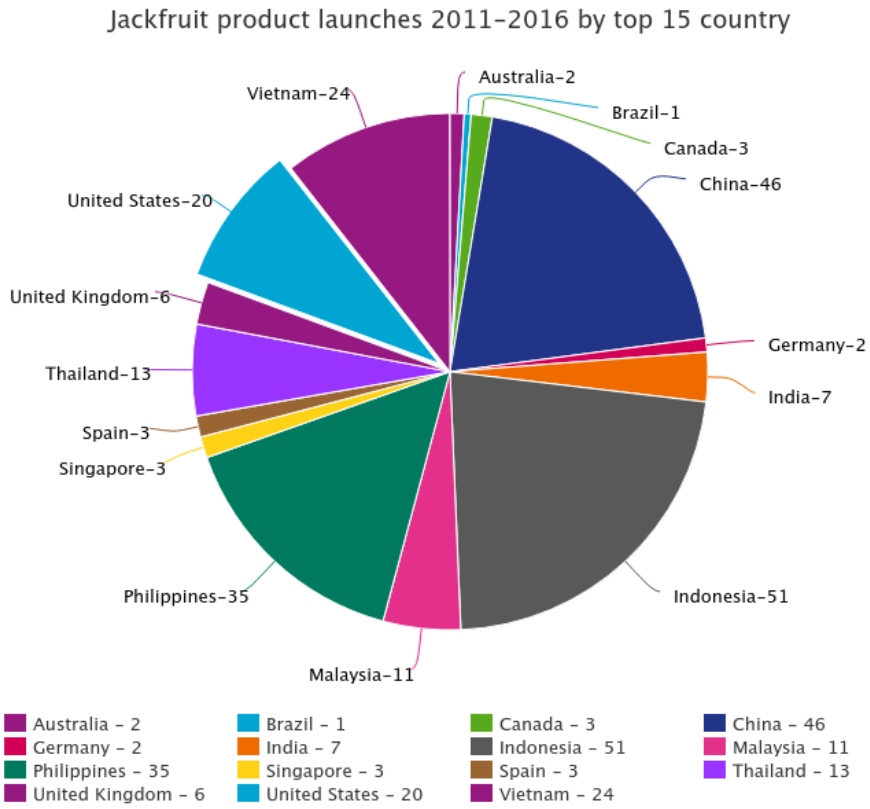


Figure A10-1. Jackfruit Product Pie Chart % by Country

Global annual product launch trend and category analysis

New launched jackfruit products, were globally tracked and searched between the years 2011 and 2016... Data from this search shows a downwards trend of launches from a total of 44 products in 2011 to a total of 31 products to 2015. However from 2016, a high growth can be observed with a record of 56 products launched overall (Figure A10-2).

Main product categories found in the analysis were:

- Snacks
- Fruits and vegetables
- Desserts and ice-cream
- Confectionary
- Bakery
- Soft drinks
- Meat, fish and eggs

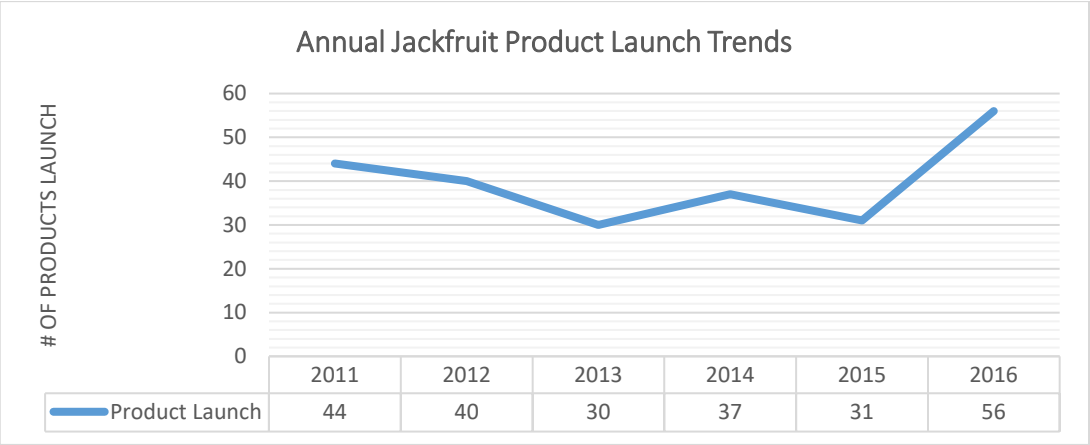


Figure A10-2. Annual Jackfruit Product Launch Trends 2011 to 2016

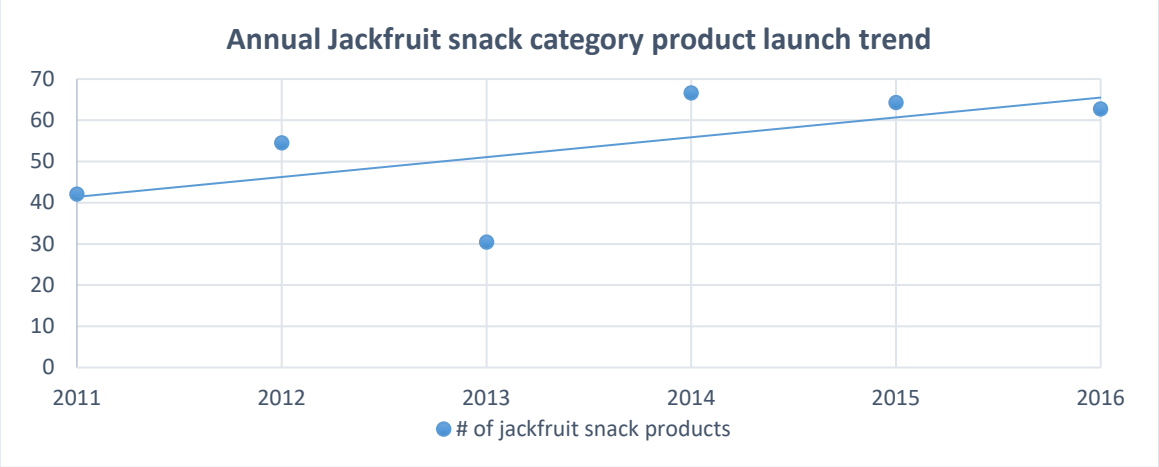


Figure A10-3. Annual Jackfruit Snack Category Product Launch Graph 2011-2016

In the snack category product launch five year comparison analysis (Figure A10-3) shows an increase of the snack proportion from 42% to 63% with a similar trend for confectionary products (Although total launch trend in 2016 were lower than 2014). Throughout the analysis (Figures A10-4, A10-5), snacks have remained as the dominate category averaging over 50% share of products launched from 2011 to 2016. However a decrease is observed in all other categories of; desserts and ice-cream, bakery and fruit and vegetable.

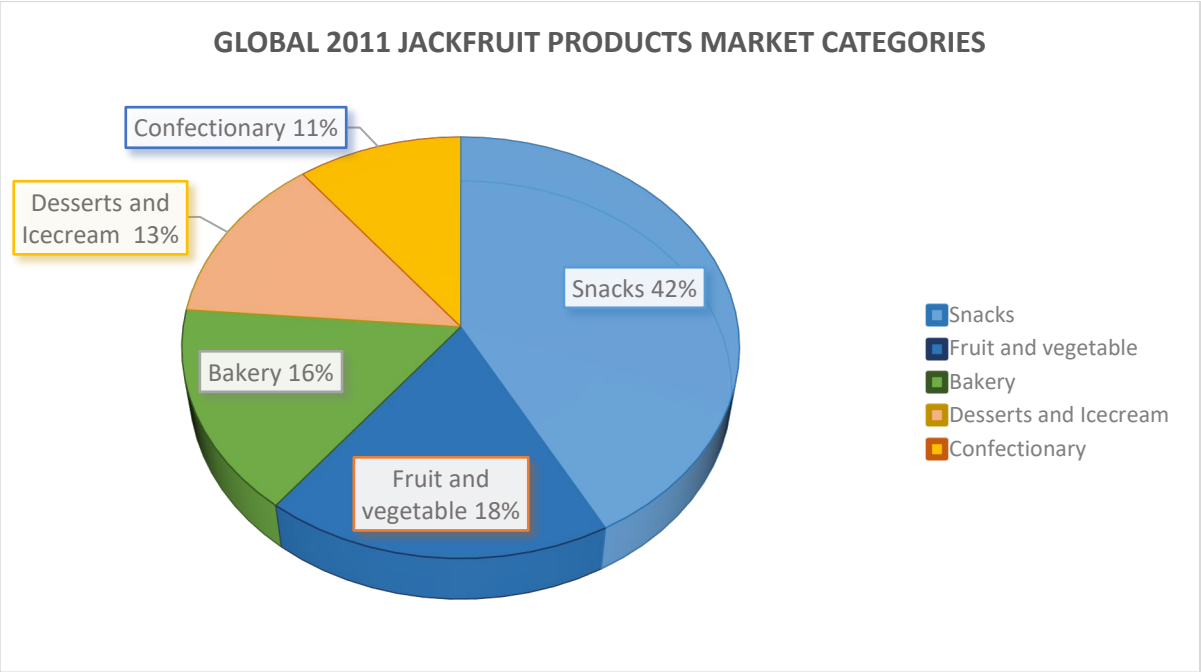


Figure A10-4. Jackfruit Product Category Pie Chart (2011)

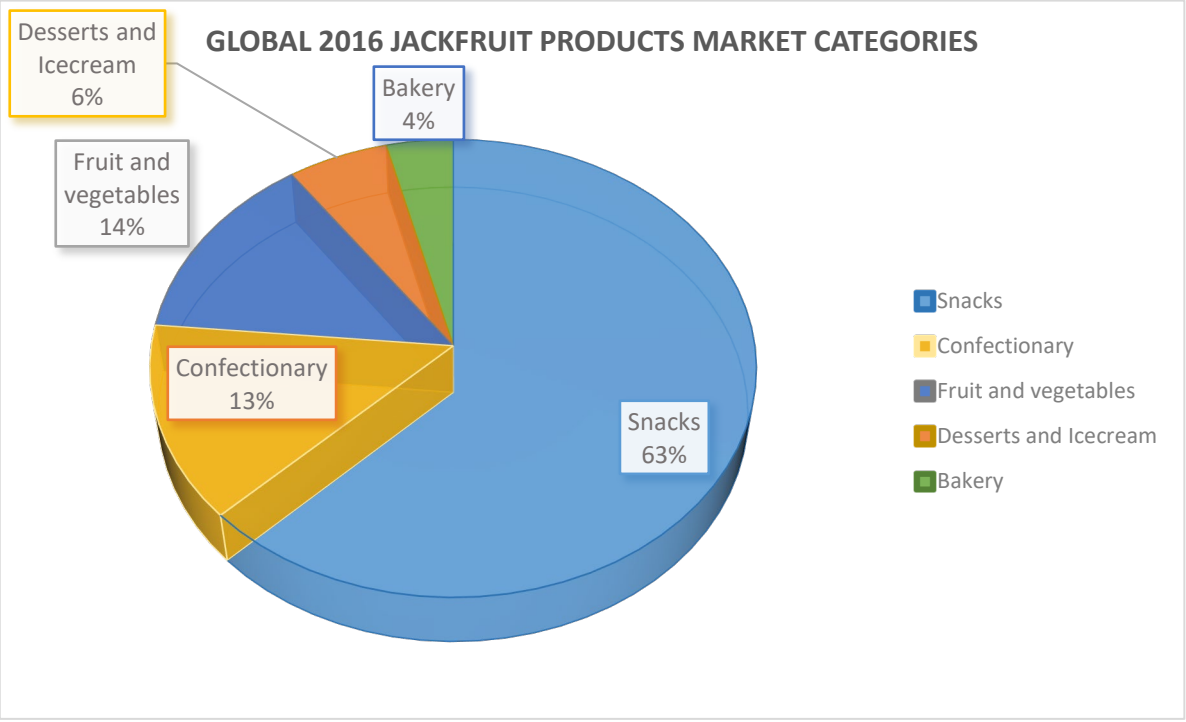


Figure A10-5. Jackfruit Product Category Pie Chart (2016)

Table A10-2. Global New Product Innovation Summary

Product name	Product Category	Country of origin	Product Description	Product image
Keya 100 Percent Jackfruit Crisps (2016)	Fruit Based Snacks	India	Freeze dried, delicious jackfruit crisps that retain all the wholesome goodness of jackfruit, in a 25 g plastic packet.	
Manila Sky Nutty Jack Ice Cream (2015)	Ice-cream	United States	Nutty Jack Ice Cream is a distinct, tropical jackfruit ice cream with roasted cashews and a hint of sea salt.	
The Jackfruit Company Curry Jackfruit (2016)	Vegetables	United States	Jackfruit with meaty texture, combined with aromatic spices for authentic South Indian flavour. Great served with rice or flatbread, or in a sandwich or wrap.	
Thach Lan Rau Cau Coconut Jelly (2015)	Chilled Desserts	Vietnam	Coconut jelly in a 160 g plastic pot.	

Product name	Product Category	Country of origin	Product Description	Product image
Cocon Mixed Pudding with Fresh Fruit Cubes (2013)	Chilled Desserts	Indonesia	Individual cups of pudding with fresh fruit cubes in assorted flavours: mango, honey melon, jackfruit and papaya, held in a plastic bag.	
Nestle Fruit Selection Ube-Langka Flavoured Low Fat Yogurt (2012)	Yogurt	Philippines	Ube and jackfruit flavoured yogurt with real fruit pieces, in a 125 g plastic cup. This nutritious yogurt contains live microorganisms for good digestion.	

Conclusion

The overall global tracked launch activity in Jackfruit products fluctuated from 2011 to 2014, before an 80% positive growth from 2015 (31 products) to 2016 (56 products). Due to jackfruit being native to South East Asia and its familiarity in the area, majority of product innovation is within Asia Pacific and North America regions. However there is also a possibility to introduce jackfruit to the European market.

In the product category, freeze dried, vacuum fried and deep fried chips are all highly produced in the snack market. It is also common for small amounts of sliced jackfruit and puree to be utilised in processed refrigerated packaged goods including puddings, yoghurt, ice creams and coconut jelly. Alternatively new product innovations in immature jackfruits are now also utilised in meat alternative for whole meal packages in combination with rice, sandwiches or wraps and advertised as a vegan, cholesterol free, low fat and low carbohydrate foods. Additionally, familiar western flavours are also being introduced to jackfruits such as sweet and smoky, barbeque and curry.

Therefore there is potential opportunities for jackfruit products to be introduced and exported to different countries. In low volume markets such as Europe or Latin America, ideal products are the snack and confectionary variety due to the extended shelf life. Conversely products with a shorter shelf life such as yoghurt, fresh cut and drinks that require refrigeration will most likely continue its trend in the Asia Pacific Region.

Component two: Preliminary Australian jackfruit variety development (2015-2016)

Compiled and written by Kent Fanning (DAF IFT)

Fruit were picked at commercially mature stage and then stored at 10-13°C prior to transport to the DAF facility at Coopers Plains, and storage at 10°C (usually 1-2 days in 2016), prior to being cut up. On arrival, the whole fruit was weighed and then immersed in water containing 100 ppm chlorine; with the water being displaced measured to estimate fruit density. The characteristics of the fruit are presented in Tables A10-3 and A10-4, below. (Whole weight – processed, refers to the weight of the fruit following storage at 10°C storage, prior to it being cut up and de-pulped).

Table A10-3. Weight, density and flesh recovery for jackfruits received in 2015 and 2016 (mean ± standard deviation)

Fruit category (number of fruit)	Whole weight – delivered (kg)	Whole weight – processed (kg)	Density (g/ml)	% product recovery (includes weight of seed within aril in seed-in product)	Number of seeds
2015					
All (18)	9.37±2.53	9.14±2.17	0.95	33.6±3.4	94±29
Amber (13)	8.55±3.00	8.61±2.75	0.96	31.7±2.9	71±8
Rajang (5)	10.59±1.65	9.94±1.27	0.95	36.5±0.7	118±15
2016					
All (17)	8.95±1.85	8.72±2.06	0.96±0.06	32.2±5.4	N/D
Amber(8)	9.14±1.74	8.87±1.93	0.96±0.08	29.6±5.1	N/D
Rajang (9)	8.74±2.08	8.54±2.36	0.96±0.05	35.6±4.3	N/D

Table A10-4. Brix, pH and moisture content of jackfruits received in 2016 (mean ± standard deviation)

	Brix	pH	Moisture content (%)
All (17)	19.7±1.8	5.09±0.18	77.9±2.1
Rajang (8)	19.3±2.4	5.07±0.11	78.8±2.7
Amber (17)	20.2±0.9	5.11±0.23	77.1±1.1

During preliminary discussions in the planning stage of the sensory work (February 2016), it was decided that a seed-in whole aril product would be the best to assess. The major reason for this was the reduction of potential damage inflicted to the aril by cutting to remove the aril. However, other commercial benefits of producing a seed-in rather than a seed-removed product, include the higher % recovery of product and the reduced processing cost and time, of not having to remove the seed (see data in Table A10-5). The average product recovery was 19.3% higher when whole arils were removed as seed-in product (38.4% of total fruit weight) rather than when seed was removed from arils (32.2% of total fruit weight).

It is estimated that 30-50% of the total processing time (from cutting up whole fruit to having seed-removed arils packed) was taken up by the process of removing the seed from the arils. Another thought in regards to a seed-in product is the option for consumers to use the seed in other dishes (for example boil to use in dips, or use in curries). Information on utilising the seed could be provided on pack via text, link to a website or smart phone QR code.

The idea of a fresh cut jackfruit product was discussed with John Trimboli from Romeo's Marketing on April 19, 2016. John was very supportive of such a product and is receiving whole jackfruit (for ~$7/kg) from North Queensland growers, at certain times of the year. Follow up discussions will be held with John in 2016/2017 in view of running trials to supply him with prototype fresh cut products to get feedback and potentially market test.

Table A10-5. Recoveries and aril weights for jackfruits received in 2016 (mean ± standard deviation)

Fruit category (number of fruit, 2016)	% product recovery (includes weight of seed and testa within aril in seed-in product)	Average aril weight (g)	% whole arils in total product recovery (includes weight of seed and testa within aril in seed-in product)
Seed-removed			
All (7)	32.2±5.4	-	-
Amber (4)	29.6±5.1	-	-
Rajang (3)	35.6±4.3	-	-
Seed-in			
All (6)	38.4±5.7	40.2±9.3	77.0±5.0
Amber (3)	35.0±7.8	44.9±8.4	75.9±6.5
Rajang (3)	42.3±8.7	33.2±6.3	78.5±2.9

Component two: Vacuum packaging evaluation (2015-2016)

Written and compiled by Kent Fanning (DAF IFT)

Multivac C400 (Wolfertschwenden, Germany) and Cryovac bags (165 x 300 x 0.07 mm) were used to evaluate the shelf life effects for fresh cut jackfruit bulbs.

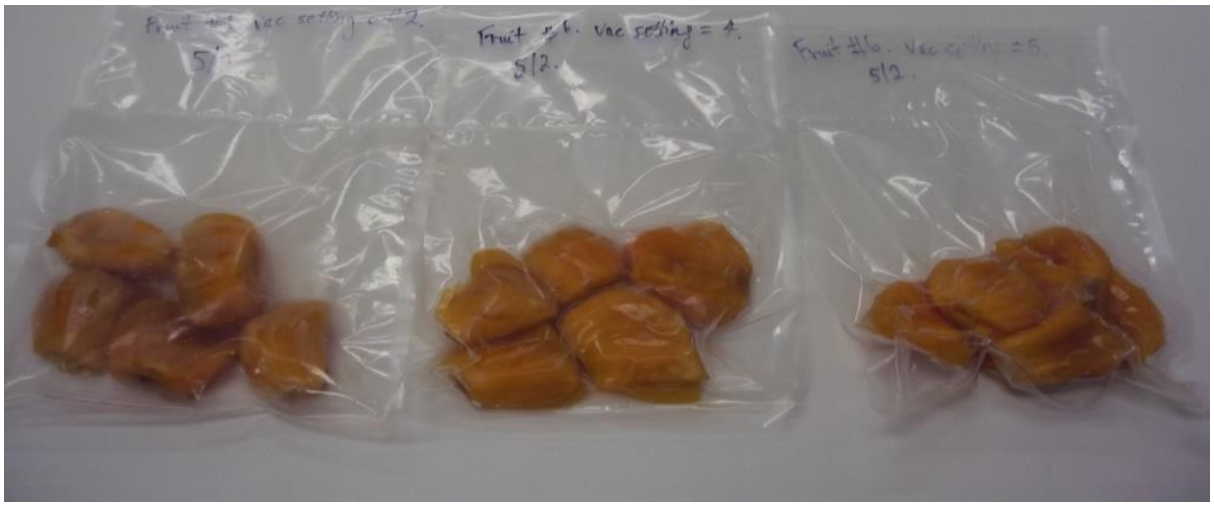


Figure A10-6. Jackfruit vacuum packaging

Dipping

Both water and ascorbic acid (0.02% and 0.05%) dips were trialled. No increased colour preservation was achieved with the dips and the flavour was 'diluted', which was regarded negatively for people who are familiar with typical jackfruit flavour. For people who are unfamiliar with jackfruit and would like less intense flavour, dipped samples may be preferred. Dipping also slightly reduced microbial loads.

Storage temperature

19 February shipment

- 5°C – no colour change over 5 days. Good texture and flavour. No gas build up in bag. Low aroma.
- 10°C – no colour change over 5 days. Some gas build up in bag by 5 days and associated off aroma by 5 days.
- 22°C – no obvious difference to 5°C /10°C for 24 hours. Some gas build up in bag by 1-3 days and associated off aroma.

26/27 February

2°C, 5C, 10°C and 22°C were compared. 2°C and 5°C appear similar (after 6-7 days storage) in regards to colour, flavour and texture. At 10°C, colour is preserved but there is gas build-up and development of off aromas by 6-7 days. At 22°C, appearance becomes compromised and gas build-up is significant by 2-3 days.

Appearance

Rajang

- At 2°C, 5°C and 10°C there was no major change in colour for Rajang over 14 days (Figure A10-7).
- There was gas build up in 10°C samples by 12 days. Moisture loss after 12 days was 8.4% (2°C), 9.4% (5°C) and 6.2% (10°C) for the three temperatures

Figure A10-7. Rajang (12 days storage at 2°C [LHS], 5°C [middle] or 10°C [RHS])

Amber

- 2°C preserved colour better than 5°C for Amber. (photos of samples following 14 days storage below, Figure A10-8).
- There was some gas build up in 10°C (Amber) by 11 days. Moisture loss after 11 days was 6.4% (2°C), 7.1% (5°C) and 4.5% (10°C) for the three temperatures.

Figure A10-8. Amber (14 days storage at 2°C [LHS], 5°C [middle] or 10°C [RHS])

Shelf life

Product was evaluated on each shelf life date by trained research scientist Kent Fanning and Research Scientist Fresh Foods Diana Liu. Sensory comments were noted and discussed as below;

Rajang

- 0 days – not dipped product was preferred with stronger flavour than dipped product.
- 5 days – generally similar. For some people 10°C was more 'overripe' in terms of flavour.
- 7 days – generally similar.
- 12 days - 2°C and 5°C had low to slight aroma (on opening of pack). 10°C samples had a slight off aroma. 2°C had some zing but 5°C was zingier (acid, fermentation) than 2°C. 5°C also had a little bitter/metallic aftertaste. Texture was good for 2°C and 5°C.

Amber

- 4 days – 5°C and 10°C samples were (becoming) acidic (fermented), less fruity, less sweet. (Amber preferred over Rajang).
- 6 days - 2°C preferred over 5°C. Not much difference between 2°C and 5°C.
- 11 days - 2°C had lost some flavour complexity, had a longer aftertaste and had a denser texture. 5°C had more 'zing' (acid and fermentation) than 2°C.
- 14 days – No samples were tasted. Both 2°C and 5°C had good aroma.

Microbiological testing

- Compared impact of storage temperature for the fruit processed on 26 and 27 February.
- Storage at 2°C and 5°C kept total plate count at or below initial levels, over 14 days storage, which would be acceptable for retail product (Figure A10-9).
- Storage at 10°C resulted in elevated counts, which would be unacceptable (>10^6).

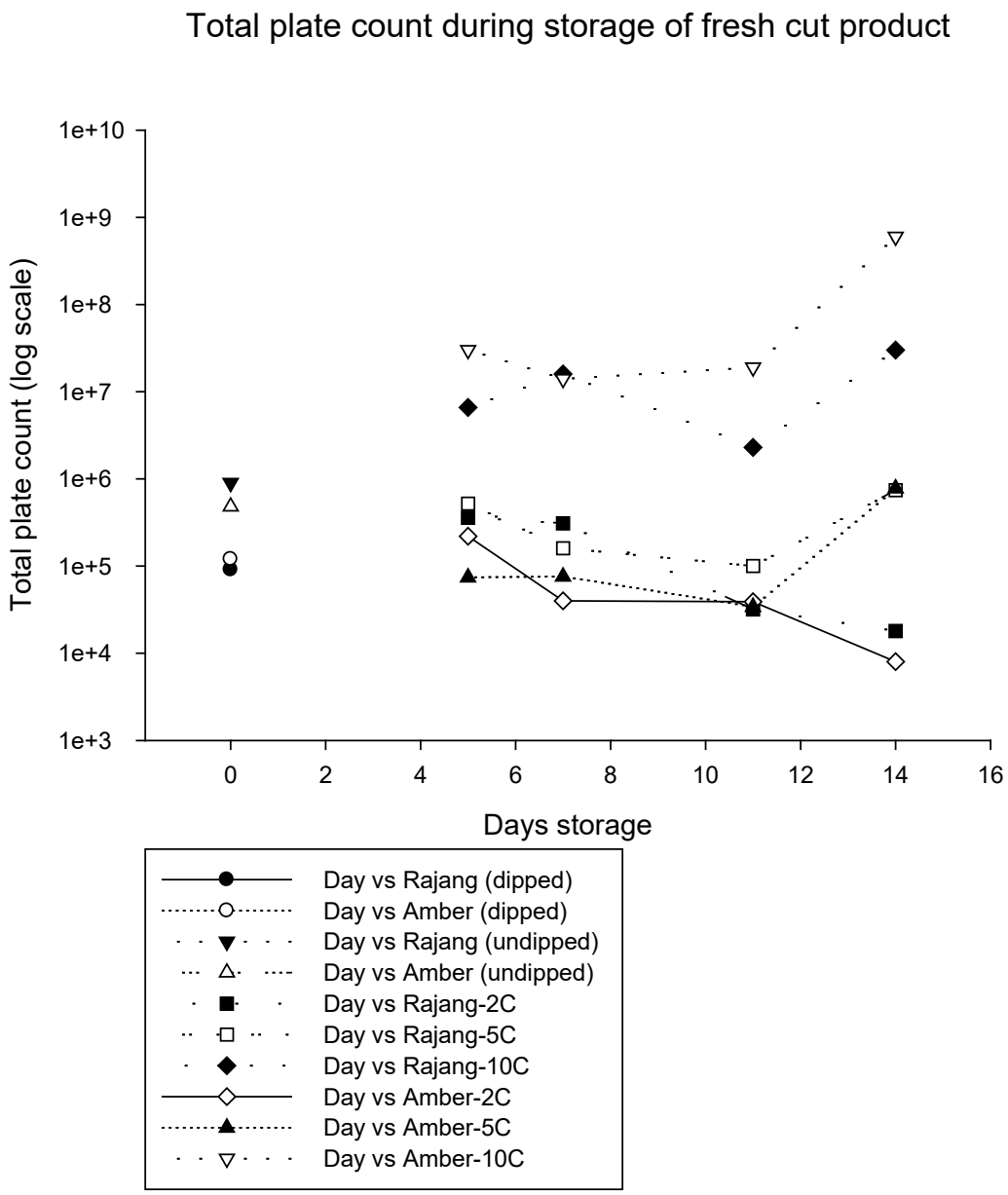


Figure A10-9. Vacuum packaging Shelf Life TPC Graph

Component two: Sensory profiling of Australian jackfruit varieties (2016)

Compiled and written by Philippa Tyler (DAF IFT)

Objectives

- Assess the sensory attributes of Jackfruit; Rajang and Amber varietals
- Quantitatively evaluate the sensory attributes of the Jackfruit varietals; with the aim of compiling a sensory profile that can be used to market the fruit
- Determine the similarities and differences of the two varietals; in terms of sensory qualities

Methodology

Sensory profiling methodologies were implemented.

- A panel of trained sensory assessors (n=10) with previous experience in the evaluation of fresh produce were recruited for the study

- Due to the unfamiliar nature of Jackfruit the sensory assessors were first introduced to the fruit; its structure, origin and how it is often used in cooking. This enabled panellists to become familiar with the new fruit and understand how its structure may impact the texture, flavour and look of the individual arils

Training sessions were conducted over a two week period whereby sensory assessors conducted the following exercises.

- Individual attribute generation; assessors were provided with one aril of each varietal placed in individual blind coded pots and asked to assess each sample for the following attributes – appearance, aroma, flavour, texture and aftertaste. Assessors noted the sensory descriptors they associated with each attribute, writing them into a table.
- Consensus; the panel discussed their individual descriptors as a group (led by the panel leader). The outcome of which was a table of sensory descriptors that the panel agree encompass all attributes of the two varietals.
- Definition; the panel and panel leader define each sensory descriptor and determine the correct sensory standard to be used.
- Practice; the sensory assessors conduct several practice sessions, using the clearly defined list of descriptors and line scales in order to quantitatively assess each varietal. The panel leader follows the progress of the panel ensuring that each assessor is using the attributes in accordance with the rest of the panel and that agreed upon during training.

Formal evaluation sessions were conducted over one week following successful completion of the training phase.

- Formal evaluations took place under controlled conditions in the isolated sensory booths at the Health and Food Sciences Precinct, Coopers Plains (HFSP).
- Samples were assessed in quadruplicate in a balanced and rotated order, to prevent order bias.
- Sensory assessors were provided with a full list of sensory descriptors, their definitions and standards and asked to familiarise themselves with these prior to sample evaluations.
- Samples were presented on blind coded paper plates, sensory assessors were provided with a method in which to consume the samples (Attachment 1). Between samples assessors were asked to cleanse their palates using water and water crackers.

Outcome

Table A10-6. Sensory Descriptors Table (Both Varietals)

Descriptor	Anchors	Definition/standard
Appearance		
Colour consistency	Low-high	how consistent the colour of the aril is from very inconsistent (low) to consistent (high)
Aroma		
Jammy	None-high	Bonne Maman strawberry conserve
Overripe banana	None-high	Overripe almost black Cavendish banana
Musty (melon)	None-high	Cantaloupe/rock melon
Pineapple	None-high	Fresh pineapple
Mandarin	None-high	Fresh mandarin
Orange lolly	None-high	Orange cordial

Descriptor	Anchors	Definition/standard
Flavour		
Overripe banana	None-high	Overripe almost black Cavendish banana
Vanilla	None-high	Vanilla bean paste
Artificial sweet	None-high	
Liquorice	None-high	Fresh soft liquorice
Orange lolly	None-high	Orange cordial
Mandarin	None-high	Fresh mandarin
Pineapple	None-high	Fresh pineapple
Texture		
Firmness	Low-high	Initial bite between incisors; including resistance and crunch
Rubbery	Low-high	On chewing between molars; the amount required to break down sample
Fibrous	None-high	Presence of fibres on chew
Juiciness	None-high	
Aftertaste		
Artificial sweet	None-high	
Cheese (musty)	None-high	Soft cheese; brie/camembert
Bitter/savoury	None-high	
Green banana	None-high	Under ripe Cavendish banana
Tongue tingling	None-high	Oral sensation

The following sensory profiles have been generated from the sensory data presented**.**

Rajang

Elicits a mid-strength aroma intensity with distinct notes of jammy and overripe banana, Rajang has a sweet aroma with hints of orange lolly. A strong flavour is characterised by an overripe banana attribute and milder notes of artificial sweetness and orange lolly. Rajang has medium firmness with a slight rubbery and fibrous texture however, it is also juicy. The artificial sweet flavour lingers into the aftertaste which also has slight notes of green banana.

Amber

Overall a milder fruit, Amber has a mid-strength aroma intensity with slight hints of jammy and musty, overripe banana is the dominant aroma characteristic detected at low-medium intensity. Flavour intensity is medium to high however only low levels of the attributes orange lolly and artificial sweet were detected. Amber is a very firm fruit, fibrous and rubbery, but like Rajang it is still juicy. Despite the mild flavour, the aftertaste of Amber is of medium intensity with a distinct green banana attribute.

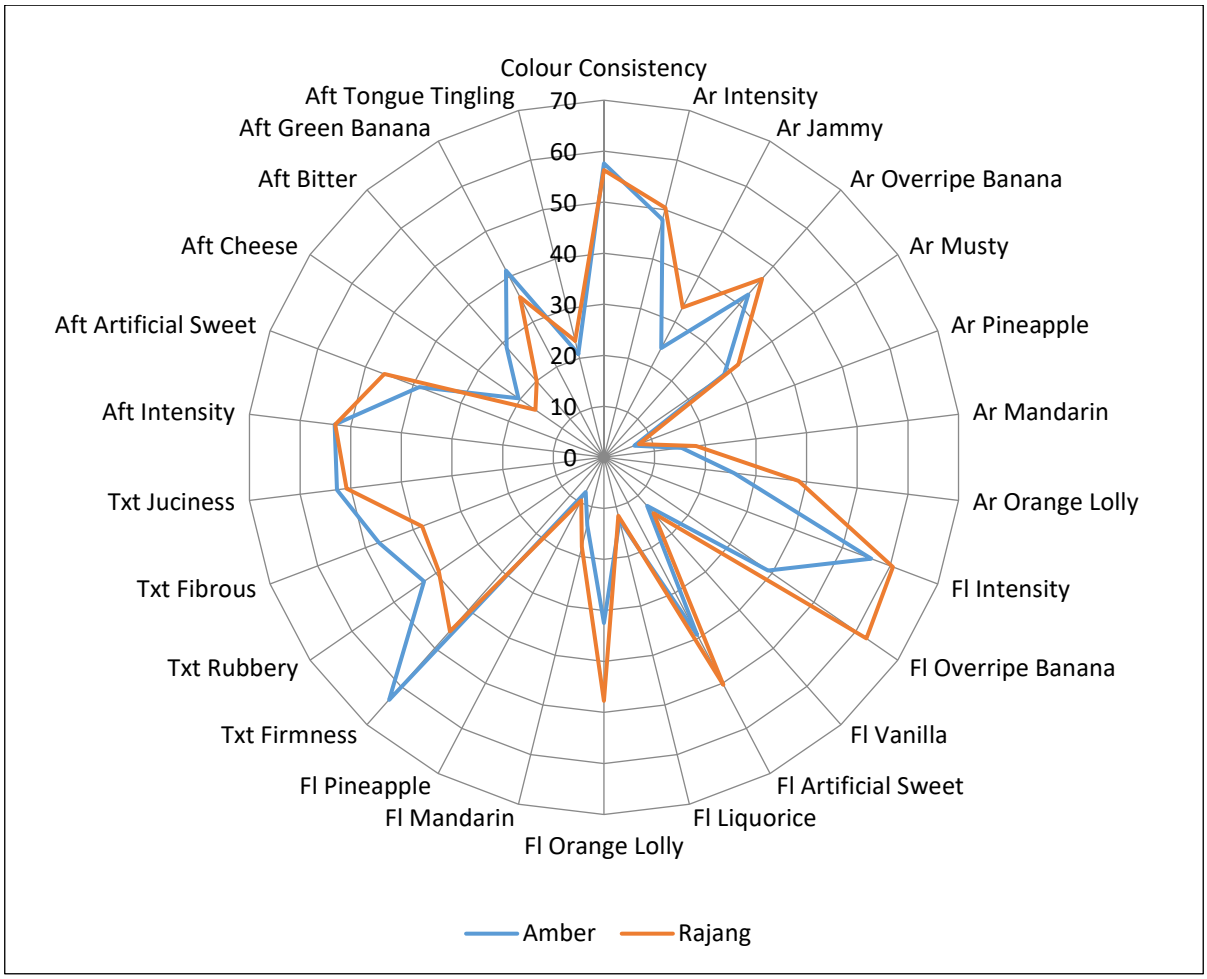


Figure A10-10. Spider plot of sensory descriptors and their corresponding scores for both Jackfruit varietals

Consumer trial - 2016

Rajang and Amber fruit were obtained from commercial grower in North Queensland, transported to Brisbane Markets and then stored from 7th March until 9th March, at 10°C. On the 9th March, fruit were cut up and whole arils, with seed in, were removed and stored in plastic trays, with lids, at 4°C.

Prior to each consumer session, 12 arils of Amber and Rajang were removed from cold store and stored at room temperature (22-23°C). Five minutes prior to each consumer session, one aril of each variety was placed onto an individual, labelled paper plate (samples were given blinding codes). 48 consumers were recruited from the Health and Food Sciences Precinct and were presented both of the samples, using a randomized sample presentation order, and asked to score overall liking, appearance, aroma, flavour and texture, using a 9-point hedonic scale. Consumers were also asked to enter qualitative comments regarding what they liked or disliked about each sample. Differences in the mean values were evaluated using analysis of variance and the Tukey HSD procedure (using Compusense software). The mean and standard deviation consumer responses are presented in Table A10-7. Only the mean response for flavour was significantly different (p=0.0464) between the two varieties.

Table A10-7. Consumer responses for the two jackfruit varieties (n=48, mean± standard deviation)

	Amber	Rajang
Overall liking (p=0.3266)	5.8 ± 2.5	5.5 ± 2.2
Appearance (p=0.1747)	5.6 ± 2.0	6.1 ± 1.8
Aroma (p=0.5863)	5.2 ± 2.2	5.0 ± 2.0
Flavour (p=0.0464)	5.9 ± 2.6	5.2 ± 2.6
Texture (p =0.3820)	6.3 ± 1.9	6.1 ± 2.0

Table A10-8 lists the % of consumers that made a comment that referred to a particular criteria (appearance, aroma, flavour, texture). As seen for the quantitative responses, the difference between Amber and Rajang was that Amber's flavour was more liked (52% [Amber] vs 33% [Rajang]) and less disliked (23% [Amber] vs 40% [Rajang]).

Table A10-8. % of consumers that had a comment for a particular criteria

Criteria	Like	Dislike
Amber		
Appearance	8%	10%
Aroma	8%	6%
Flavour	52%	23%
Texture	25%	13%
Rajang		
Criteria	Like	Dislike
Appearance	6%	6%
Aroma	8%	10%
Flavour	33%	40%
Texture	23%	13%

The main repeated qualitative comments are summarised in Table A10-9. These comments were fairly similar for both the flavour and texture of the two varieties. In comments that compared Amber and Rajang, the main repeated messages were that Amber had a stronger aroma, was sweeter and had a stronger flavour. There were only 4 comments regarding the seed (2 for Amber and 2 for Rajang). Three of these were dislikes of the large seed.

Table A10-9. Main qualitative comments

Criteria	Like	Dislike
Amber		
Appearance	Orange colour	Uneven colour
Aroma	aromatic	Mouldy
Flavour	Sweet, refreshing, juicy, interesting	Unfamiliar, after taste, over ripe
Texture	Firm, crunchy, unusual	Too firm
Rajang		
Appearance	consistent	Pale colour
Aroma		
Flavour	Refreshing, unusual, sweet, juicy	Bland, aftertaste
Texture	Crunchy, firm	Too firm

Appendix 11. Processing trials (2017)

Compiled and written by Colin Leung (DAF, IFT) and Dianna Liu (DAF, IFT).

Component three: Packaging study introduction

Literature reviews and preliminary studies completed in component one and two of the project demonstrates that non-thermal minimal processing of fresh-cut jackfruit may potentially assist in achieving better food safety and fruit quality during product shelf life. Additional research in product development will help improve economic outcomes by providing local growers and processers domestic and export market opportunities. Consumer sensory trials will also aid in obtaining data for consumer preference for jackfruit products which will provide valuable feedback for further process optimisation and future project opportunities.

This trial utilised both phyto-sanitation and dipping solution treatments in combination with three different packaging options (Polypropylene container, vacuum pack and barrier container) to evaluate product shelf life quality over 17 days. Ascorbic acid, citric acids and calcium chloride levels were evaluated from both literature reviews and research done in Philippines (PC) at Visayas State University. The purpose of this research was to complete chemical, microbiological, sensory assessments to study fruit deterioration and consumer acceptability during product shelf life.

This processing trial was completed through commercial partnership with Stewart Bro Farms at North Queensland who kindly provided all jackfruit trial samples and from Yan Diczbalis, Project Lead, Wet Tropics Agriculture, Department of Agriculture and Fisheries who provided development guidance during the project.

Specifically this experiment investigated “fresh cut” processing options and evaluated the processed products through laboratory traits as well as consumer testing. The variables included three packaging methods (Standard PP, Barrier Film, and Vacuum Packages), treatment of the jackfruit arils with or without dip, and days of storage (1, 8, 13, and 17 days).

Both pilot plant operations and shelf life evaluations were completed at Health and Food Science Precinct Facility located at Coopers Plains, Brisbane, Australia.

Component three: Packaging study methodology

Compiled and written by Colin Leung and Diana Liu (DAF, IFT)

Experimental design and description of data

The experimental design consisted of a randomised complete block design with two replicates of each of the treatments (n=24). The treatments correspond to the 3 x 2 x 4 factorial combination of the three packaging methods, two dip treatments and four storage times.

Chemical, microbiological and physical traits of the samples were tested in duplicates for each treatment. Additional measurements were made on fruit arils prior to any treatment in order to attain standard (or control) values.

The tested traits are as follows:

- Chemical traits: pH, Titratable Acid (TA expressed as %citric acid), Brix (º), Moisture (%) and Ascorbic Acid (mg/100 g FW?).
- Microbiologic traits: Standard Plate Count (CFU/g), Yeast (CFU/g) and Mould (CFU/g).
- Colour traits: L*, a*, b*, C* and h using the Minolta Colorimeter, and L*, a* and b*using a Nix Pro Colour Sensor.

- Two additional traits were measured for the Barrier Film package: Oxygen (O_2) and Carbon Dioxide (CO_2).

Sample preparation and pre-treatment

Twenty five jackfruits of *Orange Crunch variety* (Rajang Variety) with similar green to light yellow skin colour at pre-ripening stage were hand-picked at Mareeba, North Queensland, Stewart Brothers Fruit Farms on 26th March 2017. All produce were hand packaged in cushioned cartons to prevent physical damage before transported to Health and Food Science Precinct in Brisbane via Romeos Marketing Qld cold chain transport at 4°C. The external surface of the produce were dipped in Tsunami 100 sanitising solution at 80 ppm, dried for 10 minutes and chill stored at 8°C until it was yellow to light brown ripening stage prior to packaging trial on 18th April 2017.

All processes and preparation were carried out in a Safe Food accredited pilot plant facility following strict good manufacturing practice (GMP). All bench surfaces, soaking tubs, cutting boards and hand tools were sanitised with chlorine at 100 ppm prior to processing to prevent cross contamination. The pre-treatment solution dip of calcium chloride (0.75% w/v), ascorbic acid (1.0% w/v), citric acid (0.5% w/v) and phyto-sanitation Tsunami 100 solution (80 ppm) dilutions were prepared on the day of processing.

A total quantity of twenty five jackfruits weighing 80 kg were soaked in Tsunami 100 at 80 ppm solution followed by 5 minutes air drying. Samples were checked to insure good uniformity for ripeness and any deteriorated fruit bulbs found were cut and disposed.

Samples were divided randomly into two sets then each set were split between applying pre-treatment solution dip or RO water for 10 minutes followed by 5 minutes air drying. Samples were then packaged into the three packaging treatments (Polypropylene containers, barrier vacuum pouches and perforated barrier) before storing in an incubator for 17 days at 5°C.

Materials and packaging

Tsunami 100 sourced from Ecolab, Brisbane Australia is FDA (United States Food and Drug Administration) and FSANZ (Food Standards Australia New Zealand) registered antimicrobial water additive used in fruit and vegetable processing up to 80 ppm without rinsing. This product will be utilised for phyto-sanitation both external surface and internal fresh cut fruit to control microbial growth and shelf life extension. Pre-treatment ingredient including calcium chloride, ascorbic acid and citric acid were purchased from Food Ingredient Depot, Melbourne Australia.

For barrier packaging, BT97 Barrier Trays (length 229 mm, width 178 mm, depth 61 mm) and Thermasorb absorbent pads made of sodium polyacrylate polymer were purchased from Alto Packaging, Auckland, New Zealand. Perforated barrier film Lid1050S were purchased from Sealed Air, Cryovac, Brisbane, Australia.

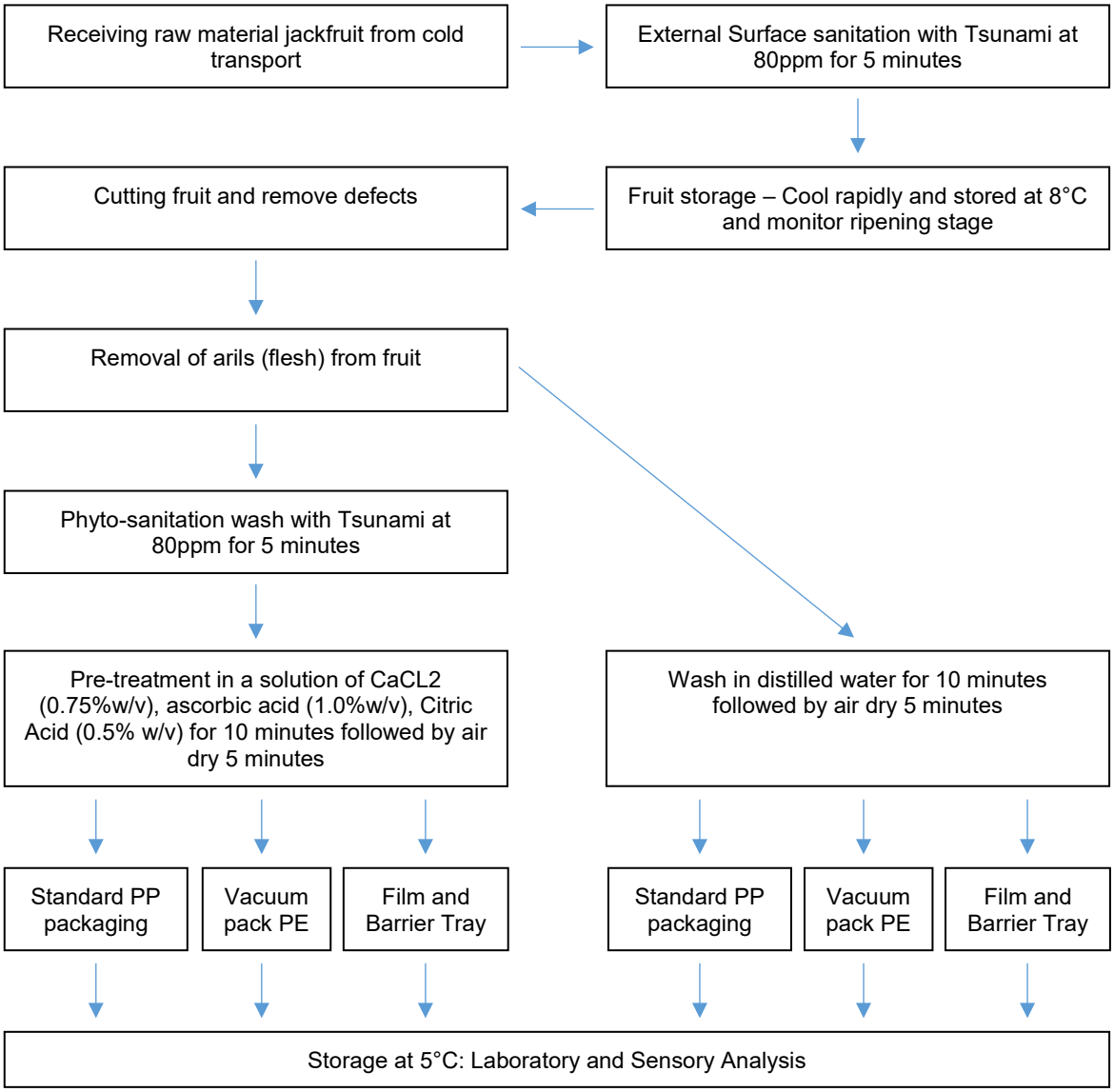
Plain clear barrier vacuum packaging pouches (length 300 mm, width 350 mm, thickness 70 µm) were purchased from Caspak, Auckland New Zealand. CA-CM700 Standard rectangle 700 ml containers (length 175 mm, width 120 mm, depth 55 mm) made of polyethylene were purchased from Cast Away Food Packaging, Brisbane, Australia.

- Mecapack S1000 MAP is a semi-automatic tray sealer that was utilised to seal all barrier packaging samples in this trial. It is compatible with both the BT97 barrier tray and Lid1050S barrier film.
- Caron 6010 Series Environmental Chamber was utilised for initial jackfruit ripening storage at 8°C and for the duration of the three week shelf life trial at 5°C.
- Multivac C400 (Wolfertschwenden, Germany)

		
Packaging type A: Black tray with film barrier	**Packaging type B: PP packaging**	**Packaging type C: Vacuum packaging**

Figure A11-1. Packaging Type Table

Shelf life trial flow diagram



Estimation of ascorbic acid

The Association of Analytical Chemists (AOAC) official method 967.21 titled, Ascorbic Acid in Vitamin Preparations and Juices, was the method of choice. Briefly, an extracting solution (3% Metaphosphoric Acid, 8% Acetic Acid), an indophenol standard solution (0.25 g 2,6-dichloroindophenol Na salt, 0.21 g $NaHCO_3$ made up to 1 L with deionised water) and a standard dye solution (1 mg/mL ascorbic acid) were prepared prior to analysis. The indophenol solution was standardised daily against the ascorbic acid standard solution prior to titration.

For each packaging sample, all jackfruit seeds were removed from the bulb then put through a food processing blender into a puree. 10 g of the subsample was weighed into a centrifuge vessel and made up to 50 g with extracting solution. Each sample was blended for 1 min with a vortex mixer at high speed then centrifuged for 5 minutes at 5000 rpm. 10 ml of the filtrate was titrated against the indophenol solution in duplicate until a rose pink end point which lasted for a minimum of 15 seconds.

Indophenol equivalent (1 mL DCIP = 2/14.1 mg Vitamin C)

pH analysis

A digital benchtop pH meter (Labchem-pH, TPS) was used for pH analysis in this trial. On the day of testing, the apparatus was calibrated with standard buffer solutions of pH 4 and pH 7 with the glass electrode being rinsed in deionised water prior to analysis. For each packaging sample, all jackfruit seeds were removed from the bulb then put through a food processing blender into a puree. The puree was transferred into a plastic beaker with the glass electrode being fully immersed to take a pH reading after waiting several minutes to stabilise. The glass electrode was rinsed with deionised water between each measurement.

Estimation of titratable acidity

The AOAC Official method 942.15 Acidity (Titratable) of Fruit Product: Glass Electrode Method was followed to perform the analysis. On each test date, the apparatus was calibrated with standard buffer solutions of pH 4 and pH 7 then the glass electrode was rinsed in deionised water prior to analysis. For each packaging sample, all jackfruit seeds were removed from the bulb then put through a food processing blender into a puree. A volume of 3 to 5 mL puree was accurately weighed into a small beaker with the addition of 10 ml deionised water.

The solution was placed in an auto-titrator (Metrohm 702 SM Titrino) for titration analysis. The electrode was immersed in the test solution and continually stirred with the addition of 0.1 M NaOH solution until it reached the end point of pH 8.2. The glass electrode was also rinsed with deionised water in between each measurement. (Equivalent factors; Citric Acid, 0.064; NAOH, 0.112N)

$$\% \text{ citric acid} = \frac{\text{Titre (ml)} \times \text{normality of NaOH} \times 0.064 \times 100}{\text{wt of sample (g)}}$$

Colorimeter analysis

Two different colorimeters were used to measure changes in colour during the shelf life trials. A factory calibrated Nix Pro colour sensor (Nix Sensor Ltd, Ontario, Canada) under D65 illuminating condition at an observer angle of 10° and the Minolta Colorimeter (Chroma meter, CR-400, Tokyo, Japan) under C illuminating condition at an observer angle of 2° which was calibrated to a Minolta certified white tile on each analysis date.

From each packaging sample, three random jackfruit bulbs were selected and a dry flat surface area was tested for both the Nix and Minolta Colorimeter. Both instrument results

were expressed as CIELAB (L* a* b*) scale average value of three replicate scans where L* corresponds to lightness and a* and b* to chromaticity coordinates for red and yellow, respectively. In addition, the Minolta Colorimeter also records L*C*h colour space where L* corresponds to lightness and C* to chroma and h as hue angle.

Estimation of moisture content

AOAC 920.151 Solids (Total) in Fruits and Fruit Products Method was followed to determine the moisture content. Weighted moisture dishes were prepared by initially drying in the oven then at 60°C cooled to room temperature in a desiccator prior to analysis. For each packaging sample, all jackfruit seeds were removed from the bulb before put through a food processing blender into a puree.

Five grams of puree sample was spread thinly onto the dried weighted moisture dish and weighed accurately to 4 decimal places. Samples were dried at 70°C under pressure using a vacuum oven for 48 hours then removed and cooled to room temperature in a desiccator. Dried samples were reweighed accurately to 4 decimal places to calculate the moisture content.

Moisture content = (Dish and sample weight – dried dish and dried sample weight) / (Dish and sample weight – dish weight) * 100

Estimation of total soluble solids (°Bx)

A digital refractometer (TDR 095C, Sinotech, Zhangzhou, China) was used to analyse the °Bx level of the samples. The apparatus was zeroed by placing deionised water at room temperature onto the prism surface and wiped clean prior to analysis.

For each packaging sample, all jackfruit seeds were removed from the bulb then put through a food processing blender into a puree. 1 mL of each pre-prepared variant was transferred with a pipette onto the prism surface for °Bx calculation (conducted at room temperature). The prism surface was cleaned and wiped with deionised water in-between each analysis.

Gas analysis

A portable headspace gas analyser for MAP packages (Check point two, Mocon Dansensor) was used to analyse gas composition for oxygen and carbon dioxide in the barrier packaging. The analyser was serviced and calibrated externally by Pryde measurement prior to the shelf life trial. A septum was placed on the packaging surface to prevent leakage prior to inserting the needle sensor, and each measurement was performed on a new barrier tray sample in duplicates,

Microbiological analysis

Approximate 10 g of sample was transferred aseptically into a stomacher bag containing 90 ml of 0.1% peptone water and homogenized for 60 seconds using a Lab Blender 400, Stomacher at room temperature (Seward Medical, UK). For yeast and mould enumeration, 0.1 ml samples of serial dilutions (1:10, diluent, 0.1% peptone water) were spread on the surface of dry DRBC media (CM0727, supplemented with Chloramphenicol supplement, SR0078E, Oxoid, Basingstoke, UK). Counts were determined after 5 days at 25°C.

For Total viable counts (TVC) enumeration, 1 ml samples of serial dilutions (1:10, diluent, 0.1% peptone water) of sample were mixed with 10 ml molten agar using the pour plate method and Plate Count Agar (PCA, CM0463, Oxoid, Basingstoke, UK). Counts were determined after incubation for 3 days at 30°C. Two replicates of appropriate dilutions were enumerated. All plates were examined visually for typical colony types and morphology characteristics associated with each growth medium.

Sensory evaluation

Compiled and written by Philippa Tyler

Objectives

- Qualitatively evaluate the sensory properties of fresh-cut Jackfruit throughout shelf-life.
- Identify similarities and differences in the sensory properties of fresh-cut Jackfruit as influenced by packaging type and treatment.
- Predict consumer perception of packaging types and treatments.

Table A11-1. Samples as subdivided by packaging and treatment

Sample ID	Packaging type	Dip
A1	Type A - Black tray with barrier film	x
A2	Type A - Black tray with barrier film	✓
B1	Type B - PP packaging	x
B2	Type B - PP packaging	✓
C1	Type C - Vacuum packaging	x
C2	Type C - Vacuum packaging	✓

Qualitative assessment

A panel of trained sensory assessors (n=10) with previous experience in the evaluation of fresh produce, including jackfruit, were recruited for the study. Panels were led by experienced panel leader Philippa Tyler.

The sensory panel first took part in a fresh-cut jackfruit evaluation exercise in order to familiarise themselves with the product prior to packaging and to become aware of the vocabulary to be used throughout the study (Attachment 1). The vocabulary used was adapted from that produced during the preliminary sensory evaluation study conducted in 2016.

Sensory panel sessions were conducted on the following days (and corresponding time points);

- Day 0 (fresh fruit) – 18th April 2017
- Day 1 – 19th April 2017
- Day 8 – 26th April 2017
- Day 14 – 2nd May 2017
- Day 17 – 5th May 2017

During each sensory panel session the panel members were presented with one whole aril of each Jackfruit sample in a blind coded plastic cup. The panel were asked to assess each product for the following attributes; appearance, aroma, flavour, texture and aftertaste.

Panellists noted down the descriptive attributes they associated with each sample and the strength/level at which it was present. For example; strong overripe banana aroma, mild orange cordial flavour, moderate glossiness.

The panel were then led in a group discussion of the most dominant and characteristic attributes of each sample. These results were collated by the panel leader in order to create a rapid sensory profile of the samples at each time point.

It is to be noted that at the point at which the samples were deemed inappropriate for consumption due to their appearance/aroma, the flavour, texture and aftertaste were not recorded.

Packaging evaluation

Following the final sample assessment, the sensory panel were asked to give feedback on the packaging types; their aesthetic appeal, ease of use and how they display the product.

Sensory evaluation

Statistical analyses of all traits were performed via Analysis of Variance (ANOVA) using GenStat 18th Edition, VSN International. The model for control plus factorial was used for the analysis of the individual traits. The blocking structure consisted of Replicate, the treatment structure consisted of Group/(Day*Packaging*Dip).

A level of significance of 5% was used for all tests. Mean comparisons, where appropriate, were performed following the least significance difference (LSD) test. Residual graphs for each trait allowed correcting or removing outliers if present. Unless specified, the residual graphs did not show departures from the ANOVA assumptions of normality and homoscedasticity.

Statistical analysis

Statistical analyses of all traits were performed via Analysis of Variance (ANOVA) using GenStat 18th Edition, VSN International. The model for control plus factorial was used for the analysis of the individual traits. The blocking structure consisted of Replicate, the treatment structure consisted of Group/(Day*Packaging*Dip).

A level of significance of 5% was used for all tests. Mean comparisons, where appropriate, were performed following the least significance difference (LSD) test. Residual graphs for each trait allowed correcting or removing outliers if present. Unless specified, the residual graphs did not show departures from the ANOVA assumptions of normality and homoscedasticity.

Component three: Packaging study results

Sensory evaluation – Qualitative shelf life evaluation of packaged jackfruit

Compiled and written by Philippa Tyler (DAF, IFT)

Outcome

Qualitative assessment

Table A11-2. Qualitative assessment of samples at Day 1.

** Attributes noted in italics were considered negative/taints of the samples and not associated with a fresh jackfruit product.*

Sample	Appearance	Aroma	Flavour	Texture	Aftertaste
A1	Low sheen Slightly dry w/little gloss *Bruising visible near tip*	Rock melon Green banana Persimmon Slight yeasty/old socks Caramel	Rock melon Sweet tropical Mandarin Persimmon Cucumber Slight vanilla	Rubbery Firm Like ripe coconut flesh	Bitter artificial *Mouth tingle*

Sample	Appearance	Aroma	Flavour	Texture	Aftertaste
A2	Variable in colour from pale yellow to orange *Bruising visible near tip & rapid bruising on cutting w/liquid lost**	Slight mandarin Grassy *Medicinal/chemical* *Metal tin*	Confectionary sweet Orange/mandarin *Sharp medicinal*	Nashi pear-like texture Variable hardness Ripe to very unripe	Bitter Apple skin *Metallic aftertaste* *Mouth tingle*
B1	Variable gloss Variable dryness *Bruising near the seed*	Orange/mandarin Orange cordial Sweet Melon Cucumber Slightly cheesy	Mandarin Orange cordial Caramel/banana Liquorice *Chemical*	Juicy Variation from chewy to mushy samples	Bitter Sweet banana *Metallic*
B2	Variable ripeness from very unripe to ripe Some very juicy and others not *Bruising*	Confectionary Lady finger banana Grassy/green	Orange lolly Artificial sweet Green rock melon *Metallic*	Soft Slightly resistant Slightly rubbery	Very bitter Artificial sweet *Tingly* *Lingering*
C1	*Bruised* *Dry* *Wrinkled* *Like preserved fruit*	Fermented apples Sweet orange Musty orange *Overripe fruit*	Mandarin Banana Vanilla/caramel *Savoury/vegetable*	Rubbery Chewy Crunchy Moist/juicy	Bitter Savoury pumpkin Orange cordial
C2	*Very overripe and bruised (more so than No Dip)* *Leathery* *Onion-like*	*Fermented/overripe fruit* *Overripe bananas* *Alcohol* *Plastic*	*Pickled* *Fermented* *Artificial sweet* *Chemical* *Sour* *Slightly rotting*	Rubbery/chewy	Grassy/green Bitter *Astringent*

Table A11-3. Qualitative assessment of samples at Day 8.

** Attributes noted in italics were considered negative/taints of the samples and not associated with a fresh jackfruit product.*

Sample	Appearance	Aroma	Flavour	Texture	Aftertaste
A1	*Darker* *Severe bruising, looks rotten* *Sprouting**	*Fermenting/overripe fruit* *Yeasty* *Slightly yeasty*	Sweet and mandarin notes detected late *Musty* *Slightly off 'lemony'* *Bitter* *Cucumber watery*	Still rubbery and chewy, little change	Sweet *Musty* *Tongue tingling*

Sample	Appearance	Aroma	Flavour	Texture	Aftertaste
A2	*Mottled* *Bruising* *Sprouting*	Mandarin/orange Melon/grassy/unripe banana	Sweet orange Sappy Acidic *Medicinal* *Bitter chemical*	Juicy/succulent *Softened but tough*	Lacking flavour Bitter *Watery* *Tongue tingle*
B1	*Dry* *Bruised inside* *Not pleasant* *Sprouting*	*Strong* *Yeasty* *Off citrus* *Mouldy melon*	*Low flavour* Artificial sweet Liquorice	Firm and crunchy *Very watery* *Slimy outside* *Tough fibrous*	Artificial sweet *Chemical/metallic*
B2	*BIG sprouts* *Very watery inside and outside* *Very bruised inside*	Sweet banana Sugary Melon *Off citrus* *Warm spice*	*Low flavour* *Watery* *Slight medicinal* *Bitter*	Tough rubbery *Less crunch*	*Astringent*
C1	*Very watery* *Packaging wrinkles* *Shrivelled*	*Strong* *Overripe pineapple* *Musty*	*Inedible*	*Inedible*	*Inedible*
C2	*Bruised* *Like rotten fruit*	*Fermented cheese* *Potato peelings* *Grassy*	*Inedible*	*Inedible*	*Inedible*

Table A11-4. Qualitative assessment of samples at Day 14.

** Attributes noted in italics were considered negative/taints of the samples and not associated with a fresh jackfruit product.*

Sample	Appearance	Aroma	Flavour	Texture (assessed using knife)	Aftertaste
A1	*Sticky/tacky* *Syrupy* *Sappy* *Residue* *Bruised/rotting* *Most sprouting* *Mucus like* *Stringy**	*Vegetable/savoury* *Grassy* *Overripe banana* *Overripe melon* *Mouldy citrus* *Yeasty*	*Inedible*	*Gel like coating/egg albumin* *Outside mushy* *Resistant*	*Inedible*
A2	*Sweating* *Bruising* *Sprouting* *Seed coating separating* Some VERY under ripe samples still look fine	*Strong* *Old peaches* *Very sweet* *Cheesy/musty/old* *Yeasty/savoury*	*Inedible*	*Tough/firm* *Rubbery* *Gooey/sticky* *Slimy*	*Inedible*

Sample	Appearance	Aroma	Flavour	Texture (assessed using knife)	Aftertaste
B1	*Rotten/bruised* *Dark* *Black mould* *Mucus stringy* *Weepy* *Sprouting* *Milky juices* *White mould*	*Beer ferment* *Yeasty* *Overripe fruit* *Old cheese*	*Inedible*	*Slimy/slippery* *Webs of goo* *Firm* *Mushy outside* *Juicy*	*Inedible*
B2	*Sweating* *Sappy* *Glossy* *Little bruising* *Sprouting* *Seed rotting*	*Off rock melon* *Green banana* *Beer ferment* *Yeasty* *Sweat/bile* *Cheesy*	*Inedible*	*Mushy outside* *Rubbery* *Internal bruising*	*Inedible*
C1	*Thawed frozen fruit* *Moist* *Clear juices* NO sticky goo *Bruised* *Shrivelled like prune* *Seed splitting/rotting* *Translucent*	*Rotten pineapple* *Potato/savoury* *Pea water* *Steamed zucchini*	*Inedible*	*Malleable but tough (bendy carrot)* *Fibrous*	*Inedible*
C2	NO sticky goo Clear juices Glossy/shiny *Bruising*	*Grassy* *Raw potato* *Rotting salad* *medicinal*	*Inedible*	Tough Firm/rubbery *Flaccid*	*Inedible*

Table A11-5. Qualitative assessment of samples at Day 17.

** Attributes noted in italics were considered negative/taints of the samples and not associated with a fresh jackfruit product.*

Sample	Appearance	Aroma	Flavour	Texture (assessed using knife)	Aftertaste
A1	*Rotting/breaking down* *Very bruised* *White mould* *Gooey/slimy/sweaty* *Yellow mucus like**	*VERY strong* *Cheesy/musty* *Fermented/rotting fruit* *Bile/acrid*	*Inedible*	*Soft seed* *'bendy carrot'* *Sticky* *Rubbery but malleable*	*Inedible*
A2	*Bruised* *Juices starting to go cloudy* *Cooked pumpkin look* *Better than A1*	Rockmelon *Cucumber* *Not as strong as A1* *Old banana* *Overripe fruit* *Old pineapple/orange*	*Inedible*	Maintained its shape – better than A1 Crispy Firm/rubbery *Fibrous*	*Inedible*
B1	*White/black/pink/blue moulds* *Brown/yellow mucus* *Slimy/sticky*	*Yeasty* *Mouldy citrus* *Strong orange/sweet lolly* *grassy*	*Inedible*	*Tough outside* *Mushy inside* *Fibrous* *Sticky/tacky*	*Inedible*

Sample	Appearance	Aroma	Flavour	Texture (assessed using knife)	Aftertaste
B2	*White/black/pink mould* *Bruised inside* *Webby/sticky* *Yellow/cream mucus* *Sprouting* *Slightly better than A1*	*Rock melon* *Pea water* *Cucumber* *Pumpkin* *Grassy/barnyard* *Sweaty* *Rotting fruit*	*Inedible*	*Firm/crunchy* *Some soft areas* *Fibrous*	*Inedible*
C1	*Translucent* *Wrinkly* *Bruised* Deep colour Clear juice NOT mucus-like *Speckled* *Sprouting*	*Potato* *Pea water* *Sweet orange lolly* *Sweet roast potato* *Grassy green* *Pineapple* *Slightly musty medicinal*	*Inedible*	*Juicy (clear)* *'Bendy carrot'* *Un-fresh vegetables* *Rubbery but not crunchy* *Breaking down inside*	*Inedible*
C2	Clear juice (not as much as C1) Deep colour *Wrinkly* Plumper than C1 *Slightly bruised* *Sprouting*	*Vegetables* *Raw potato* *Grassy* *Bean sprouts* *Pickled vegetables/vinegary* *Mung beans*	*Inedible*	*Mushy* *'bendy carrot'* *Rubbery but not crunchy*	*Inedible*

Packaging evaluation

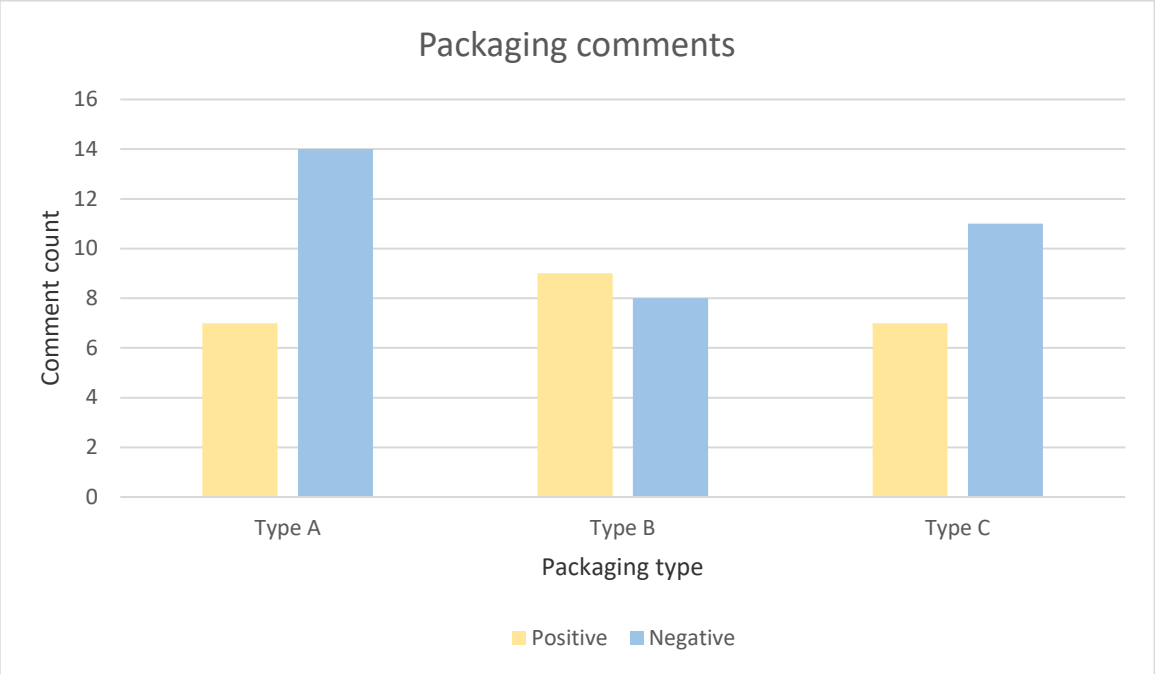


Figure A11-2. Packaging comments; collated into positive and negative statements per packaging type.

Discussion

Qualitative assessment

Sample A1 (black tray with barrier film, no dip)

- **Day 1**, sample exhibited slight external bruising on the aril however there was no negative impact on the eating quality.
- **Day 8,** the bruising had spread significantly across the arils giving them a rotten appearance, some arils assessed had also begun sprouting from their seed. The aroma detected was that of overripe/fermenting fruit and the flavour has developed musty/off characteristics. The texture was not yet influenced.
- **Day 14,** the arils were coated in a mucus-like liquid and continued to look rotten. A savoury aroma dominated, characterised by grassy/mouldy citrus attributes. The samples were deemed inedible at this time point.
- **Day 17,** white mould was present on the arils and a strong cheesy aroma was noted.

Sample A2 (black tray with barrier film with dip)

- **Day 1,** the arils had some external bruising akin to sample A1. The arils appeared to be retaining a watery fluid internally, but no impact on eating quality was noted
- **Day 8,** patchy bruising was evident and seeds had begun to sprout. Slight bitter/chemical notes were detected in the flavour but there with little else to not regarding a change in eating quality.
- **Day 14,** moisture droplets were present on the outside of the arils, noted as a sweaty appearance. The aroma given off was stronger than usual with cheesy characteristics. The sample as considered inedible at this time point.
- **Day 17,** the moisture droplets were now cloudy in appearance and the aroma was strong, smelling of old/overripe fruit.

Summary: It was concluded that sample A2 had performed better than A1 overall, showing a slower decline in appearance and eating quality.

Sample B1 (PP packaging, no dip)

- **Day 1,** sample was considered to have a very palatable eating quality. A little bruising was apparent at the tip and a slight chemical flavour was noted.
- **Day 8,** however sample had deteriorated with a dry and bruised appearance, fermented/yeasty/off-citrus aroma, slimy coating and tough/fibrous texture. There was very little flavour to this sample in general.
- **Day 14,** was considered inedible due to rotten appearance. Black and white moulds were present and the aril was weeping milk-like juices. The aroma was strong, akin to that of yeast/old cheese.
- **Day 17,** white, black, pink and blue moulds were present and the juices apparent at Day 14 were not darker in colour, akin to brown mucus.

Sample B2 (PP packaging with dip)

- **Day 1**, sample was considered to be pleasant despite slight bruising of the aril.
- **Day 8** some samples had grown large sprouts protruding through the flesh of the fruit. The sample was very moist/watery on the outside which was reflected in the mild, watery flavour. The texture of sample B2 was less crunchy than B1 at Day 8.

- **Day 14** sample B2 was also considered inedible; the sample appeared to be losing a lot of moisture, the aroma was now akin to that of yeast/cheesy/bile and the outside of the sample was mushy.
- **Day 17** white, black and pink mould was present on the sample. It was sticky to touch and covered in a yellow mucus-like liquid. The aroma of the sample was savoury, like green peas/pumpkin and also had characteristics of rotten fruit.

Summary: Both samples B1 and B2 deteriorated at similar rates, however the crunchy/firm texture that characterises jackfruit was lost earlier in sample B2.

Sample C1 (vacuum packaging, no dip)

- **Day 1**, the jackfruit arils of sample C1 were already visually impaired. The packaging had caused the samples to become squashed/wrinkled and bruised in appearance. The eating quality however had not be negatively affected.
- **Day 8**, the appearance of sample was considered unpleasant and off-putting, the arils looked shrivelled and had lost large quantities of moisture. The aroma of sample C1 was also unfavourable, with notes of musty/overripe pineapple. For this reason the sample was considered inedible.
- **Day 14**, sample was highly shrivelled in appearance, described as prune-like/bruised/rotting. The aroma was considered savoury in nature with notes of peat water/potato/steamed zucchini. However, it is important to note that no stickiness/mucus-like fluids were present.
- **Day 17**, sample had not changed significantly to that of Day 14. The juices present were still clear, the arils were shrivelled in appearance and the aroma savoury, with slight medicinal characteristics now present.

Sample C2 (vacuum packaging with dip)

- **Day 1,** sample was considered to look more shrivelled and bruised than sample C1. The aroma was already characterised by fermented/overripe fruit notes as well as slight alcohol/plastic. The flavour of sample C2 at Day 1 was already impaired, being described as pickled/fermented/sour and slightly rotting.
- **Day 8**, sample was considered inedible due to the highly bruised appearance and aroma of off-cheese and potato-peelings.
- **Day 14**, sample was losing large quantities of juice, giving a glossy/shiny appearance, these juices were still clear. The aroma however was of raw potato/rotting salad/grassy with medicinal notes.
- **Day 17**, samples C2 appeared plumper than C1 despite the loss of juice however the aroma continued to deteriorate, being characterised by attributes including bean sprouts/pickled vegetables/mung beans.

Summary: Sample C2 deteriorated more quickly than C1 with regards to appearance. By Day 17 both samples had lost significant amounts of moisture, but C1 more so than C2. The aroma and flavour of both C1 and C2 deteriorated extremely quickly, fastest of all samples in this study.

Packaging format evaluation

Type A (barrier film packaging)

Comments indicate a general negative attitude toward this packaging type. Primary concerns are with regard to the amount of free space within the packaging allowing for significant movement of individual jackfruit arils. Consumers expressed concern with potential bruising during transit and an indication of less value-for-money. In addition comments were made concerning the packaging type being more commonly used for

meat and fish products as well as the seal being hard to remove, not user-friendly and non-resealable. However, the contrasting colour between the black tray and the yellow/orange fruit was liked.

Type B (PP packaging)

Comments provide a balanced positive/negative opinion of this packaging type. Consumers were pleased with the clear packaging, providing a 360° view of the product, the reusable and resealable packaging as well as the firm material which would protect the product during transport. However, they raised concerns over the hygiene of the packaging, recommending that an additional seal would be required prior to distribution.

Type C (vacuum packaging)

In line with the sensory qualitative assessment of the jackfruit packaged in this packaging type, the appearance of the product within the packaging was considered off-putting by the consumers. Comments indicated that fruit looked/was likely to become damaged either during transit or by shoppers handling he product when in store. Consumers did however like the 360° view of the product and the hygienic nature of vacuum-packaging.

Chemistry results

Chemical traits pH, TA, Brix, and Moisture, involved nearly all significant interactions (in all packaging methods). These interactions were mainly due to Vacuum packaging following a different pattern. However, significant differences between pairs of treatments were not clear enough to identify trends. All values for ascorbic acid were similar and very low; so analysis of variance could not be carried out. Oxygen and carbon dioxide (traits only relevant for Barrier film packaging) were only affected by day of storage, with significant differences observed for day 17.

All three microbiology traits presented high variability for this experiment. Yeast and mould were measured in a mixture of categorical and numerical values, which complicated the analyses. Yeast counts were too high from day 8 for Standard PP and Barrier film packages, and kept increasing although in a very variable way for vacuum pack. Standard plate count could be analysed after removing day 8. Results from microbiology traits are highly unreliable.

Results for colour traits (both using the Minolta and Nix instruments) were highly influenced by the fact that vacuum packaging at day 1 had quite low values, i.e. darker than any other treatment combination in the experiment. For this reason, vacuum packaging followed a different mean pattern, being responsible for many significant interactions. Results from colour traits must be handled with caution.

Shelf life discussion

Overall, sensory was the main focus in this study that determines fruit quality over the shelf life period. Out of the three packaging variations trialled, packaging type C (Vacuum pack) had the poorest performance. Due to very poor fruit quality on day 8 due to bruising, off flavour and colour measurements, which show a much darker appearance in comparison with the other two types of packaging. Furthermore fruit deterioration accelerated quickly after day 8 with increase in moisture loss and decline in aroma and flavour. The pre-treatment dips seems to have little or no effect in prolonging the shelf life in packaging type C.

Both packaging type A (barrier packaging) and B (PP packaging) had similar performance with product lasting a minimum 8 days and being inedible by the panel by day 14. Pre-treatment dips had similar or no effect on packaging type B however improved fruit quality on packaging type A on day 8.

All samples have shown general issues with fruit quality and with some seed sprouting internally in the jackfruit arils over the shelf life. This was possibly related to fruit maturity

harvesting and extended cold storage prior to the trial. Microbiology traits also had presented problems with high yeast counts affecting mould results, there were also large TPC variability in the samples tested. Additionally, a research program survey was conducted on the 21st March 2017 to local retailers and wholesalers for commercial feedback, all comments were recorded in a written survey available in Attachment 7.

Component three: Packaging study methodology follow up (2018)

Sample preparation and pre-treatment

This study focuses on re-evaluating previous trials completed in section 4.2 Component Three: Packaging Study Methodology. The main emphasis on this trial will be on microbiological testing on both total plate count, yeast and mould using perforated barrier packaging materials described in Section 4.2.3-Materials and Packaging.

Fourteen jackfruits of *Orange Crunch variety* (Rajang Variety) with similar green to light yellow skin colour at pre-ripening stage were hand-picked at Mareeba, North Queensland, Stewart Bros Fruit Farms on 5th February 2018. All produce were hand packaged in cushioned cartons to prevent physical damage then transported to Health and Food Science Precinct in Brisbane via Romeos Marketing Qld cold chain transport at 4°C. Samples were checked on arrival to insure good uniformity for ripeness and any deteriorated fruit bulbs found were cut and disposed.

The external surface of the produce were dipped in Tsunami 100 sanitising solution at 80 ppm, dried for 10 minutes and stored at ambient temperature (22°C). Jackfruit was stored until a yellow to light brown ripening maturity was reached prior to packaging trial on 15th February 2018.

In conjunction with previous trial methods described in 5.2.2- Sample Preparation and Pre-treatment, all packaged samples were rapidly cooled from ambient temperature (22°C) to 4°C in a freezer before transferring to cold storage.

Sensory evaluation

For the shelf life trial days 1, 5, 12, 15, 22 and 26; two to four internal IFT participants were invited to complete a sensory evaluation worksheet for three random jackfruit packaging. One aril were selected from each packaging and comments were noted for appearance, aroma, flavour, texture and aftertastes and a final overall hedonic liking score of 1-9. Individual comments were collated and categorised in Table A11-6.

Microbiological testing

For shelf life testing, total plate count (TPC), yeast and mould tests were completed as per test methods stated in section 4.1.12, for days 1, 3, 6, 9, 13, 16, 20, 23 and 26. Three individual jackfruit from each of the three packaging types were randomly selected for each shelf life test. For this one aril was selected per packaging and each test were completed in duplicates. All results were compiled and summarised in Table A11-7.

Shelf life trial

Table A11-6. Summary of fresh cut jackfruit trial (2018)

Shelf Life	Sensory Comments	Average liking score (1-9)	Mould or significant colour changes	Photo
Day 1	Colour of arils were variable from pale yellow to dark orange. Flavours were described as sweet, banana, ripe and melon. Texture was consistently firm and crunchy. No off aroma or aftertaste were noted.	6.8	No	
Day 5	Colour of arils were variable from pale yellow to dark orange. Packaging was clear with no fogging or juice leaking. Flavours were described as fresh typical, ripe, sweet but slight bitterness were noted Texture was consistently firm and crunchy. No off aroma or and minor bitter aftertaste were noted.	5.9	No	
Day 12	Some arils showing slight bruising and slight changes, most still intact with pale to dark orange colour. Packaging was clear with no fogging or juice leaking. Flavours were described as fresh typical, ripe, sweet but slight bitterness were noted Texture was consistently firm and crunchy. No off aroma or and minor bitter aftertaste were noted.	5.0	Minor colour change only	
Day 15	Some arils showing slight bruising and slight changes, moist/translucent and darkening noted. Packaging was clear with no fogging or juice leaking. Flavours were described as tropical, light bitter, sweet and reduced flavour intensity. Texture was consistently firm and crunchy. No off aroma or and minor bitter aftertaste were noted.	5.3	Minor colour change only	
Day 22	Most changes were noted in day 22, with darker patches and colour changes with some developing a slight slimy appearance. Slight off aromas were detected and some arils were unpleasant and losing flavour. Texture was becoming spongy with less crunch.	1.2	Moderate colour change only	
Day 26	Similar appearance as day 22 with darkening and bruising with riper arils. Off aroma notes were very noticeable with alcohol/fermentation odour. Product was deemed not fit for taste testing.	NA	Moderate colour change only	

Microbiological results

Table A11-7. Microbiological summary of fresh cut jackfruit trial (2018)

Shelf life	TPC	Yeast	Mould
Day 1	200	400	<100
	100	<100	<100
	400	<100	<100
Day 3	100	<100	<100
	<100	<100	<100
	200	<100	<100
Day 6	100	<100	<100
	<100	<100	<100
	<100	<100	<100
Day 9	<100	<100	<100
	<100	<100	<100
	2000	<100	<100
Day 13	200	400	100
	3100	<100	<100
	400	<100	<100
Day 16	<100	<100	<100
	<100	<100	<100
	<100	<100	<100
Day 20	600	<100	<100
	<100	<100	<100
	300	<100	<100
Day 23	100	<100	<100
	<100	<100	<100
	<100	<100	<100
Day 26	<100	<100	<100
	<100	<100	<100
	19000	<100	<100

Discussion

In comparison with the previous study in 2017, samples in this trial had higher fruit quality and no seed sprouts observed in the jackfruit arils over the shelf life trial. The fruit maturity selection from the farm was improved and is evident from the higher average brix results completed on the day of the trial compared to the previous day 1 result (16.72 and 15.80,. Furthermore a shorter storage time (approximately one week) prior to processing also assisted with the fruit quality and decreases bacterial growth opportunities on raw materials.

The microbiological tests were significantly improved with little or no TPC, yeast or mould growth observed in all samples through from day 1 to day 26. These results also are consistent with sensory comments with no mould or yeast growth observed by participants.

Moreover, preliminary sensory evaluation showed consistent results from day 1 to day 15 with slight increase in bitterness but no changes in texture or off aromas noted. Minor colour changes and bruises become more apparent from day 12 with overall fruit quality changes were very noticeable at day 22 including off notes, unpleasant flavours and spongey texture.

Freeze drying preliminary trial

Methodology and materials

In addition 4 kg of jackfruit was separated from total sample batch that arrived on 8th February 2018. In this trail a freeze drying unit (Gamma 1-16 LSCplus, Christ, Osterode am Harz, Germany) in the pilot plant facility was utilised

Processing

1. Preparation of fresh jackfruit arils by evenly spacing out each sample on eight separate shelf plates (Approximately 500 g per shelf).
2. Pre-freeze the samples and plates prior to drying by storing in separate a -40°C freezer for 48 hours.
3. Preparation of the main unit by removing all water residues from previous drying runs and warming up the vacuum pump for at least 15 minutes.
4. Commence main drying phase by sublimation and starting the vacuum pump process.
5. The drying phase is completed by confirming when the product temperature and shelf temperature is near identical (or no further changes).

1 Ice condenser chamber
2 LSCplus user interface(see chapter 6.5.1 - "User interface")

Figure A11-3. Layout of main drying unit

Table A11-8. Jackfruit photos on all processing stages

Processing stages	Photo
Fresh jackfruit arils on shelf plates prior to both deep freezing and freeze drying process. Total of 4 kg fruit spread over eight plates.	

Processing stages	Photo
Jackfruit arils on shelf plates during the freeze drying process (72 hours total). Fruit was removed from plate and sliced further into smaller pieces to assist with process.	
Jackfruit arils on shelf plates after further freeze drying process (120 hours total)	

Results

Table 1. Freeze drying processing weight loss

Sample #	Initial product weight (g)	Freeze dried weight (g)	Weight loss %
1	410	101	-75
2	418	116	-72
3	550	96	-83
4	537	96	-82
5	511	119	-77
6	491	95	-81
7	599	104	-83
8	557	98	-82
Total Average	**509**	**103**	**-79**
Standard Deviation	67	9	4

Table A11-10. Freeze drying moisture results

Product	Moisture average (%)	Standard Deviation
Fruit after freeze drying process	5.90	0.1
	5.85	
	5.76	
	5.83	

Average	**5.83**	
Fresh fruit prior to freeze drying process	80.07	1.3
	80.15	
	82.90	
	81.53	
Average	**81.16**	

Discussion

For the calculation of the product moisture, the weight prior to and after freeze drying were utilised as per method described in 4.2.9 Estimation of Moisture Content using AOAC 920.151. The average results for the samples prior to freeze drying process resulted in an average of 81.16±1.3 and the samples after freeze drying process resulted in an average of 5.83±0.1. Therefore the total moisture loss was in the vicinity of 79%.

Overall the samples were shown to be relatively inconsistent as shown in Table A11-8 with some samples fully dried resulting in a lighter colour product and a crispy texture while some samples had a darker colour with a chewy, rubbery texture similar to other sun dried fruits. It is evident that the equipment utilised in this trial were not sufficient in capacity to reduce product moisture for the jackfruit samples tested. Processing recommendations for further trials to improve the process;

- Decrease total fruits freeze dried per processing run (from 4 kg to 2 kg).
- Increase processing time to allow for more moisture to be removed from the product.
- Using smaller, thinner, more uniform individual sample sizes initially to increase product surface area should be more consistent.
- Using an alternative freeze dryer with higher power and drying capabilities.

Attachments

Attachment A11-1: Sensory vocabulary

Descriptor	Anchors	Definition/standard
Appearance		
Colour consistency	Low-high	how consistent the colour of the aril is from very inconsistent (low) to consistent (high)
Aroma		
Jammy	None-high	Bonne Maman strawberry conserve
Overripe banana	None-high	Overripe almost black Cavendish banana
Musty (melon)	None-high	Cantaloupe/rock melon
Pineapple	None-high	Fresh pineapple
Mandarin	None-high	Fresh mandarin
Orange lolly	None-high	Orange cordial
Flavour		
Overripe banana	None-high	Overripe almost black Cavendish banana
Vanilla	None-high	Vanilla bean paste
Artificial sweet	None-high	
Liquorice	None-high	Fresh soft liquorice
Orange lolly	None-high	Orange cordial
Mandarin	None-high	Fresh mandarin
Pineapple	None-high	Fresh pineapple
Texture		
Firmness	Low-high	Initial bite between incisors; including resistance and crunch
Rubbery	Low-high	On chewing between molars; the amount required to break down sample
Fibrous	None-high	Presence of fibres on chew
Juiciness	None-high	
Aftertaste		
Artificial sweet	None-high	
Cheese (musty)	None-high	Soft cheese; brie/camembert
Bitter/savoury	None-high	
Green banana	None-high	Under ripe Cavendish banana
Tongue tingling	None-high	Oral sensation

Attachment A11-2: Individual packaging comments by packaging type.

Packaging type	Comments
Type A	Would purchase but concerned with bruising as fruit rolling around Would need easy peel tab Looks fresh and easy to view against the black tray Wouldn't buy as tray too big for fruit, needs to fit product size Packaging usually associated with meat and fish Need smaller tray as fruit might move and get bruised Clear and transparent – can see the product clearly Nice contrast in colour between JF and black tray Clear to see what your buying Looks fresh Needs smaller tray for number of arils Easy to see Moving of arils may bruise them Too little product in big pack Don't like colour of packaging Wouldn't choose this Sealed and can see product But product slips around in container Hard to grip corner to open Too few samples for size of container Rolling around could bruise
Type B	Like the reusable container as it reseals and would keep fruit fresh Easy to store in fridge or transport Easier to open product I would buy in this packaging as I like the size and firm material Container may open on transit Clear and transparent – can see product clearly Can see the product but needs something to secure it shut Low hygiene as anyone can open it and touch them Moisture build up made it harder to see them Like the clear packaging A full container indicates better value Might be opened easily impacting shelf life Looks cheap next to #1 Would need extra sealing Too easily opened/infiltrate with germs Good that you can view product from all angles

Packaging type	Comments
Type C	Does not looks aesthetically pleasing Looks hard to open Fruit looks like it might get damaged on transit I wouldn't buy in this packaging as JF looks dissolved and moist and over mature which would make me question the flavour of product Fruit might get squashed/damaged Looks too squashed and squeezed which may bruise/damage product But it would keep it succulent and ripe for consumption (maybe vac pack then in a tray?) Needs dressing up in a tray for consumer purchase Too much pressure has squashed the arils so juice comes out Looks most hygienic and pleasant as gives more focus on fruit contents rather than packaging I would go for this as looks like it would keep fresher for longer Looks like would keep fresher for longer Can see product well Smaller vac pack bag would be better It's good that product doesn't move around Temptation to squeeze the fruit for ripeness (like Avocados!) Not visually appealing But good ability to view before buying

Attachment A11-3: Castaway container product information sheet

Product Information Sheet

Product Range:	Castaway MicroReady Rectangular Takeaway Containers
Product Codes:	CA-CM500, CA-CM500-BLK, CA-CM650, CA-CM650-BLK, CA-CM700, CA-CM750, CA-CM750-BLK, CA-CM1000, CA-CMLID
Description:	Plastic takeaway food containers and lids.
Material:	Polypropylene.
Safe Handling:	Safe for use in a microwave.
Storage:	Store in a cool dry area. Keep away from fire.
Environmental Considerations:	Recyclable. ISO 14001: 2004 Certificate No. 09244/C/0001/UK/EN
Food Safety/ Quality Management Certifications:	Material safety data-sheet HP640U ISO 9001:2008 Certificate No. 92440/B/0001/UK/EN

Attachment A11-4: BT97 barrier tray product specification

PRODUCT SPECIFICATION

Product: 9x7" MAP Barrier Tray
Alto Code: As stated below
Customer: Various
Issue Date: 23/02/2013
Prepared by: Jim Cowan, Technical Manager

Alto Packaging Limited
1444 Railway Road
RD 11, PO Box 944
Hastings, New Zealand
Telephone 0800 526 000
Facsimile 0800 527 000
www.alto.co.nz

1. **Product Description:**

BT97 Barrier Tray – various depths. 9"x7" (nominal), laminated tray for extended storage life packing of meat.

This specification covers the following trays, and variants of them (eg. Other colours and trays with soaker pads added):

3002220	TRAY,BARR;BT97/30,BLK
3002221	TRAY,BARR;BT97/40,BLK
3008616	TRAY,BARR;BT97/50,BLK
3002222	TRAY,BARR;BT97/55,BLK
3009453	TRAY,BARR;BT97/60,BLK

2. **Manufacturing Specifications:**

Raw Material:
Tray materials - High Impact Polystyrene (HIPS), General Purpose Polystyrene (GPPS), Butadiene-Styrene Block Copolymer (K-Resin).

Laminate - Proprietary barrier film structure with a polyethylene seal layer.

Soaker Pad (where applicable) – Thermasorb absorbent pads containing sodium polyacrylate polymer (super absorbent polymer).

Material Compliance:
All materials are food grade polymers that meet the requirements of the US FDA code of Federal Regulations, Title 21, Section 177.1640, for safe use as a component of articles intended for use in contact with food.

Thermasorb absorbent pads comply with the following standards relating to safe food contact:

Australian Food Contact Standard AS2070;

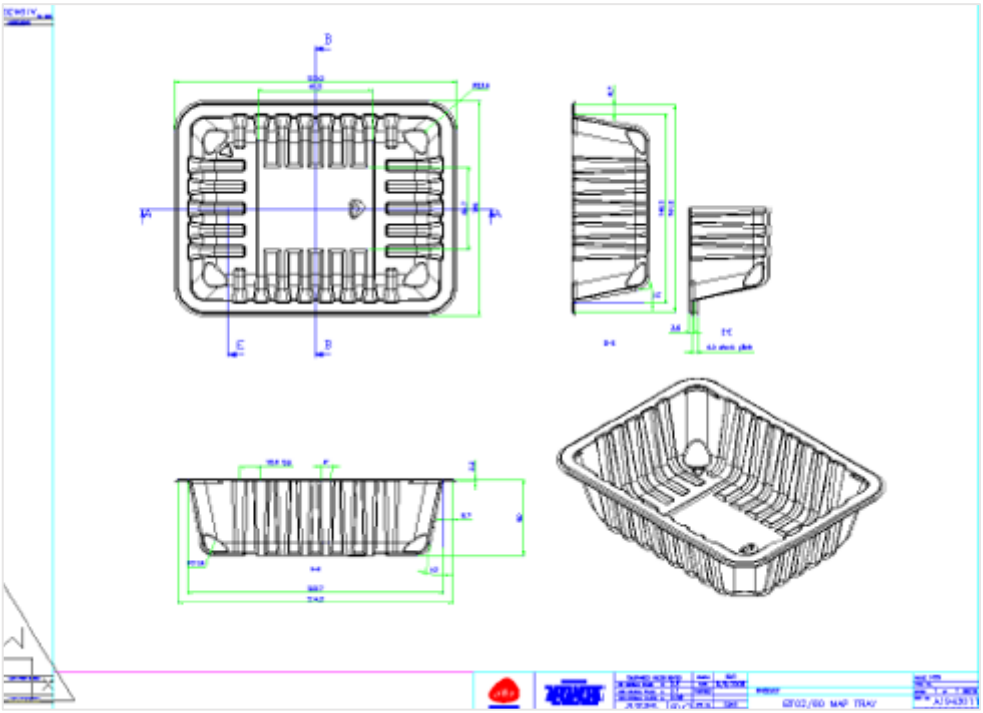
NZFSA Industry Standard 6/ Industry Agreed Standard 6, Parts 13.3.3

US Code of Federal Regulations, Title 21 Parts 170-199;

EC Directive 2002/72/EC as amended.

Colours:
Black, White, Blue, Green, Silver, Clear (Other colours by arrangement)

Soaker Pads:
Available with soaker pads pre-loaded. (45ml, 75ml, 100ml, 150ml)

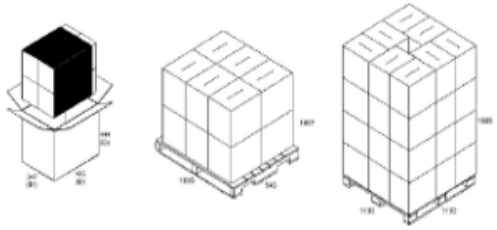


Product dimensions (Ext):	**Length:**	**220mm**
	Width:	**168mm**
	Depth:	**30, 40, 50, 55, 60mm**
	Trim tolerance (LxW): ± 2mm	
Product weight:	**23.5g (+/- 5%)**	

3. Packaging and Labelling:

Case stack:	**105 - 125/row (depending on tray variant) x 4 rows, in one plastic liner**
Case quantity:	**420 - 500**
Label Data:	**One label per case: Description, Alto code, Case Quantity, Date of manufacture, Production order number, & Case number**
Pallet Stack:	**NZ: 6 cases/layer x 2 layers – Qty 5,040 – 6,000**
	AU: 8 cases/layer x 4 layers – Qty 13,440 – 16,000

Representation only



4. Special Instructions or Requirements

Before use trays should be stored in their original packaging at temperatures below 40°C and away from direct sunlight.

Care must be taken to ensure that the sealing area of the tray flange is kept clean, and free of any debris or food product. Any contaminate on the seal area may result in an inadequate lid film bond.

Attachment A11-5: Lid1050S product specification

PROPERTIES

Applications	Lidstock for Barrier Foam & Solid Polypropylene Barrier Tray
Sales Type	LID 1050S - NLZ0046
Nominal Total Gauge	1.0 mils
Sealant Type	LLDPE
Widths Available (In.)	9.0 – 30.0
Roll Footage (Ft.)	5,250
Tensile Strength at Break (1000 psi)	Longitudinal-14.7 Transverse-13.0
Oxygen Transmission cc (24 hr., m²) 40°F., 100% RH 40°F., 0% RH 73°F., 0% RH	 Greater then 10,000 Greater then 10,000 Greater then 10,000
Moisture Vapor Transmission Gsm. (24 hr., 100 in.²) 40°F., 100% RH	Less then 0.10
Haze ASTM D-1003	9.5
Clarity ASTM D-1746	70.2
Recommended Storage Conditions	90°F. Max. Dry Storage
Minimum Use Temperature	-60°F

The above are nominal specifications. Performance will vary with each application.

This information represents our best judgment based on the work done, but the Company assumes no liability whatsoever in connection with the use of information or findings contained herein.

Sealed Air
CRYOVAC
Food Packaging Systems

To find out more about Cryovac's total systems approach to packaging, phone your Cryovac specialist at the nearest Regional office.

100 Rogers Bridge Rd
Duncan, SC 29334
(864) 433-3800

157 N. Commerce Way
Bethlehem, PA 18017-8933
(610) 694-0606

8009 34th Avenue S.
Suite 960
Bloomington, MN 55425
(612) 854-2556

440 Regency Parkway Drive
Suite 225
Omaha, NE 68114-3714
(402) 391-2083

12600 West Colfax, Suite A-270
Denver, CO 80215
(303) 233-6558

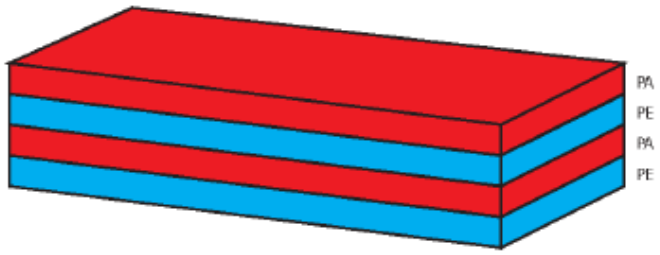
Attachment A11-6: Vacuum packaging product specification

December 2015

caspak
packaging fresh ideas

Technical Data Sheet

70um Plain CoEx Vac Bag



Property	Test Method	Value	Unit
Thickness	ASTM D4801	70	um
Oxygen Transmission Rate 23°C, Dry	ASTM D3985	56	cc / m^2 / 24 hours
Water Vapour Transmission Rate 38°C, 90% RH	ASTM F1249-06	7	g / m^2 / 24 hours
Tensile Strength (MD)	ASTM D882	25	MPa
Tensile Strength (TD)	ASTM D882	25	MPa

All of the raw materials used in the making of the films/pouches are approved for food contact according to the FDA/USDA standards by the material manufacturers and comply with requirements set forth in the FDA/USDA regulations 21 CFR section 177.1520 (Polyethylene), 177.1360 (EVOH), 175.105 (Adhesives), 177.1500 (Polyamide), 177.1330 (Ionomer) and 177.1350, 177.1570 (EP film).

CPSS REV 0

Attachment A11-7: Research program survey

Queensland Government

ACIAR DAF Jackfruit Research Program Survey

As part of the collaborators ongoing commitment to research and feedback for development of new products for our clients we would be grateful if you would complete the following questionnaire.

We will endeavour to use the results from this simple questionnaire to ensure we provide commercial feedback back to the grower.
Please spare a few minutes of your time, and return this questionnaire by email to Colin.leung@daf.qld.gov.au at Innovative Food Technologies, DAF, by 30th April 2016.
Thank you for your assistance.

1. Do you currently sell Jackfruit in Queensland? Yes / No
   If yes, at what volume/quantity? 1 TON PER SEASON (4 MONTHS OF THE YEAR)
2. Do you currently sell Jackfruit in states other than QLD? Yes / No
   If yes, at what volume/quantity? ALL BRISBANE BASED
3. Do you currently sell any fresh cut product? Yes / No WHOLESALE ONLY A213 KG
   If yes, what product(s) and how is it packaged? # 516 KG
4. Do you think there is growth opportunities for selling Jackfruit (whole) in Australia? Yes / No
   ~~MAYBE~~ MINIMAL GROWTH UNLESS BIGGER CHAINS STOCK PRODUCT.
5. Do you think there is will be customer demand and growth opportunities for Jackfruit fresh cut packaged product in vacuum or modified atmosphere packaging?
   YES ESPECIALLY IN ~~ASIAN~~ CHAIN 450g IDEAL
6. How do you think the DAF research group could assist growers and marketplace to promote new products? PUT GROWERS DIRECTLY IN TOUCH WITH COMMERCIAL.
   - RETAIL AND INFORMATION / ASPECT
   # MUST GO THROUGH AGENT MULTIPLE GROWER
7. Comments on colour and texture of the jackfruit sample.
   COLOUR, GOOD - PATCHY
   TEXTURE, GOOD - CRUNCHY
8. Comments on flavour of the jackfruit sample.
   FLAVOR, GOOD - NORMAL JACKFRUIT
   # SELL AT CAUCASIAN MARKET WITH LOW SUPPLY AROUND AREA.
9. What do you think is the ideal product size /weight of a fresh cut packaged product?
   450g - 500g - SMALLER DIMENSION USUAL APPEARANCE IS IMPORTANT.
10. What do you think about the potential MAP and Vacuum packaging?
    PREPACKING PRODUCT HAS FUTURE IF
    VACUUM LOOKS NICE BUT PREFER MAP, (LOOKS IMPORTED)
    AND NOT SUITABLE FOR CAUCASIAN MARKET

Name.. [redacted]

Signature. [redacted]

Date. 21/3/16

(WHOLESALE)

* DEMAND > SUPPLY
# USUAL ASPECT IS IMPORTANT, MUST LOOK FULL
+ IDEAL SHELF LIFE 7 TO MINIMUM 2 DAYS SUPPLY CHAIN ~~END~~ 5 DAYS ON SHELF.

Queensland Government

ACIAR DAF Jackfruit Research Program Survey

As part of the collaborators ongoing commitment to research and feedback for development of new products for our clients we would be grateful if you would complete the following questionnaire.

We will endeavour to use the results from this simple questionnaire to ensure we provide commercial feedback back to the grower.
Please spare a few minutes of your time, and return this questionnaire by email to Colin.leung@daf.qld.gov.au at Innovative Food Technologies, DAF, by 30th April 2016.
Thank you for your assistance.

BOUGHT OUT SATURDAY/ SHARE WITH FAMILY

1. Do you currently sell Jackfruit in Queensland? Yes / No
   If yes, at what volume/quantity? LOCAL 1 TON DURING SEASON
2. Do you currently sell Jackfruit in states other than QLD? Yes / No
   If yes, at what volume/quantity?
3. Do you currently sell any fresh cut product? Yes / No QUARTERS FILM

   If yes, what product(s) and how is it packaged? FULL CONFIDENCE READY FOR EATING NO COLD STORE AMBIENT STORAGE
4. Do you think there is growth opportunities for selling Jackfruit (whole) in Australia? Yes/No
   SLOW MOVER
5. Do you think there is will be customer demand and growth opportunities for Jackfruit fresh cut packaged product in vacuum or modified atmosphere packaging?
   - NOT IN CHAIN
   - SPECIALTY FRUIT SHOP)

   SMALL + SLOW MOVER - TROPICAL FRUIT
6. How do you think the DAF research group could assist growers and marketplace to promote new products?
   - FACILITATION
   - FOCUS ON GROWER

   + NO FROZEN PRODUCT
7. Comments on colour and texture of the jackfruit sample.
   AVERAGE COLOUR /
8. Comments on flavour of the jackfruit sample.
   NA

   - KENAI MUCH HAS POTENTIAL
9. What do you think is the ideal product size /weight of a fresh cut packaged product?
   500g BOTH TYPES
10. What do you think about the potential MAP and Vacuum packaging?
    PREFER CUT THAN PACKAGED AND/OR VACUUM SEAL (SLIGHT FUNGUS)

Name.... MICHAEL NGUYEN

Signature.....

Date....31/3/17.....

(SHOP OWNER)

IS 3.0 FROZEN JACKFRUIT IMPORT SELLS VERY WELL

Attachment A11-8: NIX colorimeter product specification

NIX PRO COMPETITIVE ADVANTAGES

NIX PRO COLOR SENSOR

- Patented shape that blocks out all ambient light while enabling precise sensor placement
- Intuitive interface that can be adjusted to fit unique use cases
- Has no moving parts, is durable, and easy to clean
- Our factory-calibrated sensors require no user calibration which minimizes downtime
- Capable of comparing between two colors (DE76 and DE2000)
- Best-match finding with pre-loaded color databases
- 45/0° measurement geometry optimizes accuracy on glossy surfaces
- No calibration tiles or stickers that can get lost, damaged, faded, or soiled
- Wireless use for maximum portability
- Up to 3,000 scans or six months standby on a single charge
- The sensor hardware can be white-labeled

TECHNICAL SPECIFICATIONS

Measuring Geometry	45 / 0°
Light Source	2x High-CRI LEDs designed specifically for color reproduction
Repeatability	< 0.1 DE2000
Inter-Instrument Agreement	Average of < 0.7 DE2000
Aperture Size	Circular, 15mm diameter
Battery	Rechargeable Lithium Polymer battery; >3,000 scans/charge
Interface	Bluetooth Low Energy & USB
Weight	43g
Dimensions	60mm x 42mm (w x h)

QUESTIONS?

Nix Sensor Ltd.
175 Longwood Road South
Suite 408A, Hamilton, Ontario
info@nixsensor.com
905.581.6363

Connect with us!
@nixsensor
Nix Sensor Ltd.
Nix Sensor Ltd.

Textiles & Fabrics | Paints & Coatings | Food & Agriculture | Printing & Imaging | Health & Beauty | Industrial

Attachment A11-9: Component three shelf life statistical analysis

Compiled and written by Gabriela Borgognone and Dianna Liu (IFT, DAF)

pH Analysis

Control pH= 5.11 (n= 4)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	5.06	5.26	4.73	4.84
Standard PP	Yes	5.00	5.18	4.95	4.85
Barrier Film	No	5.17	5.32	5.01	4.88
Barrier Film	Yes	5.09	5.26	5.22	5.03
Vacuum	No	5.17	5.23	5.27	5.38
Vacuum	Yes	5.06	5.19	5.12	5.19

** all values n= 2*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	0.072377	0.072377	13.53	
Replicate.*Units* stratum					
Group	1	0.000401	0.000401	0.07	0.787
Group.Day	3	0.323625	0.107875	20.16	<.001
Group.Dip	1	0.002700	0.002700	0.50	0.484
Group.Packaging	2	0.383317	0.191658	35.82	<.001
Group.Day.Dip	3	0.055367	0.018456	3.45	0.031
Group.Day.Packaging	6	0.347700	0.057950	10.83	<.001
Group.Dip.Packaging	2	0.070850	0.035425	6.62	0.005
Group.Day.Dip.Packaging	6	0.078733	0.013122	2.45	0.052
Residual	26	0.139123	0.005351		
Total	**51**	**1.474192**			

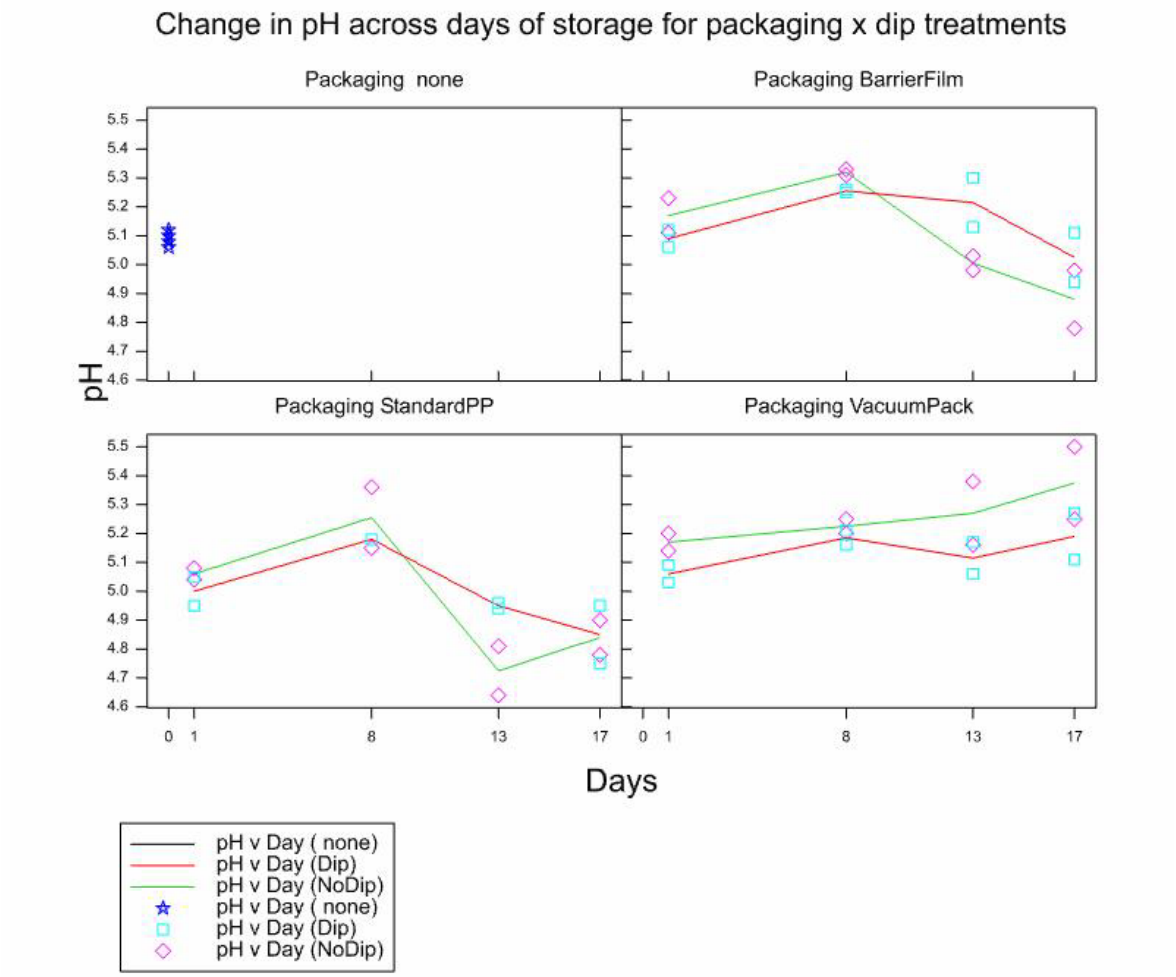
- At Day 1 none of the packaging x dip treatments were on average significantly different from each other or from the baseline Control.

- At Day 8 none of the packaging x dip treatments were significantly different from each other, and only Dip-Standard PP and Dip-Vacuum pack treatments had higher mean pH than the baseline Control.

- At Day 13 Dip and No Dip treatments for Barrier Film and Standard PP packages crossed over, while for Vacuum pack No Dip remained with a higher pH than Dip. However, there were no significant differences between Dip and No Dip mean treatments within each packaging method.

- At Day 17 Dip still had slightly higher mean pH for Dip than for No Dip treatment for Barrier Film and Standard PP packages; however these differences were not significant. For Vacuum pack the No Dip treatment had a significantly higher mean pH than the Dip treatment.

Treatments means for the pH trait ranged from 4.7 to 5.4.



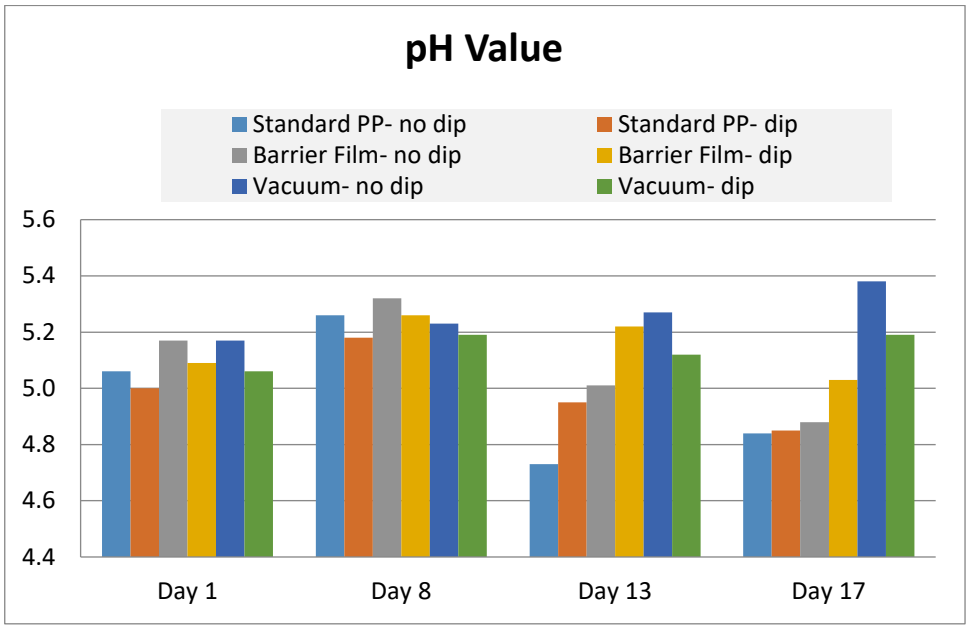
Standard errors of means: 0.0517 (min.rep), 0.0366 (max.rep)

Standard errors of differences of means: 0.0731 (min.rep), 0.0633 (max-min reps)

Least significant differences of means (5% level): 0.1504 (min.rep), 0.1302 (max-min reps)

Fisher's least significant difference test for Day.Dip.Packaging

Days	Dip Treatment	Packaging	Mean	LSD lettering	Replicates
17	No Dip	Vacuum Pack	5.38	a	2
8	No Dip	Barrier Film	5.32	ab	2
13	No Dip	Vacuum Pack	5.27	ab	2
8	Dip	Barrier Film	5.26	abc	2
8	No Dip	Standard PP	5.26	abc	2
8	No Dip	Vacuum Pack	5.23	abcd	2
13	Dip	Barrier Film	5.22	bcde	2
17	Dip	Vacuum Pack	5.19	bcdef	2
8	Dip	Vacuum Pack	5.19	bcdef	2
8	Dip	Standard PP	5.18	bcdef	2
1	No Dip	Barrier Film	5.17	bcdefg	2
1	No Dip	Vacuum Pack	5.17	bcdefg	2
13	Dip	Vacuum Pack	5.12	cdefgh	2
Control			5.09	efgh	4
1	Dip	Barrier Film	5.09	defghi	2
1	Dip	Vacuum Pack	5.06	fghi	2
1	No Dip	Standard PP	5.06	fghi	2
17	Dip	Barrier Film	5.03	ghij	2
13	No Dip	Barrier Film	5.01	hij	2
1	Dip	Standard PP	5.00	hijk	2
13	Dip	Standard PP	4.95	ijkl	2
17	No Dip	Barrier Film	4.88	jkl	2
17	Dip	Standard Pp	4.85	klm	2
17	No Dip	Standard PP	4.84	lm	2
13	No Dip	Standard PP	4.73	m	2



Titratable Acid

Control TA= 0.217 (n= 4)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	0.198	0.179	0.244	0.257
Standard PP	Yes	0.203	0.172	0.201	0.215
Barrier Film	No	0.195	0.159	0.199	0.205
Barrier Film	Yes	0.189	0.170	0.180	0.200
Vacuum	No	0.182	0.197	0.186	0.170
Vacuum	Yes	0.194	0.205	0.209	0.211

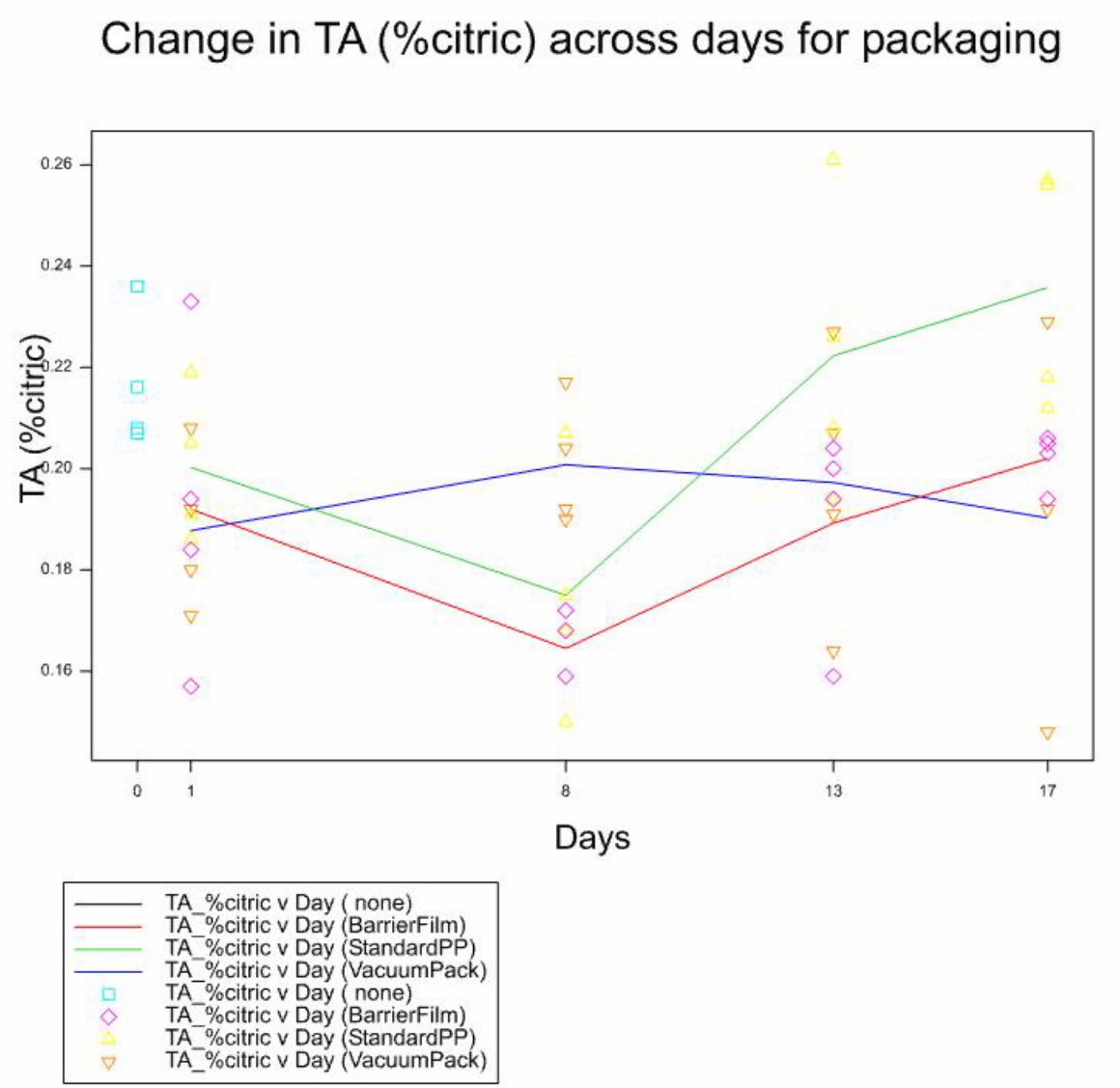
** n= 2*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	0.0016509	0.0016509	4.27	
Replicate.*Units* stratum					
Group	1	0.0015266	0.0015266	3.94	0.058
Group.Day	3	0.0058245	0.0019415	5.02	0.007
Group.Dip	1	0.0000403	0.0000403	0.10	0.749
Group.Packaging	2	0.0037953	0.0018976	4.90	0.016
Group.Day.Dip	3	0.0005502	0.0001834	0.47	0.703
Group.Day.Packaging	6	0.0061449	0.0010241	2.65	0.039
Group.Dip.Packaging	2	0.0036893	0.0018446	4.77	0.017
Group.Day.Dip.Packaging	6	0.0022852	0.0003809	0.98	0.456
Residual	26	0.0100618	0.0003870		
Total	**51**	**0.0355690**			

There were significant interactions between Day of storage and Packaging method, and between Dip treatment and Packaging method.

Day x Packaging interaction: On average the Standard PP and Barrier Film packages followed a similar pattern where the mean TA declined from day 1 to day 8 (although the decline was not significant,) and then increased from day 8 till day 17. For the Vacuum pack the levels of mean TA remained fairly constant across all storage times, with mean TA not significantly different across storage times. In effect, there were only a few treatment combinations for which TA was significantly lower than for the baseline Control, namely Vacuum pack at day 1 and Standard PP and Barrier film packages at day 8. This would imply that TA mostly remained unchanged across storage days for the three packaging methods.



Standard errors of means: 0.0098

Standard errors of differences of means: 0.0139

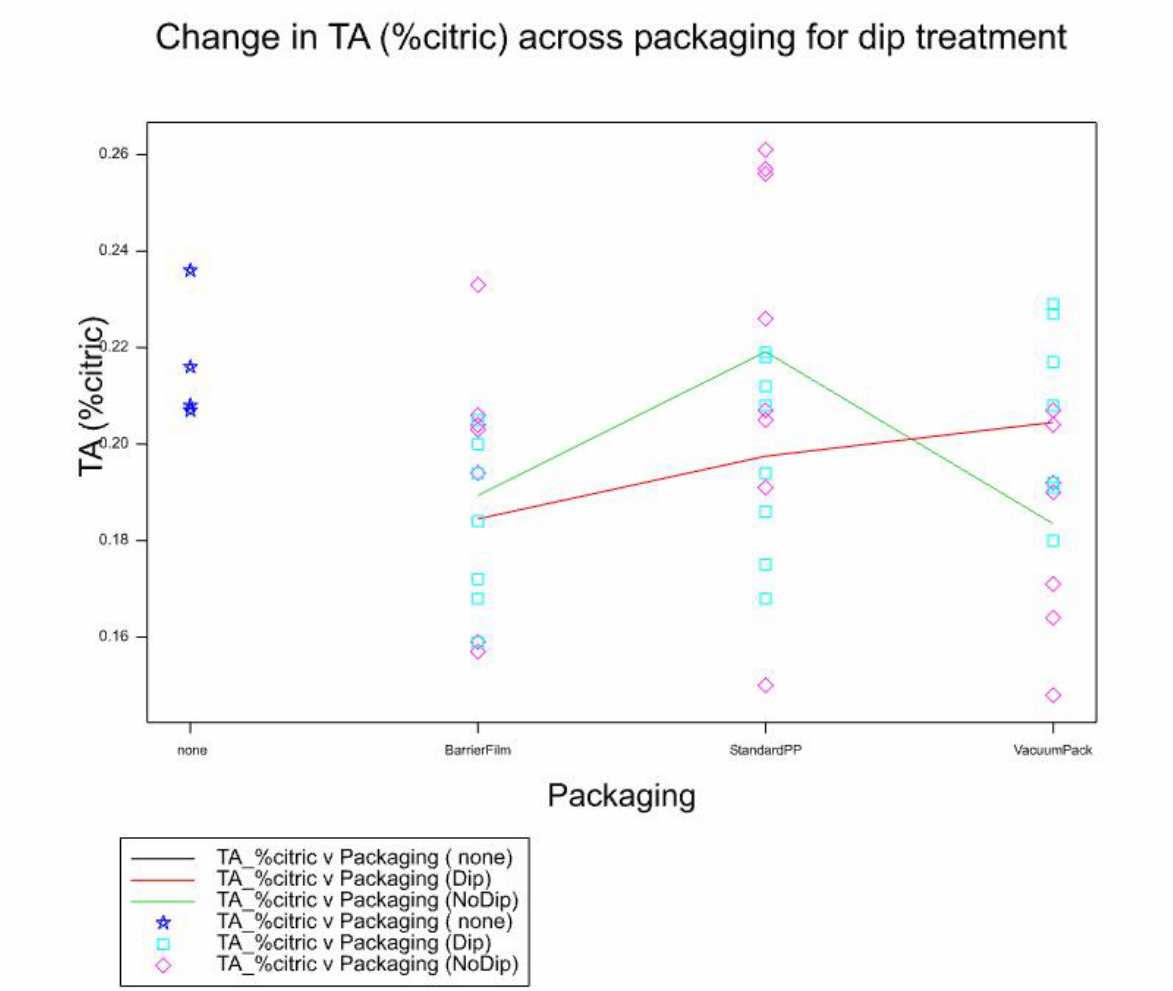
Least significant differences of means (5% level): 0.0286

Fisher's least significant difference test for Day.Packaging

Days	Packaging	Mean	LSD lettering	Replicates
17	Standard PP	0.2357	a	4
13	Standard PP	0.2222	ab	4
Control		0.2167	abc	4
17	Barrier Film	0.202	bcd	4
8	Vacuum Pack	0.2007	bcd	4
1	Standard PP	0.2002	bcd	4
13	Vacuum Pack	0.1972	bcd	4
1	Barrier Film	0.192	cde	4
17	Vacuum Pack	0.1902	cde	4
13	Barrier Film	0.1892	cde	4
1	Vacuum Pack	0.1877	de	4

8	Standard PP	0.175	de	4
8	Barrier Film	0.1645	e	4

Dip x Packaging interaction: On average the TA for Dip treatment remained mainly fairly constant for the three packaging methods (mean TA not significantly different). For the No Dip treatment, however, the Standard PP package had a significantly higher TA than for the other two. On average, Barrier Film (both with and without Dip) and Vacuum pack-No Dip had significantly lower TA than the baseline Control.



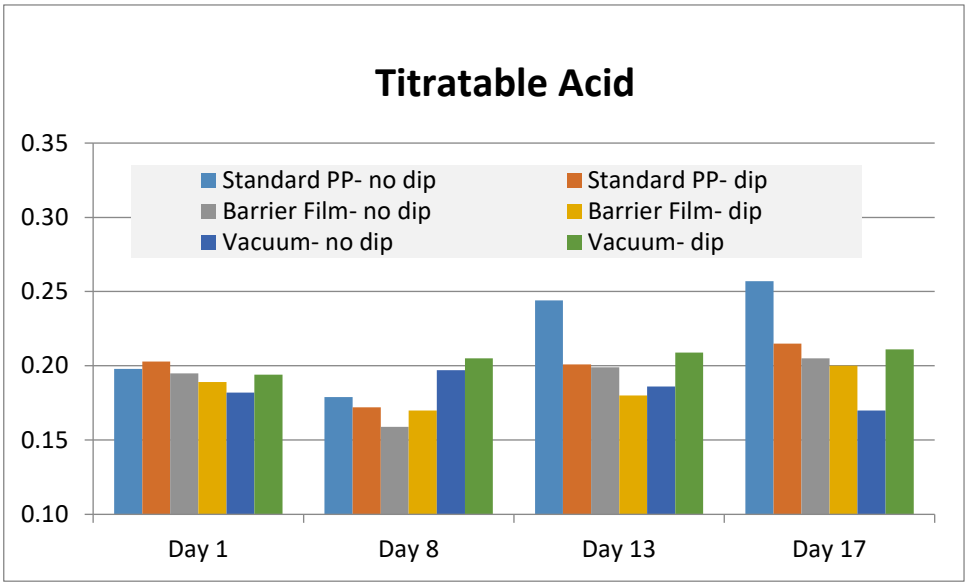
Standard errors of means: 0.0098 (min.rep), 0.0070 (max.rep)

Standard errors of differences of means: 0.0120 (max-min reps), 0.0098 (max.rep)

Least significant differences of means (5% level): 0.0248 (max-min reps), 0.0202 (max.rep)

Fisher's least significant difference test for Dip.Packaging

Dip treatment	Packaging	Mean	LSD lettering	Replicates
No Dip	Standard PP	0.2191	a	8
Control		0.2167	ab	4
Dip	Vacuum Pack	0.2045	abc	8
Dip	Standard PP	0.1975	bcd	8
No Dip	Barrier Film	0.1894	cd	8
Dip	Barrier Film	0.1845	cd	8
No Dip	Vacuum Pack	0.1835	d	8



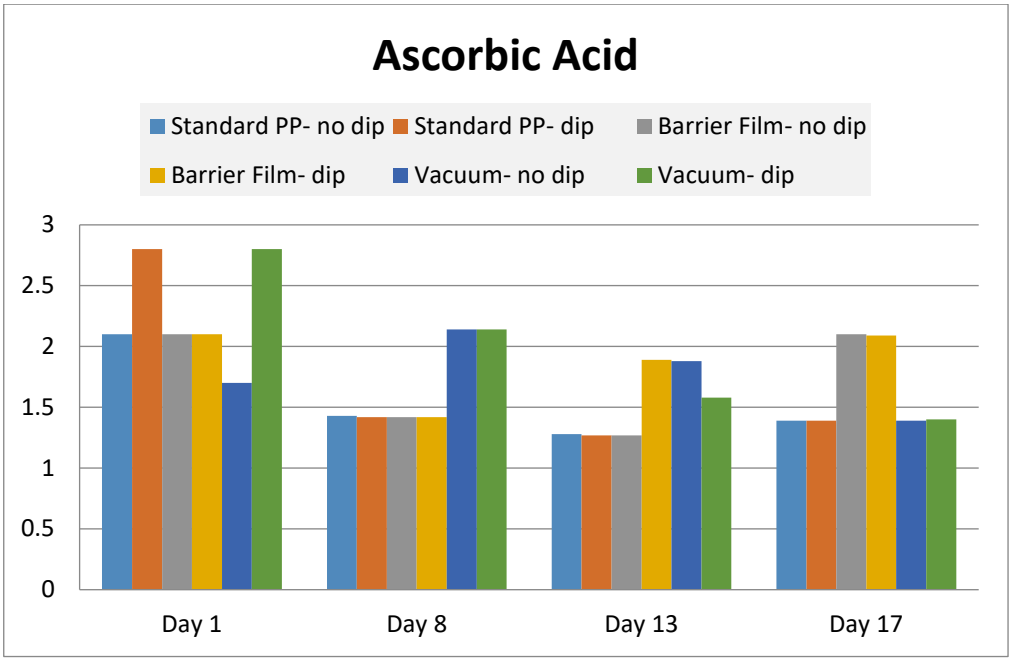
3.3 Ascorbic Acid

Control = 2.55 mg/100 g (n=4)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	2.10	1.43	1.28	1.39
Standard PP	Yes	2.80	1.42	1.27	1.39
Barrier Film	No	2.10	1.42	1.27	2.10
Barrier Film	Yes	2.10	1.42	1.89	2.09
Vacuum	No	1.70	2.14	1.88	1.39
Vacuum	Yes	2.80	2.14	1.58	1.40

** n= 2*

Ascorbic acid could not be statistically analysed because all values were too similar and therefore there was not enough variability for the analysis to be performed. There is very little Vitamin C in jackfruit and all values remained between 1.3 and 2.8 mg/100 g. This trait lacks practical relevance.



Colour

Colour traits were measured in triplicate within each replicate. That is, three arils were measured in each replicate to obtain an average replicate value. The variability among these pieces of fruit was very high; therefore measuring more than one aril was of high value. The percentage of the total variability for each of the colour traits that is due to differences amongst arils is reported with the ANOVA results.

Important note: All significances in the ANOVAs for all the colour traits are affected by the fact that the two replicates for Vacuum Pack at Day 1 had seemingly darker colouration than for later days when measured. This mainly implies that this treatment combination (i.e. Vacuum pack-Day 1) dominated the trends and was responsible for most interactions to be significant. All interpretations must be handled with caution. ANOVA tables, tables of means with LSD lettering and relevant graphs are presented for these traits.

Minolta Colorimeter traits

Control L*= 80.04 (n= 12)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	78.86	79.55	77.03	74.36
Standard PP	Yes	78.43	77.59	78.05	65.73
Barrier Film	No	78.27	76.19	75.81	70.54
Barrier Film	Yes	78.19	74.99	77.44	68.80
Vacuum	No	53.93	67.63	67.76	67.06
Vacuum	Yes	54.52	64.20	64.98	60.85

** n= 6*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	21.59	21.59	0.72	
Replicate.Tray stratum					
Group	1	849.46	849.46	28.18	<.001
Group.Day	3	778.19	259.40	8.61	<.001
Group.Dip	1	134.81	134.81	4.47	0.045
Group.Packaging	2	5439.56	2719.78	90.23	<.001
Group.Day.Dip	3	183.56	61.19	2.03	0.136
Group.Day.Packaging	6	1505.53	250.92	8.32	<.001
Group.Dip.Packaging	2	46.58	23.29	0.77	0.473
Group.Day.Dip.Packaging	6	70.31	11.72	0.39	0.879
Residual	24	723.40	30.14	1.67	
Replicate.Tray.Fruit_No stratum		106	1911.09	18.03	
Total	**155**	**11664.10**			

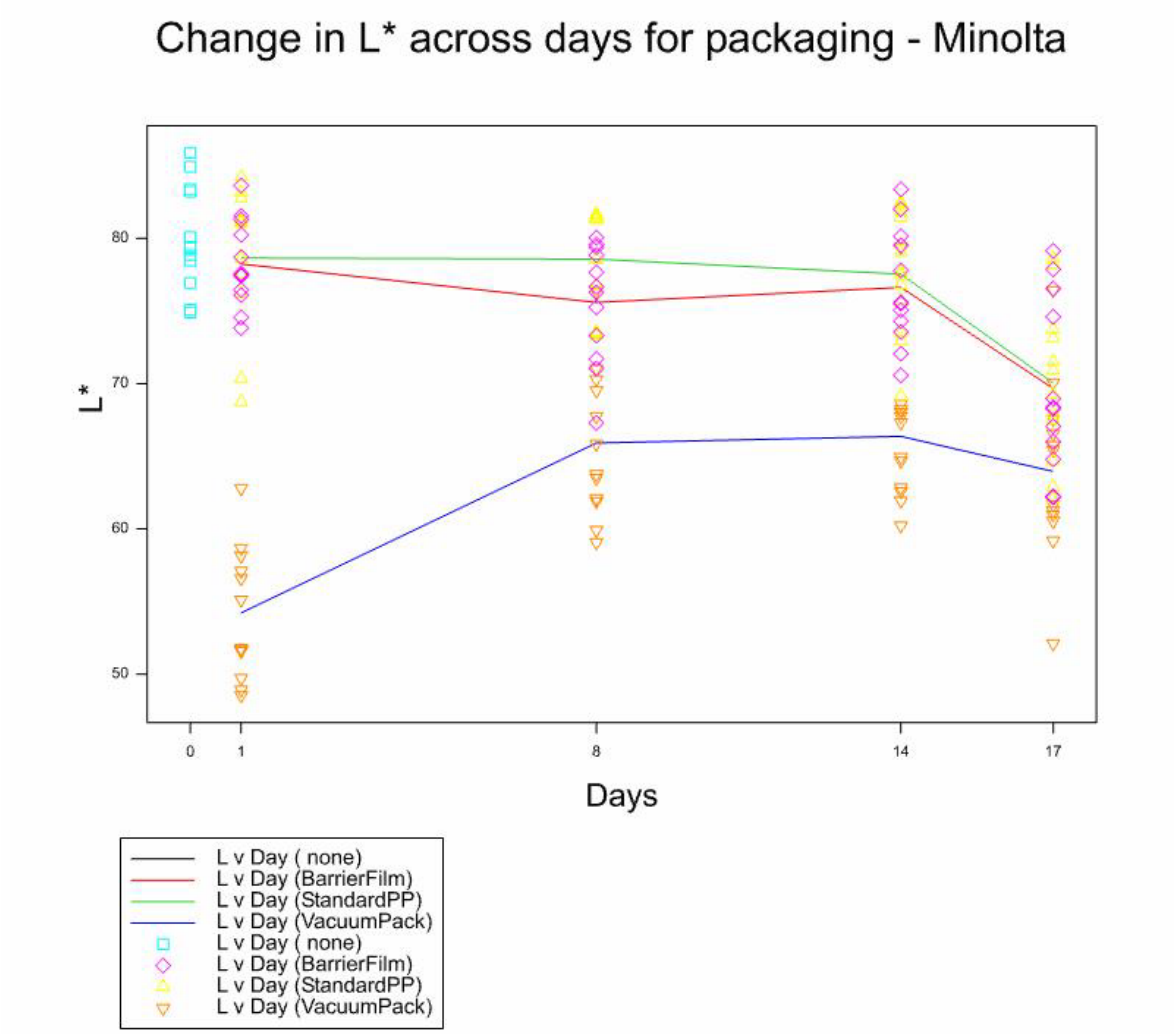
There were a significant main effect of Dip treatment (baseline Control, Dip and No Dip treatments are on average all significantly different form each other).

The interaction of Day x packaging was highly significant, mainly driven by Vacuum pack at day 1. Average L* values for Standard PP and Barrier Film packages were not significantly different from the baseline Control for days 1, 8 and 14, and significantly lower for day 17. For Vacuum pack, average L* values were significantly lower than baseline control at day 1 and significantly higher than day 1 for days 8, 14 and 17, and not significantly different from each other for days 8-17. Average L* for Vacuum pack was significantly lower than Standard PP and Barrier film packages for days 8 to 17.

Variability between pieces of fruit represented 16% of the total variability in L*.

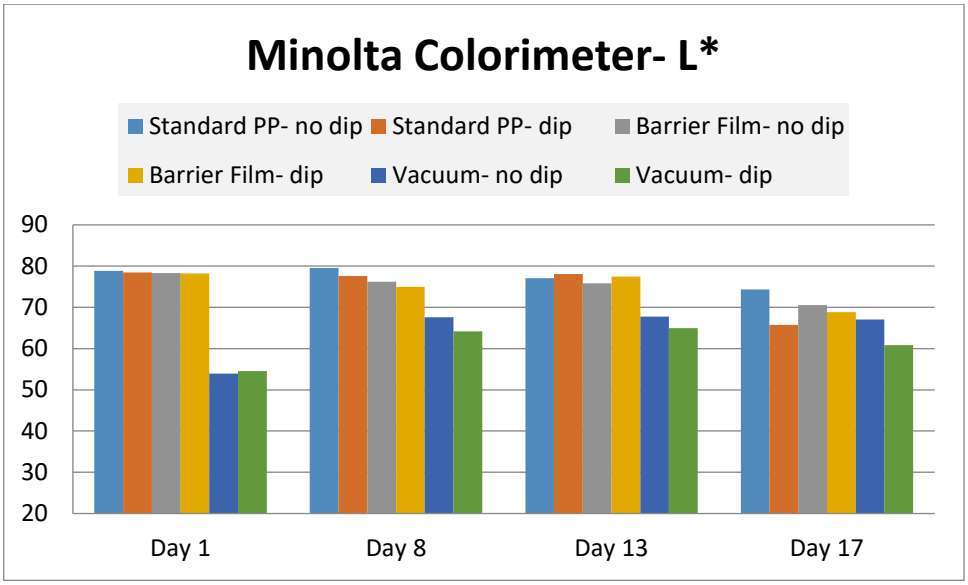
Fisher's least significant difference test for Dip

Dip treatment	Mean	LSD lettering
Control	80.04	a
No Dip	72.25	b
Dip	70.31	c



Fisher's least significant difference test for Day.Packaging

Day	Packaging	Mean	LSD lettering
Control		80.04	a
1	Standard PP	78.65	a
8	Standard PP	78.57	a
1	Barrier Film	78.23	a
14	Standard PP	77.54	a
14	Barrier Film	76.62	a
8	Barrier Film	75.59	a
17	Standard PP	70.05	b
17	Barrier Film	69.67	b
14	Vacuum Pack	66.37	bc
8	Vacuum Pack	65.92	bc
17	Vacuum Pack	63.96	c
1	Vacuum Pack	54.22	d



Control a*= 2.53 (n=12)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	3.13	3.52	3.40	3.77
Standard PP	Yes	3.82	4.07	3.90	2.91
Barrier Film	No	3.09	4.84	3.03	4.48
Barrier Film	Yes	4.45	2.03	2.62	3.74
Vacuum	No	1.37	3.86	-0.31	0.77
Vacuum	Yes	-0.27	-1.34	0.41	-1.45

** n= 6*

Analysis of variance

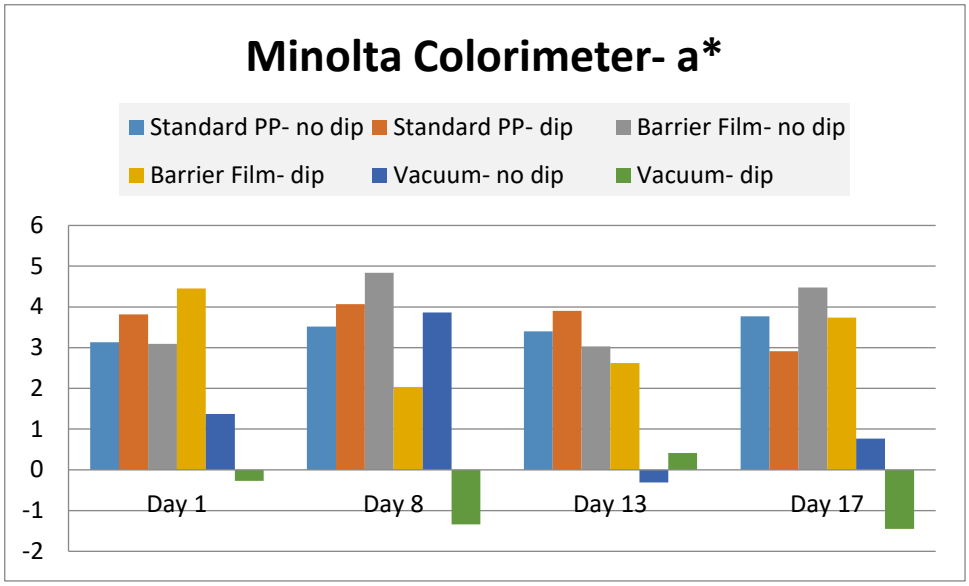
Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1		23.941	23.941	2.80	
Replicate.Tray stratum						
Group	1		0.004	0.004	0.00	0.983
Group.Day	3		10.551	3.517	0.41	0.746
Group.Dip	1		27.601	27.601	3.23	0.085
Group.Packaging	2		310.798	155.399	18.20	<.001
Group.Day.Dip	3		50.203	16.734	1.96	0.147
Group.Day.Packaging	6		23.788	3.965	0.46	0.828
Group.Dip.Packaging	2		35.800	17.900	2.10	0.145
Group.Day.Dip.Packaging	6		42.640	7.107	0.83	0.557
Residual	24		204.888	8.537	1.55	
Replicate.Tray.Fruit_No stratum		105	(1)	577.625	5.501	
Total	**154**	**(1)**	**1292.358**			

For a* there was a significant effect of packaging. Vacuum pack had on average significantly lower average a* than the rest, which were not significantly different from each other or from the baseline control.

Variability between pieces of fruit represented 44.7% of the total variability in a*.

Fisher's least significant difference test for Packaging

Packaging	Mean	LSD lettering
Standard PP	3.563	a
Barrier Film	3.535	a
Control	2.529	a
Vacuum Pack	0.433	b



Control b*= 48.11 (n=12)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	48.66	50.17	50.72	55.06
Standard PP	Yes	51.16	51.43	52.87	51.86
Barrier Film	No	50.03	52.09	50.74	51.91
Barrier Film	Yes	53.74	56.75	52.76	51.52
Vacuum	No	37.00	55.18	50.28	48.12
Vacuum	Yes	38.37	49.14	51.28	44.65

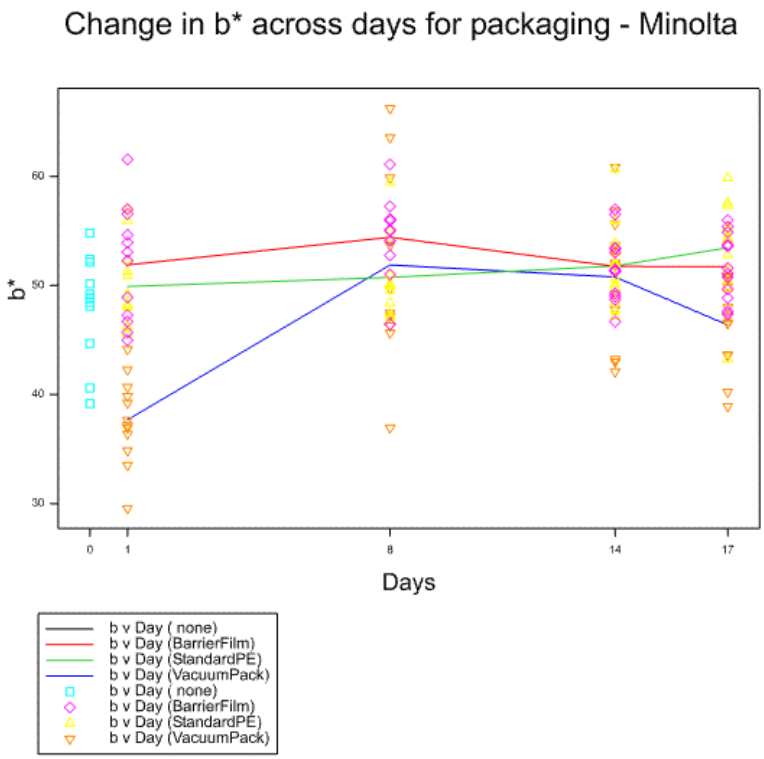
** n= 6*

Analysis of variance

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1		237.22	237.22	5.54	
Replicate.Tray stratum						
Group	1		51.84	51.84	1.21	0.282
Group.Day	3		770.12	256.71	5.99	0.003
Group.Dip	1		3.11	3.11	0.07	0.790
Group.Packaging	2		820.38	410.19	9.57	<.001
Group.Day.Dip	3		135.61	45.20	1.05	0.387
Group.Day.Packaging	6		1024.65	170.77	3.98	0.007
Group.Dip.Packaging	2		133.27	66.64	1.55	0.232
Group.Day.Dip.Packaging	6		133.35	22.22	0.52	0.788
Residual	24		1028.57	42.86	2.97	
Replicate.Tray.Fruit_No stratum		104	(2)	1498.52	14.41	
Total	**153**	**(2)**	**5615.17**			

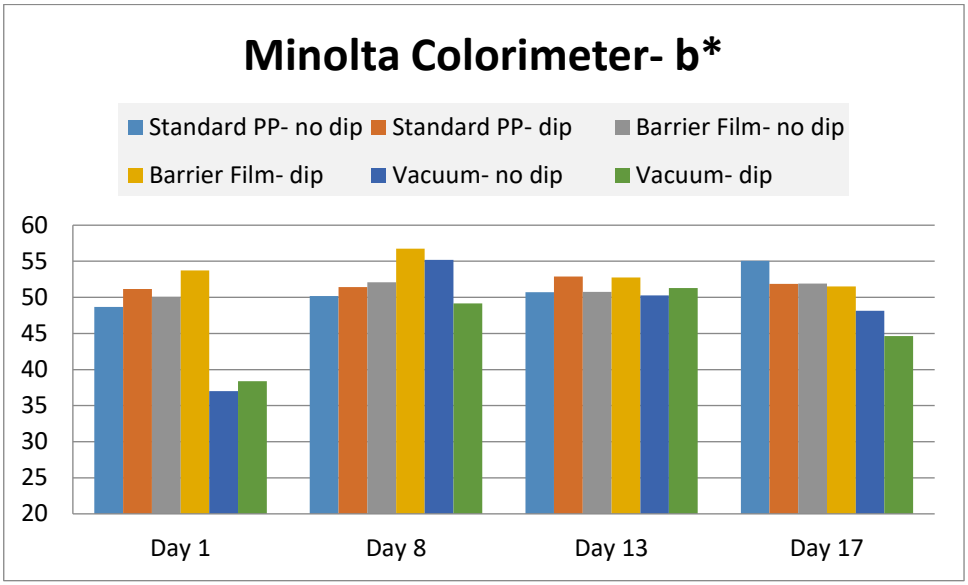
There was a significant interaction between Days of storage and packaging method for b*. The interaction is mainly induced by Vacuum pack at day 1 being so much lower than the rest.

Variability between pieces of fruit represented 26.7% of the total variability in b*.



Fisher's least significant difference test for Day.Packaging

Days	Packaging	Mean	LSD lettering
8	Barrier Film	54.42	a
17	Standard PP	53.46	ab
8	Vacuum Pack	52.97	ab
1	Barrier Film	51.88	abc
14	Standard PP	51.79	abc
14	Barrier Film	51.75	abc
17	Barrier Film	51.72	abc
14	Vacuum Pack	50.78	abc
8	Standard PP	50.58	abc
1	Standard PP	49.91	abc
Control		48.11	bc
17	Vacuum Pack	46.38	c
1	Vacuum Pack	37.68	d



Control C*= 48.03 (n=12)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	48.78	50.32	50.86	55.20
Standard PP	Yes	51.35	51.60	53.05	52.02
Barrier Film	No	50.17	52.35	50.88	52.12
Barrier Film	Yes	53.97	56.80	52.87	51.75
Vacuum	No	37.05	55.35	50.31	48.23
Vacuum	Yes	38.47	49.20	51.39	44.68

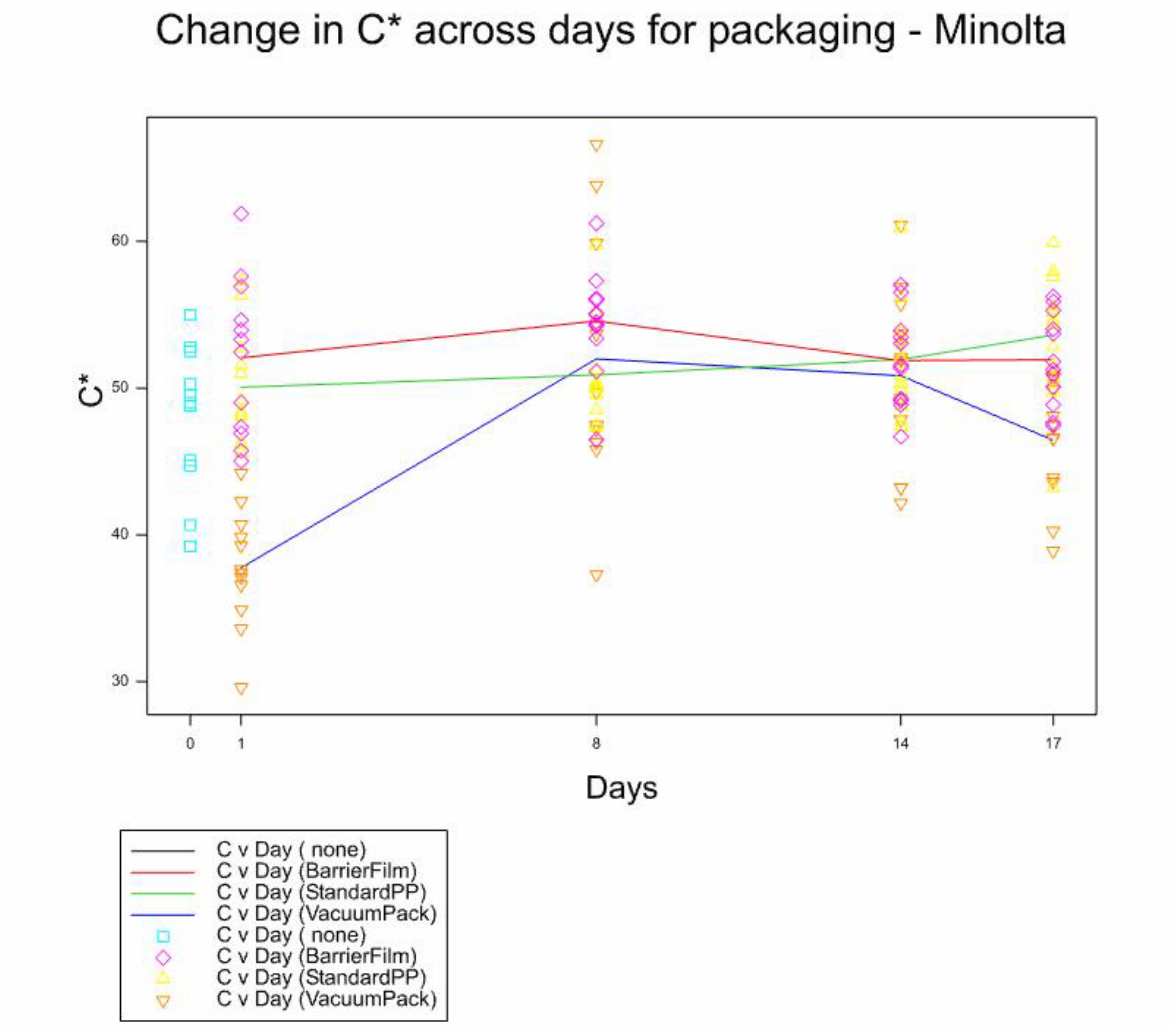
** n= 6*

Analysis of variance

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1		234.72	234.72	5.39	
Replicate.Tray stratum						
Group	1		62.96	62.96	1.45	0.241
Group.Day	3		769.91	256.64	5.89	0.004
Group.Dip	1		2.96	2.96	0.07	0.796
Group.Packaging	2		845.28	422.64	9.70	<.001
Group.Day.Dip	3		142.13	47.38	1.09	0.373
Group.Day.Packaging	6		1030.97	171.83	3.94	0.007
Group.Dip.Packaging	2		133.03	66.52	1.53	0.238
Group.Day.Dip.Packaging	6		132.90	22.15	0.51	0.796
Residual	24		1045.50	43.56	2.92	
Replicate.Tray.Fruit_No stratum		104	(2)	1552.69	14.93	
Total	**153**	**(2)**	**5725.64**			

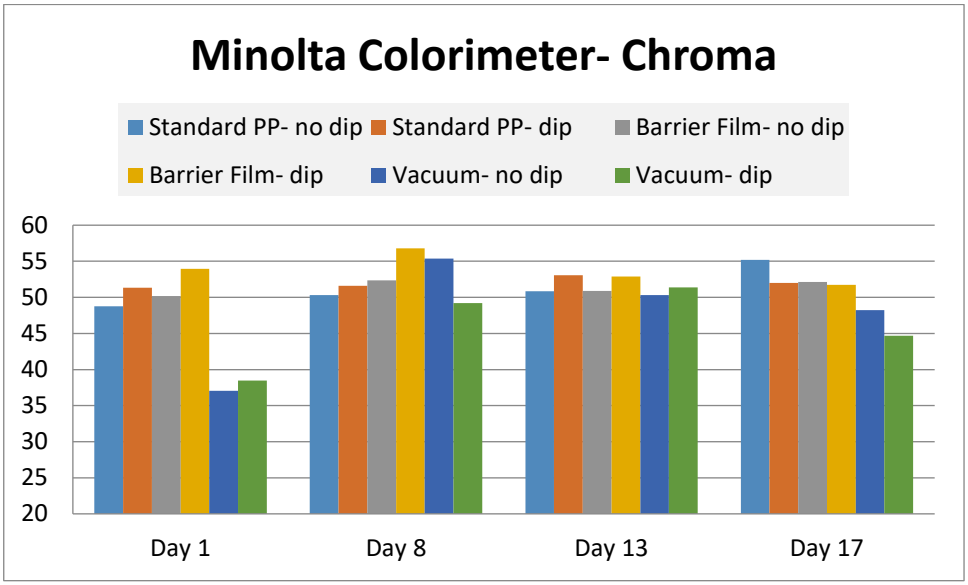
The results are basically the same as for b*, given that a* is so low. There was a significant interaction between Days of storage and packaging method for C*. The interaction is mainly induced by Vacuum pack at day 1 being so much lower than the rest.

Variability between pieces of fruit represented 27% of the total variability in C*.



Fisher's least significant difference test for Day.Packaging

Days	Packaging	Mean	LSD lettering
8	Barrier Film	54.57	a
17	Standard PP	53.61	a
8	Vacuum Pack	53.1	ab
1	Barrier Film	52.07	ab
14	Standard PP	51.95	abc
17	Barrier Film	51.94	abc
14	Barrier Film	51.87	abc
14	Vacuum Pack	50.85	abc
8	Standard PP	50.74	abc
1	Standard PP	50.07	abc
Control		48.03	bc
17	Vacuum Pack	46.46	c
1	Vacuum Pack	37.76	d



Control h angle= 87.24 (n=12)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	86.42	85.95	86.15	86.04
Standard PP	Yes	85.87	86.03	85.89	87.01
Barrier Film	No	86.49	84.77	86.66	85.09
Barrier Film	Yes	85.36	87.99	87.06	86.04
Vacuum	No	88.06	86.96	90.38	89.22
Vacuum	Yes	90.43	91.84	89.99	91.84

** n= 6*

Analysis of variance

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1		23.938	23.938	2.35	
Replicate.Tray stratum						
Group	1		0.298	0.298	0.03	0.866
Group.Day	3		7.333	2.444	0.24	0.868
Group.Dip	1		44.277	44.277	4.35	0.048
Group.Packaging	2		427.141	213.570	20.96	<.001
Group.Day.Dip	3		46.263	15.421	1.51	0.236
Group.Day.Packaging	6		19.543	3.257	0.32	0.920
Group.Dip.Packaging	2		32.131	16.065	1.58	0.227
Group.Day.Dip.Packaging	6		28.877	4.813	0.47	0.822
Residual	24		244.559	10.190	1.38	
Replicate.Tray.Fruit_No stratum		105	(1)	773.633	7.368	
Total	**154**	**(1)**	**1647.763**			

For h* there was a borderline main effect of Dip (p=0.048), probably lacking practical significance (Table 17), and a significant main effect of Packaging. Vacuum pack was significantly different from the rest (Table 18).

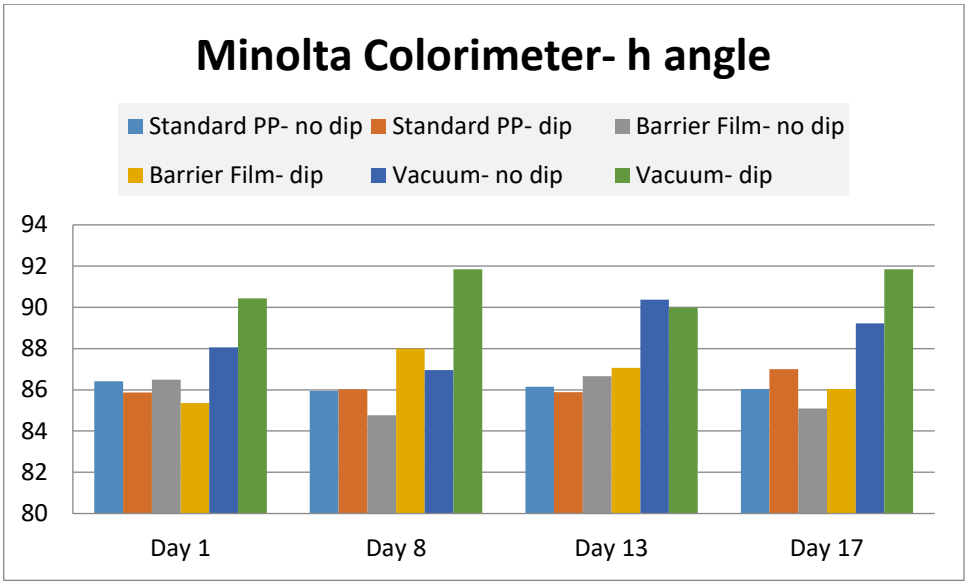
Variability between pieces of fruit represented 47% of the total variability in h*.

Fisher's least significant difference test for Dip

Dip treatment	Mean	LSD lettering
Dip	87.96	a
Control	87.24	ab
No Dip	86.85	b

Fisher's protected least significant difference test for Packaging

Packaging	Mean	LSD lettering
Vacuum Pack	89.84	a
Control	87.24	b
Standard PP	86.19	b
Barrier Film	86.18	b



Nix Pro Colour Sensor traits

NIX L*

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	79.99	78.65	76.17	70.63
Standard PP	Yes	75.54	78.92	78.35	63.55
Barrier Film	No	76.54	76.05	75.35	66.98
Barrier Film	Yes	76.20	73.60	75.62	67.05
Vacuum	No	50.01	66.58	63.98	65.77
Vacuum	Yes	50.50	63.80	65.65	59.33

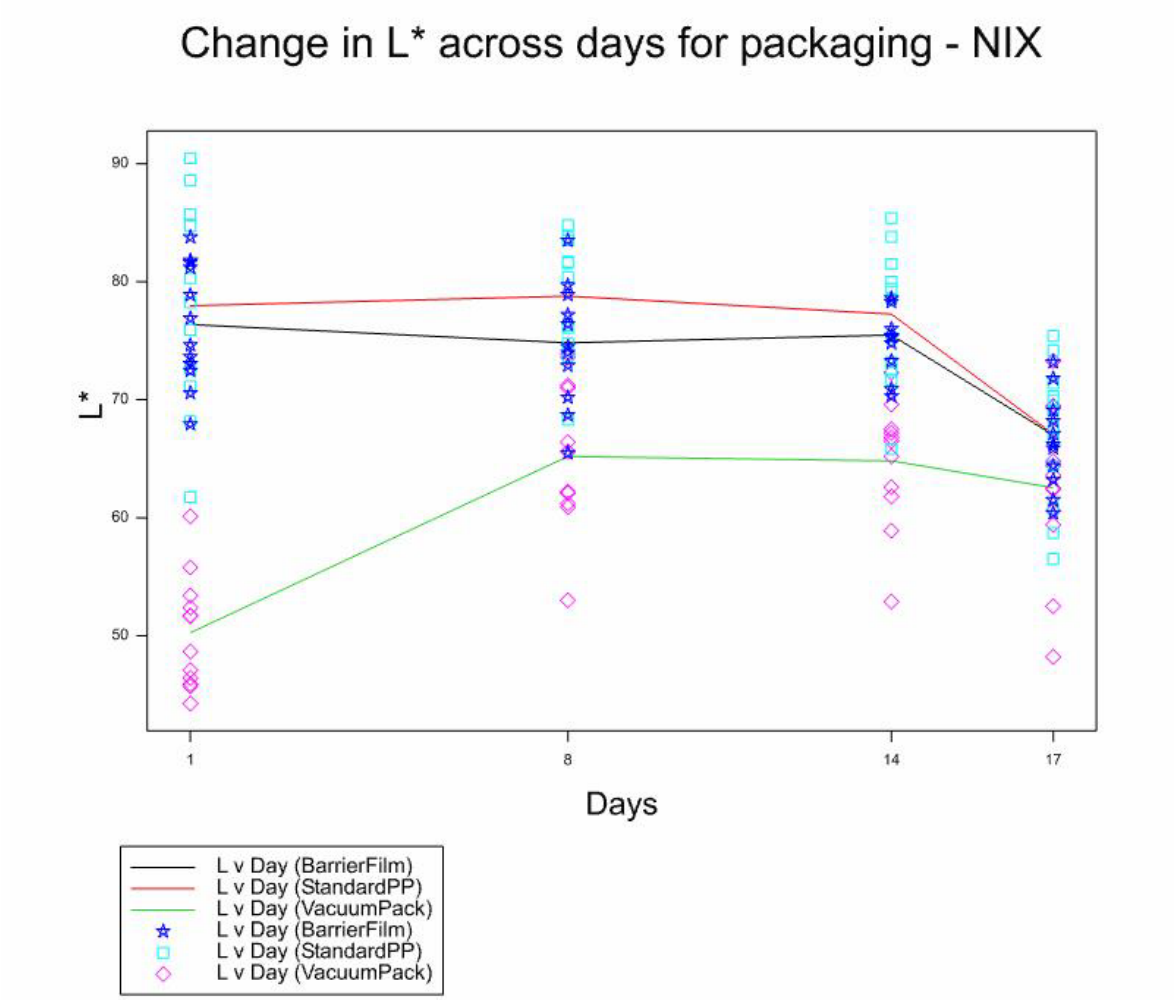
** n= 6*

Analysis of variance

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1		195.76	195.76	6.02	
Replicate.Tray stratum						
Day	3		1384.66	461.55	14.19	<.001
Dip	1		93.63	93.63	2.88	0.103
Packaging	2		5965.60	2982.80	91.68	<.001
Day.Dip	3		154.42	51.47	1.58	0.221
Day.Packaging	6		2133.13	355.52	10.93	<.001
Dip.Packaging	2		20.86	10.43	0.32	0.729
Day.Dip.Packaging	6		152.42	25.40	0.78	0.593
Residual	23		748.27	32.53	1.07	
Replicate.Tray.Fruit_No stratum		95	(1)	2883.08	30.35	
Total	**142**	**(1)**	**13730.18**			

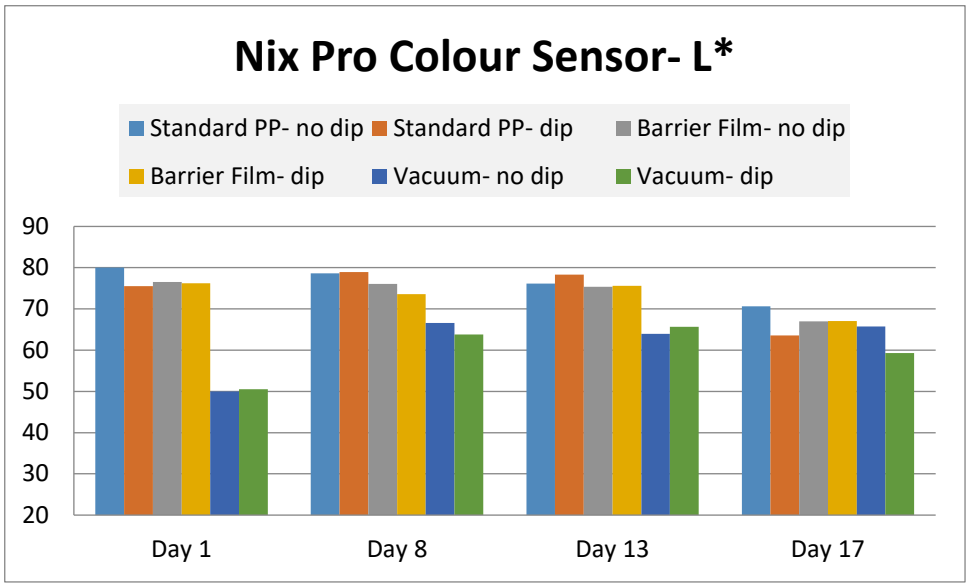
There was a significant interaction between Days of storage and Packaging method for L*. This interaction was driven by Vacuum pack followed a different pattern from the other two packaging methods, with a very low mean at Day 1. Standard PP and Barrier Film packages were not significantly different on average L* for days 1, 8 and 14, and had significantly lower average L* for day 17. On average, Vacuum pack at days 8 and 14 was not significantly different from Standard PP and Barrier Film packages at 17 days.

Variability between pieces of fruit represented 21% of the total variability in L*.



Fisher's least significant difference test for Day.Packaging

Day	Packaging	Mean	LSD lettering
8	Standard PP	78.78	a
1	Standard PP	77.39	a
14	Standard PP	77.26	a
1	Barrier Film	76.37	a
14	Barrier Film	75.48	a
8	Barrier Film	74.83	a
17	Standard PP	67.09	b
17	Barrier Film	67.02	b
8	Vacuum Pack	65.19	b
14	Vacuum Pack	64.82	b
17	Vacuum Pack	62.55	b
1	Vacuum Pack	50.26	c



NIX a*

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	7.20	7.58	7.75	7.88
Standard PP	Yes	8.40	8.48	8.42	6.88
Barrier Film	No	7.70	9.03	7.05	7.45
Barrier Film	Yes	8.94	5.95	7.58	7.60
Vacuum	No	4.42	7.76	4.02	4.25
Vacuum	Yes	2.27	1.78	2.47	1.70

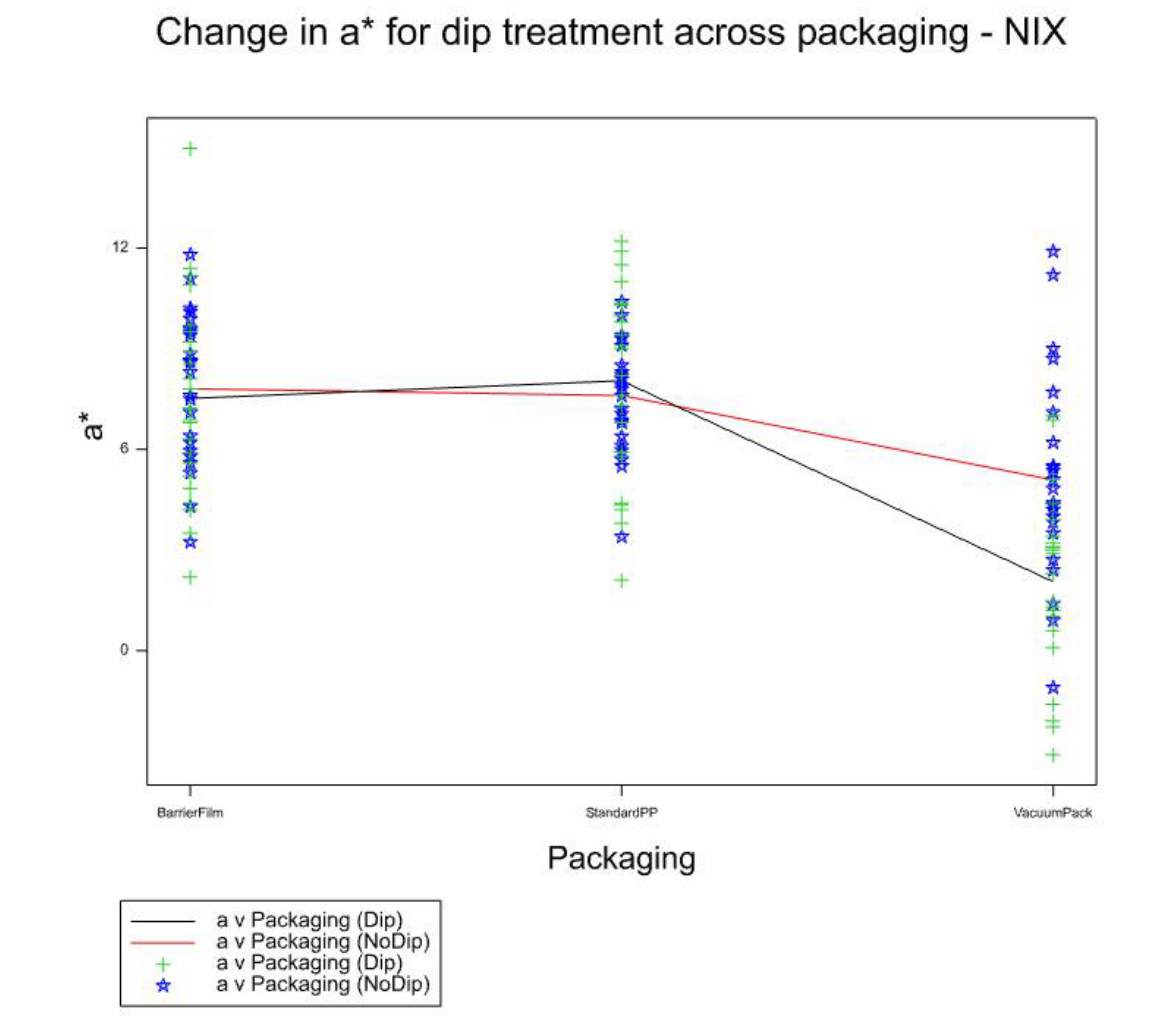
** n= 6*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	18.133	18.133	2.23	
Replicate.Tray stratum					
Day	3	12.553	4.184	0.51	0.677
Dip	1	33.197	33.197	4.08	0.055
Packaging	2	557.631	278.816	34.25	<.001
Day.Dip	3	43.639	14.546	1.79	0.178
Day.Packaging	6	20.448	3.408	0.42	0.859
Dip.Packaging	2	80.553	40.277	4.95	0.016
Day.Dip.Packaging	6	32.210	5.368	0.66	0.683
Residual	23	187.235	8.141	1.27	
Replicate.Tray.Fruit_No stratum		96	614.310	6.399	
Total	**143**	**1599.910**			

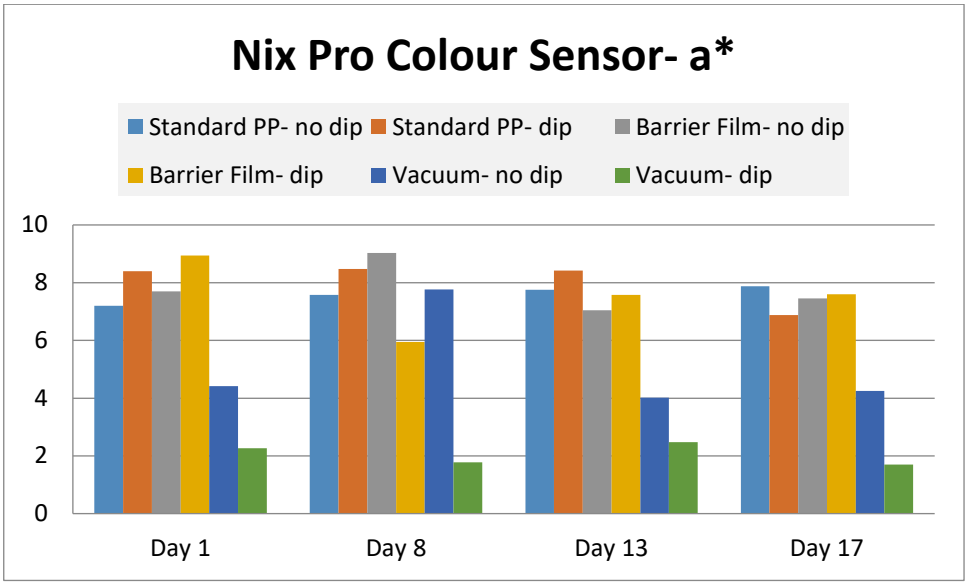
There was a significant interaction between Dip treatment and Packaging method for a*. Average a* was not significantly different for Barrier Film and Standard PP with Dip and No Dip treatments. Vacuum pack was on average significantly different from the other two packaging methods and Dip and No Dip treatments were significantly different from each other for Vacuum pack.

Variability between pieces of fruit represented 38.4% of the total variability in a*.



Fisher's least significant difference test for Dip.Packaging

Dip treatment	Packaging	Mean	LSD lettering
Dip	Standard PE	8.046	a
No Dip	Barrier Film	7.808	a
No Dip	Standard PE	7.605	a
Dip	Barrier Film	7.519	a
No Dip	Vacuum Pack	5.089	b
Dip	Vacuum Pack	2.055	c



NIX b*

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	47.54	48.22	48.50	50.95
Standard PP	Yes	52.49	53.72	51.88	50.17
Barrier Film	No	50.63	49.02	50.53	46.68
Barrier Film	Yes	53.39	55.05	51.87	51.08
Vacuum	No	32.71	50.43	50.12	46.02
Vacuum	Yes	35.55	49.28	49.38	43.60

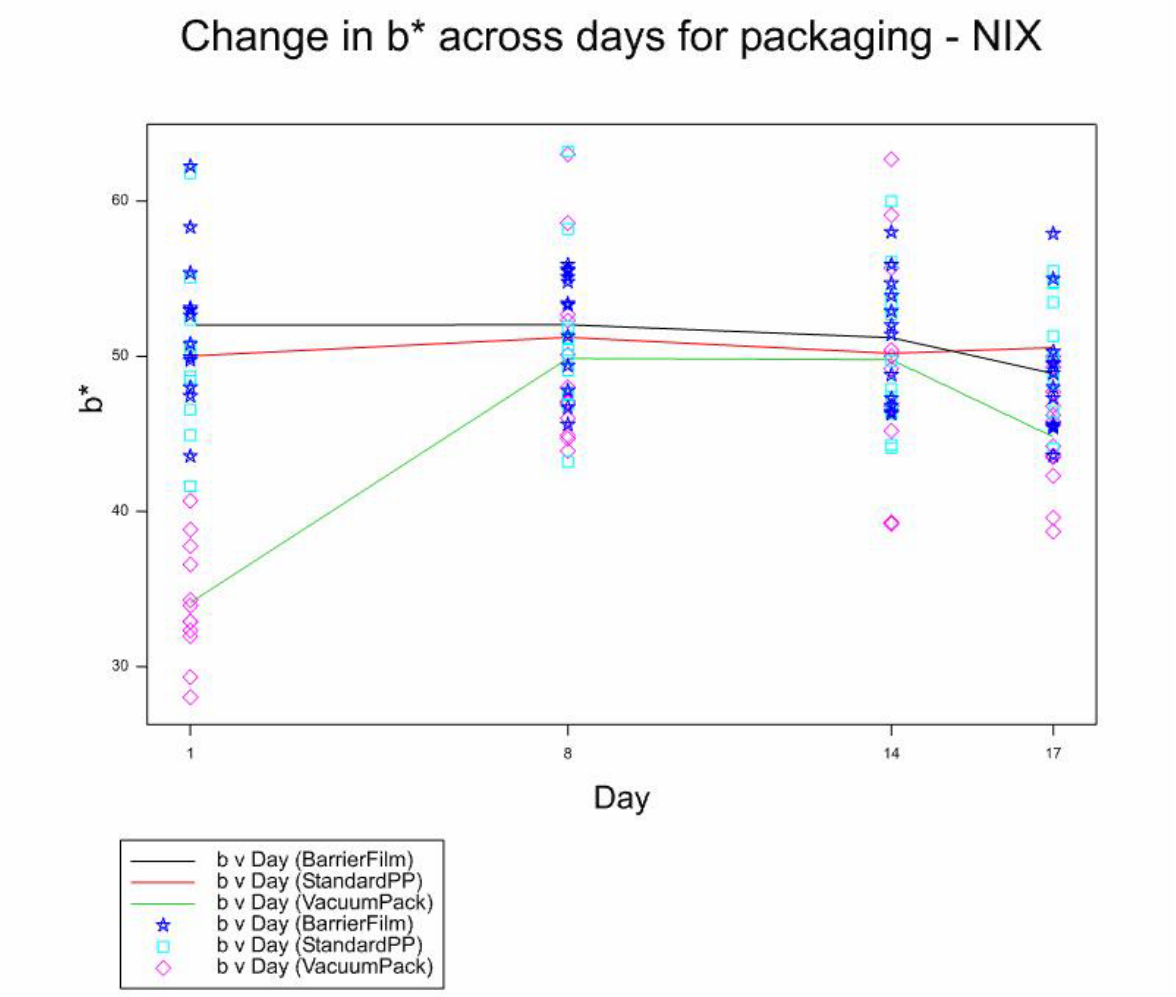
** n= 6*

Analysis of variance

Source of variation	d.f.	(m.v.)	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1		152.98	152.98	3.91	
Replicate.Tray stratum						
Day	3		666.86	222.29	5.69	0.005
Dip	1		146.69	146.69	3.75	0.065
Packaging	2		1285.93	642.96	16.45	<.001
Day.Dip	3		74.96	24.99	0.64	0.597
Day.Packaging	6		1288.42	214.74	5.49	0.001
Dip.Packaging	2		142.90	71.45	1.83	0.183
Day.Dip.Packaging	6		88.38	14.73	0.38	0.886
Residual	23		899.12	39.09	2.21	
Replicate.Tray.Fruit_No stratum		94	(2)	1660.39	17.66	
Total	**141**	**(2)**	**6317.46**			

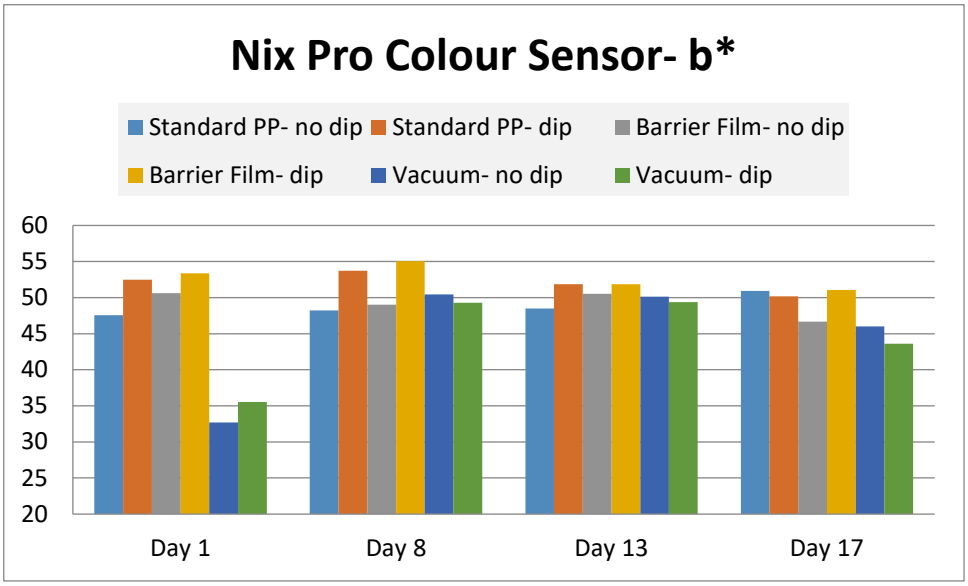
The interaction between Days of storage and packaging method was significant. It was mainly driven by Vacuum pack follows a different pattern form the rest. In general, average b* values for the days x packaging combinations are not significantly different except for vacuum pack at day 1 being significantly different from the rest.

Variability between pieces of fruit represented 26.3% of the total variability in b*.



Fisher's least significant difference test for Day.Packaging

Days	Packaging	Mean	LSD lettering
8	Barrier Film	52.03	a
1	Barrier Film	52.01	a
14	Barrier Film	51.2	a
8	Standard PP	51.06	a
17	Standard PP	50.56	a
14	Standard PP	50.19	a
1	Standard PP	50.02	ab
8	Vacuum Pack	49.86	ab
14	Vacuum Pack	48.9	ab
17	Barrier Film	48.88	ab
17	Vacuum Pack	44.81	b
1	Vacuum Pack	34.13	c



Moisture

Control = 81.24 (n=4)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	82.51	82.60	84.41	83.55
Standard PP	Yes	81.04	81.66	83.29	85.20
Barrier Film	No	82.53	82.87	83.53	84.14
Barrier Film	Yes	82.25	82.54	81.86	84.32
Vacuum	No	82.38	81.73	81.81	83.19
Vacuum	Yes	82.44	82.85	83.24	84.22

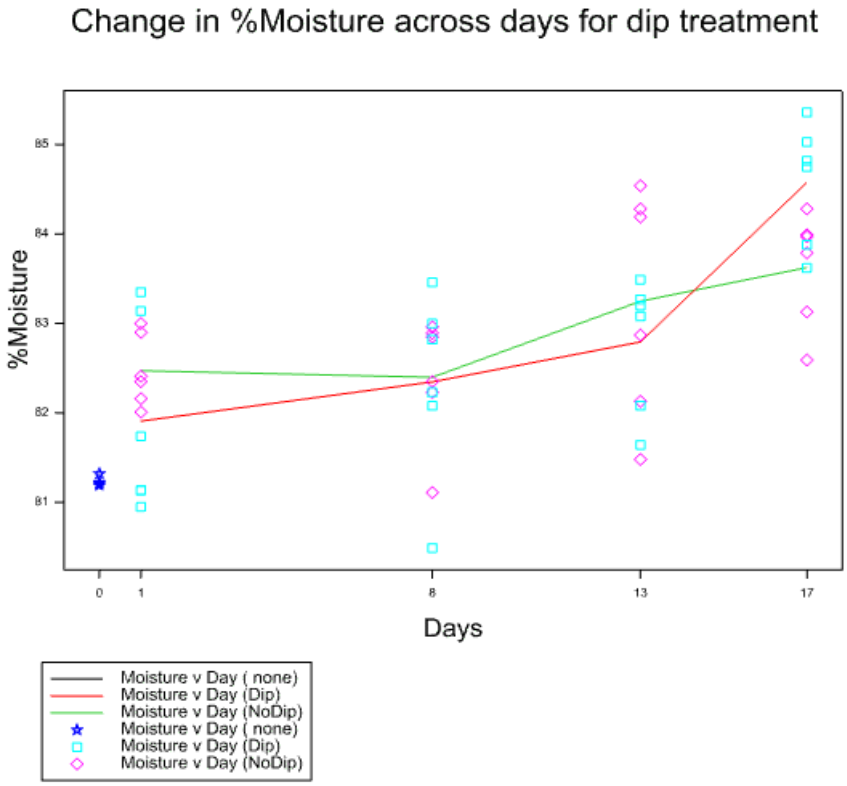
** n= 2*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	0.3946	0.3946	0.83	
Replicate.*Units* stratum					
Group	1	10.4963	10.4963	22.16	<.001
Group.Day	3	26.8462	8.9487	18.89	<.001
Group.Dip	1	0.0105	0.0105	0.02	0.883
Group.Packaging	2	0.8757	0.4379	0.92	0.409
Group.Day.Dip	3	4.2876	1.4292	3.02	0.048
Group.Day.Packaging	6	6.0324	1.0054	2.12	0.085
Group.Dip.Packaging	2	5.2889	2.6444	5.58	0.010
Group.Day.Dip.Packaging	6	4.7785	0.7964	1.68	0.166
Residual	26	12.3168	0.4737		
Total	**51**	**71.3276**			

There were significant interactions of Day of storage and Dip treatment (p=0.048) and of Dip treatment and Packaging method (p=0.014).

Day x Dip interaction: Between Days 1 and 13 Moisture % for No Dip treatment was slightly higher than for Dip treatment, however not significantly higher. For day 17 Moisture % for Dip treatment was significantly higher than for No Dip treatment. Furthermore, Moisture % was not significantly different between treatments for days 1 and 8. Mean moisture % for all treatment combinations were significantly higher than for the baseline Control except for Dip at Day 1.



Standard errors of means: 0.3441 (min.rep), 0.2810 (max.rep)

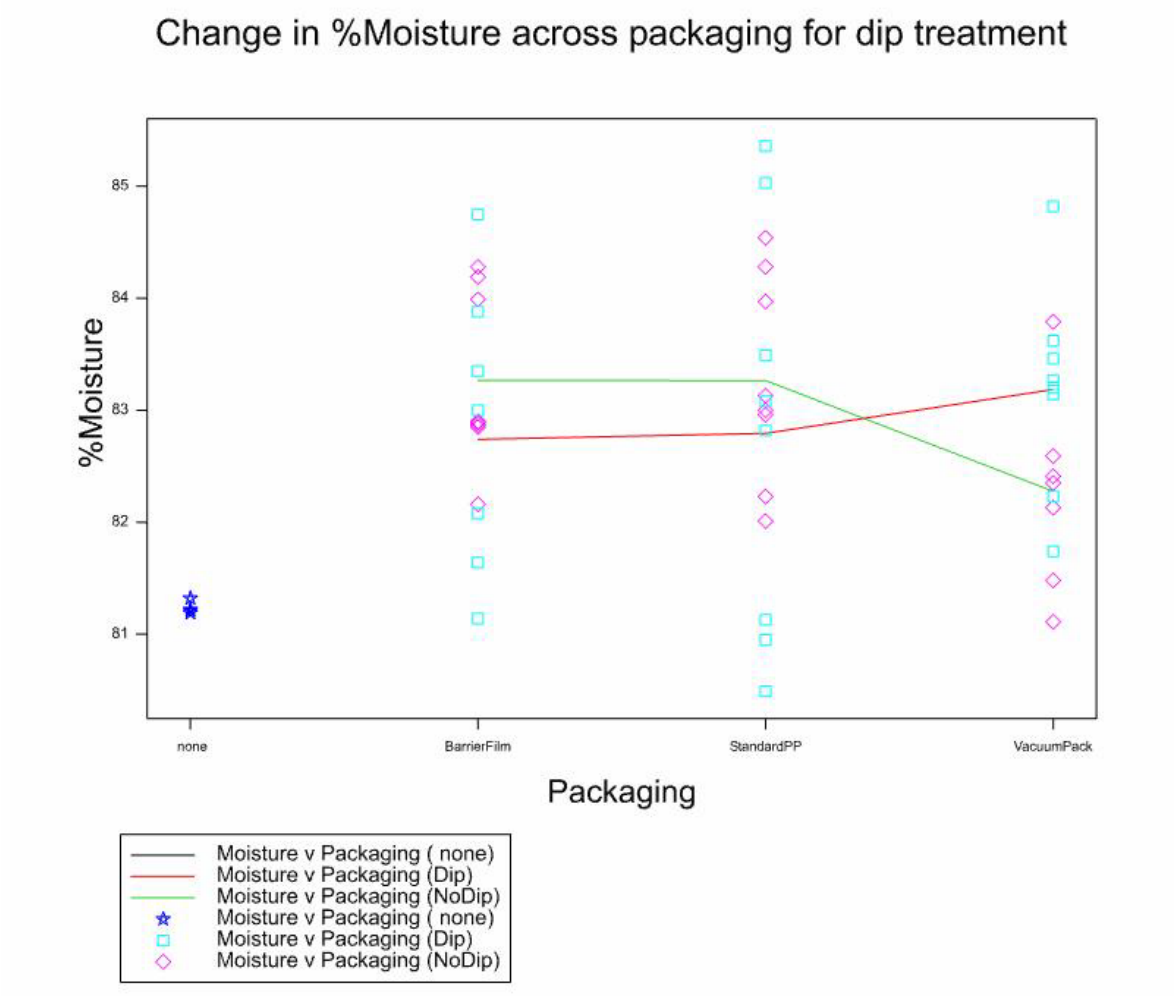
Standard errors of differences of means: 0.3974 (max.rep), 0.4443 (max-min reps)

Least significant differences of means (5% level): 0.8168 (max.rep), 0.9132 (max-min reps)

Fisher's least significant difference test for Day.Dip

Day	Dip treatment	Mean	LSD lettering	Replicates
Control		81.23	a	4
1	Dip	81.91	ab	6
8	Dip	82.35	bc	6
8	No Dip	82.4	bc	6
1	No Dip	82.47	bcd	6
13	Dip	82.79	cd	6
13	No Dip	83.25	de	6
17	No Dip	83.63	e	6
17	Dip	84.58	f	6

Dip x Packaging interaction: Average Moisture % for all Dip x Packaging combinations was significantly higher than for baseline Control. Moisture % for Dip treatment remained basically constant with no significant differences across the packages while for No Dip treatment only Vacuum pack was significantly lower than the rest.



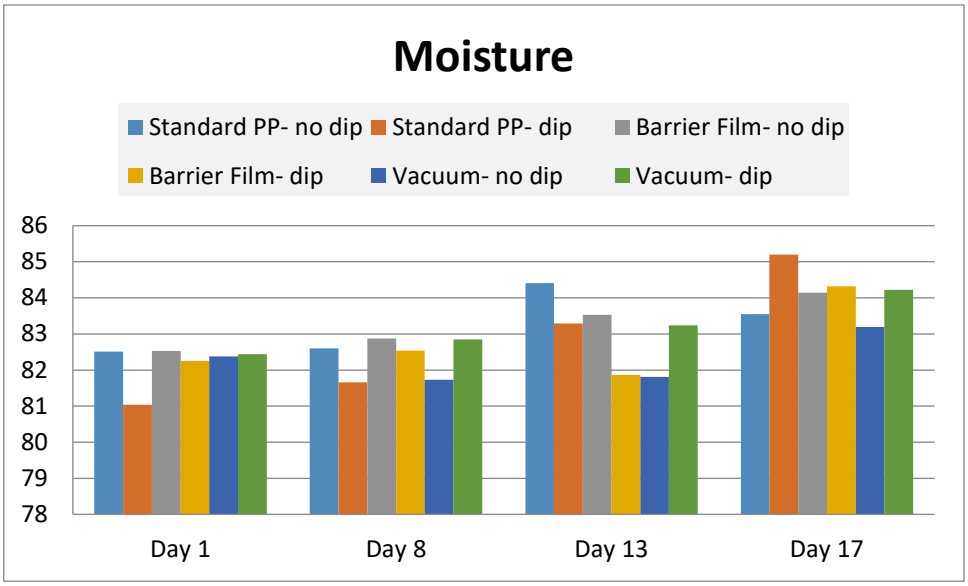
Standard errors of means: 0.3441 (min.rep), 0.2433 (max.rep)

Standard errors of differences of means: 0.3441 (max.rep), 0.4215 (max-min reps)

Least significant differences of means (5% level): 0.7074 (max.rep), 0.8664 (max-min reps)

Fisher's least significant difference test for Dip.Packaging

Dip treatment	Packaging	Mean	LSD lettering	Replicate
Control		81.23	a	4
No Dip	Vacuum Pack	82.28	b	8
Dip	Barrier Film	82.74	bc	8
Dip	Standard PP	82.79	bc	8
Dip	Vacuum Pack	83.19	c	8
No Dip	Standard PP	83.27	c	8
No Dip	Barrier Film	83.27	c	8



Brix ratio

Control Brix = 17.47 (n=4)

Package	Dipping	Day 1	Day 8	Day 13	Day 17
Standard PP	No	16.2	15.5	14.25	15.85
Standard PP	Yes	16.45	16.35	15.5	13.75
Barrier Film	No	15.2	15.4	14.9	14.85
Barrier Film	Yes	15.5	15.3	16.45	14.35
Vacuum	No	15.8	16.25	16.85	14.8
Vacuum	Yes	15.55	15.25	14.95	14.5

** n= 2*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	0.6031	0.6031	1.49	
Replicate.*Units* stratum					
Group	1	15.8021	15.8021	39.02	<.001
Group.Day	3	8.9156	2.9719	7.34	0.001
Group.Dip	1	0.3169	0.3169	0.78	0.385
Group.Packaging	2	0.6350	0.3175	0.78	0.467
Group.Day.Dip	3	2.8073	0.9358	2.31	0.100
Group.Day.Packaging	6	4.4400	0.7400	1.83	0.133
Group.Dip.Packaging	2	3.0650	1.5325	3.78	0.036
Group.Day.Dip.Packaging	6	8.0833	1.3472	3.33	0.014
Residual	26	10.5294	0.4050		
Total	**51**	**55.1977**			

There was a significant interaction between Days of storage, Dip treatment and Packaging method.

The average patterns for Brix of Dip and No Dip treatments varied for the three packaging methods.

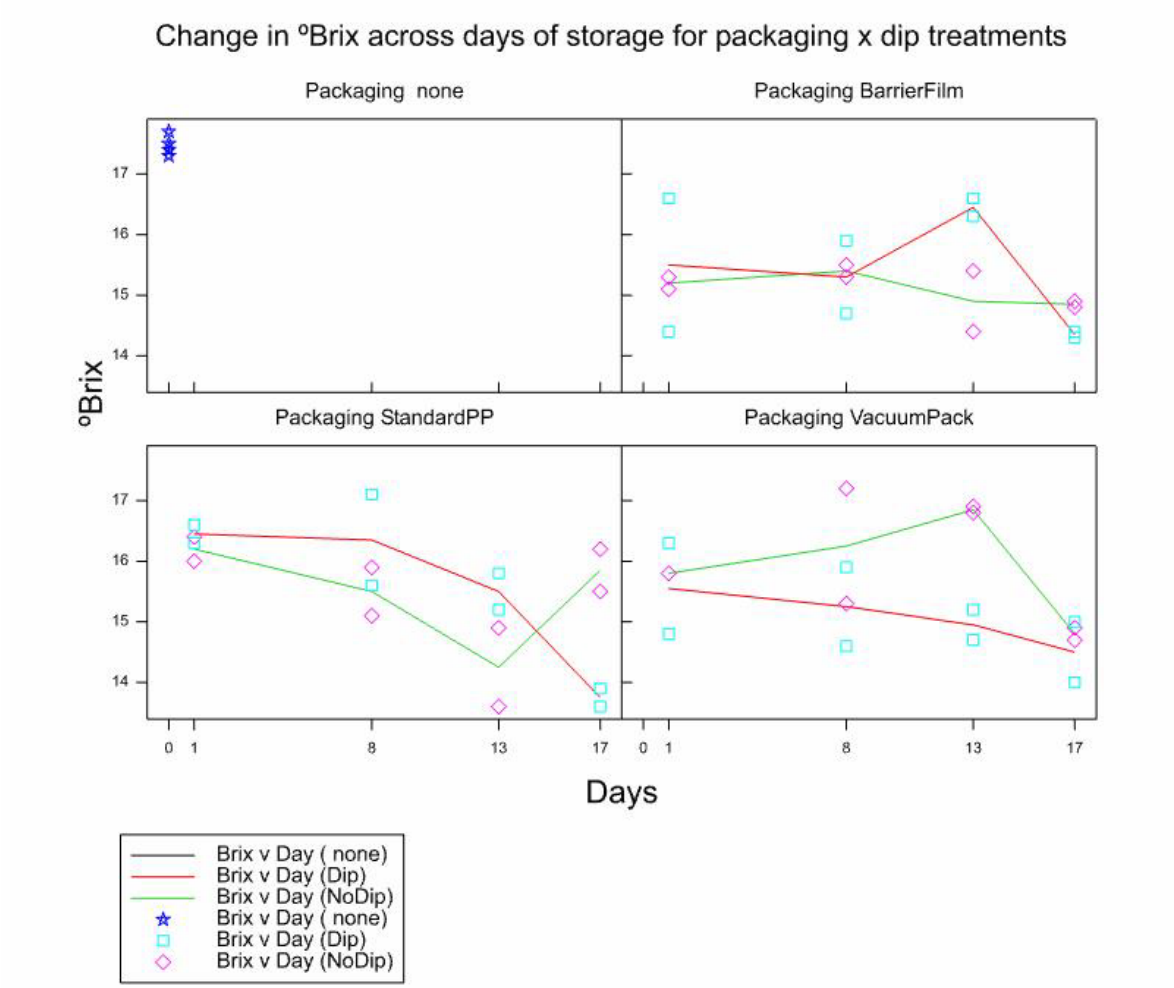
- For the Barrier Film package, brix for the Dip treatment remained constant and significantly lower than the baseline Control from day 1 to day 8 and then significantly increases at day 13 to decrease again at day 17; brix for the No Dip treatment remained relatively constant with means across days of storage not significantly different.

- For the Standard PP package, brix for the Dip treatment declined from day 1 to day 17, although only the decline at day 17 is significant; brix for the No Dip treatment declined from day 1 to day 13 and increased at day 17.

- For the Vacuum pack, brix for the No Dip treatment increased, although not significantly, from day 1 to day 13 and then significantly decreased at day 17; brix for the Dip treatment declined from day 1 to day 17 but this decline was not significant (Table 4).

- Largely, mean values for brix were not significantly different form each other within each packaging method and to a large extent across packaging methods either.

- Mean brix for the baseline Control was the highest of all treatments. Only 4 other treatment combinations were not significantly different from the Control, which means that in general brix was significantly lower for most treatment combinations.



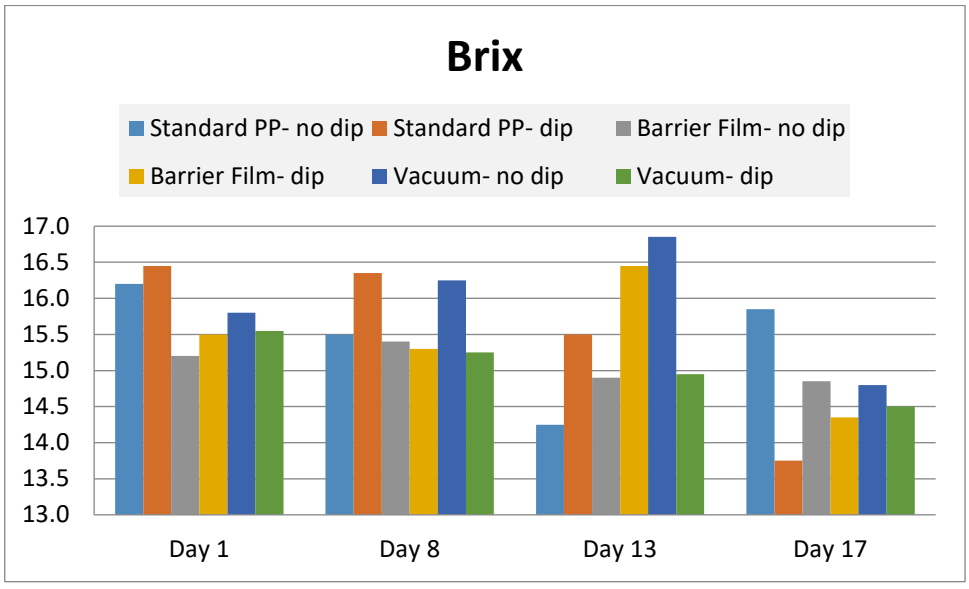
Standard errors of means: 0.45 (min.rep), 0.3182 (max.rep)

Standard errors of differences of means: 0.6364 (min.rep), 0.5511 (max-min reps)

Least significant differences of means (5% level): 1.3081 (min.rep), 1.1328 (max-min reps)

Fisher's least significant difference test for Day.Dip.Packaging

Days	Dip treatment	Packaging	Mean	LSD lettering	Replicates
Control			17.47	a	4
13	No Dip	Vacuum Pack	16.85	ab	2
13	Dip	Barrier Film	16.45	abc	2
1	Dip	Standard PP	16.45	abc	2
8	Dip	Standard PP	16.35	abc	2
8	No Dip	Vacuum Pack	16.25	bcd	2
1	No Dip	Standard PP	16.2	bcde	2
17	No Dip	Standard PP	15.85	bcdef	2
1	No Dip	Vacuum Pack	15.8	bcdefg	2
1	Dip	Vacuum Pack	15.55	bcdefgh	2
1	Dip	Barrier Film	15.5	cdefgh	2
8	No Dip	Standard PP	15.5	cdefgh	2
13	Dip	Standard PP	15.5	cdefgh	2
8	No Dip	Barrier Film	15.4	cdefgh	2
8	Dip	Barrier Film	15.3	cdefgh	2
8	Dip	Vacuum Pack	15.25	cdefgh	2
1	No Dip	Barrier Film	15.2	cdefgh	2
13	Dip	Vacuum Pack	14.95	defghi	2
13	No Dip	Barrier Film	14.9	efghi	2
17	No Dip	Barrier Film	14.85	fghi	2
17	No Dip	Vacuum Pack	14.8	fghi	2
17	Dip	Vacuum Pack	14.5	ghi	2
17	Dip	Barrier Film	14.35	hi	2
13	No Dip	Standard PP	14.25	hi	2
17	Dip	Standard PP	13.75	i	2



Microbiological analysis

Standard Plate Count (CFU/g)

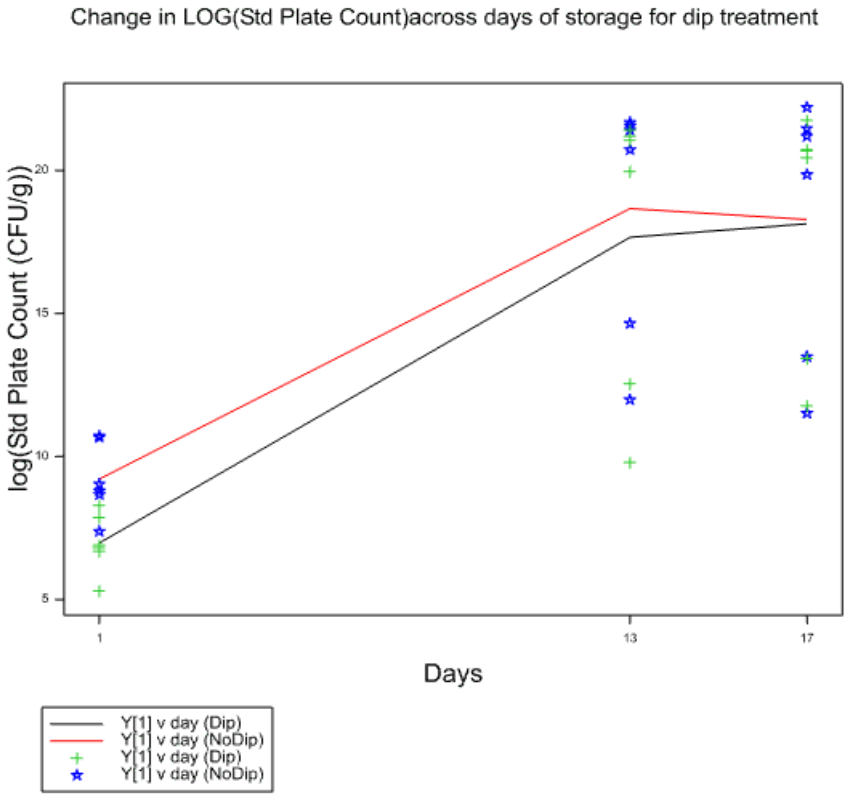
Note: Residuals for this trait did not follow a normal distribution; therefore a log transformation was required. Back-transformed means are provided along transformed means. Day 8 was excluded from the analysis because the values for most samples were ">2.5 million", which is a categorical and not a numerical value.

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	10.4568	10.4568	14.12	
replicate.*Units* stratum					
Day	2	815.4194	407.7097	550.55	<.001
Dip	1	11.4936	11.4936	15.52	0.001
Packaging	2	265.9278	132.9639	179.55	<.001
Day.Dip	2	6.5820	3.2910	4.44	0.028
Day.Packaging	4	141.1894	35.2973	47.66	<.001
Dip.Packaging	2	1.6893	0.8447	1.14	0.343
Day.Dip.Packaging	4	2.8656	0.7164	0.97	0.451
Residual	17	12.5894	0.7406		
Total	**35**	**1268.2132**			

There was significant interaction of Day x Dip and Day x Packaging.

Day x Dip interaction: At Day 1 the mean plate counts for Dip and No Dip treatments were significantly different. For Days 13 and 17, there were no significant differences between Dip and No Dip treatments in mean standard plate counts.



Standard errors of means: 0.351

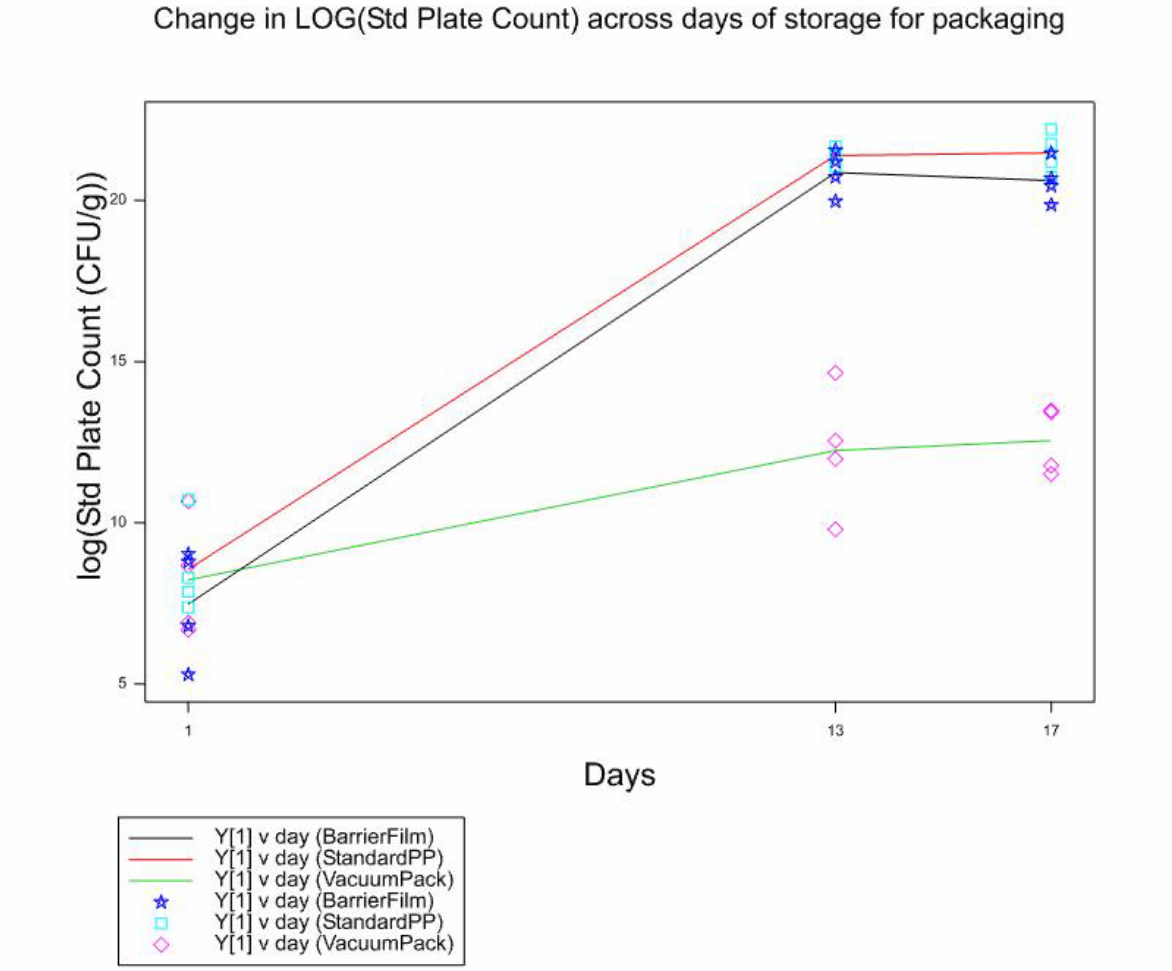
Standard errors of differences of means: 0.497

Least significant differences of means (5% level): 1.048

Fisher's least significant difference test for Day.Dip

Day	Dip	Mean log(Std Plate Count)	LSD lettering	Back-transformed Std Plate Count mean
1	Dip	6.98	a	1.07E+03
1	No Dip	9.21	b	1.00E+04
13	Dip	17.66	c	4.67E+07
17	Dip	18.14	c	7.55E+07
17	No Dip	18.29	c	8.77E+07
13	No Dip	18.67	c	1.28E+08

Day x Packaging interaction: At Day 1, the mean standard plate counts for all three packaging methods were not significantly different from each other. For days 13 and 17, mean standard plate counts were not significantly different for Barrier Film and Standard PP packaging methods; however Vacuum packaging had a significantly lower mean standard plate count than the other two.



Standard errors of means: 0.430

Standard errors of differences of means: 0.609

Least significant differences of means (5% level): 1.284

Fisher's least significant difference test for Day.Packaging

Day	Packaging	Mean log(Std Plate Count)	LSD lettering	Back-transformed Std Plate Count mean
1	Barrier Film	7.48	a	1.77E+03
1	Vacuum Pack	8.23	a	3.75E+03
1	Standard PE	8.56	a	5.22E+03
13	Vacuum Pack	12.24	b	2.07E+05
17	Vacuum Pack	12.55	b	2.82E+05
17	Barrier Film	20.61	c	8.93E+08
13	Barrier Film	20.86	c	1.15E+09
13	Standard PP	21.39	c	1.95E+09
17	Standard PP	21.47	c	2.11E+09

Yeast (CFU/g)

For this trait a simple descriptive table with some means or individual values for replicates (when variability between replicates was too extreme to obtain a mean) can be presented (Table 11). No inferences must be made and no statistical analyses can be performed. Most values were in a categorical scale.

For Day 1, on average, yeast seemed lower for samples with Dip treatment than for samples with No Dip. However, no statement on significant differences between these means can be made. For days 8 and up, Standard PP and Barrier Film packages reached the maximum that can be counted, at >25,000 for both Dip treatments. Vacuum pack showed very variable results, where dip seemed to have maintained counts lower on average.

Mean Yeast for the different packaging x Dip treatment x Day of storage combinations.

Packaging	Dip treatment	Days of storage			
		1	8	13	17
Standard PP	No Dip	2050	>25,000		
	Dip	150			
Barrier Film	No Dip	350			
	Dip	100			
Vacuum Pack	No Dip	400	~2800	<100; >25,000 (*)	16,000; >25,000 (*)
	Dip	150	<100	<100	~1100

(*) values for the two replicates presented

Most values for this trait were either <100 or could not be detected. No reliable data was obtained to present as a summary.

Headspace Analysis for Barrier Film Packaging

Oxygen (O_2)

Dipping	Day 1	Day 8	Day 13	Day 17
No	20.4	20.4	19.3	18.7
Yes	20.5	20.6	20.0	19.2

** n= 2*

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.

Replicate stratum	1	0.0056	0.0056	0.02	
replicate.*Units* stratum					
Day	3	6.1569	2.0523	7.68	0.013
Dip	1	0.5256	0.5256	1.97	0.203
Day.Dip	3	0.2569	0.0856	0.32	0.811
Residual	7	1.8694	0.2671		
Total	**15**	**8.8144**			

There was a significant effect of Day of storage on Oxygen content. Mean oxygen content decreased with time, however significances were not extreme: mean content at day 17 was significantly lower than at days 1 and 8 (Table 7).

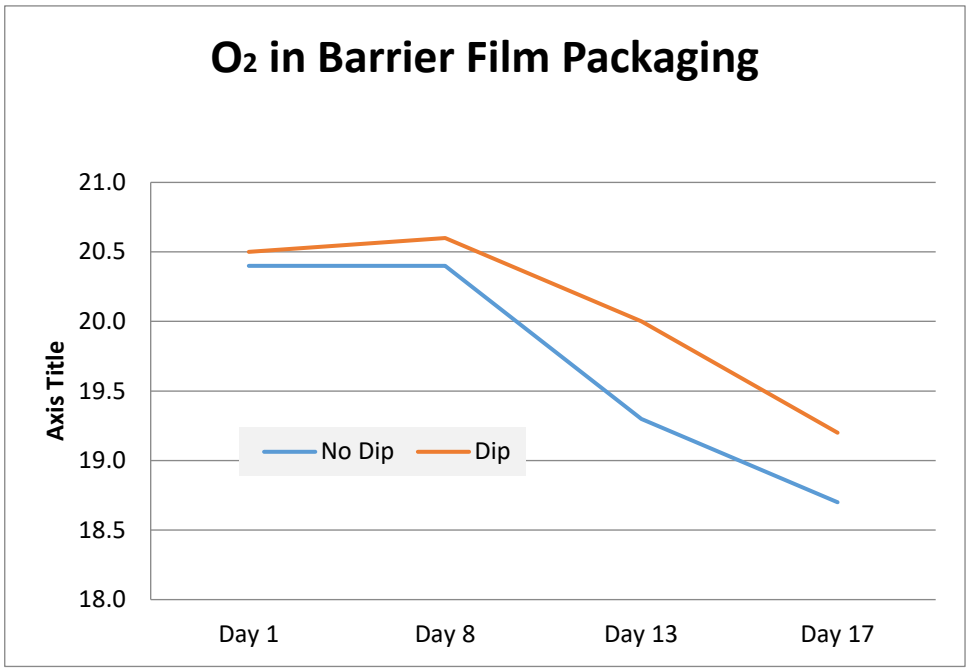
Standard errors of means: 0.258

Standard errors of differences of means: 0.365

Least significant differences of means (5% level): 0.864

Fisher's least significant difference test for Day

Day	Mean	LSD lettering
8	20.45	a
1	20.42	a
13	19.65	ab
17	18.95	b



Carbon Dioxide (CO_2)

Dipping	Day 1	Day 8	Day 13	Day 17
No	0.8	0.8	2.3	3.2
Yes	0.9	0.7	1.5	2.5

* *n*= 2

Analysis of variance

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replicate stratum	1	0.0156	0.0156	0.03	
replicate.*Units* stratum					
Day	3	11.2719	3.7573	6.73	0.018
Dip	1	0.6006	0.6006	1.08	0.334
Day.Dip	3	0.5419	0.1806	0.32	0.809
Residual	7	3.9094	0.5585		
Total	**15**	**16.3394**			

There was a significant effect of Day of storage on Carbon dioxide content. Mean carbon dioxide content decreased with time, however significances were not extreme: mean content at day 17 was significantly higher than at days 1 and 8 (Table 8).

Standard errors of means: 0.374

Standard errors of differences of means: 0.528

Least significant differences of means (5% level): 1.250

Fisher's least significant difference test for Day

Day	Mean	LSD lettering
8	0.75	a
1	0.825	a
13	1.85	ab
17	2.8	b